ADAPTIVE TRAFFIC CONGESTION CONTROL MECHANISM IN SMART VEHICULAR NETWORK

A Thesis

Submitted in partial fulfillment of the
requirementsfor the award of the degree of

DOCTOR OF PHILOSOPHY

IN

COMPUTER SCIENCE &ENGINEERING

BY

Gurpreet Singh Shahi

Registration No. – 41600103

SUPERVISED BY

Dr.Ranbir Singh Batth

Associate Professor,

Department of Computer Science &Engineering

LOVELY PROFESSIONAL UNIVERSITY

PUNJAB

2021

DECLARATION

I, **Gurpreet Singh Shahi**, student Ph.D. Research Scholar. CSE, **Lovely Professional University,** bearing **Registration Number**:**41600103**, submit this thesis work entitled **"Adaptive Traffic Congestion Control Mechanism in smart vehicular network"** to **Lovely Professional University, Phagwara, Punjab** for the award of the P.HD. degree in Computer Science and Engineering and declaring that the work done is genuine and produced under the guidance of **Dr.Ranbir Singh Batth**

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

Date: **Gurpreet Singh Shahi**

Place:Phagwara,Punjab P.HD. CSE (Part-time)

Registration number:41600103

CERTIFICATE

This is to certify that the work presented in this thesis entitled **" Adaptive Traffic Congestion Control Mechanism in smart vehicular network"** is the own work of **Gurpreet Singh Shahi**conducted in the Department of Computer Science and Engineering **Lovely Professional University, Phagwara, Punjab**under my supervision. This work has not been submitted earlier to any University/Institution for any research degree to the best of myknowledge.

Date: **Signature of ResearchSupervisor**

Place: **Dr.Ranbir Singh Batth**

Associate Professor

ABSTRACT

With the growth of the economy in the various developing and developed nations,the continuous rise in urban population, demand for road travel has drastically increasedover the past few decades. The number of vehicles on the roads has been increased exponentially. With this, the traffic-related problems like jams and road accidents have also been increased. There is a strong need fora smart vehicular ad-hoc networkfor smooth movement and better management of vehicular connectivity across the given roadnetwork. Also, the traffic conditions are dynamic so an adaptive mechanism is needed for congestion detection and finding the optimal path for the vehicles on the road network.

In this research, a comparative study of existing route-findingalgorithms like Dynamic Dijkstra,Dynamic A star, Contraction hierarchies(CH), and Floyd Warshall algorithms is done using the SUMO simulator.Contraction hierarchy's results are found to be good in finding the shortest path.The average speed ofthe vehicle and travel time is considerably improved using the CH mechanism.To detect congestion during heavy traffic flow especially in urban areas.A Multi-metric road guidance mechanism(MRGM) is proposed which is adaptive. It considers multiple metrics to analyze the traffic congestion conditions and based on the conditions, effective optimal routes are suggested to the vehicles. The simulation of the proposed mechanism is performed with the SUMO simulator by using the python script. The performance of the proposed model has been compared with existing congestion control and rerouting techniques and it is proved that the proposed road guidance mechanism performs better in terms of fuel efficiency, travel time, and travel distance.The traffic flow is getting disrupted due to traffic jams, congestions, collisions, and various other hazards. As a result of this the average fuel consumption, travel time, and pollution level is rising at a faster rate. The average speed of travel for vehicles slows down. For handling traffic flow problems another mechanism is proposed (PTFM) that is based on the pre-processing of information of routes and vehicles.The information is stored on an additional node which is called a shortcut node. This information is used in the future to guide the vehicles to follow better routes. In this research, the proposed mechanism is compared with the existing mechanism NRR, DIVERT and RE-route. The results of PTFM outperform the existing solutions.

ACKNOWLEDGEMENT

I would like to express my deep sense of respect and gratitude towards my supervisor Dr. Ranbir Singh Batth (Associate Professor), Department of Computer Science and Engineering Lovely Professional University, Punjab, who has been the guiding force behind this work. I thank him for introducing me to the field of Smart Vehicular Ad-hoc Networks and allowing me to work under his supervision. Without his invaluable advice and assistance, it would not have been possible for me to complete this thesis. I am greatly indebted to him for his constant encouragement and invaluable advice in every aspect of my academic life.

I must express my very profound gratitude to Dr. Simon Edgerton(Department of ComputerScience and Information Technology, La Trobe University, Australia) for providing me with unfailing support and continuous encouragement throughout my years of study and through the process of researching and writing this thesis. This accomplishment would not have been possible without him.

I gratefully acknowledge the support and help provided by my father, mother, and wife. I also thank all the faculty members of the Department of Computer Science and Engineering, Lovely Professional University, Punjab for their valuable suggestions and support throughout my research work.

Above all, I offer praises and thanks to The Almighty God for the divine guidance and strength throughout my project work

Thank you.

Gurpreet Singh Shahi

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

Abbreviation	Explanation
ITS	Intelligent Transportation System
GPS	Global Positioning System
GSM	Global System for Mobile Communications
SVR	Support Vector Regression
ANN	Artificial Nural networks
AUTM	Actual Urban Traffic Simulative Model
V2X	Vehicle To Everything
V2I	Vehicle To Infrastructure
V2V	Vehicle To vehicle
I2I	Infrastructure to infrastructure
IVC	Inter vehicular Communication
VA	Vehicle Agent
AP	Access Point
P2P	Peer To Peer
VANET	Vehicular Ad hoc Network
RSU	Road Side Unit
OBU	On-Board Unit
ISC	Info Station Center
QoS	Quality Of Service
CH	Contraction Hierarchies
MRGM	Multi-metric road guidance mechanism

TAZ	Traffic Assessment Zone
PTFM	Pre-processing based traffic flow mechanism
VTF	Vehicle Traffic Flow
VCD	Vehicle Congestion Density
GUI	Graphic User Interface
SUMO	Simulation of Urban Mobility
NS2	Network Simulator 2
TRACI	Traffic Control Interface

LIST OF PUBLICATIONS

1. G.S Shahi, **R.S Batth**, S. Egerton, 2020 "MRGM: An Adaptive Mechanism for Congestion Control in Smart Vehicular Network", ***International Journal of Communication Networks and Information Security*** *12 (2).* https://www.ijcnis.org/index.php/ijcnis/article/view/4684/404

2. G.S Shahi, **R.S Batth**, S. Egerton, "A Comparative Study on Efficient Path Finding Algorithms for Route Planning in Smart Vehicular Networks," ***International Journal of Computer Networks and Applications***, vol. 7, no. 5, pp 157166., 2020. https:doi.org/10.22247/ijcna/2020/204020

3. G. S. Shahi, R. Singh Batth and S. Egerton, "PTFM: Pre-processing Based Traffic flow Mechanism for Smart Vehicular Networks," ***2021 2nd International Conference on Intelligent Engineering and Management (ICIEM), United Kingdom***, 2021, pp. 119-126, DOI: 10.1109/ICIEM51511.2021.9445291.

