Cloud-Based Intelligent Framework Design to Collect Traffic Data and Notify Accidents: In the case of Addis Adama Expressway

By Ashenafi Dabera

A Thesis Submitted to the department of Computer Science and Engineering,
School of Electrical and Computing

Presented in Partial Fulfillment of the Requirement for the Degree of Master's in Network Engineering

Office of Graduate Studies
Adama Science and Technology University

Feb 2023
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Name of Advisor: Dr. Mesfin Abebe

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Approval Page

I, the advisor of the thesis entitled “Cloud-Based Intelligent Framework Design to Collect Traffic Data and Notify Accidents: In the case of Addis Adama Expressway” and developed by Ashenafi Dabera, hereby certify that the recommendation and suggestions made by the board of examiners are appropriately incorporated into the final version of the thesis.

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We, the undersigned, members of the Board of Examiners of the thesis by Ashenafi Dabera have read and evaluated the thesis entitled “Cloud-Based Intelligent Framework Design to Collect Traffic Data and Notify Accidents: In the case of Addis Adama Expressway” and examined the candidate during open defense. This is, therefore, to certify that the thesis is accepted for partial fulfillment of the requirement of the degree of Master of Science in Computer Science and Engineering.

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Final approval and acceptance of the thesis is contingent upon submission of its final copy to the office of Postgraduate Studies (OPGS) through the Department Graduate Council (DGC) and School of Graduate Committee (SGC).

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Declaration

I hereby declare that this Master Thesis entitled “Cloud-Based Intelligent Framework Design to Collect Traffic Data and Notify Accidents: In the case of Addis Adama Expressway” is my original work. That is, it has not been submitted for the award of any academic degree, diploma or certificate in any other university. All sources of materials that are used for this thesis have been duly acknowledged through citation.

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Recommendation

I/we, the advisor(s) of this thesis, hereby certify that I/we have read the revised version of the thesis entitled “Cloud-Based Intelligent Framework Design to Collect Traffic Data and Notify Accidents: In the case of Addis Adama Expressway” prepared under my/our guidance by Ashenafi Dabera submitted in partial fulfillment of the requirements for the degree of Masters of Science in Computer Science and Engineering. Therefore, I/we recommend the submission of revised version of the thesis to the department following the applicable procedures.

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List of Acronyms

ADR	Accident Data Recorder
AIFS	Arbitration Inter-Frame Space
API	Application Program Interface
ASI	Accident Severity Index
CCH	Control Channel
CCU	Central Control Unit
CSC	Cloud Service Consumer
CSP	Cloud Service Provider
CU	Control Unit
DSRC	Dedicated Short-Range Communication
ECU	Electronic Control Unit
EDR	Event Data Recorder
GPIO	General Purpose Input/Output
GPS	Global Positioning System
GSM	Global System for Mobile
GUI	Graphical User Interface
I2C	Inter-Integrated Circuit
IBM	International Business Machines
IDE	Integrated Development Environment
IEEE	Institute Of Electrical and Electronics Engineers
IMU	Inertial Measurement Unit
IOT	Internet Of Things
IP	Internet Protocol
ITS	Intelligent Transportation System
MAC	Media Access Control
MANET	Mobile Ad-Hoc Network
MEMS	Micro Electro-Mechanical System
NIST	National Institute of Standards and Technology
OBU	On Board Unit
RSU	Road Side Unit
RTA	Road Traffic Accident
SCH	Service Channels

TCP	Transport Control Protocol
V2I	Vehicle To Infrastructure
V2V	Vehicle To Vehicle
V2X	Vehicle To Everything
VANET	Vehicular Ad-Hoc Network
WAVE	Wireless Access for Vehicular Environments
WHO	World Health Organization
WSN	Wireless Sensor Network

Abstract

On-road accidents are a key issue for road safety and are a major source of loss of lives and property both for drivers and passengers. Even with all the modern developments in the field of vehicle design, transportation infrastructure and in-vehicle technology, Addis Adama Expressway are considered to be one of highly trafficked and accidental roads in the country. which usually cause a high death toll. Sizeable portion of these deaths occur due to a delayed response by medical care providers and rescue authorities. Timely accident detection, location detection and concurrent action informing an emergency responders could drastically increase the chances of survival of an accident victim. This paper proposes a multi-tier real-time accident detection and notification framework for Addis Adama Expressway. The proposed multitier approach utilizes a IoT-based vehicular environment, V2X Communication, Edge and Cloud computing. In this work, vehicles are equipped with an On-Board Unit (OBU) that includes accelerometer and gyroscope sensors for reliable and timely accident detection along with a Global Positioning System (GPS) module for identification of accident location. In order to facilitate vehicle to infrastructure communication, OBU in each vehicle incorporates a wireless networking interface. A vehicle OBU detects an accident by periodically measuring the acceleration and the angular velocity of the vehicle. Once an accident occurs it generates an alert message. It then sends the message along with the accident location, time and plate number to an intermediate device, placed at the edge of the road called an edge device. An edge device works based on edge computing technology and performs function of receiving the notification, pre-processing of data and effectively works as a link between a vehicle and cloud computing tier. As notification message received at edge device, it finds the nearest emergency responder and makes a request to the identified emergency responder. In addition, a significant issue those relevant authorities currently facing is the real-time visualization, analysis and permanent storage of data obtained from the vehicular tier. In light of this, a cloud computing tier, which is hosted on azure cloud service provider is proposed. Besides the framework has been evaluated through experts in automotive industries, IT sectors and relevant authorities in terms of achieving the outlined objectives and requirements.

Key Words: Edge Computing, Cloud Computing, V2X Communication, Sensors, Accident detection

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

According to estimates from the World Health Organization (WHO), 1.35 million people die globally each year as a result of traffic accidents (WHO, 2018). Another 20 to 50 million people suffer non-fatal injuries, and many of them go on to become disabled. Between the ages of 15 and 44, the productive sectors of the population accounted for more than half of all traffic deaths worldwide. Motorcycle riders make up 23% of fatal traffic accidents around the world, followed by pedestrians (22%), cyclists (5%), car occupants (31%), and other road users (19%). The victims of automobile accidents, their families, and entire nations suffer severe economic losses. These expenses are brought on by the cost of medical care, the loss of wages for those who pass away or become disabled as a result of their injuries, and the cost of caring for loved ones who must take time off from their jobs or studies to tend to the injured. Most nations lose 3% of their gross domestic product to road accidents.

More than 90% of road fatalities occur in low- and middle-income countries. Despite only driving 20% of all vehicles, men account for the bulk (80%) of fatalities. Estimates of the severity of traffic injuries in low-income countries are often based on police records and sporadically on hospital registry data, but both sources suffer from underreporting. Despite having the highest rate of fatal road traffic accidents, with regional averages of 24.1 fatalities per 100,000 people and global rates of 18 fatalities per 100,000 people, the African region continues to have the lowest motorization among the six regions of the world. Even in high income countries, those from lower socioeconomic backgrounds are more likely to be involved in traffic accidents. If certain preventative measures are not taken to lower this percentage, traffic accidents will rise to the sixth most prevalent cause of mortality by the year 2030.

Road Traffic Accidents (RTA) are a prevalent public health issue in Ethiopia. According to a Ministry of Transport report (Mekonen, 2020), Ethiopia is one of the worst countries in the world for RTA, which kills and injures many road users every year. Of the nearly 2000 people who die as a result of RTA, 48% are pedestrians, 45% are passengers, and 7% are drivers. RTA also costs the country between 400 and 500 million ETB each year. Amhara region

accounted for 27.3% of all road traffic accident-related deaths in Ethiopia in the years 2008 to 2009, which is the largest percentage of any region (Deme, 2018). In metropolitan areas, Gondar, Bahir Dar, and Dessie each had a pedestrian mortality rate of 86.3%, 54.8%, and 48.5%, respectively. RTA in developing nations, especially Ethiopia, is still a neglected and under reported topic that has to be investigated and solutions to be found quickly, despite the growing obstacles.

RTA fatalities have a variety of reasons, but the main ones include driver error, careless driving, old vehicles, and ineffective emergency services. According to (Sanathra et al., 2019) research, it is a waste of time and resources to require a caller to describe their location before assistance is sent because the emergency response infrastructure is currently unable to locate a user's precise location in an emergency. It's very important at this point in the response time period. One of the most crucial elements in lowering mortality and property damage is the time it takes to reach the first responder (which might be an ambulance, firefighter, police officer, or bystander). Delays in location identification and notification prohibit any units from being sent to the scene and squander time that could be utilized to provide first aid that could save lives.

The goal of these research paper is to design a framework that automatically collects accident data, analyzes it, and rapidly alerts users to incidents in order to decrease the number of casualties by giving victims of road accidents prompt medical attention. The suggested framework is made up of three different sub-systems (Vehicle environment, Edge-gateway tier and Cloud Platform). The car environment is in charge of gathering accident event data together with other data via the Internet of Things (IOT). It then generates a notification that is forwarded to the Edge gateway platform for additional processing via a vehicle to infrastructure connection mechanism. On the other hand, the edge gateway layer is in charge of Temporary storage and processing the data collected from the vehicle environment so that it can determine the precise position of the incident and nearest emergency response. The processed data will then be sent to the cloud platform and emergency response agencies for the necessary action. Using the permanent storage, processing, and visualization capabilities provided by the Cloud platform layer, road accident data may be investigated and analyzed for several applications, including for policy-making, research, and documentation.

This proposed system is bounded by two basic requirements which are contextual awareness and timeliness. Regarding the first requirement, when an accident occurs and the system knows about the incident, then it can provide the exact location to the people who are offering the rescue services, thereby, it can efficiently improve the probability of victim’s

survival. With this functionality, the system can provide the first responders with contextual awareness. Moreover, the system is also delay-sensitive to detect an accident. For the system to perform better, it is required that the accident-related information should reach the nearest hospital so that the relevant authority can treat the victims or the injured persons properly.

1.2 Statement of the Problem

One of the leading causes of deaths and injuries worldwide is traffic accidents. Every year traffic accidents result in roughly 1.35 and close to 50 million fatal and non-fatal injuries respectively. Ethiopia ranks among the top nations for traffic accidents. According to studies, the Addis Adama Expressway alone reported an average of 417 crashes every two and a half years. Around 672 accidents on the expressway were reported as a result of these crashes, resulting in 285 injuries to people and 387 damages to property. Of the total number of injuries to people, 37 were fatal, 65 were serious, and 183 were minor. Our findings demonstrate that, in spite of advancements in in-vehicle technology and transportation infrastructure, traffic accidents continue to occur on the Addis Adama Expressway, frequently with a significant mortality toll. Although there are many reasons why people die or become injured after an accident, a significant number of those cases are due to delayed emergency intervention. The most important factor in an emergency is frequently time. In this study, we provide a framework for quick communication between the accident site and emergency responders, for reducing the amount of time needed to process data by supplying the precise position of the accident scene, and for notifying the appropriate mobilizations to be dispatched.

1.3 The Research Questions

Question 1 What are the factors that affect traffic accidents?

Question 3 What are the existing vehicular accident management challenges?

1.4 Objectives of the Study

1.4.1 General Objective

The general objective of the study is to design a Cloud-Based Intelligent Frame work that collect Data and Notify accidents on the Addis Adama Expressway.

1.4.2 Specific Objectives

- Design and test a prototype for Instant detection and notification of accidents automatically using accelerometer, GPS module and gyroscope sensors
- Design and evaluate vehicle accident notification system using edge computing mechanism
- Design a cloud platform framework for traffic data collection and visualization
- Evaluate the designed framework through expertise in the field of the study.
- To identify and recommend future research directions for further investigation on improving the developed framework.

1.5 Significance of the study

This system has significance in different perspective. From the user point which includes traffic police station, Drivers, hospitals, ambulances, fire fighters and mainly the general public. It aims to change current system (manual system) to the cloud-based system that reduces information gathering and response time.

This research provides the following main significances to the end users.

- More effective and efficient to collect, analysis and notification of emergency's
- Feasible with respect to technology and economically
- Increases the effectiveness of communication between parties
- Reduce the time to perform and provide emergency responses
- Different documents related to accidents and Emergency responses are being stored in integrated database
- Reduce the number of causalities of because of delayed responses

1.6 Scope and Limitation of the study

The scope of this study is to develop the cloud-based accident data collection, analysis and notification system for timely manner emergency response. The aim of the thesis is to design cloud-based framework which aims to perform the following tasks:

- Record accident information in detail that includes location and other relevant information
- Perform required analysis on the recorded data
- Notify the emergency responders in timely manner and collaborate with emergency responders
- Due to the telecommunication infrastructure constrains the data collection, analysis and notification systems can be subjected to delay. Beside that due to the constraints in the construction of Road Side units in our Highways implementing the whole framework is not feasible. Also, the thesis does not include any pre accident mechanisms it only focuses on the post-accident scenarios.

1.7 Organization of the Thesis

This Thesis is organized with six chapters. Chapter one presents introduction of the thesis including background about causes of accidents, statement of problem, objectives, significance, scope and limitation of the study. The next part of the thesis discuses about literatures related to existing accident detection and notification framework and their limitations. Chapter three presents about the methodology of the study. In chapter four, proposed framework and its implementation is discussed. The results and discussion of thesis is presented in chapter five and finally the research is concluded and future works are presented in chapter six.

CHAPTER TWO

LITERATURE REVIEW AND RELATED WORK

2.1 Introduction

This chapter discusses the phrase "cloud computing" from various specialists and organizations, the main forms of cloud deployment, service delivery models, and related technologies, as well as the current framework for accident handling and the difficulties it faces. The chapter also covers related papers and their shortcomings.

2.2 Cloud Computing

In its contemporary form, cloud computing first appeared in early 1996 (White et al., 2011), and today it is one of the computing paradigms with the quickest rate of growth. This is due to the advantages of its high computing power, low cost of services, high performance, scalability, accessibility, and availability. Since there isn't a single definition that applies to all cloud professionals and specialists, each one has their own definition of cloud computing. Simply described, cloud computing is an information technology model that offers customers over the network services like computing or processing power, storage power, and any type of technological services.

Important elements of cloud computing, as well as cloud services and deployment tactics, are described under the NIST definition. "Cloud computing is a model for enabling convenient, on-demand network access to a shared pool of configurable computing resources (such as networks, servers, storage, applications, and services), that can be swiftly provisioned and released with little management effort or service provider interaction (Mell and Grance, 2011). Despite the possibility of service brokers, the cloud service provider (CSP) and the cloud service consumer are the two fundamental actors in the context of cloud computing, according to the NIST definition (CSC). Cloud computing is a system that makes it possible to access a variety of shared resources such as networks, storage, servers, services, and applications, on demand and for a fee per use over the internet and without actually having to buy them (Meena et al., 2014). A new category of network-based computing that utilizes the Internet to offer users on-demand services is referred to as "cloud computing" in general. Since clouds are essentially invisible to users and apps, there are no barriers or obstacles to using clouds on either side.

2.2.1 Architecture of Cloud Computing

The two components of the cloud computing architecture are the front end and the back end. They were all connected to one another via a network. The front is what the client (user) sees, and the back is the cloud of the system. A cloud computing systems architecture can be broken down into four layers, as shown in Fig. 2. 1(Zhang et al., 2010): the physical layer, the infrastructure layer, the platform layer, and the application layer.

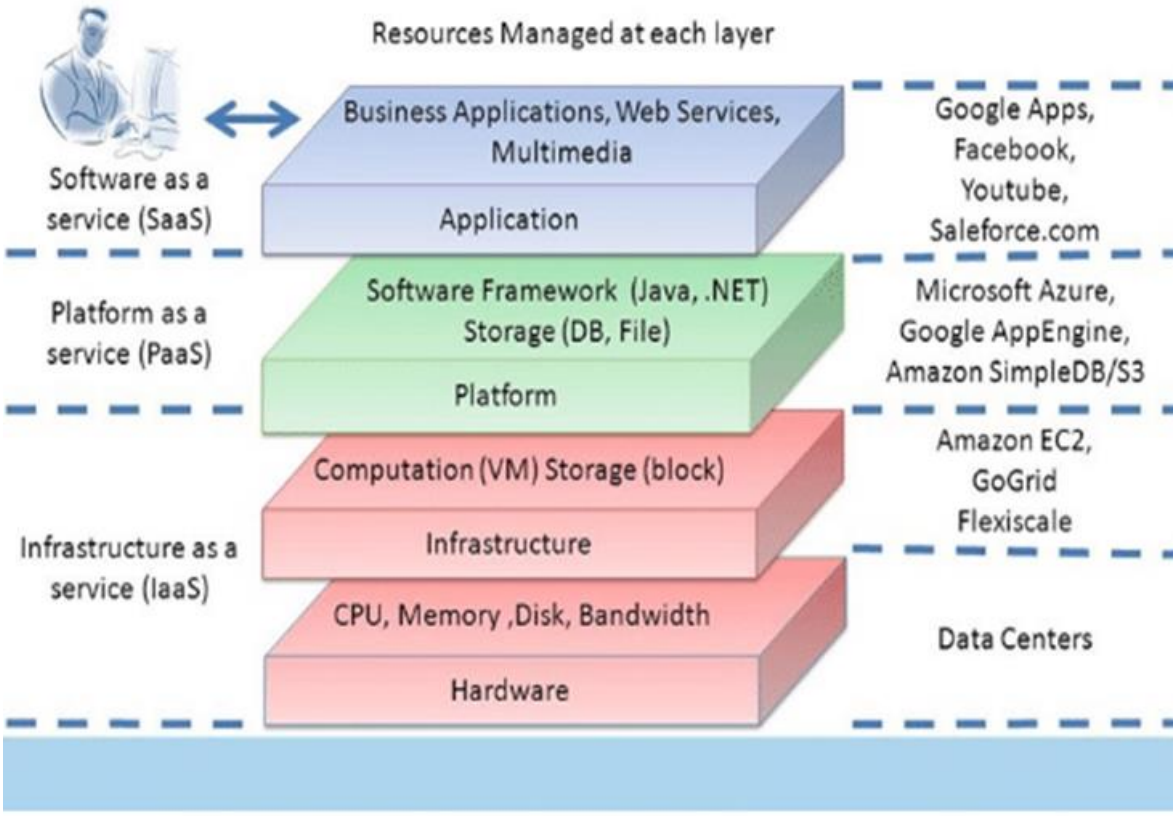

Fig 2. 1 Architectural layers of cloud computing (Zhang et al., 2010)

The Hardware layer: The hardware layer, which is the lowest layer of the cloud architecture, is primarily concerned with all the hardware that powers clouds. Hardware can comprise routers, servers, switches, power and cooling systems, among other things.

The infrastructure layer: Also called the virtualization layer, the infrastructure layer is where all the servers are pooled together into one using Virtual machines.

The Platform layer: The platform layer comprises the operating system and other requisition structures and is based over the infrastructure layer.

The application layer: the topmost layer and contains applications that directly interact with the end-user.

2.2.2 Important Features of Cloud Computing

Cloud computing has a lot of different features.

On-demand self-service: without the assistance of the service provider, the user can control computing capabilities.

Easy Maintenance: The servers are easily maintained, and occasionally there is little to no downtime. Resources that are driven by cloud computing frequently receive updates to maximize their potential and capabilities.

Large Network Access: There are no geographical restrictions while using the resources or services when using cloud computing, which allows remote access to the services.

Economical: The CSP will need to be paid by the client for the space they have used. There are no hidden fees or other costs that must be paid. Since the administration is frugal, some space is typically given up for free.

Rapid elasticity: Rentable capabilities can be readily scaled up or down, allowing the end user to buy whatever quantity whenever they want.

Security: Cloud computing will create snapshots of the data so that in the event that it is lost or a server is damaged, a copy of the data will be saved on another server that is inaccessible to third parties or unauthorized users. With a device and an internet connection, the user can access the storage service quickly and reliably from anywhere in the globe.

Resource Pooling: It indicates that the cloud service provider used a multi-tenant approach to pool computer resources and deliver services to a number of clients.

Automation: Automation in cloud computing refers to the capacity of a cloud service to be installed, configured, and maintained automatically.

2.2.3 Cloud Computing Deployment Models

The type of cloud environment depends on ownership, scale, and access as well as the nature and purpose of the cloud and the cloud deployment methodology. The ownership and location of the servers you're using are specified by a cloud deployment model. It describes your cloud infrastructure's design, what you may change, and whether you can use services or if you have to build everything from scratch. The connections between your infrastructure and your customers are also based on the types of cloud deployment. Based on how it is used, cloud computing is categorized into numerous categories. Public cloud, private cloud, community cloud, and hybrid deployment model are the four primary categories, as indicated in Fig 2. 2.