4. G.Singh, P.Gupta, M.H.A Wahab, "Smart Collision Avoidance and Hazard Routing Mechanism for Intelligent Transport Network," ***IOP Conf. Series: Materials Science and Engineering 226 (2017) 012107.***https://iopscience.iop.org/article/10.1088/1757-899X/226/1/012107

CHAPTER 1: INTRODUCTION

1.1 TRAFFIC CONGESTION

In developing countries such as India, urbanization has resulted in huge population growth in metro cities such as New Delhi and Mumbai. A large city's and nation's economic and social development is greatly influenced by the transportation network [1]. By now, the Indian population is increasing at an annual pace of 3%. According to a study, by 2021, 500 million people are living in metropolitan areas [2]. With such rapid urban population growth, mobility demand, as well as the number of automobiles on the road, has increased. As the number of vehicles on the road has grown, traffic congestion has become a significant problem in metropolitan areas.

In our everyday lives, traffic congestion is a serious problem. A variety of reasons may be linked to the rapid rise in traffic in various locations. The primary explanation is an increase in population, which has resulted in an increase in the number of vehicles on the road. Several other problems contribute to traffic congestion such as inadequate infrastructure, ineffectual supervision of road capacity,etc. The development of every developing country's Gross Domestic Product (GDP) is hampered by traffic congestion. Various issues occur as a result of traffic congestion, including increased air emissions, car maintenance costs, travel time, and so on. A research study [3] estimates that Rs. 600 billion is lost yearly (time and fuel wastage) due to traffic congestion on motorways.

1.1.1 Important Issues Related to Urban Traffic Management System

Congestion in the traffic has become a big issue in many places as the counting of vehicles on the road has been increased exponentially. There are two forms of traffic congestion to be considered here. The first is recurrent traffic congestion, which happens daily at the same time and in the same location. The second type of traffic congestion is non-recurring congestion, which occurs at random; as if it is an unanticipated event. The volume of traffic will increase as a result of this one-time impact. Because it involves real-time traffic knowledge and assessment, as well as critical traffic management judgments, non-recurring traffic congestion detection is more complex than recurring traffic congestion detection. [4].

Another cause of traffic congestion is the drawback ofthe roadways management system toadequately manage the traffic volumes on the roads. To begin the process of congestion, we must first identify the causes of congestion. Six causes of traffic congestion are identified in a study by the US Federal Highway Administration. The causes of congestion and their contributions are depicted in Figure 1.1. The term "bottleneck" refers to a spot on the road where the width of the road narrows. Vehicle crashes and stalls are referred to as "traffic accidents." The word "work area" refers to tasks such as road repairs, new road construction, and maintenance. Congestion isalso caused by “inclement weather” such as heavy rainfall, snowfall, and fog. When a traffic light controller fails, then the volume of traffic is disturbed; this is referred to as "bad signal timing." Strikes and marathons are examples of "rare occurrences" that result in increased traffic volume and congestion. As a result of traffic accidents and exceptional incidents, the traffic density may increase even more. Future research could focus on creating a dynamic and responsive traffic control system that assures smooth traffic flow during peak hours.

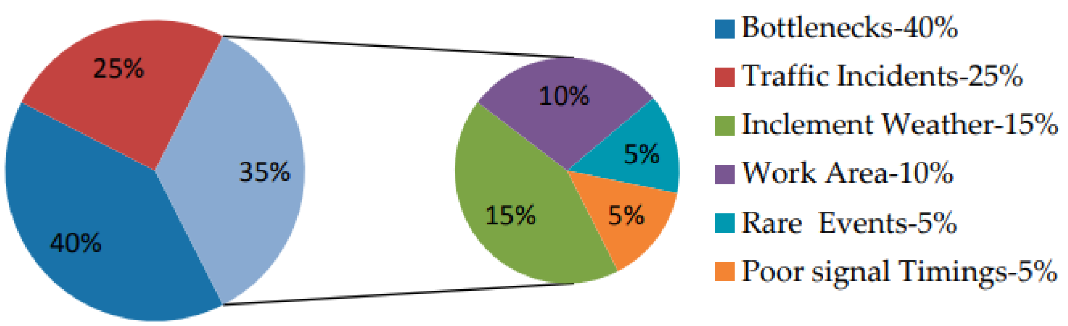

Figure 1.1: Sources of urban traffic congestion

1.1.2 Design Requirements for Traffic Management System

When developing a new traffic management system to reduce congestion in urban and metropolitan regions, the following design factors should be taken into account:

- Public transportation infrastructure with a hierarchical structure.
- Users and traffic management systems should have access to accurate real-time traffic information.
- The traffic control system should make decisions quickly.

- At intersections, emergency vehicles are given priority to preserve lives and property.
- The system must be able to track traffic collisions.
- The security of a smart city traffic system should be a priority.

1.2 INTELLIGENT TRANSPORTATION SYSTEM (ITS)

Wireless networking technology advancements and the improvement of vehicular network standards have paved the way for the introduction of ITS in recent years. ITS refers to the combined use of advanced sensors, computers, electronics, and telecommunication technology, as well as management policies to improve the safety and performance of transportation systems. [5].The main aim of ITS is to assess, create, analyze, and incorporate sensors, information communications technologies, and concepts to improve traffic flow efficiency and improve environmental quality, save energy, and save time for drivers, pedestrians, and other traffic classes.ITS aims to use appropriate technology to build "more intelligent" highways, vehicles, and users. Several ITS innovations were developed and implemented in many countries during the 1980s. The Japanese firm Zero-Sum Ltd., which specializes in ITS, and the Ahmadabad Municipal Corporation have launched a pilot project on real-time traffic details. In India, this was the first ITS solution with a fully integrated commercial framework. One of the major ITS achievements was achieved in China during the “Asian Games 2010” for parallel traffic control and management [6]. An ITS application identify, monitor, and reduce congestion intelligently based on online data that defines traffic conditions such as traffic density, speed, journey time, the geographic location of vehicles, and the current time. The key challenge in achieving this aim, however, is determining how to predict traffic congestion and reroute vehicles effectively by taking into account the time effect on potential traffic in an area of interest [7].