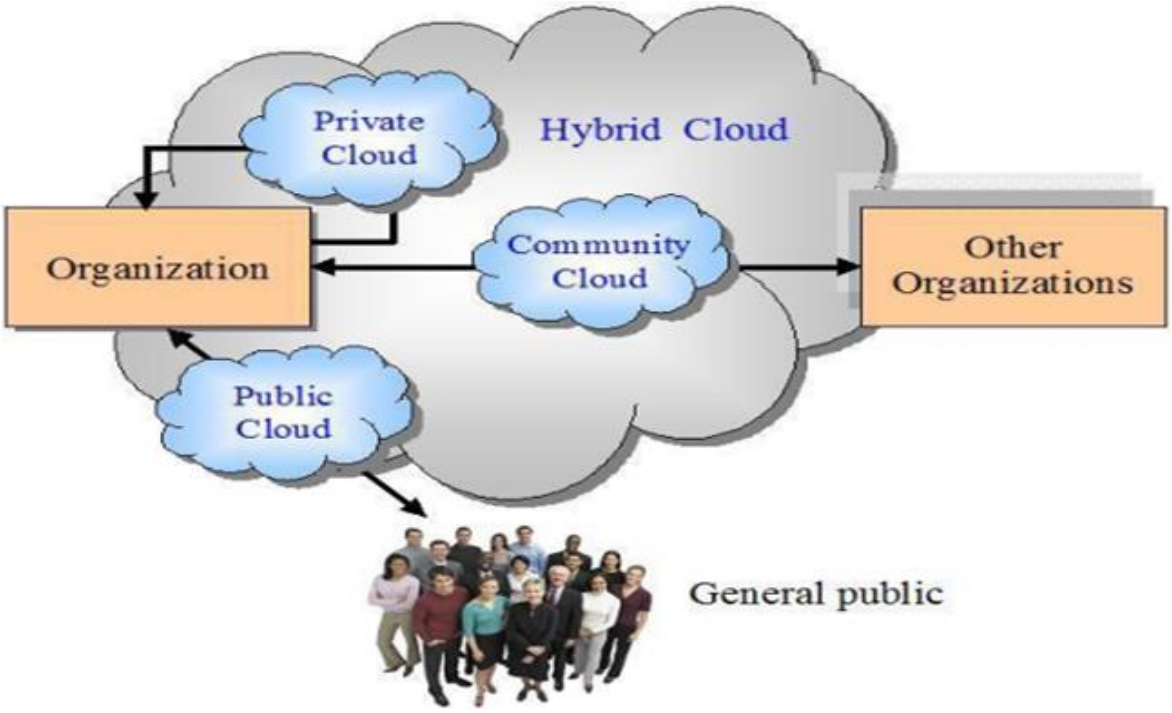

Fig 2. 2 Cloud Computing Deployment Models (White et al., 2011)

A. Public cloud

It is a cloud in which a cloud service provides services for various resources to the general public. The cost of initially purchasing infrastructure and managing the resources required to put up such infrastructure is thereby reduced for the client. In this cloud model, the infrastructure is owned by the cloud service provider rather than the consumer. Thanks to this form of cloud hosting, customers and users can easily access systems and services. Public cloud usage has fewer security requirements than using other clouds because anyone can utilize cloud services. Security in the public cloud is always at risk.

B. Private Cloud

In stark contrast to the private cloud deployment paradigm is the public cloud deployment model. It makes reference to clouds that are managed and structured by companies and provide cloud services to customers all over the world. The key distinction between a private cloud and a public cloud is the ability to access systems and services within a certain boundary or organization. You can tell the difference in how you handle all of the hardware. The private cloud offers more freedom in resource management, data security, and privacy. These clouds are often referred to as interior clouds.

C. Community Cloud

It allows a number of enterprises to access systems and services by deploying the private cloud. It is a distributed system created by mixing the features of several clouds to satisfy the particular needs of a community, industry, or business. The infrastructure of the community may be shared by the body that has shared objectives or duties. This type of cloud service offers affordable computing as well as control over shared resources, collaboration, and security.

D. Hybrid Cloud

By fusing the public and private spheres together with a layer of proprietary software, hybrid cloud computing makes an attempt to fix the flaw. You can host the app in a secure place and gain from the financial advantages provided by the public cloud by utilizing a hybrid solution. A hybrid cloud uses both public and private clouds to run some of its service infrastructure.

2.2.4 Cloud computing service models

Cloud computing service refers to the various services provided by the cloud service providers. The services of the cloud computing can be divided in the three ways as illustrated in Fig 2. 3.

A. IaaS (Infrastructure as a Service)

IaaS stands for infrastructure as a service, which is what cloud service providers offer. The cloud service entails a technique for offering anything over IP-based connectivity as part of an on-demand service, from operating systems to servers and storage. In other words, the facility offered to the consumer is a rental for basic computing resources such as processing, storage, and others. IaaS systems like IBM Cloud and Microsoft Azure are well-known examples.

B. PaaS (Platform as a Service)

PaaS refers to the development services that the customer obtains from cloud service providers. In this situation, the cloud service provider gives the client access to a development environment, such as a database and storage space, so they may fulfill their

development needs. PaaS, the third layer of cloud computing, is regarded as being the most challenging. It pertains to providing Platform layer resources like help with operating systems and software development frameworks. This strategy includes platforms like Salesforce and Microsoft Azure.

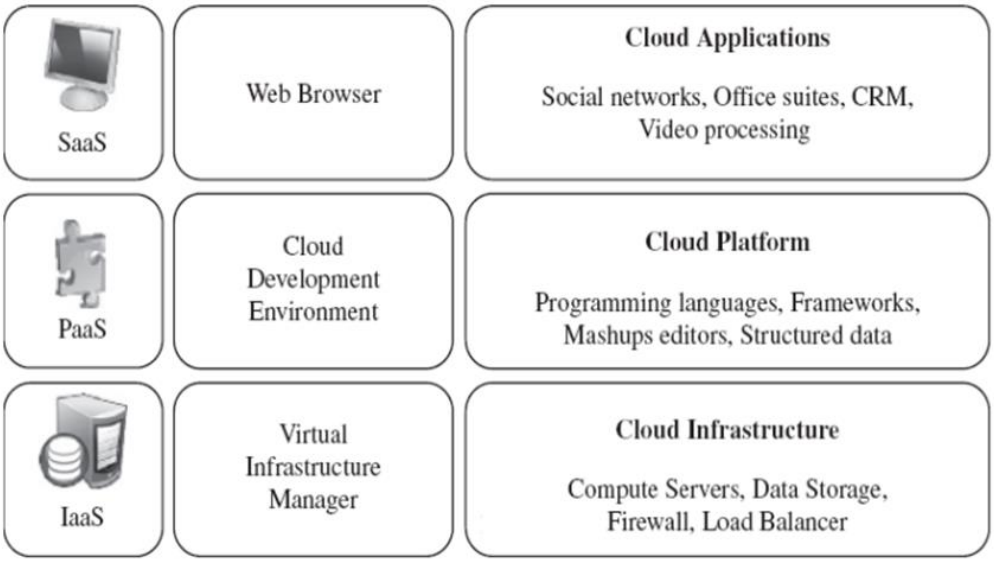

Fig 2. 3 Cloud Computing Service Models (Dar et al., 2019)

C. SaaS (Software as a Service)

Software as a service, or SaaS, is a cloud computing strategy that service providers use to electronically distribute software to organizations. In this case, the client has access to email software thanks to the cloud service provider. Under the SaaS model of software distribution, an application is hosted as a service and made accessible to consumers via the Internet.

2.2.5 Cloud Computing in Accident Management

Cloud computing will certainly alter the transportation options and services offered by the automotive industry (Llopis et al., 2021). The use of cloud computing to manage auto accidents is one emerging paradigm in transportation services. Quick and timely computing resources are needed for processing, communication, and storage when dealing with the accident. Because there are so many service providers who offer services through the cloud, it's possible that the services required to handle accidents will be established in the accident cloud. Traffic police can store and analyze traffic data using Amazon Web Services' Simple Storage Service and Elastic Compute Cloud, for example (Sheth et al., 2021). This type of

computing has many advantages for handling accidents. In order to treat the injured and offer trauma care quickly and effectively after an accident, reports state that a lot of computing resources are needed. Additionally, there is an increasing demand for speedier communication services, and cloud computing seems to provide incredible benefits for communicators.

The Could Computing opens up an enormous array of software applications, as well as lightning-fast processing power, boundless storage, and the capacity to effortlessly communicate and analyze information via knowledgeable network businesses like Google and IBM. Every time you use the Internet, a browser makes all of this available to you. Because police and hospitals may take use of the use of mobile devices and wireless connections for data transmission related to accidents, there is no need to construct large and complex systems (Fernandes et al., 2015).

For difficulties relating to accidents and traffic, having on public cloud is advised. Public clouds are intrinsically "out of organization" on open Internet sites, therefore running the accident cloud in this category is encouraged but not necessary. Private clouds set up on the grounds of medical facilities, law enforcement agencies, or even insurance companies, may present unique post-accident management and trauma treatment challenges. Public clouds are particularly transparent since they are run by external parties who are not directly involved in any direct business, forcing transparency in the system. In order to make access to these services more straightforward, easier, and quicker, various apps from various agencies, such as police, hospitals, and insurance providers, can be combined on the servers of the cloud, on one storage system, and networks. Public clouds are crucial for poor nations because they can benefit from easier access to expertise and trauma management. Cloud-based traffic and accident services, which are primarily required by traffic police and accident controllers, offer a way to reduce accident risk and expense by offering a flexible, if temporary, extension to the cyber infrastructure required by various agencies, including law enforcement and hospitals (Glen and Rich, 2010). For the exclusive use of particular clients, such as insurance companies, specialized private clouds can be built. These clouds can offer the highest level of data control, security, and service quality for the providers of life insurance and auto insurance. The interested insurance companies have a specific infrastructure and have control over how their applications for insurance claims and obtaining accurate accident information are organized on it. Since insurance businesses have

different requirements than the government and the police, private clouds can be implemented both inside insurance companies' datacenters and at colocation facilities.

Cloud computing can be used to represent the services being offered at any of the identified layers, from hardware to apps. The police and insurance companies are interested in both the car and the individual who is operating it while being treated in a hospital. The cloud computing industry offers the SPI model of cloud computing as a service (Dikaiakos et al.,2009). SaaS may run programs on demand and handle communication between numerous channels, like police, hospitals, and insurance, using one version of the software that runs in the cloud. By using Platform-as-a-Service (PaaS), a user has the option of deploying programs they have either created themselves or purchased into a cloud architecture. a service that offers a layer of software as a service that hospitals, trauma centers, and insurance providers can use to create higher-level services. Insurance businesses and traffic police, who demand services like storage, require IaaS. IaaS assesses capabilities through modulated services that are provided across the network to satisfy the requirements of various agencies, like the police and insurance companies.

2.3 Edge Computing

The growth of the Internet of Things (IoT) has allowed a variety of widely dispersed things to connect to and communicate with one another, creating previously unheard-of data explosions. Cloud computing has been used to process these data bursts due to its fast-processing speed and large storage capacity (Bittencourt et al., 2018). Although real-time or latency-sensitive applications are increasingly in demand, and network bandwidth restrictions are becoming the bottleneck of cloud computing for such a vast volume of data, these problems still cannot be handled by employing simply cloud computing. Therefore, a new computing paradigm, known as Edge computing, has been proposed as a complement to the cloud solution.

Edge computing attempts to boost low-latency, mobility, network bandwidth, security, and privacy by bringing compute, communication, and storage closer to edge devices and end users and extending cloud services to the network's edge. These are just a few IoT application examples that may demand lightning-quick response times and mobility capabilities, making data transfer delays intolerable. Just a few more examples of latency-sensitive applications include smart grids, smart healthcare, smart transportation, and emergency response.

Processing lags and resource congestion will increase as more IoT applications need to be addressed (Devi and Muthuselvi, 2016). Since edge computing mixes network edge devices and cloud data centers with ease, it is marketed as a more realistic method to overcome these constraints.

Numerous heterogeneous devices at the network's edge are continuously connected to one another to collaboratively provide elastic compute, communication, and storage services in a geographically distributed computing architecture known as fog computing (Abirami and Chitra, 2020). The main characteristic of fog computing is the extension of cloud services to the edge of the network. It brings processing, communication, control, and storage closer to end users by combining local resources. Data is used by the widely scattered network edge devices. Network transmission volume and data transfer time are significantly reduced as a result (Tao et al., 2019). The fog paradigm successfully addresses real-time or latency-sensitive application requirements and dramatically decreases network bandwidth limitations.

2.3.1 Edge Computing Architecture

For edge computing, a variety of architectures have been put forth. Most of them are derived from the basic three-layer structure. In order to address these issues with low latency, high reliability and security, high performance, mobility, and interoperability, edge computing adds an additional resource-rich layer between end devices and the cloud. The hierarchical design of fog computing is depicted in Fig. 2.4.

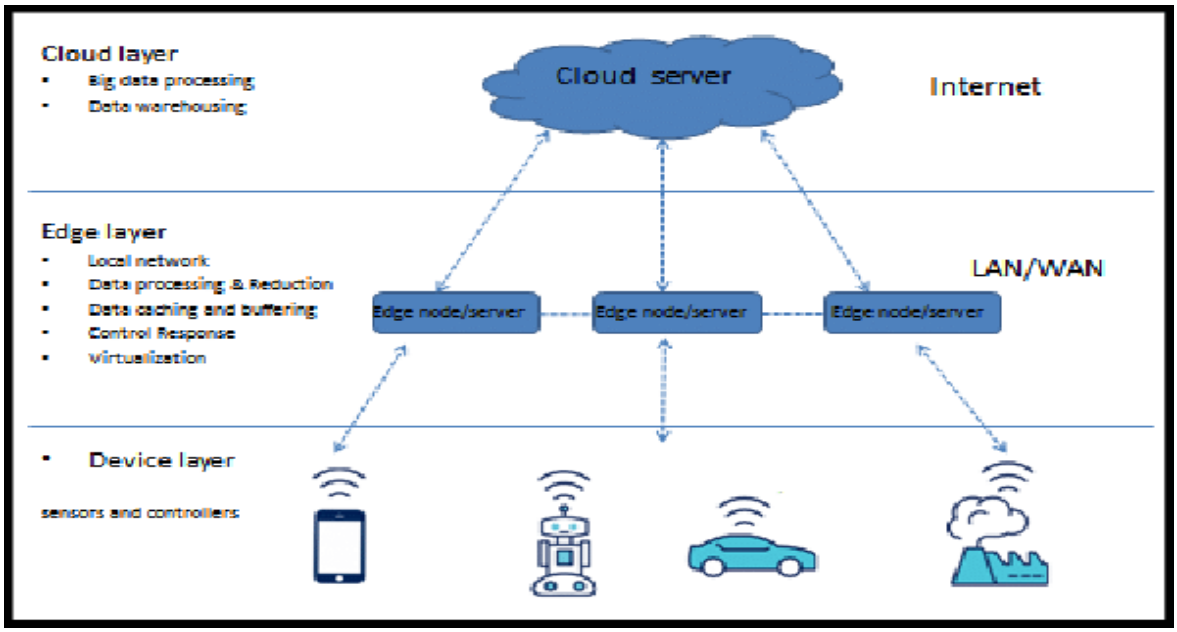

Fig 2. 4 Hierarchical architecture of Edge computing (Tao et al., 2019)

The hierarchical architecture is composed of the following three layers:

Device layer: This layer is the one that is closest to the user and the real world. It includes a range of IoT gadgets, including sensors, smartphones, automated driving systems, smart cards, readers, and more. These gadgets are typically geographically widely scattered. They are responsible for collecting feature data from real objects or events and transmitting it to a higher layer for processing and storage.

Edge layer: This layer is located at the edge of the network. The edge computing layer is composed of numerous edge nodes, including routers, gateways, switchers, access points, base stations, specific fog servers, etc. They have the tools necessary to analyze, transmit, and temporarily store the detected data they have just acquired. Applications that require real-time analysis and are sensitive to latency can employ the edge layer.

Cloud layer: The cloud computing layer, which is composed of numerous high-performance servers and storage devices, provides a variety of application services, such as smart homes, smart factories, and smart transportation.

2.3.2 Characteristics of Edge Computing

Edge computing carries out the tasks of computation, communication and storage on near-user network edge devices. Its service capabilities to the end users are the most basic

characteristic of edge computing and the most significant advantage compared with other traditional computing models. Furthermore, there are some characteristics and advantages listed as follows:

A. Low latency and real time interactions

Edge nodes at the network edge locally acquire the data generated by sensors and devices, process and store data by network edge devices in local area network. It significantly reduces data movement across the Internet and provides speedy high-quality localized services supported by endpoints.

B. Save bandwidth

Edge computing performs data processing and storing between end nodes and traditional cloud by extending compute and storage capabilities to the network edge.

C. Geographical distribution and decentralized data analytic

In contrast to cloud computing, which is more centralized, edge computing services and applications support geographically distributed deployment. It is made up of many widely scattered nodes that can track and determine the positions of end devices in order to support mobility. The decentralized design of edge computing means that data analytics are close to the customer rather than processing and storing data in a centralized data center remote from the end-user.

D. Heterogeneity

Edge nodes are typically deployed in a range of environments and exist in a number of form factors, including physical nodes and virtual nodes (Yousefpour et al., 2019). High-performance servers, edge routers, gateways, access points, base stations, etc. are typically included.

E. Interoperability

Edge nodes and end devices are typically deployed in separate contexts because to their diverse nature, which allows them to come from different suppliers. To handle a wide range of services and smoothly support some services, edge computing must be able to interoperate and collaborate with many suppliers (Yousefpour et al., 2019).

2.3.3 Comparison of Cloud, edge and fog computing

Table 2. 1 Comparison between Cloud, edge and fog computing

Parameters	Cloud computing	Edge computing	Fog Computing
Architecture	layered	Hierarchical & distributed	Hierarchical & distributed
Latency	High	Low	Low
Real time communication	Supported	Supported	Supported
Mobility	Restricted	Supported	High
Number of Server nodes	Few	Large	Large
Geographical distribution	Centralized	Decentralized	Decentralized
Proximity to end devices	Far	Near	Near
Energy consumption	High	Low	Low
Bandwidth cost	High	Low	Low

2.3 Existing Accident detection and Notification Frameworks

A basic overview of current and selected road accident detection frameworks is given in this section. These frameworks apply a technique that notifies the emergency center of the accident's crucial information in a considerably shorter amount of time using automatic accident detection. These gadgets make use of smartphones, GSM, GPS, VANET, and mobile applications.

2.3.1 Smartphone based Framework

In order to deliver the information in the case of a traffic incident, smartphone-based accident detection (Fig. 2.5) uses Internet services provided by a cellular network operator. The precise position of the accident scene is determined by the GPS system.

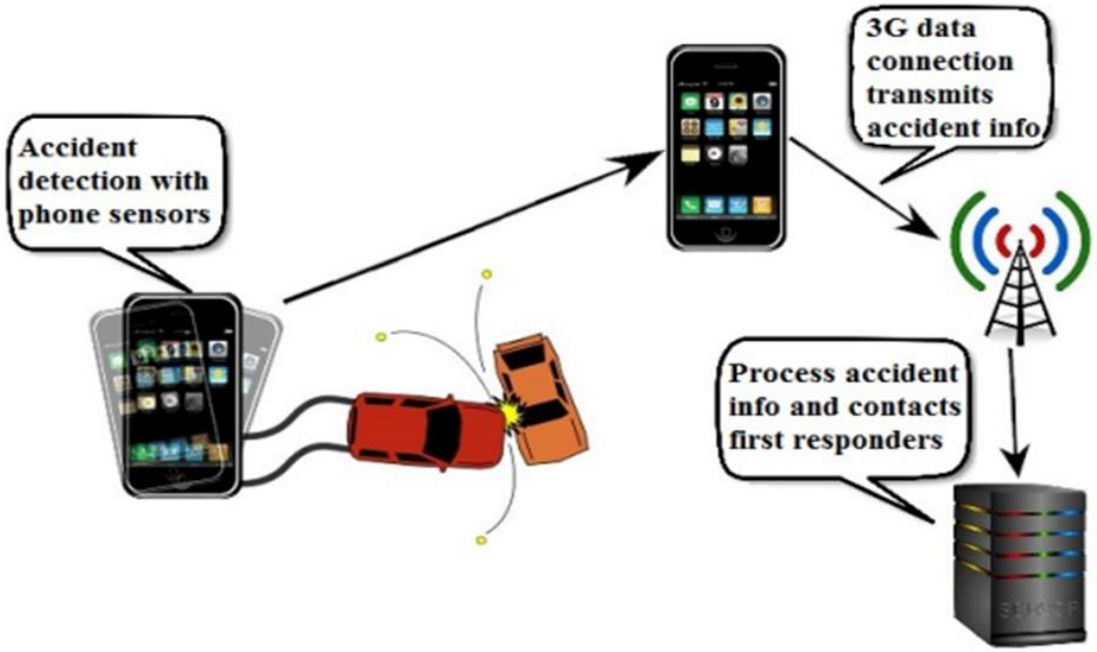

Fig 2. 5 Smart Phone based accident handling mechanism (Ahmad, 2018)

The automatic detection of accidents using mobile devices is described in (Ahmad, 2018). Automakers like GM and BMW have implemented an automatic accident reporting system, as can be shown in Fig. 2.5. They use sensors like accelerometers and airbag deployment monitors in their vehicles to detect an accident incident, and they subsequently transmit this information to the response center via the onboard cellular radios. Sadly, most automobiles don't have a system for automatically alerting the driver to a collision. Instead, a smartphone is used, which not only detects accidents but also automatically communicates this information to the appropriate department. When compared to automatic collision notification systems, smartphones have a number of advantages, including portability and the capacity to provide accident detection notification systems in various types of vehicles, including motorbikes and bicycles. Furthermore, because every smartphone is associated with its user, it is easy to identify the victim. When a collision occurs, a smartphone's sensors identify the GPS location, speed, and acoustic signature of the vehicle and send this

information to a central server, which subsequently sends it to the emergency department, using a built-in cellular connection.