1.2.1 ITS Architecture

ITS is a worldwide development that has piqued the attention of transportation experts, the automotive industry, and policymakers:

As per the Figure, 1.2 components of ITS can be described as:

- **Automated Data Collection:** It necessitates in-depth and precise strategic planning via hardware and capable software. Some of the hardware which is already in use for data collection includes automatic vehicle tracking, GPS-based vehicle locators, cameras, sensors, and so on. With such a large amount of data, analyses such as traffic counting, surveillance, speed, time, location, and delay can be performed.
- **Transmission of data:** It is a crucial aspect of the ITS technology since it enables quick and real-time data transmission. A traveler can get a traffic-related alert by SMS, the internet, onboard car devices, and other methods.
- **Analysis of Data:** The data analysis includes various things like adaptive logical analysis, data cleaning, and data syntheses. The data analyzed is used to forecast traffic situations and conditions in the future. After data processing, the real-time details such as travel time, delay, road incidents, path changes, work zones, diversions, and so onare used for analysis purposes[8].

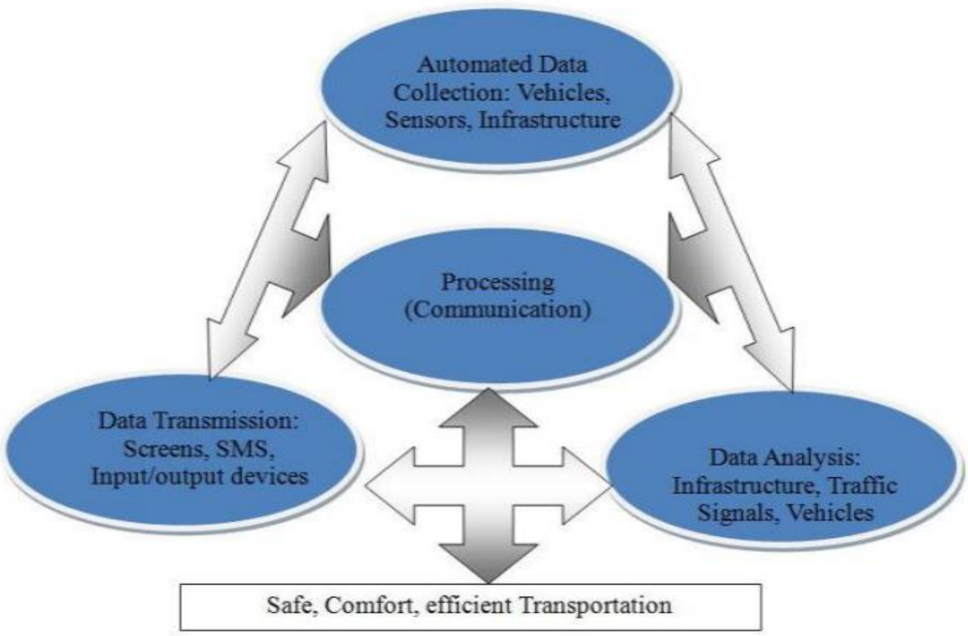

Figure 1.2: ITS components

1.3 TRAFFIC JAM DETECTION TECHNIQUES

Avoiding traffic jams is critical in every transportation system. However, because these jams can be caused by a multitude of factors, using a single methodology to detect them is not always safe [9]. Detecting traffic jams can be done in many ways, as detailed below:

1.3.1 Image Processing

In this approach, an image is captured through a camera which is taken as input and then process to detect traffic jams by measuring the density of vehicles.

1. **Background extraction**: In video surveillance systems, background extraction is a common method for detecting moving objects. While background subtraction provides detailed feature information, it has the drawback of being highly sensitive to scene changes induced by external events and lightning effects. A real-time streaming-based approach for intelligent transportation systems uses a background registration method to detect the vehicle in each picture of frame [10]. The sender transmits the encoded vehicles and backgrounds at various bit rates. Two different bitstreams of vehicles and history are decrypted at the remote site for vehicle monitoring and counting. To diagnose traffic events, important transportation parameters are obtained and analyzed. There is a method for identifying jam episodes by analyzing the road history function using numerous background photos[11]. The corner function of the retrieved backdrop image is analyzed to identify a traffic gridlock. The algorithm has been proven to be both stable and real-time in tests. A self-adaptive context extraction system based on histogram statistics and multi-frame average prevent the picture trail-blur issue by using a pure multi-frame method [12].

2. **Foreground extraction:** It is a method for processing digital data and calculating traffic density in real-time using video pictures [13]. There is a program that uses image processing techniques to recognize autos and analyze traffic flow and density. The density discrepancies calculated by the program may develop if the digital camera's alignment for both a reference and a traffic picture isn't the same. As a result, the machine must take the images in the same orientation for the best results. Visual-based approaches must deal with extreme lighting variations, shadows, or swaying trees, as well as shifting clouds. To address the aforementioned issues, a vehicle detection approach that does not include context modeling is designed [14].

3. **Aerial photographs**: Many ground-based methods to traffic data collection fail in disasters and large-scale incidents. In such a case, the issue of gathering traffic data occurs. The task of detecting vehicles on the street or highways using aerial images has proven to be difficult and widespread. A vehicle tracking algorithm based on Three Line Scanner Imagery is designed [15]. Three 1- dimensional cameras(CCD) are mounted on the imaging plane in a three-line scanner. To reduce the complexity of the procedure, this method employs an explicit model. A new technique [16] describes a density counting method that compares a live video frame in real-time to a reference image and searches for only vehicles in the area of interest. This system has the advantage of not requiring sophisticated sensor-based systems.

1.3.2 Sensing Techniques

On highways, sensors are frequently employed to track traffic congestion. Sensors are frequently classified as intrusive or nonintrusive. Microwave radar is currently a non-intrusive technique used over roadways that are based on laser and optical systems. Depending on the sensing principle utilized, current intrusive traffic flow sensors are categorized as magnetometers, inductive loops, or pressure switches. These sensors are either embedded in or affixed to the road's top surface.

1. **Inductive loop sensors**: To count the passing automobiles, inductive loops are placed at a specified area. Vehicles traveling over inductive loops on the roadbed are recognized, and more advanced sensors compute vehicle length, speed, and width, as well as the distance between the traveling vehicles. While this technology is capable of operating at any speed, it has a high error rate when it comes to detecting and delivering traffic data. Negatives include the difficulty of constructing inductive loop systems, the time-consuming maintenance, and the inability to handle traffic locally [17][18]. Large and small cars occupying every available location along the road are detected by a loop sensor [19]. To achieve reliable results, the segregation of vehicles pattern analysis is conducted using fuzzy logic implementation. While inductive loop detectors are a viable choice, they have a high failure rate when used on substandard roads, and also during maintenance, they create traffic congestions.

2. **Magnetometers**: A non –intrusive wireless sensor network is used for counting cars in an automated traffic management system [20]. Unlike other technologies, magnetic sensors are unaffected by environmental influences, resulting in more dependable and robust data. The various test results prove that this technology works effectively in rural and non-urban areas where a low-cost solution is required. A prototype of a wireless sensor network system consists of magnetic sensors is used to [21] detect traffic congestion. With adequate signal amplification and data analysis, this gadget can be used to identify automobiles utilizing magnetic sensors.

3. **Acoustic sensors:** A sensor network system for traffic monitoring in the smart transportation systems is based on sound transducers (passive) which are put in a non-intrusive/obtrusive manner at the motorway roadside to offer real-time traffic information for dynamic queue congestion identification [22]. This device will show traffic flow in complete real-time at a given temporal or spatial scale. The infrastructure is based on the self-contained, install-and-forget design that incorporates a low-power sensor networking interface and TCP/IP via UMTS communication to the back-end computing environment. On a freeway test site, extensive experimental demonstrations for long-term operation are offered.

1.3.3 Techniques for Probing Vehicles

1. **Global positioning system based:** This system is used to collect data of traffic andpropagate information on traffic bottlenecks with the help of GPS devices in the vehicles. Traffic signals and GPS traces from probe cars are used to partition the road network into parts [23]. Within each line, thresholds of temporal and spatial speed values are computed to identify traffic as congested or free-flowing. Tens of thousands of GPS cell phones will be implanted in a variety of automobiles in a specified area for a six-month study. These phones' data has been utilized to create algorithms for calculating travel times, selecting ideal sensors, and safeguarding user privacy. Hidden Markov models are used to supplement GPS data alongside Wi-Fi localization information and map GPS traces to road segments in a new way. A traffic jam warning system in [24][25] identifies places with regular traffic congestion using data from GPS-enabled devices such as cell phones, computers, and cars.. A framework in [25]is used to detect traffic jams

based on vehicle GPS trajectory, which addresses the shortcomings of prior jam detection systems, which only offer information about particular jams.

2. **Smartphone-Based:** Smartphones can now help with current traffic jam detecting methods thanks to technology improvements. Other traffic vehicle sensors can be used in conjunction with smartphones that have GPS or A-GPS capabilities, as well as Cell-ID. The traffic and road conditions in Bangalore, India, using cell phones are tracked via GSM and GPS[26]. Traffic congestion is detected on the lane if the on-phone accelerometer senses appropriate braking and the on-phone microphone detects substantial honking[27].

1.4 CONGESTION AVOIDANCE TECHNIQUES

As traffic congestion increases, the need for congestion control strategies for traffic management grows. To escape traffic congestion, these methods employ a variety of technologies and tactics. Monitoring road network traffic is one of these methods and is used to forecast and prevent congestion at frequent road network bottlenecks.

1.4.1 Vehicle rerouting using a Prediction Algorithm

Vehicle rerouting based on traffic density predictions, which advises drivers to shift routes from crowded to uncongested locations proves to be a superior choice for congestion avoidance. To forecast future traffic patterns, the bulk of prediction systems rely on historical traffic data. A technique for traffic prediction that incorporates both historical and real-time traffic data exists. Based on the traffic prediction result, a routing method is developed that is capable of providing intelligent route services suitable for complex route guiding systems. The algorithms have been put to the test in both complex metropolitan settings and the metropolis. Path determination is used to develop scalable routing systems based on user preferences and adaptive paths for traffic situations [28]. The techniques are n-SVR and ANN system for vehicle speed prediction [29]. By offering course direction, this technology can help to avoid traffic congestion. An actual urban traffic simulative model is designed to anticipate and prevent traffic congestion (AUTM)[30]. The map and transfer (MT) conversion, optimal spatial evolution rules, and a congestion-avoidance routing algorithm are the three fundamental components of their methodology. To obtain the actual urban cellular spaces, the MT conversion approach was devised, which employs optimized spatial evolution principles for better vehicle dynamics modeling. AUTM is a traffic simulation tool that can anticipate the impact of installing overpasses and roadblocks. A congestion-avoidance routing system is created in city simulations, allowing automobiles to dynamically change their trajectories to their destinations, resulting in traffic optimization. Extensive experimental models are utilized in a variety of real-world cities. The outcomes of prediction are promising even in the worst-case scenario. The accuracy of the traffic congestion forecast is better than 89 percent, with a road density prediction deviation of less than 0.2. This model can be used to implement a sophisticated traffic light strategy to improve city traffic flow.

1.4.2 Vanet-based congestion avoidance

Vehicles share information about local traffic situations and utilize this information to optimize their routes in Vanet-based congestion avoidance. A new possible approach based on Vehicle-2-X (V2X) technology employs decentralized wireless vehicle-to-vehicle communication. It has introduced a new technique that navigation devices can use to figure out how to get around crowded highways. Each automobile broadcasts to adjacent cars the average speed of a road segment. As a consequence, vehicles recalculate their routes depending on the currently permitted speeds on their neighborhood's road segments whenever this information is received. Simulations were performed to evaluate what kind of benefits their strategy might offer. The simulation findings show that employing more intelligent route computation, navigational systems based upon V2X technology may improve future transportation system vehicular traffic. The outcome is influenced by several factors in the scenario. V2X message transmission may be obstructed by high buildings near highways, leading to a substantial rise in packet collisions. [31]. As a result, after receiving this information, cars recalculate their routes depending on the currently allowed speeds on their neighborhood's road segments. The simulation findings indicate that navigation systems based on V2X technology may improve the overall traffic efficiency of future transport networks by utilizing more intelligent route calculations. The outcome is influenced by many variables in the situation. Elevated structures near roads may impede the transmission of V2X messages, resulting in a significant increase in packet collisions. [31]. By adopting a city-wide highway pricing approach, a road pricing model is proposed for avoiding and decreasing traffic congestion in urban regions. The road cost of the network adjusts dynamically in reaction to road congestion and popularity, enabling real-time road traffic management and congestion reduction. The pricing-based traffic control algorithm, according to simulation findings, lowers bottlenecks by normalizing traffic volumes across the entire traffic network. Inter-vehicle connection (IVC) technology may be used to communicate road charges to drivers [32]. In a multi-agent-based approach for network congestion and Path Allocation using Virtual Agent Negotiation [33], vehicle agents (VAs) in the local area communicate with one another before being assigned strategic options along their path (CARAVAN). Route allocation choices are made jointly at these intersections. To transmit traffic data and conduct dispersed processing, VAs use inter-vehicular communication (IVC). Each VA offers its own independently determining route preference information to arrive at the initial route allocation. To maximize the allocation, a series of virtual negotiating agreements are utilized. Since these interactions are interactive, no physical touch is required, lowering communication expenses. This technique allocates suitable routes fast and with little intervention. Signal timing optimization

A traffic light control system that is smart will aid in the relief of traffic during emergencies while also preventing future congestion. To optimize traffic flow, numerous strategies for signal timing optimization exist. Because of their potential as optimization approaches, evolutionary algorithms are good solutions to road traffic management and congestion avoidance concerns. A real-time evolutionary optimization methodology that is multi-agent-based is designed for managing urban traffic in the field of traffic signal control[34]). The green signal timing was set online to do this. The technique outperformed a fixed time-dependent traffic controller when compared to the latter. A special-purpose simulation program for optimizing traffic signal light time has been proposed to minimize traffic congestion [35]. To construct an adaptive t traffic control system, a hybrid strategy is used that combines a fuzzy logic technique with merely a neural network-based method [36]. The preset traffic data and the SUMO, NS-2, and GLD simulation methods, as well as the multi-module strategies,are used, to model and implement those modules and algorithms.