2.3.2 GSM and GPS based Framework

Accident detection system employing GPS and GSM (Fig. 2.6); data is delivered via GSM cellular technology in the event of a traffic accident. The location of the accident scene is determined using the GPS system. (Zhang et al., 2010) Shows autonomous accident detection and communication using GSM and GPS technologies. The GPS satellites are used to pinpoint an incident's exact location, speed, time, and direction. The pre-recorded numbers are informed of the vehicle's specific position using GSM. Values for latitude and longitude are included in the message. To locate the accident, one can use these values. A GSM modem allows two-way communication similar to a regular phone using a sim card.

Fig 2. 6 GSM and GPS based Accident detection Mechanism (Zhang et al., 2010)

2.3.3 Vehicular Ad-hoc Network (VANET) based Framework

The VANET-based accident detection system uses an ad hoc network to connect moving automobiles to notify the emergency department of an accident (Fig. 2.7). Vehicular ad hoc networks involve communication between vehicles as well as communication between vehicles and infrastructure (VANETs). An accident management system that integrates VANET with systems that use cellular technology in public transportation enables the potential of real-time communication among cars, ambulances, hospitals, roadside units, local authorities, and cloud servers. An innovative smart phone integrated driving safety app and a traffic light priority control system are modeled in (Gabauer and Gabler, 2005) in an

effort to make room for emergency cars. Road Side Units, a server, and Management of Road Traffic Information Retrieval in VANET Environment.

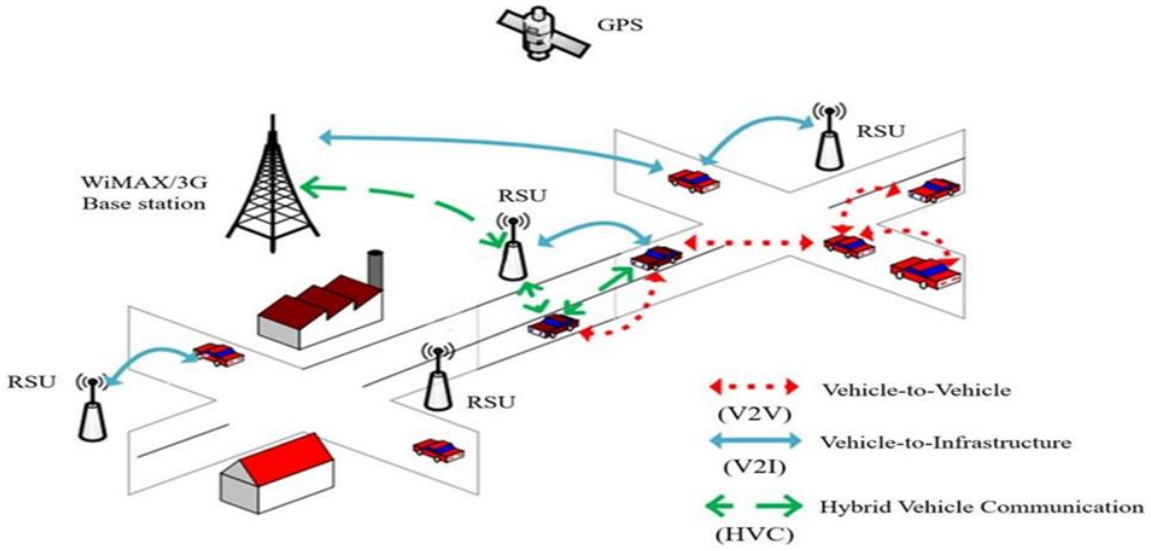

Fig 2. 7 VANET Based Accident Handling Mechanism (Khan et al., 2018)

The VANET accident detection method in (Khan et al., 2018) makes use of an airbag system and a collision sensor. VANET, an ad hoc network connecting moving vehicles, relays the communication to the rescue team. The transmission is sent across the VANET to the rescue team. An warning message is issued, starting with broadcasting to every vehicle on the road from a source node. The VANET structure is made up of the On-Board Units (OBU), which are fixed within the vehicle, and the Road Side Units (RSU), which are fixed alongside the road. The OBU and RSU communicate with one another via dedicated short-range communication (DSRC) (Dar et al., 2019).

2.3.4 Using Mobile application-based frameworks

When an accident occurs, a mobile application-based accident detection system immediately detects it and dials 911 over a mobile network operator. (Thompson et al., 2010) Presents smartphone applications for accident detection. the action taken by the European Commission to make it mandatory for all automobiles to have the eCALL Mobile application installed. The mobile application eCALL automatically recognizes an accident. Calling the emergency number after an accident alerts the emergency medical services that help is required. The call is made to the closest emergency facility through the cellular network. The application's graphical user interface (GUI) consists of a sizable square with one of the

colors reds, green, or yellow present. The hue denotes the state of the road at a specific time. On the GUI, there is a gray circle with text-based information inside of it. On the GUI, you can examine the traffic situation, the position of a dangerous situation up ahead, or the site of an accident.

2.4 Challenges Associated with Existing architectures

The difficulties in detecting auto accidents and communication systems are discussed in this section. The lack of connection between the smartphone and the vehicle is a significant obstacle in the development of software to detect crashes. Contrarily, traditional in-vehicle auto accident detection systems rely on internal sensors (such as airbag deployment sensors) and can infer that any incidence of significant acceleration or deceleration is the result of an accident. Smartphone applications that aim to replace or improve the functioning of traditional in-vehicle systems must reconsider these presumptions.

2.4.1 Detecting Accident without Electronic Control Unit Interaction

Conventional in-vehicle accident detection systems communicate directly with the vehicle's electronic control units and rely on sensor networks throughout the vehicle (ECUs). Airbag deployment, vehicle rollover, and acceleration/deceleration are all detected by these sensors. The location of the vehicle's point of impact, the number of times it was struck, the severity of the collision, and airbag deployment are just a few of the metrics from these sensors that help create a thorough accident profile. Applications for detecting accidents on smartphones must deliver comparable data. But gathering data about the car is more difficult without direct access to ECUs. It is impractical to expect drivers to connect their cellphones to these accident/event data recorders (ADRs/EDRs) every time they get in the car, which would require a standardized interface (physical and software) to ensure compatibility. This is true even if many cars feature ADRs/EDRs. Furthermore, although while many modern vehicles feature ADR/EDR, any smartphone application that necessitated communication with an onboard computer would be useless in vehicles without one. Therefore, it is important to gather the same or comparable data using only the smartphone's built-in sensors.

2.4.2 Preventing False Positives

Vehicle-based accident detection systems monitor a network of sensors to determine if an accident has occurred. Instances of high acceleration/deceleration are due to a large change

in velocity over a very short period of time. These speeds are hard to attain if a vehicle is not controlled by a human driver, which simplifies accident detection since we can assume any instance of high acceleration constitutes a collision involving human drivers. However, since smartphones are portable, achieving such speeds is not as difficult. Because of the mobility of smartphones, it is difficult to programmatically distinguish between a real vehicle accident and a dropped pocketbook or a fall on a hard surface (Ali and Alwan, 2017). Smartphone-based accident detection programs may become ineffective by wasting emergency responders' time responding to incident reports that aren't auto accidents if they can't effectively recognize and reject false positives.

2.4.3 Interoperability Issues

Internet of vehicles (IoV) is becoming more prevalent in the automotive industry (Fernandes et al., 2015). Typically, an IoV ecosystem is made up of elements like on-board units, vehicle-to-anything communication, smartphones, mobile internet, etc. A task towards connecting resources of the cars over the internet for data analysis is the creation of an intelligent transportation system through communication with the outside world and with the vehicle itself. Monitoring traffic flow, road conditions, and pollution levels can all be done with the use of this information. The requirement for smooth interoperability support is one of the main issues with such a system. The system's heterogeneity in terms of the various components it contains is the fundamental cause of this. Different sensors that are installed in the cars can produce data in various encoding formats. Each sensor may communicate using a distinct radio protocol and representation of the data, in addition to utilizing a different protocol to represent the data.

2.5 Related work

In (Derdus and Ozianyi, 2014), the proposed system detects accident and severity of the emergency level with the help of mechanical (accelerometer) and medical sensors (pulse and muscle). After detecting basic information, installed server finds out the nearest hospital location with the help of GPS system. It sends a message for an ambulance. In order to clear the path on the way to accident's location, the client application on the ambulance generates alert messages.

In (Mell and Grance, 2011) the concept of cloud computing was developed by Cisco in 2015. Fog can be a low-power communication medium that expand the services provided by the

cloud the stitch of the web. In relation to the way in which the cloud manages information computing, storage and application services for end customers; fog also does the same. In fog computing, design, storage and application information is distributed geographically, not as in the cloud.

A system that ensures making emergency facilities available to accident victims as early as possible by letting relatives, hospital or a rescue team know the accident spot with the help of modules embedded in the vehicle (Nasr et al., 2016). GPS module to detect the accident location and Shock Sensors are attached to the microcontroller to determine the accident, GSM module sends a message with the information of accident location and the time to the predefined numbers so that help can be made available. The message sent with the help of the GSM module will appear like this - Message for accident: “Accident occurred. Please send help.”

The Proposed system in (Khaliq et al., 2019) presents the conceptual cloud-based architecture for intelligent transportation system. Cloud computing can be used to process time sensitive and location related data. The paper concludes that by shifting the boundaries of the data center service to a location-independent service (Cloud-Fog-Edge computing) it's possible to process location-related data.

In (Sanathra et al., 2019) the paper aims to design and implement a mobile application for car accident notification. It sends an electronic report and notification including the location and type of incidents. The paper depicts the framework of proposed notification system, which consisted of three phases: The first phase is the user needs to fill the required information of the incident involving car number, vehicle type, vehicle Status, a number of people dead and injured and the accident location based on Google Map and also photo for the accident to a mobile application. The second part of the framework is the communication and internet company, which provides the network users to access the World Wide Web and then send/receive data. The final face is the framework of the web-based notification system, which uses the stored information in the cloud storage for managing, sending a notification

Cloud computing can enhance the processing and storage capabilities of wireless sensor networks (WSNs) and improve the performance of WSNs in terms of energy consumption, analytics, computation power, computing latency, and quality of service (QoS). Therefore, merging WSNs and cloud computing is a trend that is expected to result in a computing

paradigm called sensor cloud (Ahmad, 2018). In sensor clouds, the weak communication capabilities of WSNs prolong data uploading to clouds and may thus impede the realization of this computing paradigm

The study in (Zaldivar et al., 2011) reveals that sensor clouds are largely responsible for the emergence of various smart community applications, such as real-time monitoring of agriculture and irrigation systems, by providing strong computation capabilities. A smart environment usually comprises thousands of dispersed sensors that are deployed to collect information on agriculture and irrigation systems. These data can be further stored, processed, and analyzed by using cloud services to constantly track the health of the crops. Furthermore, the study indicates that the data collected from smart transportation systems can also be processed in the cloud. Therefore, the status of the driver and fuel level can be determined, and the arrival time of smart vehicles can be predicted (Sneha and Gawande, 2013).

In (Leens, 2009), a major issue in sensor clouds is the transmission of repeated data from a cloud to sensor users, a procedure that usually increases demands on resources, bandwidth, and energy consumption. Another issue arises when multiple sensor cloud users simultaneously request the same data. In this case, large amounts of data need to be transferred concurrently from the cloud to users, leading to the consumption of increased resources in terms of energy and bandwidth.

A trust-assisted sensor cloud model has also been proposed in (Gabauer and Gabler, 2005) to improve the user experience. In the model, sensory data are collected from sensor nodes on the basis of the trust value assigned to the sensor node. If the sensor node trust value satisfies a certain threshold, which defines the trust level of the sensor node, then the data will be forwarded to data centers. The high computation capabilities of data centers allow for the efficient storage and processing of large amounts of generated data efficiently while maintaining the trust level. Although this model enables trust-based data collection on sensor clouds, the trust values are defined based on the negative and positive behavior of sensor nodes and data centers, which are not fully justified and may be impractical.

The authors in (Jia and Ngoduy, 2016) have presented a novel distributed, sustainable framework for data collection in cloud-based crowd sensing systems. The framework incorporates an opportunistic reporting mechanism that minimizes sensing and reporting

costs while maximizing the utility of data collection in a smart environment. The framework was deployed in a real urban environment with a large number of participants. This research analyzed the relationship between the cost imposed on participants and the information collected from the proposed framework. The results revealed that the framework helps minimize unnecessary energy consumption during data collection in sensor clouds. However, the presented model still requires caching policies for buffering and delivering data to the cloud.

A paper illustrated in (Udgata and Suryadevara, 2021) proposes a model that allows the sensor to monitor the patient's symptom by automating the method of gathering patient's data via sensors connected to medical devices and conveying this information to the medical centers cloud for the purpose of storage, processing, and dissemination using Docker container and raspberry pi. The collected monitored data transmitted to the gateway via Bluetooth and then to the cloud server through Docker container using the internet. Thus, enabling the physician to diagnose and monitor health problems wherever the patient is. As depicted in fig below the proposed system involves four main components: sensors, raspberry pi, server, and users.

Mobile cloud computing for emergency health care model, using a cloud computing server to reduce the responding time of emergency health care is presented (Abirami and Chitra, 2020). When a person is exposed to a health problem or a traffic accident is occurring, its process will start from mobile application with searching for nearest medical center or specialist; will get the data from cloud server. In addition, the user could be able to sort the results by availability time, specialization category or previous feedback and voting rates it could help the user to choose the better experience specialist. The model architecture consists database hosted in cloud server, mobile and web application.

A paper presented in (Fernandes et al., 2015) provides vehicle-based cloud architecture for smart transport management in major cities as depicted in Fig 2.8. These mechanisms are used to store information and allow heterogeneous communication between multiple devices, while simultaneously managing vehicle mobility and generating data flows.

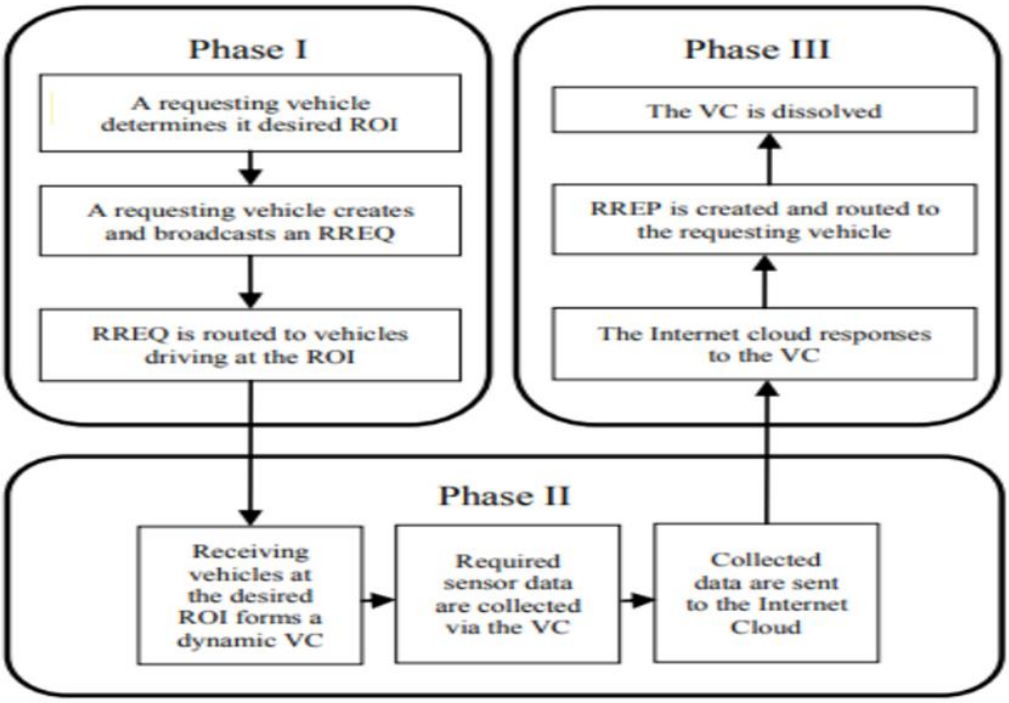

Fig 2. 8 Smart Transport Management system (Fernandes et al., 2015)

In (Zhang et al., 2010) propose a virtualized cloud-based System that enables health care's and first-responders to constantly monitor a patient's position and be alarmed in case of emergency. Positioning is made available through an embedded device carried by the patient that performs the proximity and cell identification techniques (Wi-Fi and GSM) also sends the geo location data to a Cloud-based application for further processing. In case that the patient drifts away from his/her premises, the application retrieves the closest-to-the-patient third party agents (hospital, police, volunteers, first-responders, etc.) through the Location-to-Service-Translation protocol, and alerts them about the emergency situation via a SIP-based VoIP communication channel.

In (White et al., 2011) it studied about how common home-based computing platforms become obsolete in dealing with large volume of data that require fast processing and resource-demanding infrastructure for rapid analysis and response, while sophisticated installations prove to be too costly. Thus, it proposes a Cloud Computing paradigm for remote resources provision along with the Services' Virtualization concept for assets' elasticity and scalability arise as the driving forces in AAL deployment, due to its omnipresence and resource-rich characteristics.

A paper presented (Khan et al., 2018) focuses on improving accident data collection by using a Smartphone-based application called CrashData. The application's aim is to improve data collection, while supporting mobility, ubiquity and accuracy. Using the application data are sent to a central database for storage and can be retrieved by the same application. The application provides a web interface for office-based managers, who can use Google maps to identify accident hotspots by mining location information from the database.

The heartbeat of the passenger and the tilt of the car are used to detect crashes in (Dar et al., 2019) presented, and the emergency services are notified using this information. Additionally, an accident was discovered by monitoring the vehicle's inbuilt GPS receiver data for abnormally rapid deceleration rates and recording it.

In an article (Ahmad, 2018), the Medium Access Control (MAC) layer in WSNs was examined in order to enhance the real-time data collecting method. In order to provide quick transmission of the detected events on the road towards the Traffic management services, it developed an updated backoff selection strategy for the IEEE 802.15.4 protocol. With this modification, messages reporting incidents or hazardous events are given less of a backoff than messages providing routine traffic or weather updates.

A work in (Todica, 2020) demonstrates how smart phones can act as a portable "black box" that can detect traffic accidents and record information about accident events by capturing the streams of data offered by their accelerometers, compasses, and GPS sensors. Additionally, WreckWatch, a mobile client/server application created to automatically detect automotive accidents, is shown as the architecture for detecting auto accidents.

Table 2. 2 Related work, their contribution and limitation

Title	***Year***	***Contributions***	***Limitation***
A Mobile Solution for Road Accident Data Collection system (Derdus and Ozianyi, 2014).	July 2014	Improved accident data collection using smartphone app.	The system has few users.

An IoT approach to vehicle accident detection, reporting, and navigation (Nasr et al., 2016).	2016	Conveyed IoT based system to notify and locate accidents.	The system works only on preinstalled mobile application.
Road Accidents Detection, Data Collection and Data Analysis Using V2X Communication and Edge/Cloud Computing (Khaliq et al., 2019).	August 2019	Provided a low-cost multi-tier approach for detection and notification of accidents	The application of on-board unit is not feasible in the current vehicles
Car Accident Detection and Notification System Using Smartphone (Ali and Alwan, 2017).	April 2017	Conveyed a mechanism to detect accidents at a low and high speed.	System lacks the functionality to send emergency notification to the nearest emergency center.
Providing Accident Detection in Vehicular Networks through OBD-II Devices and Android-based Smartphones (Zaldivar et al., 2011).	2011	Offered a new smart vehicle paradigm.	The maintenance process of system is expensive operation.
Utilizing the Emergence of Android Smartphones for Public Welfare by Providing Advance Accident Detection and Remedy by 108 Ambulances (Patel, 2013).	2013	Studied key issues in advance accident detection and emergency responses	The probability of false positive will be increased and false alarm will be reported because of phone tilt.

Automatic Accident Detection and Reporting Framework for Two-Wheelers (Mell and Grance, 2011).	2011	Proposed and cheap intelligent frame work for two wheels.	There is no emergency response. It's limited to accident detection.
Mobile Application for Automatic Accident Detection and Multimodal Alert (Meena et al., 2014).	2014	Increased communication efficiency by using multimodal alert	Using a smartphone to detect accidents lowers the reliability as false positives might be triggered.
Delay-Aware Accident Detection and Response System Using Fog Computing (Dar et al., 2019).	2019	Utilized fog computing to minimized delay in emergency response	Energy consumption that comes with fog computing is high and also the security of such computing.
Using Smartphones to Detect Car Accidents and Provide Situational Awareness to Emergency Responders (Thompson et al., 2010).		Studied key issues and proposed smartphone-based accident detection.	The sudden acceleration leads to false alarm

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Overview

This research studies issues that a rise regarding accident detection, notification and collection of relevant data's that stakeholders (drivers, passengers, emergency responders) might face during a car accident. In this chapter the research methodologies such as methods, techniques and tools used to complete the study are discussed.

3.2 Research Design

The research design is intended to provide an appropriate framework for a study. A very significant decision in research design process is the choice to be made regarding research approach since it determines how relevant information for a study will be obtained; however, the research design process involves many interrelated decisions. Hence, this study employs a descriptive research design to provide cloud-based accident detection, notification framework. Descriptive research portrays an accurate profile of persons, events, or situations. This design offers to the researchers a profile of described relevant aspects of the phenomena of interest from an individual, organizational, and industry-oriented perspective. A descriptive research design which is the type of quantitative designs is the best approach since descriptive research measures the results at a moment in time. It is applicable to phenomena that can be expressed in terms of quantity or number. Therefore, a quantitative design is used to manipulate the data and to evaluate the prototype results on this study.

During designing the proposed framework, we have tried to maintain the essential characteristics of cloud computing, hardware resources such as the networks, storage and etc. as well as software components, services and the relationship between these entities. Therefore, researchers need to deeply visualize the possible solutions and decide for the optimum solutions by focusing on some design principles. The overall methodology of the study is presented in Fig 3.1.

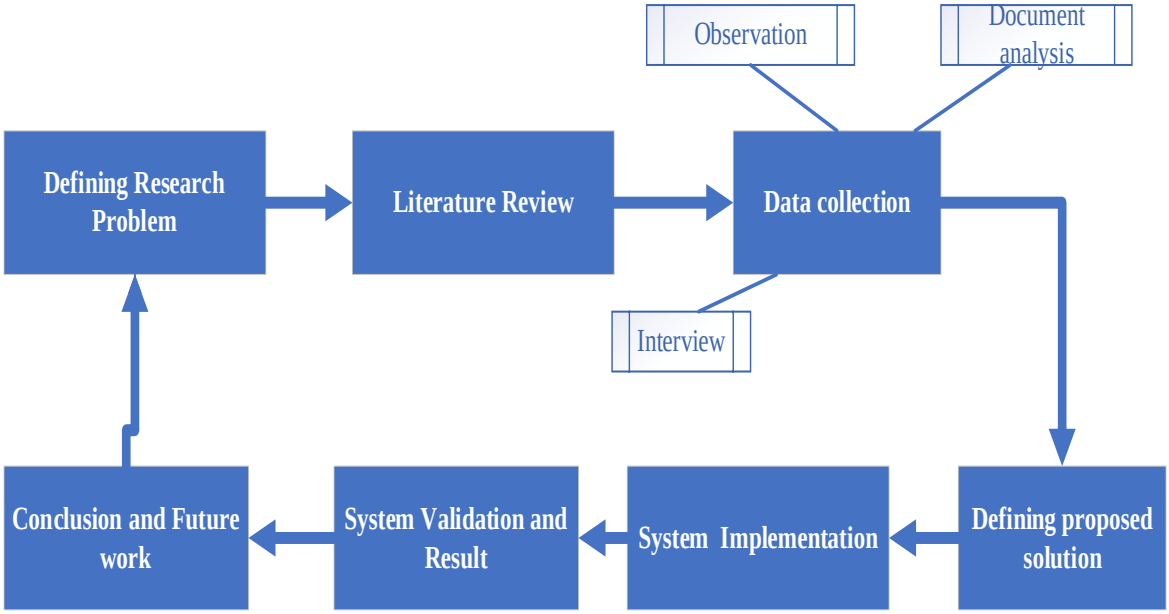

Fig 3. 1 Research Design Process

3.3 Data collection technique

This study employed a mixed type of methods. The first part of the study consisted of a series of one-on-one interviews with key stakeholders (managements, government bodies and industries experts) to know how they feel about accident handling mechanisms already deployed and field observation is undertaken. A secondary data was collected by using document analysis from different sources like conference articles, reports, thesis, journal and white paper from research links such as Google scholar, SpringerLink etc.

The primary data collection enables to collect a written document such as organization's rule and regulations as well as how Road traffic accident is detected, notified to the emergency responders and how relevant information's are handled for future use. It also gives requirements of the stake holders and how the current solution can be enhanced. And the secondary data collection allows identifying methods and techniques to include in the proposed framework and to address the identified requirements.

3.4 Framework Development

After engaging several stakeholders (Transport sector managements, passengers and relevant others) to identify existing challenges and requirements. And by studying several state-of-the-art solutions and emergency response frameworks a multi-tier cloud-based framework (Vehicular, edge gateway and cloud platform tier) to collect traffic data and

notify accidents is proposed. The detailed architecture and the functionalities of each tier of the proposed framework has been discussed in chapter 4.

3.5 Evaluation Methodology

The evaluation of the framework criteria for the proposed framework were prepared based on the enhancement it provides, feasibility, requirements identified are achieved or not, and weather proposed framework achieves the required objective or not. Finally, the evaluation was performed by the developer during the implementation of the prototype and results are presented in chapter 5.

3.6 System Development Tools

In this study the following development software tools are used to implement different parts of the proposed framework.

- Node.JS: is an open-source JavaScript runtime environment used to develop the backend server for the edge gateway platform and also used as frontend tool to develop emergency responder application.
- Microsoft Visio tools for designing diagram associated with the thesis.
- Microsoft Office: for documentation of the whole thesis.
- Google Maps API: To visualize geographic locations
- Arduino Integrated Development environment (IDE): used to develop sketches for the accident detection mechanism of the framework.
- C programming language is used to write a sketch for accident detection of the prototype
- Necessary and used hardware tools have been explained in their respective section of the proposed framework.

CHAPTER FOUR

PROPOSED FRAMEWORK

4.1 Description of Proposed solution

The proposed multi-tier architecture for “Cloud-Based Intelligent Frame Work Design to Collect Traffic Data and Notify Accidents: In the case of Addis Adama Expressway” is described in the part that follows. The overall suggested multi-tier emergency response framework is divided into two sub-tasks: the first portion concentrates on the module that seeks to identify an accident and notify the control room with pertinent information. The second section focuses on the analysis of saved data, such as accident locations, causes of accidents, injury and fatality statistics from accidents that occurred in a certain area, to determine why the accidents occurred. The suggested system is made up of a number of parts, each serving a different purpose, i.e., On-board unit, Edge node (Control unit) and Cloud platform as shown in Fig 4.1. First, the vehicles ought to have an on-board unit (OBU) that can automatically identify accidents and transmit relevant information about them. The in-vehicle OBUs continuously track the vehicle's acceleration and orientation in order to spot accidents. When an accident occurs, the most crucial information, including the vehicle's license plate number, the position (latitude and longitude) and type is sent to the adjacent Edge node (Control Unit). Combining V2V and V2I communications allows for the notification of detected accidents. The vehicle can produce messages to be broadcast by neighboring cars until they reach the control unit if it cannot gain direct access to the Control unit (CU) on its own.

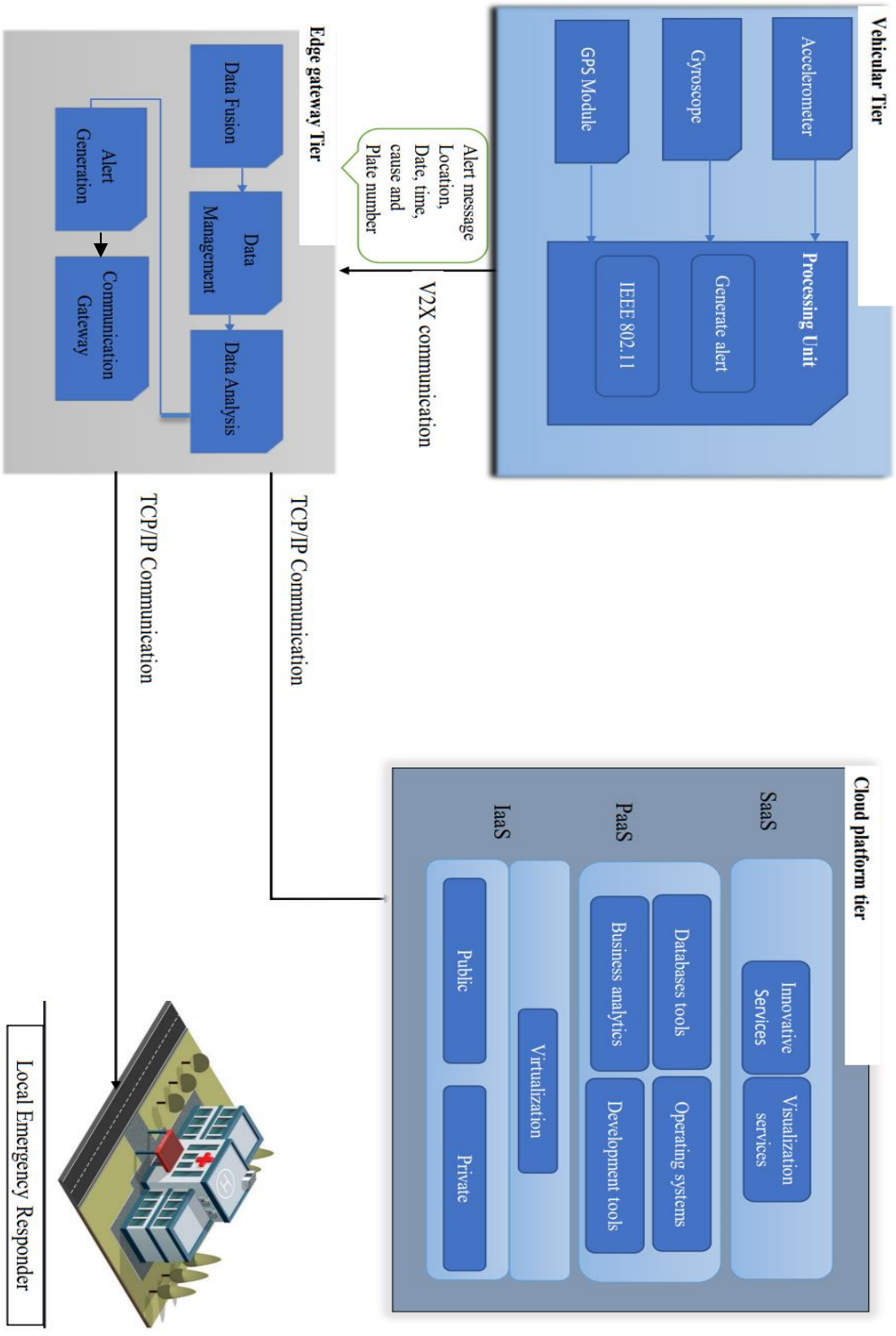

Fig 4. 1 Proposed multi-tier architecture

These messages, when disseminated among the vehicles in the area where the accident took place, also serve the purpose of alerting drivers traveling to the accident scene and its possible interference on the normal traffic flow. An efficient warning message dissemination protocol should be used in order to select the most appropriate forwarding node for the

message (Meena et al., 2014). This allows maximizing the percentage of informed vehicles and reducing the time elapsed between the accident occurrence and its actual notification to each specific vehicle while simultaneously reducing the amount of traffic generated in the wireless channel.

The control unit is the second tier of the suggested architecture (CU). It is more manual to manage and interpret the recorded data at the Edge because all of the smart gadgets are mounted on-board inside the car. Instead of being at the far-off cloud in this instance, the Edge node is located nearer the source of data generation. Additionally, just the processed data needs to be transferred to the cloud, reducing network traffic, rather than all of the recorded data. The control unit's Edge node is in charge of receiving the warning message sent by the OBU, preprocessing it, temporarily storing it, and notifying the necessary emergency services and the cloud server of the situation. It is expected that each control room in each zone of the city is linked to the cloud platform. Therefore, the locally obtained data information (from a specific zone) is transferred to the cloud for additional data analysis.

Cloud Platform is the third tier of the architecture. which is set up in a cloud accepts alerts for accidents and acts appropriately. The cloud platform is in charge of storing and retrieving data from data packets that have been received. Additionally, the sensor data may yield insightful details on the frequency of incidents over time, across various Zones. And on the basis of it, the cloud platform handles data visualization utilizing a variety of tools. Based on the specified architecture above in the subsequent section we will explain about the detailed architecture, working mechanism and implementation of each tier i.e., On-board sensors, IoT or Edge gateway, and Cloud platform of the proposed architecture

4.2 Tier one On-board Unit

4.2.1 Overview

Through an OBU of the proposed system, we will attempt to illustrate the overview of the accident detection and notification tier in this part. The primary goal of the OBU is to gather information from sensors inside the vehicle to identify potentially accident situations and report them to the closest Control unit. The OBU should feature accident detection, timeliness, reliability and sending alert notification to the control-room. These features in a particular system can help to identify an unpredictable situation on the road like accidents. When an accident occurs and the system knows about the incident, then it can provide the

ease to the people who are offering the rescue services, thereby, it can efficiently improve the probability of victims survive. Moreover, the system has to be delay-sensitive to detect an accident. According to Fig. 4.2, every vehicle inside a given zone of the system is outfitted with an OBU that has embedded esp8266, GPS, and MPU6050 modules. These modules aid in the accident detection, and the OBU processing unit is utilized to process the information gathered. Vehicle to infrastructure (V2I) communication is used to send an alert message to the deployed control room in a specific area when an accident is discovered. The control room keeps track of any accidental data and notifies the hospital of an emergency so that first help can be provided.

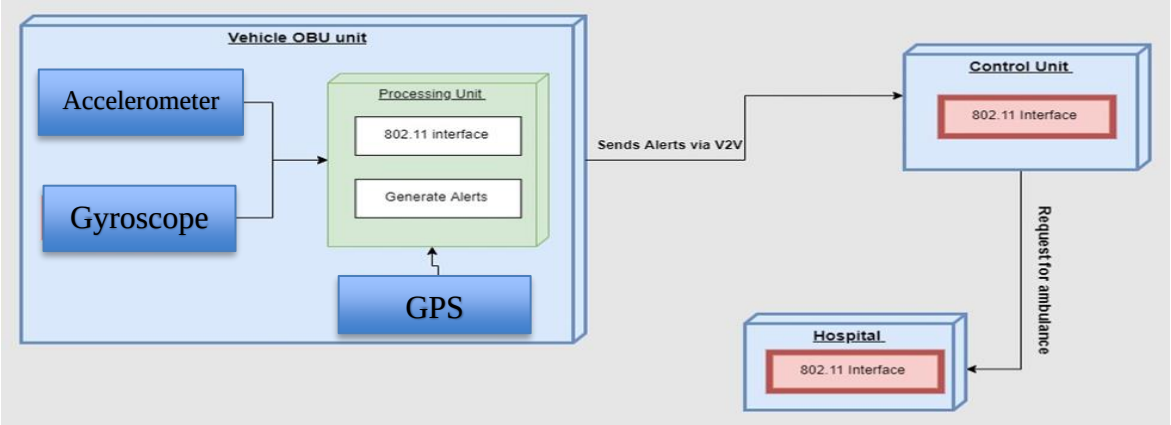

Fig 4. 2 Proposed system architecture of automatic accident detection and notification

4.2.2 Internal structure of OBU

The OBU main goal is to detect collisions by keeping an eye on sensor data that should be mounted within the car as an On-Board-Unit (OBU). The OBU system is shown in Fig. 4.3. Before sending an alarm to the control room, this OBU evaluates and verifies the data that has been collected. The following hardware is used by the prototype application that has been implemented and by the in-vehicle OBUs.

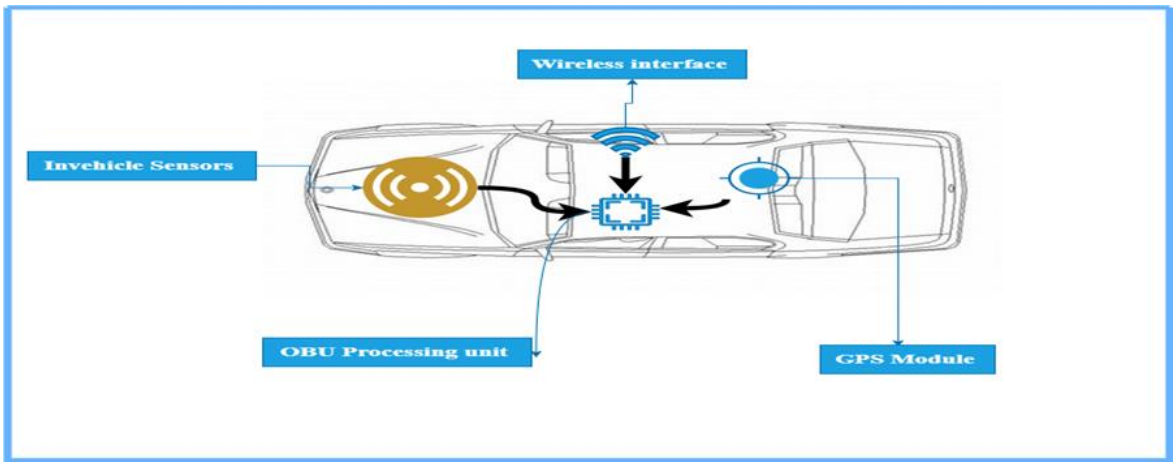

Fig 4. 3 On Board unit internal structure

The in-vehicle sensors are required to gather specific information about the vehicle. The OBU processing unit is in charge of gathering, interpreting and processing the data from sensors to determine whether an accident occurred, and notifying dangerous situations to nearby vehicles and to the CU using wireless interface. Also, this unit should able to have access to a positioning device such as a global positioning system (GPS).

4.2.3 Selection of compatible hardware

ESP8266

ESP8266 is built on the open-source, Lua-based ESP8266-12E WiFi System-On-Chip by Esperessif. It is ideal for Internet of Things applications and other circumstances requiring wireless connectivity. An open-source, inexpensive, low-power MCU (microcontroller unit) development board is the ESP8266ESP8266 wifi module. It includes 17 GPIO pins, 11 of which are digital I/O pins, 1 analog pin, 4 PWM pins, 2 pairs of UART pins. ESP8266 has a maximum clock speed of 160MHz, 128Kb of RAM, and 4 MB of Flash memory (80 -160). 80mA is the operating current (average). The ESP8266 integrates an 802.11b/g/n HT40 Wi-Fi transceiver chip for Wi-Fi connectivity, giving it the added benefit of being able to set up its own network and accept connections from other devices. This chip and the Arduino are both prototyping boards containing microcontrollers that can be programmed using the Arduino IDE, thus they have a lot in common (Todica, 2020). We selected this specific board due to its built-in support for IoT and Arduino ide.