1.5 VEHICULAR ADHOC NETWORKS

The vehicular ad hoc networks (VANETs) are intended to be a key component of the ITS system for providing low latency and highly efficient vehicular communication. It has long been used to provide privacy and security while also reducing traffic congestion. With the growth of VANETs, the delivery of many services is gaining more attention from ITS. It allows vehicle drivers to interact and synchronize with each other to prevent dangerous conditions before they happen, thus enhancing driver protection and relaxation [37].

VANET is often referred to as wheeled networks, which are utilized to provide connectivity among vehicle nodes. Vehicular nodes are self-organized and link with one another in a less environmentally sound infrastructure. The IEEE Committee has established the IEEE 802.11p standard for VANETs, recognizing that the ad-hoc vehicle network is essential for the provision of safety-associated applications in the Intelligent Transportation System. The primary goal of VANET is to create an intelligent framework for transport. In building vehicular communication, the DSRC may play an important role. The DSRC has a range of around one thousand meters [38].

Inter-networking via VANETs has been getting huge motivation over the past few years. Realizing its increasing importance, academia, major automotive manufacturers, and government agencies are making efforts to develop VANETs. VANET has mobile nodes, typically sensor vehicles, static networks, and fixed roadside access points (RSAP). Depending on the coverage requirements, this device comprises a grouping of GPS and cellular communication modules. One of this technology's main services is to support drivers with protection so that road injuries can be reduced. Protectingonboard passengers is the main service offered by this form of network. VANET's key requirements are high processing power, large storage space, adequate energy, and node movement estimation [39].

1.5.1 VANET Architecture

In VANET there are three key elements: Roadside Unit (RSU), and On-Board Unit (OBU), and channel as demonstrated in Figure 1.3. Normally, the RSU is static all along the paths, while OBU is housed inside the vehicle. All RSUs are interconnected with each other along the route. The OBU, on the other hand, handles contact between vehicles and the RSUs on the network.

- **RSU:** The key RSU functions include (i) expanding the range of VANET communication by sending messages to other OBUs and RSUs. (ii) Applications for running protection, like traffic situation coverage or accident alert. (iii) Supplying OBUs with Internet Access.

- **OBU:** An OBU comprises a processor, memory, network unit, and sensors for resource commands. Later the OBU observers and collects the data to create messages that are delivered via wireless media to nearby vehicles.

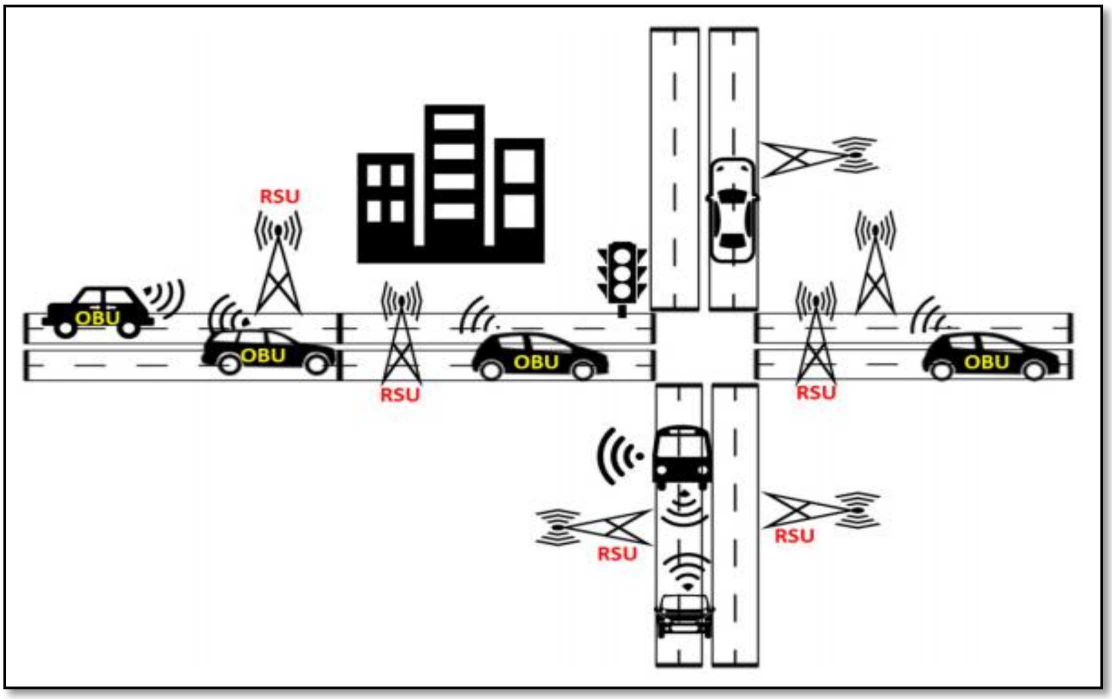

Figure 1.3: VANET Components

- **Channel:** Two main features which differentiate the wireless channel in VANET: first, spectrum sharing, Which is dedicated for various VANET applications, and second, major global frequency band groups. The wireless channel's key problems are inaccuracy, signal distortion, and path loss[40].

In VANETs, there are many kinds of wireless connections that can be used for data routing as shown in Figure 1.4. The accessible wireless connections are:

1. **vehicle-to-vehicle (V2V):** It permits vehicles to work together to exchange data. VANET tolerates vehicles identified by the OBUs portion to connect and connect without requiring infrastructure provision to share security and request messages. For disseminating information to a group of vehicles, this communication network usually uses a multi-hop broadcast.

2. **vehicle-to-infrastructure (V2I) or infrastructure-to-vehicle (I2V):** The structure offers current data and internet access to vehicles through this connection. As a result, they will obtain up-to-date updates on current events as well as traffic on nearby highways. In this, the vehicle can connect with immobile devices on the vehicle's side. A vehicle may communicate with RSU through an ad-hoc network to collect traffic data, environmental data, or even link to the Internet. To broadcast these data, the RSU can also connect to OBUs. For RSUs that are close by, this communication field usually utilizes a specific hop transmission with plenty of bandwidth (every kilometer).