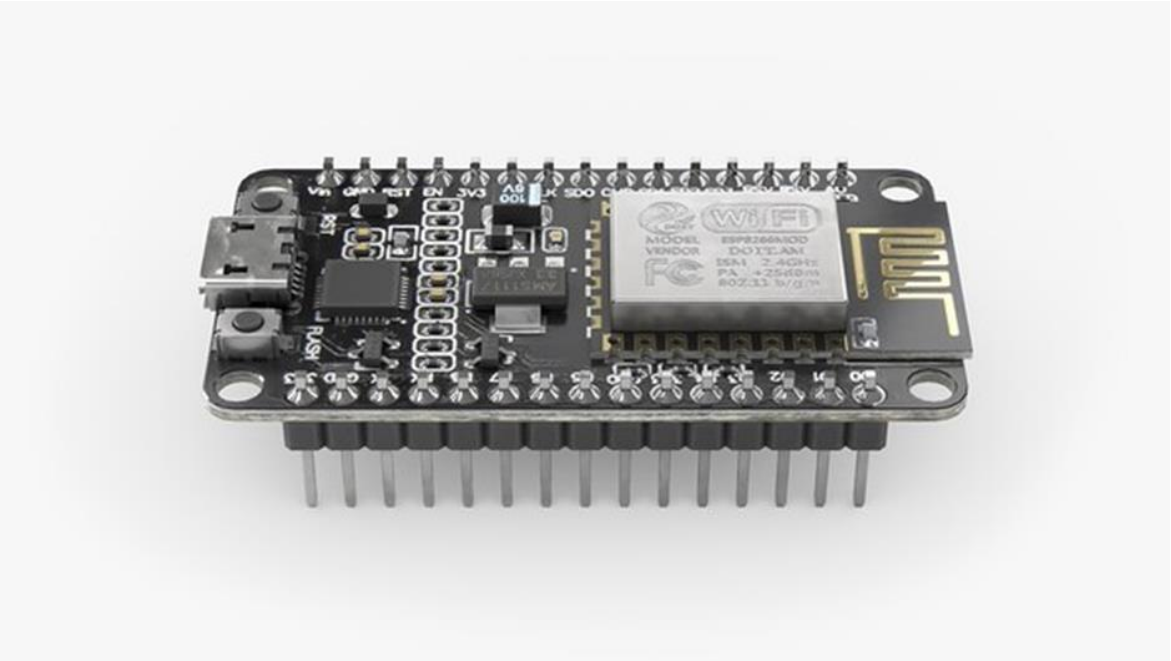

Fig 4. 4 Node MCU esp8266

Inertia measurement unit sensor

In order to detect an unexpected, abrupt, or sudden change in the speed or trajectory of a vehicle while driving, one needs an accelerometer, an effective electromechanical instrument. An MPU-6050 Inertial Measurement Unit (IMU) is used in this prototype. MPU-6050 is made up of a three-axis accelerometer and a three-axis gyroscope. It aids in the measurement of motion-related characteristics such as velocity, direction, acceleration, and displacement. The acceleration forces on each axis are provided by the accelerometer, and the rotation angles on each axis are gathered using the gyroscope. An electromechanical device called a triple-axis accelerometer measures acceleration force. These forces might be static, like the continual pull of gravity on your feet, or they might be dynamic, brought on by the accelerometer moving or vibrating. The MPU-6050 accelerometer (Fig. 4.5) offers a programmable range of 2g, 4g, 8g, or 16g, while the gyroscope has a range of 250°/sec, 500°/sec, 1000°/sec, or 2000°/sec. We chose accelerometer and gyroscope parameters that are suitable for a moving vehicle: 8g and 500°/sec, respectively. Inter-Integrated Circuit communication protocol, also known as I2C protocol, is used by Node mcu and MPU-6050 to connect with one another (Leens, 2009). Due to its compatibility with the Node mcu board for exact readings, we chose this particular model of sensor.

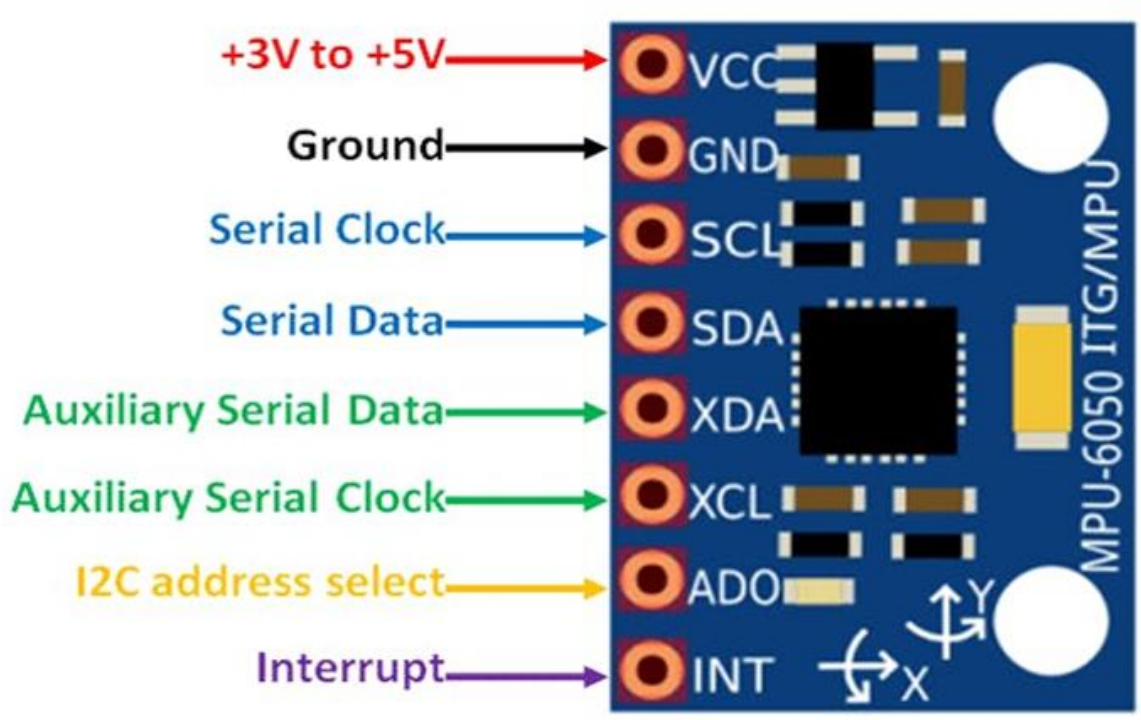

Fig 4. 5 MPU 6050

GPS Module

The precise location of the accident must be determined in order to deliver medical care and first aid quickly. Neo-7M GPS Chip (Fig. 4.6) board was employed in our prototype to pinpoint the accident's site. Satellite signals are used by the GPS to calculate an object's current location, time, and velocity. The breakout board is based on a GPS chip from U-box called the NEO-7M, which is a premium GPS module with an integrated antenna. It has the industry's highest tracking sensitivity (-161 dB), can monitor up to 22 satellites over 50 channels, uses just 45 mA of current, and can update its location five times per second.

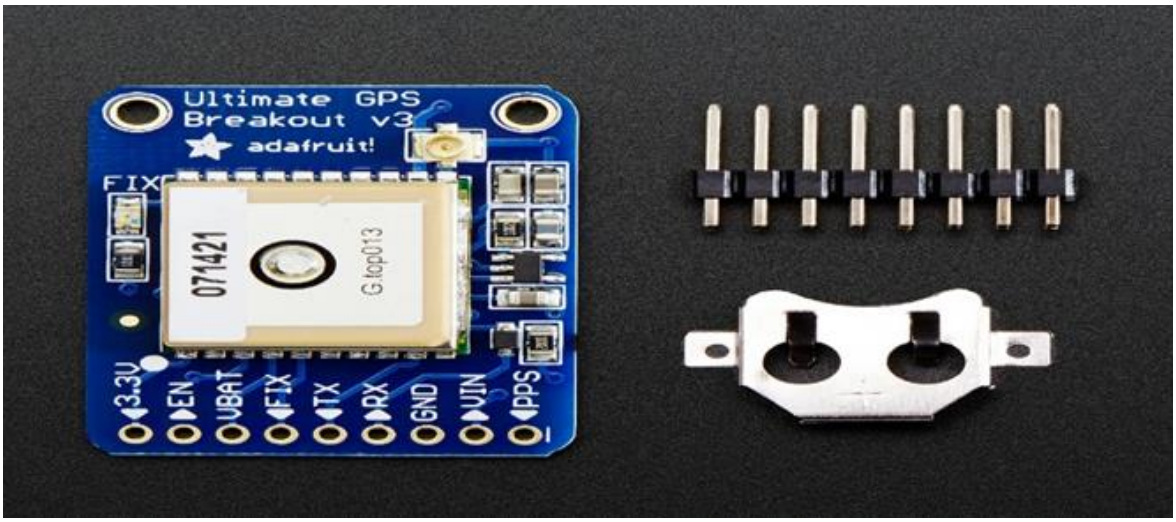

Fig 4. 6 GPS Module

4.2.4 Accident detection mechanism

Determining the occurrence of accident is the OBU's initial objective. When it comes to traffic accidents, there are two key events that set them off. According a study made by (Abera, 2019) a total of 1,348 vehicles were involved in road accidents in Addis Adama expressway in the first three years of its launch. of all this about 33.5% of accidents occurred due to rear-end collision while about 31% occurred due to vehicle rollover. Based on this we started the process of detecting a road accident using these primary events, namely collision and roll-over. A car may collide frontally, laterally, rearward, or even diagonally during a traffic accident. All those forms of accidents should be recognized in order to create an efficient autonomous accident detection mechanism because any of those directions could result in an accident.

Scenario I Collison

An object slamming into another one causes a collision, which is a situation where there is an abrupt change in speed. A mobile vehicle's speed rapidly slows whenever it strikes a stationary object or another moving vehicle approaching from either direction, which could lead to passenger casualties. The direction, alignment, and speed of the two objects colliding determine the severity of the collision. This implies that an important characteristic for collision/accident detection systems to take into account is the acceleration produced after a vehicle incident. Acceleration is the term used to describe the change in speed (V) with time (V/t). In their research on accident detection systems, authors (Sanathra et al., 2019) utilized

the 4g (g = 9.8 m/s2) threshold as the point at which a road vehicle accident occurs. European Standard EN1317 (Gabauer and Gabler, 2005) defines Accident severity index (ASI) to evaluate road side restraints that are employed to lessen the severity of crashes. This standard has levels of acceleration severity index (ASI) to quantify the severity of a collision impact. The impact severity level A is the least severe, while the most severe level is C. This indicates that there is a chance of suffering a significant injury on level B and higher. We have used tri-axial accelerometer to measure the longitudinal (a_x), lateral (a_y), and vertical (a_z) acceleration components in order to detect the accident. By taking shift in two subsequent readings using an accelerometer and a set sampling rate δt. If the condition exists at time t, a collision detection event is initiated under the assumption of a predetermined threshold value ΘC to reduce false alarms.

$$\frac{\sqrt{(a_x(t)-a_x(t-\delta t))^2+\left(a_y(t)-a_y(t-\delta t)\right)^2+(a_z(t)-a_z(t-\delta t))^2}}{\delta t} \geq \Theta C \ldots\ldots \text{Eq 4.1}$$

Holds true. Here, a_x,a_y,$a_z$denote the acceleration measurements in the body frame coordinate system of the accelerometer.

Scenario II Roll-over

Vehicle rollovers frequently result in more severe injuries and greater vehicle damage, making them riskier. In the event of an incident, vehicles may roll over, which is a situation that could result in serious injuries or even fatalities to passengers. When a vehicle flips over, it has rolled off its main axis. Analyzing the rotation of the car's three major axes over time is important to find such rotations. In order to minimize false alerts, we specify a threshold angular speed ΘR (47 deg/sec or 1 rad/s) leads to rollover of the vehicle that is equivalent to the scenario where a collision happens. Then, a roll-over detection event is triggered at time t, if the condition

$$\sqrt{\left(v_\phi(t)\right)^2+\left(v_\psi(t)\right)^2+\left(v_\zeta(t)\right)^2} \geq \Theta_R \ldots\ldots\ldots\ldots \text{Eq 4. 2}$$

holds true. In this context, vϕ, vψ and vζ denote the angular velocities for pitch, roll and yaw in the body frame coordinate system of the gyroscope, respectively.

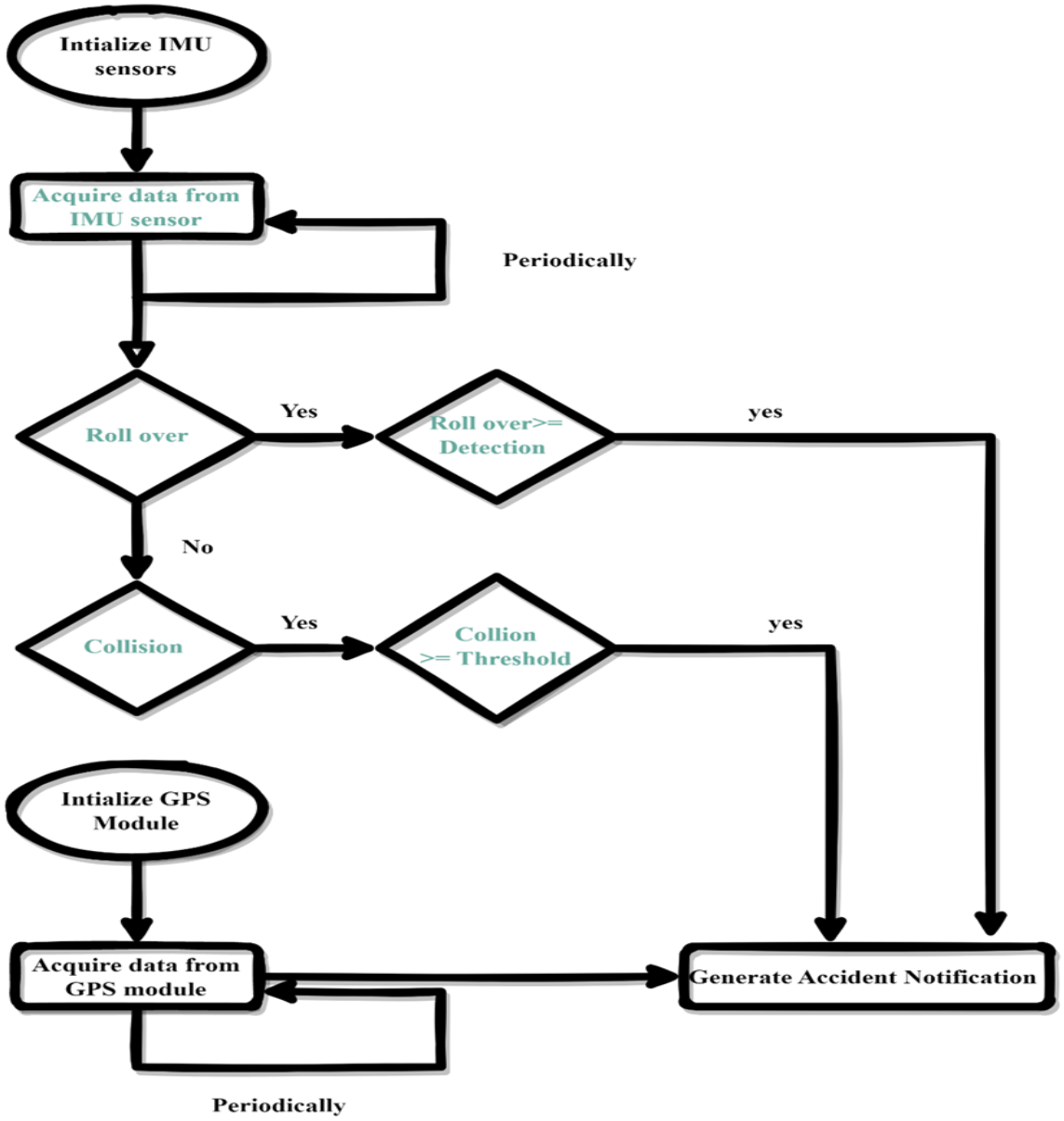

Fig 4. 7 Flow diagram Event based flow of accident detection

Fig. 4.7 shows a flowchart of the detection module. Each module (IMU and the GPS device) and its communication with the main module is presented in the flow chart. Note that each module is continuously updating data, and one thread is used to synchronize the modules. Within each emergency message, the latest GPS information is included. As each emergency message includes the information of GPS coordinates of the respective incident, a server deployed in control room can utilize these coordinates to find the emergency medical aid nearby the accident location via Haversine's Formula.

4.3 Tier Two Control Unit

4.3.1 Overview of the control unit

The cloud has been essential in enhancing and expanding the capabilities of IoT networks. Only a small portion of the tasks that traditional sensor networks have outsourced to the cloud include computation offloading, service management, data storage, monitoring systems, and offline analysis of massive amounts of data. Such compute-intensive applications on resource-constrained mobile devices are made possible by the cloud, which offers nearly limitless resources and a large range of services. IoT cloud-based architectures are now dealing with a number of difficulties in order to meet the rising need for high performance. For applications demanding real-time operations and mission-critical communications, depending only on cloud infrastructures can become a bottleneck in terms of both latency and bandwidth requirements. Although the current paradigm of cloud computing improves the capabilities of devices with limited resources, it is unable to meet the demands of location awareness, mobility support, and low latency (Wu and Buyya, 2015). As a result, it's crucial to create effective network edge entities that serve as an interface between cloud services and IoT devices. In this regard, we suggest a control unit (CU) structure based on the idea of edge computing. Edge computing is distinguished by its wide geographic dispersion, support for mobility, and close closeness to end users. Edge computing attempts to improve quality of service (QoS) for real-time applications like transportation, industrial automation, networks of actuators and sensors, and real-time big data analytics. These applications require location awareness, low latency, heterogeneity support, and heterogeneity. An evolving network infrastructure with the goal of providing low-latency, bandwidth-efficient, and resilient accident response services is defined by the edge computing paradigm (Thiruvasagam et al., 2021). It is worth clarifying that this approach does not intend to replace cloud-based infrastructures, but rather, it aims to increase computation, networking, and storage resources at the network edge by acting as intermediate layer placed between Accident scene and Cloud. In our specific study the edge nodes can be installed specific locations of addis- Adama expressway and in charge of receiving notifications of accidents from the OBUs installed in vehicles. In particular, is responsible for dealing with warning messages, retrieving information from them, and notifying the emergency services around the expressway about the conditions under which the accident occurred.

4.3.2 The Control Unit architecture

As the interface between the sensor domain and the cloud network in current IoT implementations, a gateway is necessary (Udgata and Suryadevara, 2021). However, the functionality of gateways is frequently restricted to traffic forwarding and protocol conversion in the solutions described in the literature (Beniwal and Singhrova, 2022). The main concept of this study is to construct a flexible and adaptable architecture while utilizing emerging software solutions and architectural concepts to improve fundamental gateway functionalities. Fig 4.8 shows the internal architecture included in the CU to achieve all of the architectural requirements for Addis Adama Expressway. The first step for the CU is to receive a warning message from an accident vehicle, and so there must be a module waiting for the arrival of messages and obtaining their different fields. When a new accident is notified, a dedicated module identifies the nearest medical center using its analysis capability and from database of medical centers. When the information has been correctly managed, the notification module sends messages to the emergency services and the cloud services, including all the information collected, the estimated severity, the recommended set of resources, as well as additional information about the vehicles involved in the collision (for preliminary planning of the rescue operation) in the future.

4.3.3 Functional unit of the gateway tier

Data Fusion:

The first step for the CU is to receive a warning message from a collided vehicle, and so there must be a module (data fusion) waiting for the arrival of messages and obtaining their different fields of information.

Data Analysis:

Edge computing furnishes on-demand resources for processing huge amounts of Realtime big data. Processing big data in the edge network reduces the traffic in the network and the workload on the cloud server (Mehdipour et al., 2016). Edge computing can complement the services provided by cloud computing. For instance, in a large-scale environment monitoring system, regional and local data can be collected and mined at edge servers, thereby enabling timely responses in emergency cases.

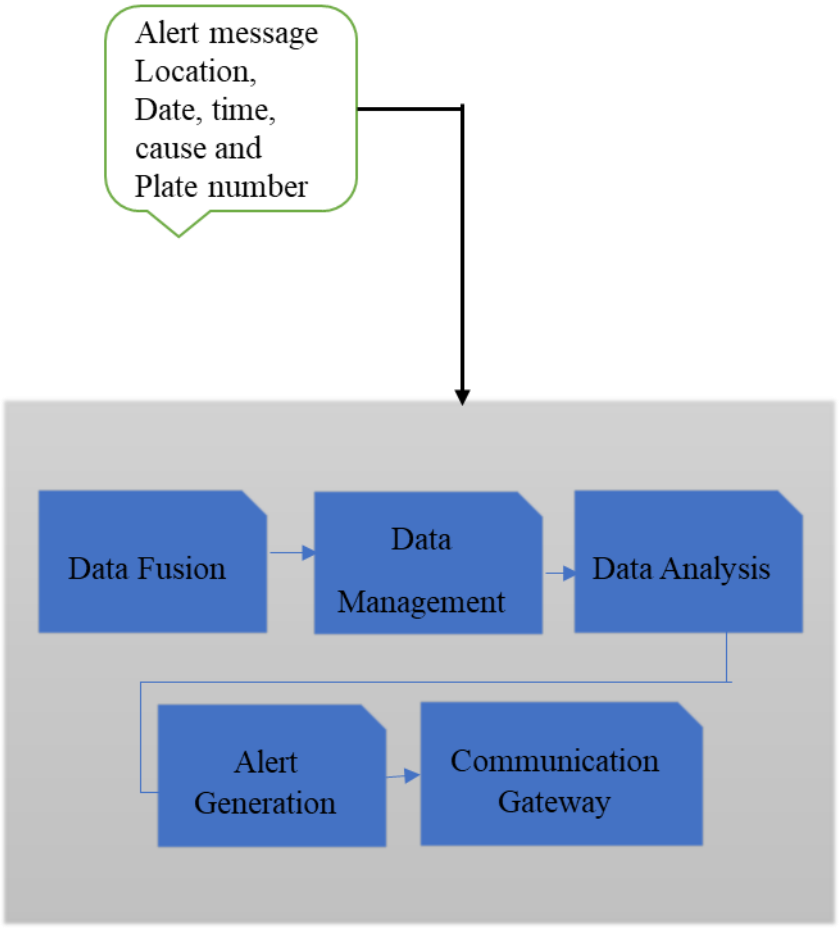

Fig 4. 8 The Control unit architecture

When a new accident notification is received, this module will determine the location of the nearest emergency responder based on the location of the accident scene using Haversine Formula.

$$\text{haversine}\left(\frac{d}{r}\right) = \text{haversin}\,(\phi_2 - \phi_1) + \cos(\phi_1)\cos(\phi_2)\,\text{haversin}\,(\lambda_2 - \lambda_1) \ldots \text{Eq 4. 3)}$$

In the haversine formula, d represents the distance between the accident location and the hospital r represents the radius of the earth. Where, ϕ and λ represent the longitudes and latitudes, respectively.

Database management:

This module typically updates the databases for local hospitals and information on automobile accidents in a certain area. The database of vehicle accident information contains all the information that is currently available for each vehicle.

Alert Generation:

The notification module notifies the emergency services after the information has been properly managed. The messages include all the information gathered, the estimated and the suggested set of resources, and the accident's location.

Communication Gateway:

This module is responsible for the communication between vehicular tier in one side and emergency responder and cloud server in the other side.

4.4 Tier Three-Cloud Platform

4.4.1 Overview

Requirement to gather, integrate and process all potential real time data flowing from the accident scene are key requirements that present in the existing emergency response architectures in Addis Adama Expressway. These incidents highlight the weaknesses in important infrastructures and transportation areas by posing an urgent need for quick, effective actions, frequently in the face of extreme uncertainty. The converged infrastructure, limitless scalability, and shared service-based cloud computing technology can provide an immediate solution for the high dynamic, resilient, and adaptable needs defining the processing and storage capacity of the control units. These make it easier to access integrated intelligence facilities in emergency management enabling integrated store, processing and analysis emergency domain data from a variety of heterogeneous at the cloud server level. In the subsequent sections, highlight the proposed cloud tier framework in terms of the need in emergency response.

4.4.2 Cloud Platform architecture

Cloud computing together with wireless connectivity with all sensors operating in different emergency scene anywhere any time enables effective emergency response during car

accident. In our specific operating scenario, each emergency event may involve multiple sites. Moreover, multiple emergency events can potentially overlap in the same time. For these reasons, neither extension of the control units, nor the number of resources available for managing collection and processing of field-related information is predictable in advance. Because this uncertainty, the computing infrastructure supporting operations during the emergency management, including the store, retrieve and run-time processing must be flexible and elastic, and must be able to guarantee a rapid recovery.

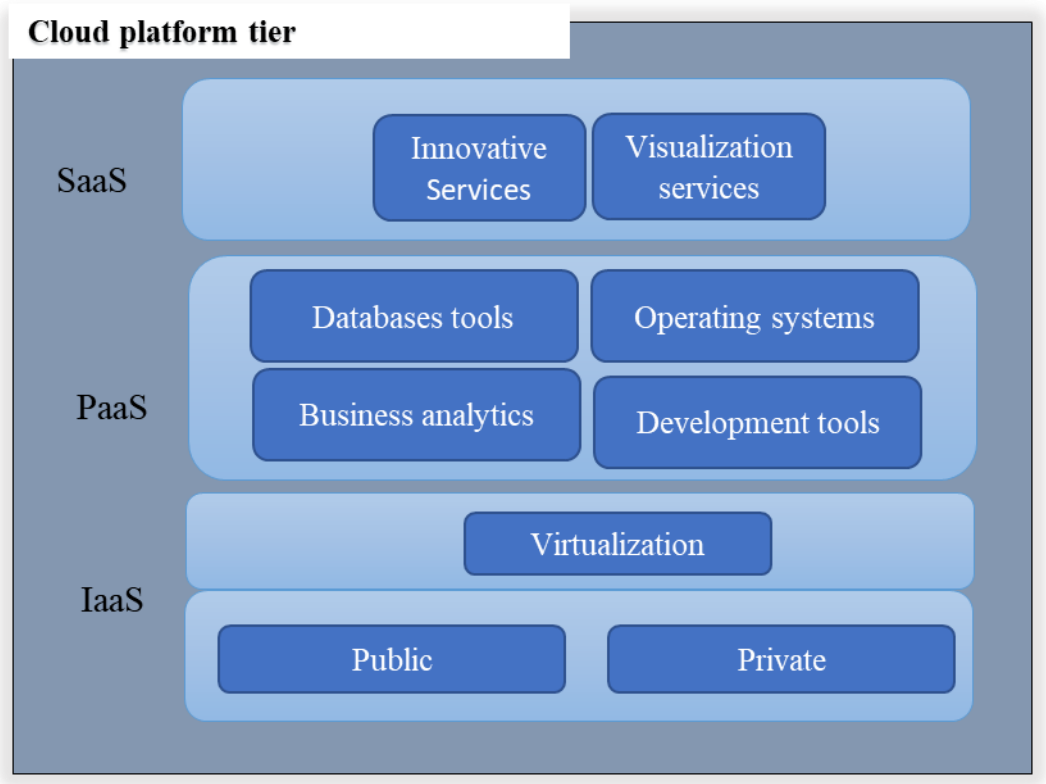

Fig 4. 9 Cloud platform Tier

Furthermore, if there are numerous simultaneous events to manage or if network complexity suddenly increases, the limited private resources allocated at the individual edge computing level for crisis management may pose a serious problem. Due to them, it becomes necessary to dynamically and on-demand expand the private infrastructure. All of the aforementioned problems will be resolved via a flexible architectural framework that encourages collaboration between various groups. To manage the computational and storage resources required for operations in emergency situations, we thus provide a hybrid cloud architecture for guaranteeing the required level of flexibility to manage multiple control unit's run-time and storage services. The cloud platform is responsible for data retrieval from the received

data packets, Additionally, it provides data storage and handles visualization with the help of a front-end tool. At the same time for respecting local equipment limitations or boundary constraints. The standard NIST layered framework is used to model and represent the proposed cloud architecture for emergency management, which includes the "Infrastructure as a Service" (IaaS), "Platform as a Service" (PaaS), and "Software as a Service" (SaaS) layers, each of which is appropriately specialized for our particular goals (Fig. 4.9)

Hybrid Infrastructure as a Service (IaaS) stratum

The lowest level is called Hybrid IaaS Stratum, and it mixes both private and public compute, storage, and networking resources. With a single instance of a server, computing and networking resources that are dedicated infrastructure for that customer only, the architecture's private cloud capability gives the Ethiopian Roads better control, privacy, and security services. Due of its public cloud feature, various emergency responders can access the architecture (police, government, hospital etc). Tight integration of these resource classes is achieved using high-level network virtualization components of clouding component.

Platform as a Service (PaaS) Stratum

The PaaS Stratum offers all of the specialized run-time features required for our specific operating scenario. This layer, which is a cloud development and deployment environment, offers the resources to create different configurations for managing databases, advanced analytics, and other components. Data from the sensors and edge nodes can be gathered and stored using the PaaS database development capability. These gathered data may provide helpful information regarding the frequency of accidents over time, certain geographic areas, and other pertinent data. Effective accident prevention strategies can be developed by performing a thorough and understandable analysis of the data collected from each control unit (edge node) using the business intelligence (analysis) service of the PaaS stratum to at least lessen their occurrences, if not to completely get rid of them. By locating high-risk accident locations for the rescue operation, emergency resources like ambulances and paramedic staff can be stationed nearby if strong preventive measures seem difficult to apply.

Software as a Service (SaaS) Stratum

SaaS stratum is provided at the top level. To get useful insights from collected and analyzed data, a non-technical person from a relevant authority or institution would need precise data

in a proper way. It is necessary to have a graphic, intuitive, and interactive tool. These cloud-based programs at SaaS stratum known as visualization tools assist in representing raw data in understandable graphical formats such as customized bar charts, pie charts, column charts, and more.

4.4.3 Selection of Cloud service provider (CSP)

The cloud service providers and cloud services they offer are discussed, analyzed, and chosen in this section. Companies that provide network services, infrastructure, or commercial applications are known as cloud service providers (CSP). Using network connectivity and on a demand basis, businesses or individuals can access the data center where the cloud services are hosted. To support internal services and applications, people and businesses don't need to create their own infrastructure; instead, they can acquire the services from the CSP, which offers the services to a large number of clients from a shared platform (Wu and Buyya, 2015). In the industry, there are a lot of cloud service providers. Amazon Web Services, Microsoft Azure Services, Google App Engine, and IBM Computing on Demand are ranking Among the top. In this table, the researcher has chosen a few CSPs, discussed them in detail, and compared them to some parameters that are pertinent to our particular research topic.

Table 4. 1 Comparison of Cloud Service Providers

Parameters	Amazon web services	Microsoft azure	Google Cloud engine
Year	Founded in 2006	Founded in 2008	Founded in 2011
Market share	31%	20%	7%
Services	173 Cloud services	Over 600 services	100 Products
Cost	Pay-as-you-go model	Pay-as-you-go model	Affordable than both
Locations	25 geographic regions	54 regions	25 regions

Starting with the cloud service provider (CSP) that can best meet our requirements for software as a service (SaaS) and platform as a service (PaaS), which are the most suitable layers to deploy the visualization and data analysis services, respectively, cloud selection is undertaken. As a result, Microsoft AZURE is well-positioned to offer those services. The company offers a wide selection of over 600 services in 54 regions higher than any other

CSP’s. Microsoft Azure releases ten new products, services, and improvements every quarter as a result of years' worth of research and development work. Azure is the best-in-class hybrid cloud vendor that provides the flexibility to rapidly provision computer resources as needed.

4.5 Communication Mechanism

Communication mechanism is the backbone emergency response and enable network connectivity. Communication protocols define the data exchange formats, data encoding, addressing schemes for devices and routing of packets from source to destination. Other functions of the protocols include sequence control, flow control, and retransmission of lost packets. In the next, we will propose the communication mechanism, protocols between the three tiers of the proposed architecture.

4.5.1 V2V and V2I communication

Vehicle To Vehicle mechanism is one of the main components in the Vehicular Ad Hoc Network (VANET) networks the main target of which is to open direct communication between vehicles. United States is using a predefined band 5.9 GHz. IEEE 802.11p is used as a standard component in United States Vehicle to Vehicle current production implementation (Jia and Ngoduy, 2016). VANET is considered as Mobile Ad Hoc Network (MANET) with some differences, like considering the vehicle as a node in the network. There are several existing communication technologies for V2V and for V2I. The Table 4.2 provides a comparison of Existing Communication Technologies for V2V Communication from many perspectives (Characteristics, Efficiency, etc.)

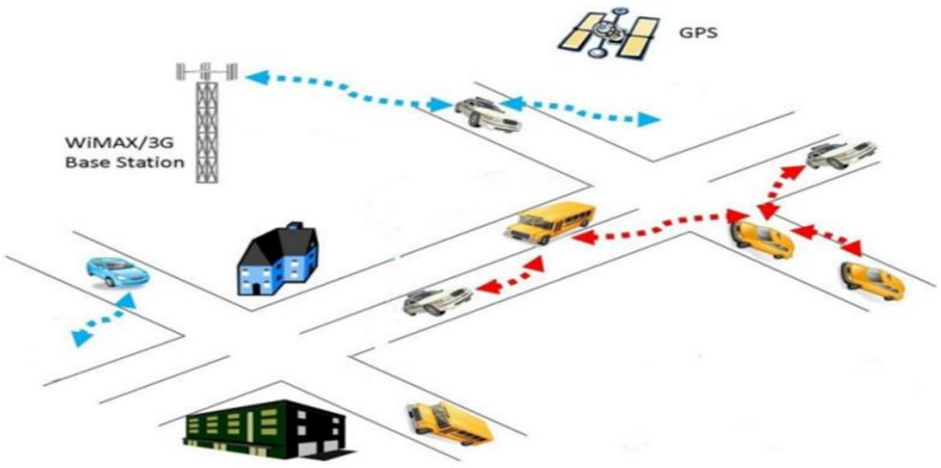

Fig 4. 10 V2V and V2I Communication Model (Jia and Ngoduy, 2016)

Dedicated Short Range Communication primarily specifies the interface for road side to vehicle communication through roadside beacons. It operates in 5.9GHz frequency band, which is dedicated for road safety, traffic efficiency and infotainment communication. DSRC is the most reliable communication model in Vehicle to Vehicle to supply wireless communications features for ITS programs within a 1 KM range at standard speeds of the highway (Wu et al., 2013). DSRC has become evolved with a major goal of authorizing technology that assists programs for communication and safety between cars and infrastructure to reduce collisions. DSRC is a wireless connection based on mutual way communication. Usually, the range capability is from short to medium which permits the transmission of critical information. The concerned authorities are using a predefined band already reserved for the VANET and approximate variety of 1KM for use through Intelligent Transportation Systems (ITS) mobility applications and vehicle protection (El Zorkany et al., 2020).

Table 4. 2 V2V Communication Technologies

Communication Technologies	***Communication Protocols***	***Range***	***Characteristics***
DSRC	IEEE 802.11p	1000 m	High Data Transfer Rate Reliable for large networks

Infrared	IEEE 802.11	10 m	Reliable, mature and easy to master
Bluetooth	IEEE 802.15.1	10 m	Low Power Good Communication Security
Wi-Fi	IEEE 802.11a/b/g	76~305 m	High Data Transfer Rate
UWB	IEEE 802.15.3a	10 m	Anti-interference ability
Zigbee	IEEE 802.15.4	100 m	Low-Cost Low Power

Vehicle To Infrastructure and Vehicle to Vehicle programs are making use of the Dedicated Short-Range Communication which may additionally have the capacity to seriously reduce the number of the fatal styles of crashes through actual time advisories alerting drivers to pressing risks–like swerving to the road edge closely, cars stopped in advance, impacted lanes all through integration, the existence of nearby cars and communications gadgets. Dedicated Short-Range Communication is the current exclusive wireless connection with short-range that offers Privacy and Security, Safety Programs Prioritization, Flexibility, High Accuracy, Acquisition of Network, Low Latency and Particular certified bandwidth (Kenney, 2011).

DSRC Spectrum Allocation

In 1999, the U.S. Federal Communication Commission allocated 75MHz of Dedicated Short-Range Communications (DSRC) spectrum at 5.9 GHz to be used exclusively for vehicle-to vehicle and infrastructure-to-vehicle communications. The primary goal is to enable public safety applications that can save lives and improve traffic flow. As shown in Figure 2, the DSRC spectrum is structured into seven 10 MHz wide channels. Channel 178 is the control channel (CCH), which is restricted to safety communications only (Kenney, 2011). The two channels at the ends of the spectrum band are reserved for special uses (Wu

et al., 2013). The rest are service channels (SCH) available for both safety and non-safety usage.

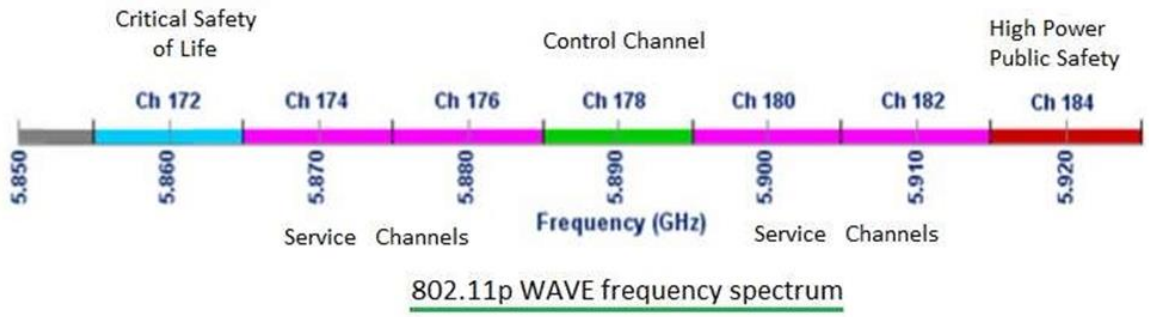

Fig 4. 11 Frequency Spectrum of DSRC (Kenney, 2011)

Communication Protocol

The protocol stack for vehicular networks has to deal with communication among nearby vehicles, and between vehicles and fixed roadside equipment considering their distinct characteristics. Since there is no coordination or prior configuration to set up of a VANET, there are several challenges in the protocol design. For a while, Dedicated Short-Range Communication is using IEEE802.11p. IEEE 802.11p has been developed as amendment to IEEE 802.11 standard specifications in order to support ad-hoc communication between vehicles and between vehicle and infrastructure network. There are changes made to PHY (Physical) and MAC layers for the same. IEEE 802.11p is also known by names such as WAVE (Wireless Access for Vehicular Environments) and DSRC (Dedicated Short-Range Communication). The main objective of 802.11p compliant devices is to improve traffic efficiency and have safety in the traffic flow (i.e., to prevent accidents) (Ucar et al., 2018). It uses the Carrier-Sense Multiple Access with Collision Avoidance to support the scenario if a node wants to transmit a data it will check the network medium, and if the medium is available for an AIFS (Arbitration Inter-frame Space).

4.5.2 TCP/ IP Communication

Transmission Control Protocol (TCP), which is connection-oriented, reliable, full duplex, and connection-oriented, provides the foundation for edge communications with cloud platforms. It belongs to the core group of Internet protocols. It is positioned between the Application Layer and the Network Layer, which are utilized to deliver reliable services. It

is a connection-oriented communications protocol that facilitates message exchanges between various devices over a network. For end-to-end communication between devices, this protocol outlines how data should be addressed, stored, transported, encoded, and decoded.

4.6 Framework Implementation Overview

The personnel, information, software and procedures that were contributed to the successful partial implementation of the proposed framework Ethiopian Roads are mentioned in this section.

4.6.1 Personnel Involved

All phases of the implementation process were directly overseen by the document's author and the advisor of the thesis. Informal consultations with a number of coworkers, stakeholders, emergency responders and acquaintances in the area of the thesis has been held.

4.6.2 Framework Implementation Steps Overview

The proposed framework implementation is carried out by splitting it into three tasks. To reduce the number of fatalities, the first step is to develop a client-side system that automatically detects vehicular accidents and alerts about traffic accidents in a timely manner. The second step involves developing a server-side application which acts as an edge-gateway (control room) platform to analyze the recoded data to identify nearby emergency responder, their causes, and the specific region of casualty. Finally, we have developed a client-side application to which serves as emergency responder. The subsequent occurrence of events related to the three tasks, namely automatic accident detection and emergency notification, deployment of the edge gateway platform and emergency responders has been presented in the following steps.

Vehicle On board Unit implementation

- Acquisition of hardware i.e., esp8266, MPU6050, GPS Sensors and needed software all associated tools.
- In accordance with the methodology assembling and testing of the hardware modules has been conducted.