3. **infrastructure-to-infrastructure (I2I):** The RSUs can connect over a wired channel to communicate on-road security, or they can connect to the Internet over external cellular networks like GSM, GPRS, and 4G[41].

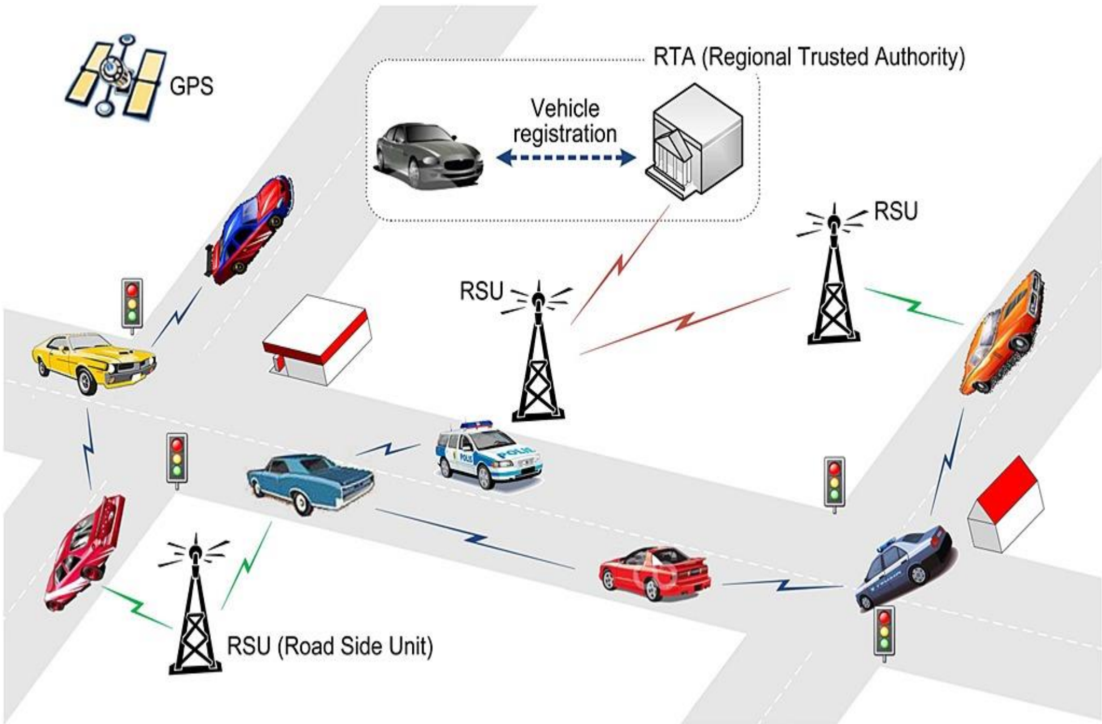

Figure 1.4: VANET Architecture

1.6 EMERGING VEHICULAR NETWORK APPLICATIONS

The infrastructure is only a few hops away from the vehicles in a grid (WiFi, cellular, satellite, etc.). Traffic control, infotainment, security, speed management, accident management, and speed suggestion are just a few of the applications for VANETs.

1.6.1 Content downloading

Peer-to-peer information sharing is perhaps the best example of the relationship between the wired Internet and the vehicle grid. Drivers in the vehicular network have access to "location-based and aware" information in addition to standard file downloads from the Internet. This covers both time-sensitive and non-time-sensitive content (e.g., emergency vehicle video streaming) [42], as well as content that may be postponed, such as proximity advertising and marketing segments [43]. Roadside access points (such as those found at petrol stations) or automated billboards are used for this. Due to a paucity of access points bandwidth, mobile users are encouraged to use Torrent-style P2P file sharing to assemble the package (Figure 1.5).

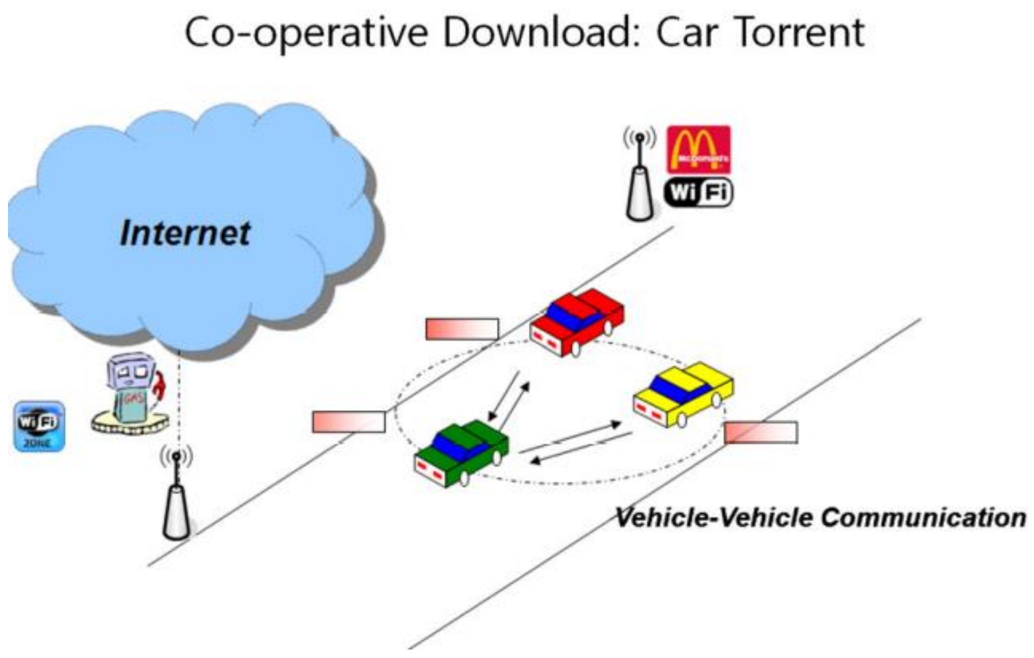

Figure 1.5: Content downloading

1.6.2 P2P location significant advertising

Software that gains from numerous neighbors downloading is "Ad Torrent" [43]. Consider the situation of a driver who wants to download trailers for movies that are playing near him. After the movie, the driver also wants to eat at a specific restaurant.

This information must all be acquired in a short amount of time. It takes an unnecessary amount of time and is prone to traffic congestion to drive up to an access point every time. Multichip uploading from the far access point or via LTE is not possible due to wireless TCP limitations. It also has the potential to overwhelm the system with the data flow. Instead, with Ad Torrent, the access point transmits randomly selected ad pieces tothe passing cars. Following that, each car uses an outbreak ("gossip") strategy to disperse the parts in a probabilistic manner. As a result, the neighborhood is inundated with advertisements. Because individual vehicle desires are fleeting, learning must be centralized on Internet servers.

1.6.3 P2P (driver to driver) interaction

In this, a network between vehicle to vehicle is established for transferring the content Consider a hazardous highway traffic or safety situation, such as heavy traffic, bad weather, a natural or man-made accident, or even a hostile assault. Multimedia information, such as video, may be transmitted from one or more lead cars towards vehicles trailing many miles behind to "visually" educate automobiles following several miles behind. They will be in a better position to make an educated choice (like turn around) than if they had just received a warning text message.

1.6.4 Sensing the environment

Sensor hubs, such as vehicle networks, are increasingly being used for constructive urban monitoring and data exchange, and publication. Each vehicle may detect one or more events (such as street pictures and identifying harmful substances), process sensed data (such as license plate identification), and send messages to other cars. Traditional sensor networks are incapable of handling the volume of data generated by automobiles. Instead of providing data to sinks regularly, they can retain it. [44][45][46]. The core concept is to leverage vehicle mobility and wireless broadcasting to send summaries (meta-data) of data held in vehicles on the go. To sense the environment various sensors are used like video, medical sensors, and for communication Wi-Fi, ZigBee, andBluetooth among other things is used. (Figure 1.6)

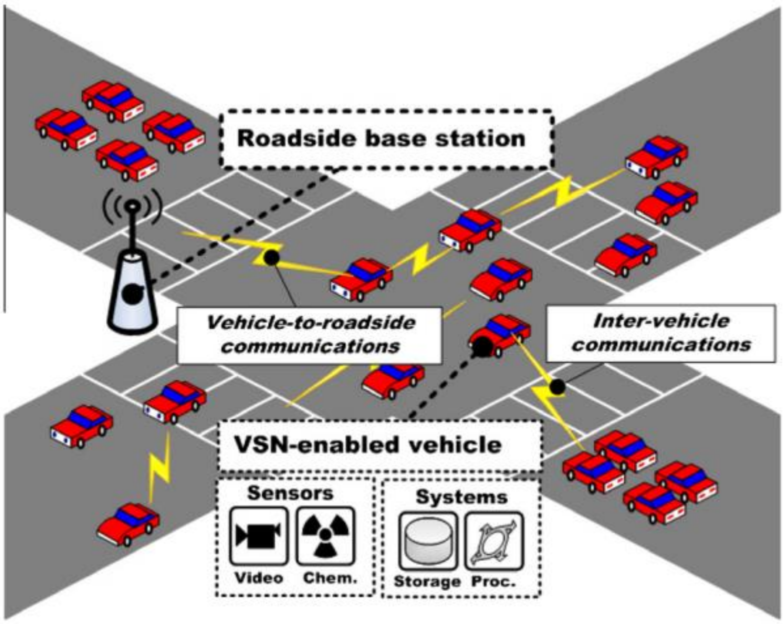

Figure 1.6: Urban sensing

1.6.5 Infotainment

This application offers a variety of entertainment services to drivers and passengers, including music, texting, video gaming, vehicle connectivity, Internet access, insurance services, fleet management, and multimedia downloads. This category also includes all amenities and software that contribute to the comfort and luxury of the driver. These resources include weather data provisioning, traffic updates, and various driver interests like nearby parking, markets, restaurants, sports, and multimedia sharing. Figure 1.7 depicts how passengers can use video calling applications or stream multimedia files, such as music while driving. MP3 is a digital audio format [47][48].

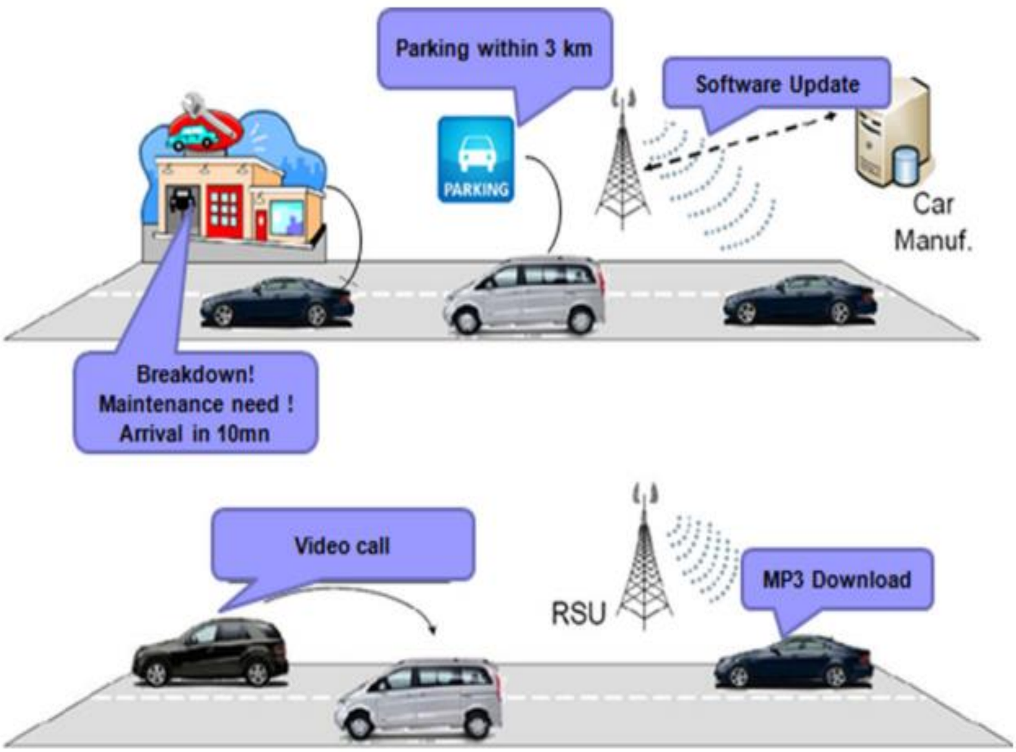

Figure 1.7: Infotainment application in VANET

1.6.6 Traffic Management

This application adjusts the vehicle's velocity according to the velocity of vehicles ahead or even behind; it sends messages among vehicles describing their position, velocity, and acceleration using V2V communication. In the meantime, the structure obtains the road's speed limit through I2V interaction.It also contains value-added services such as cooperative navigation.