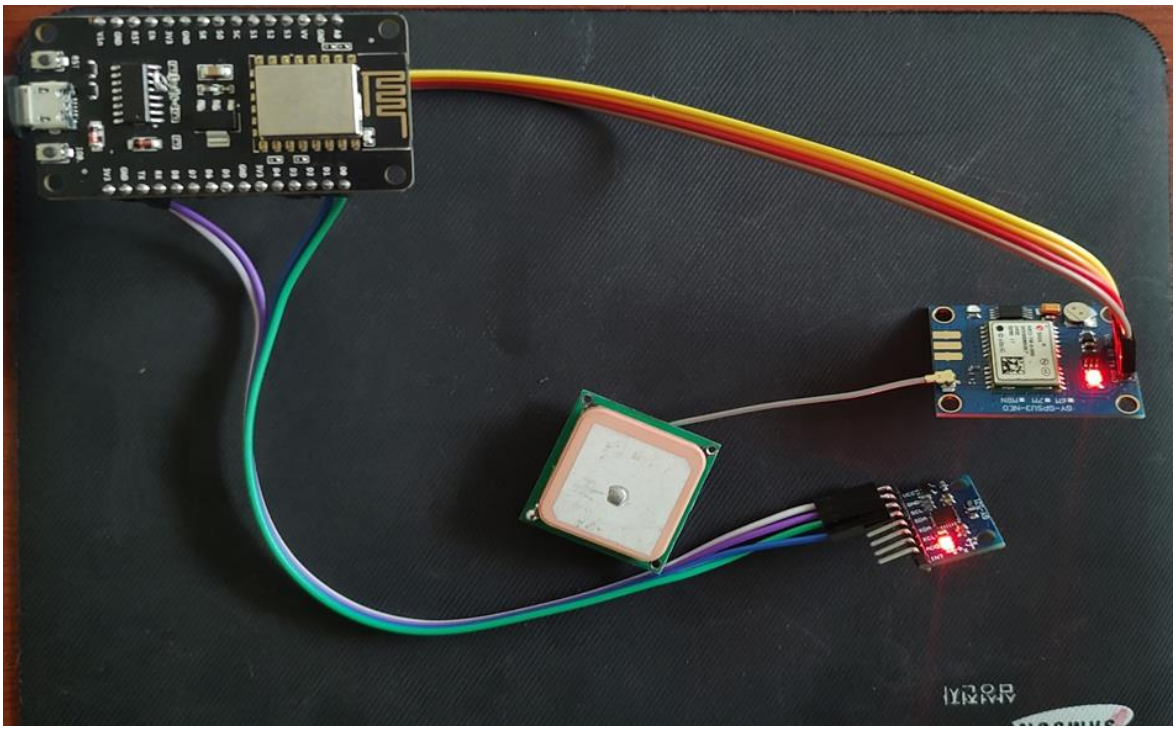

Fig 4. 12 Vehicle on Board Unit

- Integration of hardware modules into one system and testing were carried out to ensure proper functioning of the system in accordance with the design. (Fig 4.12)
- A client-side application has been developed using a C programming language for vehicle on boar processing unit detects an accident event with the help of IMU MPU6050 and takes geographical information (latitude and longitude) from the installed NEO 7M GPS sensor of OBU.
- A vehicle client-side application in access point mode is used connect and notify to server-side application.

Edge Gate Way Side Implementation

- We have developed a server-side application using Node Java Script programming language
- When an event of an accident is detected successfully, the acquired data information is transferred to the control room using web socket where an Edge node is deployed to handle particular data. (Fig 4.13)
- When a notification of accidents received at Control Room using a web socket, it calculates the nearest medical centers using the haversine formula and send notification to the specific medical centers.

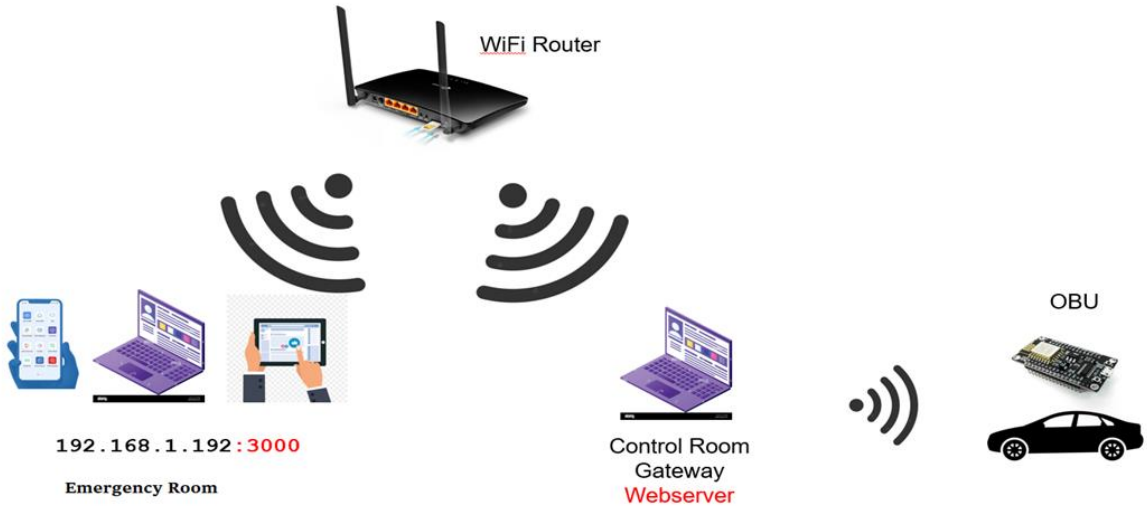

Fig 4. 13 Schematic diagram of the framework implementation

Emergency responders side implementation

- Finally, an emergency responder webpage that runs on a browser has been developed
- The webpage receives notification from control room and displays the location of the accident on the webpage of the emergency responder.

CHAPTER FIVE

RESULTS AND DISCUSSION

In evaluation of the developed framework, the objective was to determine if the proposed framework achieved the specified requirements. Testing started early in the development of the system, but thoroughly carried out after the development of the entire framework. we acquired the results for accident detection and emergency alert notification. Additionally, the framework has been analyzed for packet delivery delay, accuracy and update on the emergency room.

5.1. Accident Detection Module

Testing the vehicle OBU in real surroundings (in a real car accident) is not realistic or practicable due to safety concerns, severe damage, and a lack of facilities that can be utilized to imitate the accident scenario. However, several examples that simulate the conditions of the suggested detection phase technique have been created and tested against in a controlled environment. In these tests, a four-wheel robotic car was used to evaluate the planned OBU while simulating an accident. Additionally, we have adjusted threshold values to 5,5 and $30m/s^2$ for x, y and z axis of the car respectively. For roll-over, any reason cause the gyroscope in any axis (x,y,z) exceeds the threshold of 2.0 rad/s is considered a roll-over

5.1.1 Evaluation to determine the possibilities of preventing false alarm

In carrying out these test, 50 rollover and collision scenarios were initiated against accelerometer and gyroscope sensors. Impacts with magnitudes less than the pre-set threshold for an accident were not transmitted beyond the on-board electronic processing unit (node mcu) of the vehicle. This test was significant in that small vehicle impacts are not accidents and false alarms are well prevented. As presented in the Fig 5.1 below this test on mpu6050 sensors in the prototype returned positive result. The values obtained from accelerometer and gyroscope with AcX = ax(t), AcY = ay(t), AcZ = az(t) and GyX = vφ(t), GyY = vψ(t) and GyZ = vζ (t) are depicted in Fig 5.1 below.

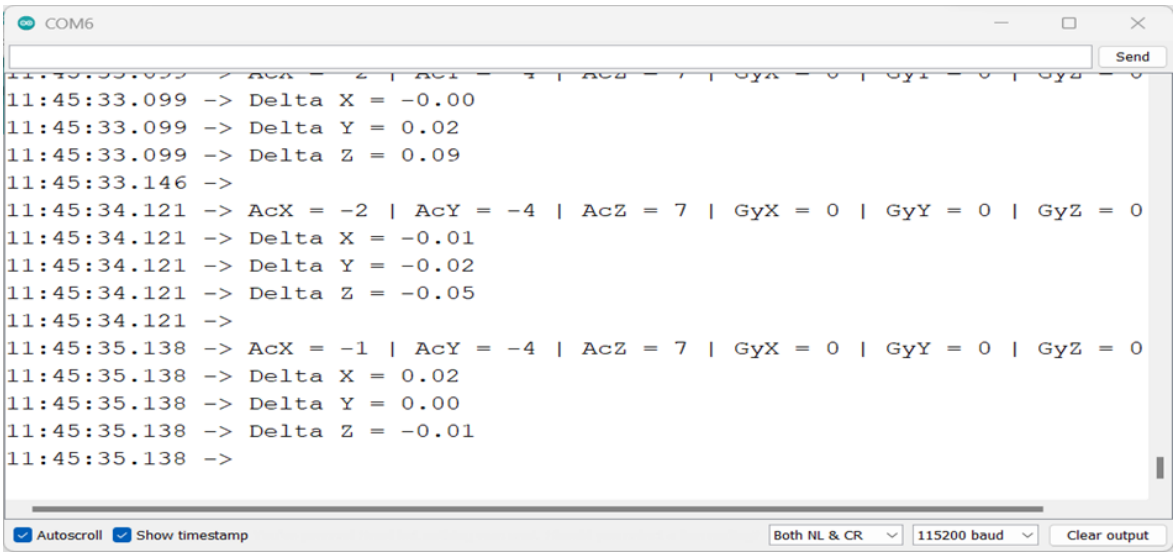

Fig 5. 1 Reading from the accelerometer and gyroscope sensors

5.1.2 Evaluation to determine the possibilities to detect collision and roll-over on and above pre-set threshold values

As depicted in the figures below, the test results of the implemented system to examine its ability of accident detection by reading the accelerometer and gyroscope values has been carried out. By calculating the difference between current and previous values of accelerometer and gyroscope are taken after every δt = 2 s, if the difference values in the in-accelerometer values in x and y direction are more than certain pre-determined thresholds then a collision is detected (Fig 5.2). Delta_X, Delta_Y and Delta_Z denote the difference between two consecutive values that are obtained from an accelerometer.

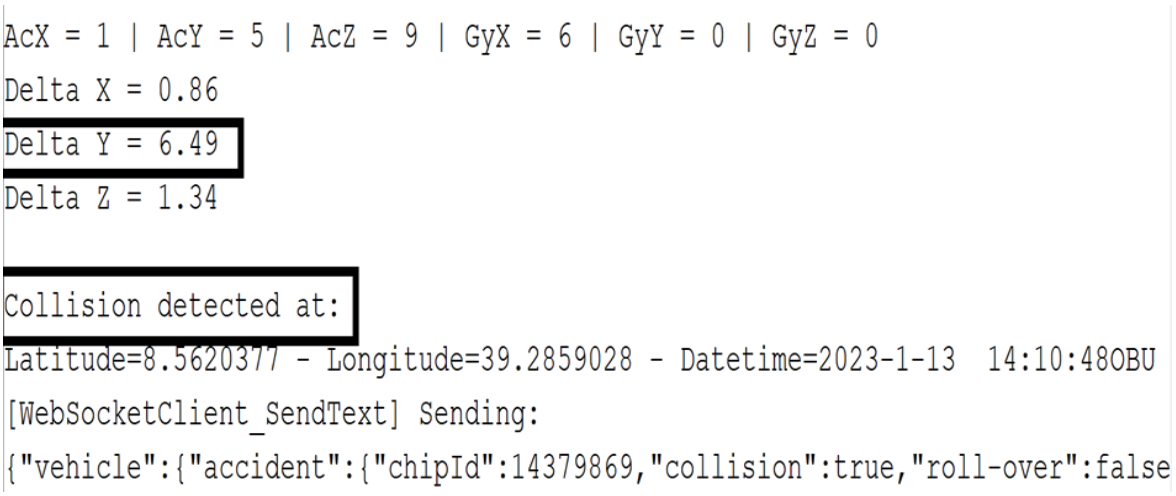

Fig 5. 2 The detection of Collision as result of the accident

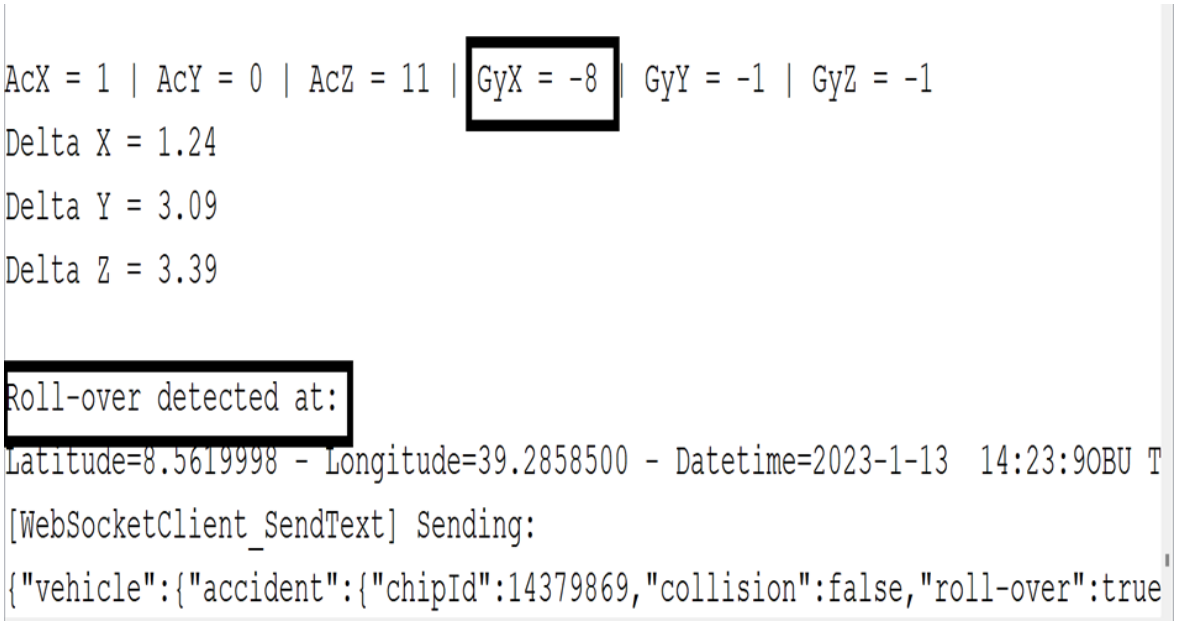

Fig 5. 3 Detection of roll-over as result of the accident

As it is presented in Fig 5.3, the vehicle's OBU's gyroscope is used by vehicle to collect data, which is then analyzed to determine how much the vehicle has rotated over a predetermined period of time and if gyroscope values in X, Y or Z directions are above the predetermined threshold values a roll-over has been detected in the vehicle.

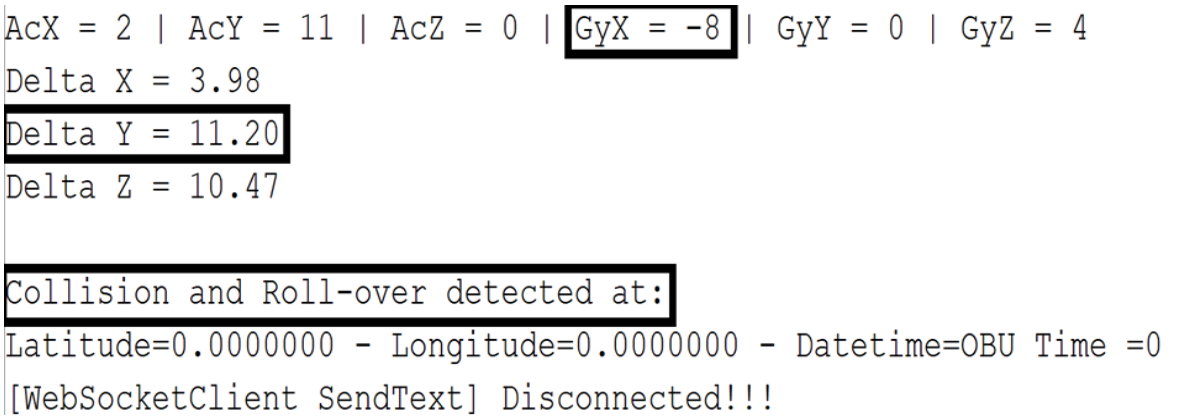

Fig 5. 4 Detection of roll-over and collision as result of accident

As indicated in the above Fig 5.4 a simultaneous collision and roll-over has been detected in the vehicle. With this test we are able to determine that the proposed vehicle detection tier is able to identify accidents within microseconds after the incident of an accident.

5.1.3 Evaluation to determine accuracy in detecting the exact location of the accident

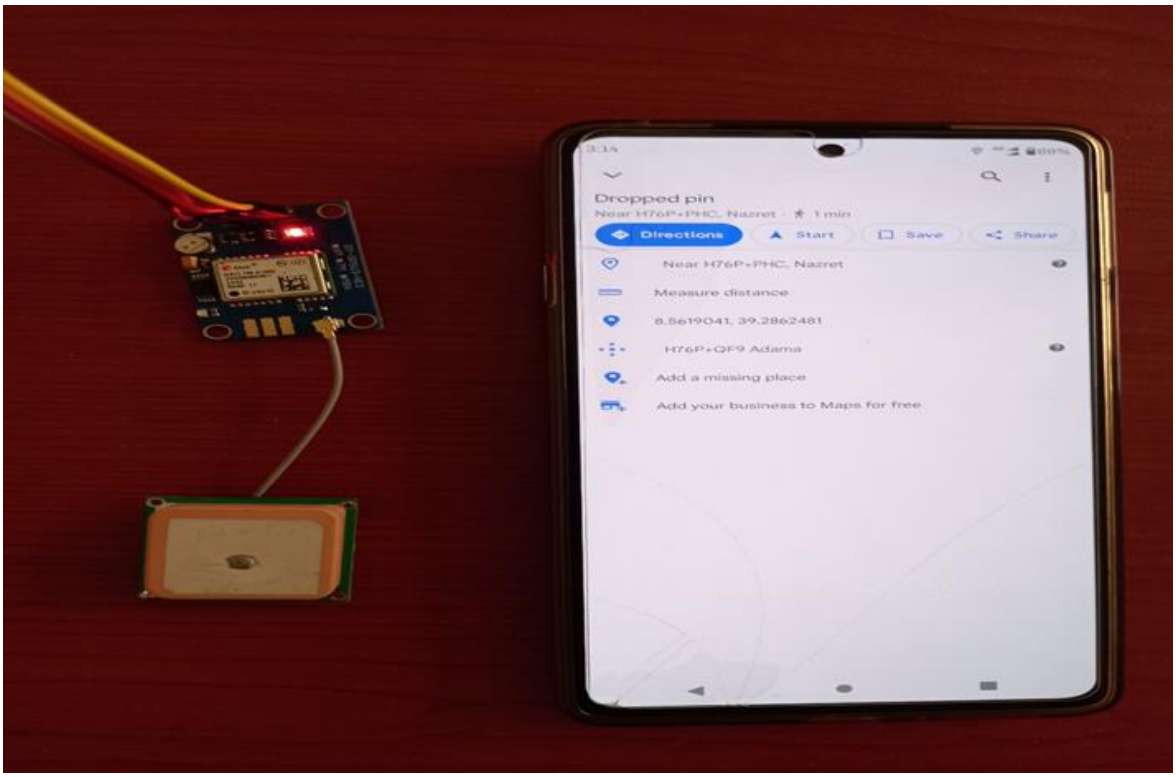

Fig 5. 5 Test to determine accuracy of the GPS module

As stipulated in the specific objectives of these thesis, pinpointing the exact location of the accident is crucial objective of the proposed framework. In light of this, the accuracy of the vehicle OBU is evaluated in generating GPS satellite or location data for the accident scene. A phone handset with GPS capability is utilized to assess the precision of the location coordinates provided by the OBU. The most recent update of the impact site's coordinates was compared to information from the mobile phone handset. A sample of the location comparison between the two devices is shown in Table 5.1. From our test we have noticed, fast and efficient communication has been facilitated between the module and the satellite in extracting the actual location of in terms of the longitude and latitude results. Also, we obtained slight variation on samples taken on both devices.

Table 5. 1 GPS test result comparison

Smart Phone GPS Reading		Neo 7M GPS Reading		Deviation	
latitude	longitude	latitude	longitude	Deviation lat	Deviation lor
8.5621873	39.2865853	8.5625	39.286547	-0.0003127	3.83E-05
8.5632754	39.2867811	8.563104	39.286759	0.0001714	2.21E-05
8.560349	39.2867091	8.564351	39.286699	-0.004002	1.01E-05
8.563291	39.285784	8.563205	39.285725	8.6E-05	5.9E-05
8.561783	39.285883	8.56177	39.285862	1.3E-05	2.1E-05

This inaccuracies in the location data happened because of the differences in GPS system's technology used Mobile phone handset and the Ublox Neo 7M GPS. However, the variances are slight and won't have an impact on the system's successful deployment. The objective of locating the scene of the accident using this GPS returned positive results according to the laid down requirements.

5.2 Communication between vehicular environment and Control unit

A particular area in the road has the control room (edge node) application installed. The control room app initializes and awaits a trigger event, as shown in Fig. 5.6, before processing and sending a notification for the emergency assistance service.

Fig 5. 6 The control room is listening the emergency notification

When the control room receives a call about an emergency, it uses the Haversine formula to analyze the scene of the incident and identify the closest emergency response. Then, as seen

in Fig. 5.7, it sends an emergency message email to the hospital that has been identified asking for the delivery of emergency personnel.

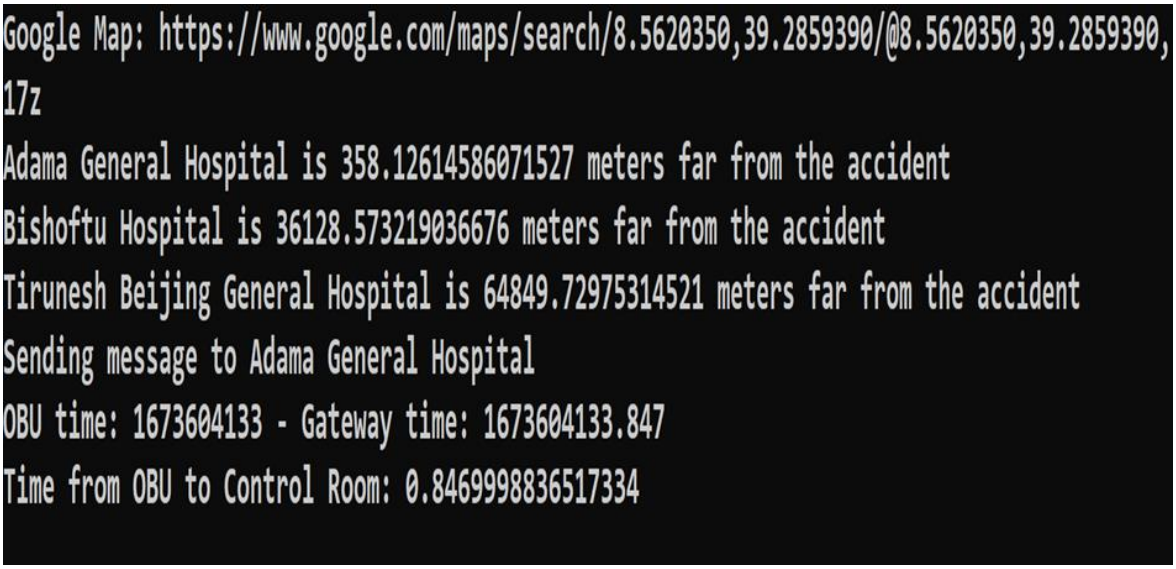

Fig 5. 7 Control Room Calculates Nearby Emergency Responder

As in Fig 5.8, the application installed in emergency responder room is first initialized and ready to receive an emergency from the control room.

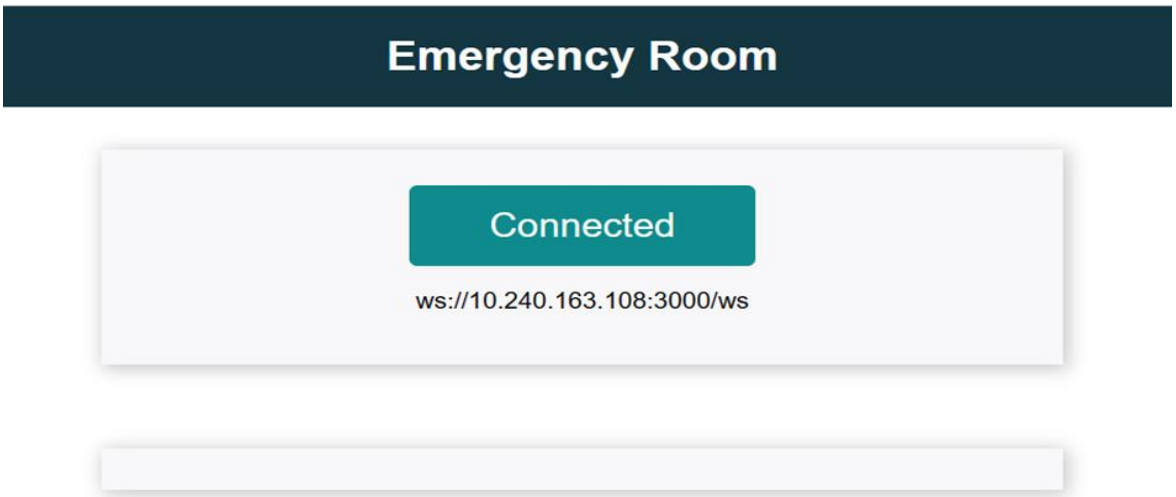

Fig 5. 8 Emergency room ready to receive notification

5.2.1 Test to determine latency in data delivery

The latency was tested to make sure that the edge gateway (Control unit) platform could support real-time data streaming. Two different time frames are taken into account to

calculate the delay (i.e., the latency from the time accidents is received on the OBU to the edge node considered to be the first-time frame and the latency from the edge node to the emergency room considered to be the second time frame). We calculated the entire end-to-end delay (OBU to Emergency room) of the created system by summing these various time frames. Each time the experiment was done, a mix of 10 roll-over, collision, and both situations were submitted to the control room. The experiment was run ten times, with an hour elapsed between each run. In order to prevent measuring latencies brought on by other factors, the experiment was carried out on the same physical equipment with the control room situated at the same distance from the OBU and emergency room. The experiment's findings were quite positive; an average latency of 2.304166 seconds and latency ranged from 1.868999 sec in the best scenario to 3.046999ms in the worst-case scenario is recorded.

5.2.2 Test to determine the accuracy in finding the nearest emergency responders

This test is conducted to determine the ability of the developed control in finding the nearest emergency responder during an accident. This test is conducted by providing three sets of emergency responders location to the control room and initiating accident scenario from specific places. The first set of emergency responder location are wolkite university referal hospital, welliso st.luke hospital and Black lion hospital. We have intiated the accident scenario in wolkite city and the control room has selected wolkite university referal hospital as nearest emergency responder. The second test is conducted by taking the location of adama general hospital, Bishoftuu hospital and Tirunesh beijing general as emergency resonders location and intiated the accident scene from Adama science and technology university compound. During these test adama general hospital has been selected as nearby emergency responder. Based on this test, the control unit has achieved 100% success rate.

5.3 Test to determine emergency room received and updated the critical vehicle accident data accurately.

5.3.1 Test to determine updating Accident vehicle Details on the emergency room

The time taken and the success rate of the accident incidence update in the emergency room were recorded. A successful update includes the vehicle information, the accident site's longitude and latitude coordinates, cause of the accident and the accident date and time.

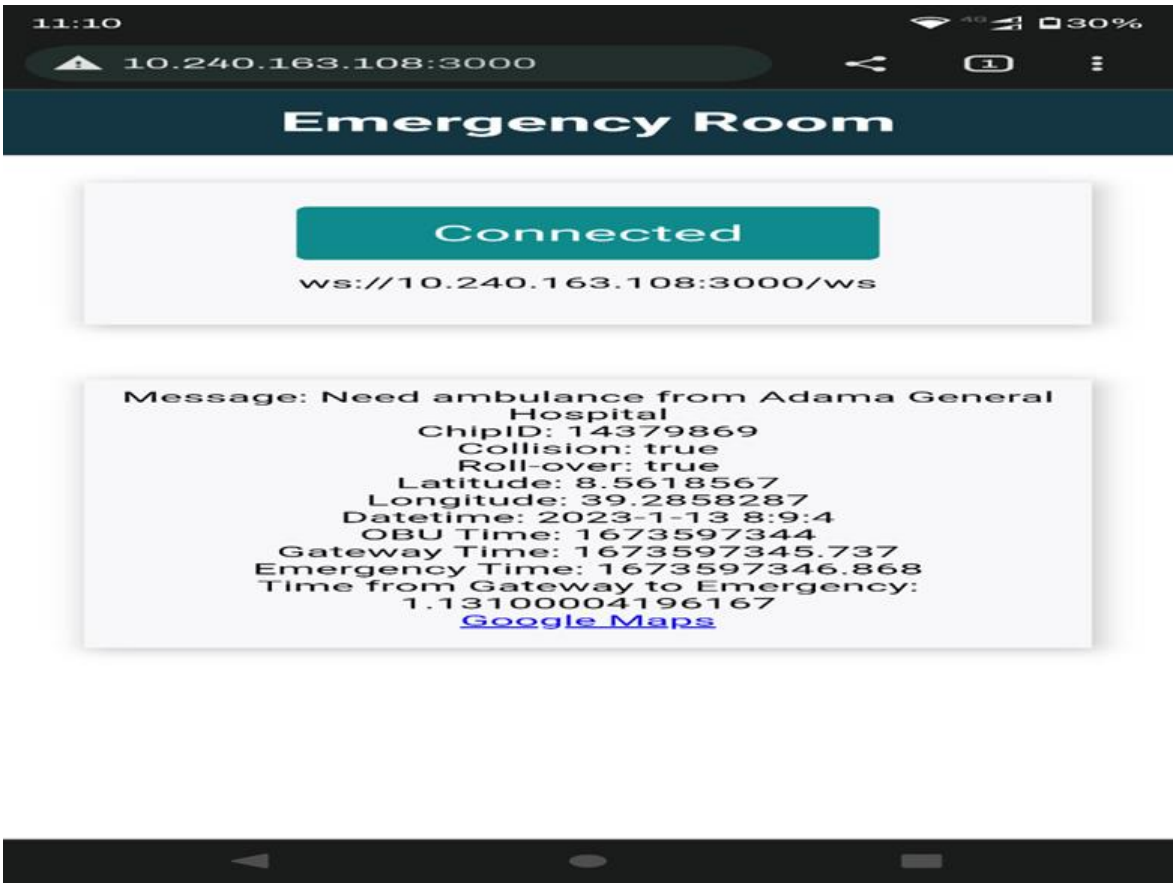

Fig 5. 9 Update on the emergency room

In accordance with the scenarios initiated at 5.1.2 occurrences of were examined using information from the prior evaluations that was produced by initiating mix of scenarios on the sensors.

Table 5. 2 Test results on emergency room update

Details	Success	Failure
Updating Accident vehicle Details	46	4
Updating Location of accident	43	7
Updating Date and Time of Accident	47	3
Update the cause of the accident	47	3

In these tests, we managed to determine if the developed framework able to update the most crucial piece of information about the accident is able to be displayed at every vehicle accident incidence happens. The evaluation of these test resulted in positive result.

5.3.2 Test to determine quickly users can access and view the emergency room platform

These tests are carried out in order to assess the effectiveness of emergency room of the framework in providing access and view to vehicular accident information to the relevant stakeholders. We have conducted the tests in using the following parameters as bench mark I) successful browsing and view II) successful accident information enquiry and display III) successful display of the location of the accident on a digital map (IV) successful delivery of new accident notification on cloud platform. More than 50 access have been made into the emergency room platform and information about the aforementioned parameters was collected and record. Testing results for the effectiveness of platform is summarized below in the table 5.3.

Table 5. 3 Test results efficiency measurement

Cloud Platform Efficiency Parameters	Success	Failure
Successful login and browsing	47	3
Accident information enquiry and display	46	4
Accident location display on digital map	47	3
New accident notification	48	2

5.4 Evaluation of expertise in the field of the study

After partial implementation of the proposed framework (i.e., OBU, Control unit, Emergency responders) and the results acquired. We went to ask around 18 individuals who are in the automotive industries, IT sectors and different stakeholders in the Transportation sectors. We provided a total of three different questions to each category of the respondents (Appendix I) specific to their area of concern. The results of evaluation of the proposed framework based on the criteria's have been presented below

Table 5. 4 Validation from Automotive Sector respondents.

Respondent	Enhancement				Implementation feasibility				Overall Framework			
6	Very Good	Good	Fair	Poor	Very Good	Good	Fair	Poor	Very Good	Good	Fair	Poor
	2	3	1	0	3	2	1	0	4	2	0	0
%	33.3	50	16.6	0	50	33.3	16.6	0	66.6	33.3	0	0

Table 5. 5 Validation from IT sector respondents.

Respondent	Real time processing				Enhancement in accident management				Overall Framework			
6	Very Good	Good	Fair	Poor	Very Good	Good	Fair	Poor	Very Good	Good	Fair	Poor
	3	3	0	0	4	1	1	0	4	1	1	0
%	50	50	0	0	66.6	16.6	16.6	0	66.6	16.6	16.6	0

Table 5. 6 Validation from Transportation sector respondents

Respondent	Relevance				Effectiveness				Overall Framework			
6	Very Good	Good	Fair	Poor	Very Good	Good	Fair	Poor	Very Good	Good	Fair	Poor
	3	2	1	0	4	2	0	0	3	3	0	0
%	50	33.3	16.6	0	66.6	33.3	0	0	50	50	0	0

We provided a same question to each category of the respondents regarding the overall proposed framework, 61.1% of respondents give it a very good rating, followed by good and fair ratings of 33.33% and 5.55%, respectively. We have asked automotive sector respondents about the enhancement made to the existing vehicular accident detection mechanism and rated very good (33.3%), good (50%), and fair (16.6%). Regarding the implementation feasibility of the vehicular tier of the proposed framework the respondents rated very good (50%), good (33.3%) and fair (16.6%). We have asked IT sector respondents about the enhancement made to the current accident management and notification system and rated very good (50%) and good (50%). Regarding performance of edge gateway in terms of providing real-time processing and latency constrained emergency situation the respondents rated very good (66.6%), good (16.6%) and fair (16.6%). We have asked Transportation sector respondents about relevance of the framework and rated very good (50%), good (33.3%) and fair (16.6%). Regarding the effectiveness of the proposed framework the respondents rated very good (66.6%) and good (33.3%).

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

The volume of vehicles on the road has increased along with the population. This increase in traffic on the roadways has led to congestion, traffic accidents, and noise. Both the government and drivers' cooperation and dedication are necessary to save and protect lives. Due to this, significant resources will be required in order to achieve and maintain a very high level of road safety. Numerous parties have worked hard to create a wide range of applications for managing traffic accidents, which have been made possible by cutting-edge technologies. Despite these efforts, countless precious lives and valuable property are still lost in car accidents as a result of prompt medical assistance not being given at the earliest opportunity. Here, it is essential to develop a general-use framework that can instantly identify traffic collisions and issue the least expensive feasible notice for medical assistance. In this study, we presented a multi-tier, intelligent framework that can provide stakeholders with quick service in such situations (i.e., vehicle, control unit, and cloud tiers). Electromechanical sensors that are put on vehicles as part of the vehicular tier of the framework enable timely and precise detection of accidents caused by vehicle rollover and collision. Additionally, it creates an alert message regarding the collision and utilizes vehicle to infrastructure connection to send an emergency alert to the control center. The framework's final tier was created using cloud and edge computing technologies. These are two of the most well-known new concepts for managing enormous volumes of data created by IoT. Although each of these technologies has unique benefits and drawbacks, combining them would benefit the system as a whole. As a result, these technologies have been effectively combined in this research. Edge technology is employed in the created vehicular accident detection and notification system to build a control room that can be put in various locations along the road to provide services including data unloading, preprocessing, storage, and communication. When the control room receives an emergency message, it determines the nearest hospitals and creates a message for emergency assistance for the scene of the accident. After then, an emergency is sent to the scene of the accident. The hardware utilized in the prototype is inexpensive and has a straightforward design.

The created technology significantly decreased the latency of data transmission and greatly improved communication overall. Furthermore, a cloud platform has been designed for this research investigation. In this regard, the cumulative data are transferred to the central database for long-term storage once the rescue operation is over utilizing the proposed approach. Later, this information can be retrieved from the database and subjected to an insightful analysis. The cloud-stored data may enable the relevant authorities to formulate policies and put in place practical steps to lower the number of injuries and fatalities brought on by traffic accidents.

6.2 Recommendations

After a thorough analysis of data and results, the following recommendations are hereby made:

- The ICT department of emergency responder should be encouraged with infrastructure and training with Computer system necessary for successful deployment of the framework.
- As the research involves multi-disciplinary research approach, to implement or put in to practice the developed framework it needs the involvement of different stakeholders (i.e., automotive industries should work to try equip vehicles with sensors needed for successful detection and notification of accidents.)
- Ethiopian Road administration should be in charge and work in collaboration with other stakeholders in building necessary road side unit and infrastructures
- The researcher recommended fast and reliable telecommunication infrastructure should be provided by Ethio Telecom without interruption to make the accident management successful.
- The researchers highly recommend that the future researchers to see further towards improving the accuracy of accident detection and reliability of communication.
- The researchers highly recommend that the future researchers to see further towards improving the deployment location of edge node so as to enhance data collection from sensors from the vehicles and communication between emergency responders

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Appendix

Appendix I Interview

Interview questions to evaluate the proposed framework

1. What they feel about the overall designed framework (in terms of providing safety, functionality and others)

Very Good ☐ Good ☐ Fair ☐ Poor ☐

Evaluation criteria for automotive sector respondents

1. The extent to which the designed vehicle accident detection and notification framework brought enhancement to the current vehicle accident detection

Very Good ☐ Good ☐ Fair ☐ Poor ☐

2. The extent to which the designed vehicle accident is feasible to be implemented in the current vehicles

Very Good ☐ Good ☐ Fair ☐ Poor ☐

Evaluation criteria for IT sector respondents

1. The extent to which the designed edge computing framework perform in terms of providing real-time processing and latency constrained emergency situation

Very Good ☐ Good ☐ Fair ☐ Poor ☐

2. The extent to which the designed framework provides enhancement to the current accident management and notification system in addis-adama expressway

Very Good ☐ Good ☐ Fair ☐ Poor ☐

Evaluation criteria for transportation sector respondents

1. The extent to which the objectives and designed proposed system respond to beneficiaries, global, country and partner/institution needs.

Very Good ☐ Good ☐ Fair ☐ Poor ☐

2. The effectiveness to which the proposed framework delivers, or is likely to deliver, results in an economic and timely way.

Very Good ☐ Good ☐ Fair ☐ Poor ☐

Appendix-II Sample Code

Sample code from accident detection

```
void MPU_Setup()
{
  pinMode(LED_BUILTIN, OUTPUT);
  LocalMPUBegin();
}

void MPU_Task()
{
static unsigned long lresend_time = 0;
if (g_isCollision || g_isRollOver)
  {
if (millis() - lresend_time >5000)
    {
      lresend_time = millis();
if ((int)g_location.lat == 0&& (int)g_location.lon == 0)
      {
        GPS_GetCurrentLocation(g_location);
if ((int)g_location.lat != 0&& (int)g_location.lon != 0)
        {
          DynamicJsonDocument
doc(VEHICLE_JSON_MSG_LEN_MAX);
          LocalCreateDetectionMsg(doc);
String jsonString;
          serializeJson(doc, jsonString);
          WebSocketClient_SendText(jsonString); }}}
return;
  }

if   (g_mpuInit   &&   (millis()   -   g_measureTime)   >=
MPU_MEASURE_INTERVAL)
  {
    g_measureTime = millis();

    sensors_event_t a, g, temp;
float deltax = 0, deltay = 0, deltaz = 0;
char buffer[256];
    memset(buffer, 0 , 256);
    g_mpu.getEvent(&a, &g, &temp);

    deltax         =         abs(a.acceleration.x         -
g_accValue.acceleration.x);
    deltay         =         abs(a.acceleration.y         -
g_accValue.acceleration.y);
    deltaz         =         abs(a.acceleration.z         -
g_accValue.acceleration.z);

    memcpy(&g_accValue, &a, sizeof(sensors_event_t));
```

```
    sprintf(buffer, "AcX = %d | AcY = %d | AcZ = %d | GyX =
%d | GyY = %d | GyZ = %d\n"
"Delta X = %.2f\nDelta Y = %.2f\nDelta Z = %.2f\n",
                    (int)a.acceleration.x,
(int)a.acceleration.y, (int)a.acceleration.z,
                    (int)g.gyro.x,           (int)g.gyro.y,
(int)g.gyro.z,
                    deltax, deltay, deltaz);
```

Sample code from control room server

```
var fs = require('fs');
var url = require('url');
var http = require('http');
var WebSocket = require('ws');

const hospitals = [
  {name: "Adama General Hospital", lat: 8.56061, lon:
39.28213},
  {name: "Bishoftu Hospital", lat: 8.75158, lon: 38.98044},
  {name: "Tirunesh Beijing General Hospital", lat: 8.87802,
lon: 38.78986},
];

function requestHandler(request, response) {
    fs.readFile('./index.html', function(error, content) {
        response.writeHead(200, {
'Content-Type': 'text/html'
        });
        response.end(content);
    });
}
// create http server
var server = http.createServer(requestHandler);
var ws = new WebSocket.Server({
    server: server, path: "/ws"
});
var clients = [];

function broadcast(socket, data, isBinary) {
//console.log(clients.length);
for (var i = 0; i < clients.length; i++) {
if (clients[i] != socket) {
            clients[i].send(data, { binary: isBinary });
        }
    }
}

const R = 6371
```

```
const TO_RAD = (3.1415926536 / 180)
```

Sample to Code to calculate the location

```
function HAVERSINE_CalcDistance(lat1, lng1, lat2, lng2)
{
var dx = 0.0, dy = 0.0, dz = 0.0;
      lng1 -= lng2;
      lng1 *= TO_RAD, lat1 *= TO_RAD, lat2 *= TO_RAD;

      dz = Math.sin(lat1) - Math.sin(lat2);
      dx = Math.cos(lng1) * Math.cos(lat1) - Math.cos(lat2);
      dy = Math.sin(lng1) * Math.cos(lat1);
      returnMath.asin(Math.sqrt(dx * dx + dy * dy + dz * dz)
/ 2) * 2 * R * 1000; // *1000 for metres
```