1.6.7 Driving Alert

This app assists drivers on the road by guiding and assisting them in the event of road bottlenecks, collisions, traffic incidents, traffic congestion, accidents, and more. It also offers parking advice and notification, as well as toll booth collection. If a driver requires assistance or a software upgrade, communication with car manufacturers is also possible. Nearestparking and automated maintenance are examples of details that a user of VANET can obtain with high accuracy and a variety of options.

1.6.8 Road Safety

This system is used to improve travel safety and prevent serious accidents. V2V and V2I communications are utilized to enhance road protection by offering traffic security warnings, lane-altering warnings, and accident warnings, among other things. Passengers, pedestrians, and drivers are all covered by this application. Emergency vehicle alert, lane change warning, emergency brake warning, accident warning, traffic condition warning, and pedestrian crossing warning are among the safety applications as shown in Figure 1.8[49].

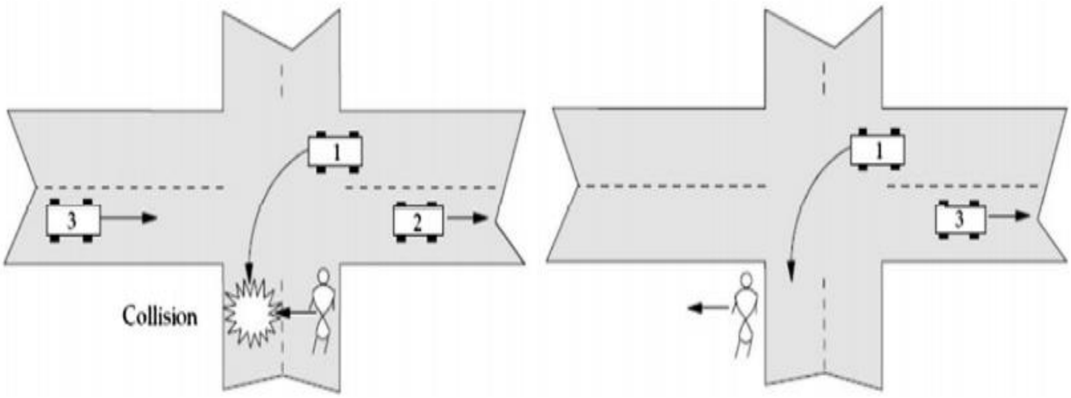

Figure 1.8: Pedestrian crossing warning

1.6.9 Traffic Efficiency and Management

Traffic efficiency technologies reduce vehicle traffic and prevent congestion by delivering up-to-date information and records regarding neighborhoods that are distributed in space and time. Speed control services and cooperative navigation services are two examples of this type of system. It also provides real-time and dependable information, traffic flow, and road risk. Notification of speed limits A traffic control situation at a road intersection is depicted in Figure 1.9. When a vehicle senses a pothole on the road, it transmits out an alert message to nearby vehicles. This mission can be completed by any one of the vehicles or RSU.

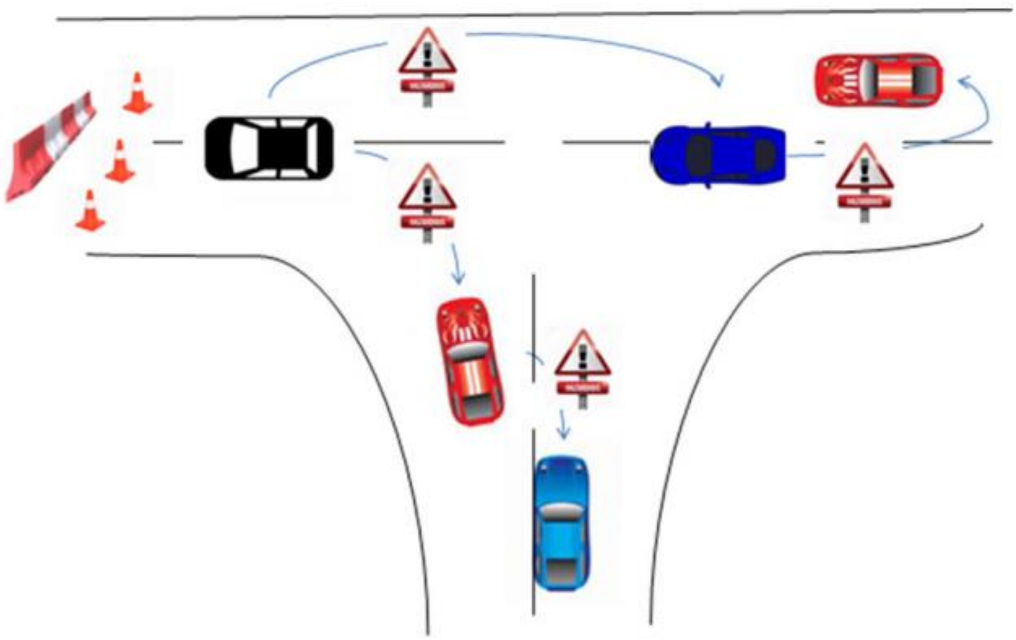

Figure 1.9: Traffic management application

1.6.10 Urban Sensing

This program focuses on V2V transmission; the vehicle gathers enough data regarding the road condition through its sensors, and the in-vehicle system processes this information to decide the road condition and issue a driver alert to other vehicles. The RSU is mounted ahead of the curve to send packets to potential vehicles warning them of the curve's position, the speed necessary to safely manage the curve, and existing road situations.

1.6.11 Road Condition Alert

When visibility is poor, this application aims to avoid a crash at the united stage. The system can warn vehicles attempting to merge as well as the remaining vehicles on the lane if there is an unsafe situation. At the intersection, the device collects and processes data, and if an unsafe condition is detected, it sends out alert messages to vehicles.

It sends warning signals to other vehicles on the road using V2V communication. This device is designed to warn vehicles regarding dangerous road situations created by ice that make the road slippery, to avoid accidents [50].

1.6.12 Public Services

Since much of an emergency vehicle's response time is spent on the way to the destination, public protection applications goal to support drivers and emergency groups by reducing journey time and delivering assistance when an accident occurs. This device also ensures that emergency services can get to their destinations without having to sit in traffic, This mission was achieved by disseminating warning signals using V2V transmission among vehicles driving on the identical path to clean the lane for the emergency vehicle. This communication provides details regarding the emergency vehicle's speed, location, lane info, and distance. It also provides traffic flow monitoring and a stolen vehicle tracker [41].

1.7 TYPES OF VANET SYSTEM ARCHITECTURE

There are four types of VANET system architecture which are described as follows:

1. **Centralized:** The main component of the framework is located on a centralized server in this type of architecture. Specifically, the program's key functions are handled by a single unified component. If all or most of the data is kept and processed on a centralized server, the collapse of that server would result in the entire system failing. Services are typically provided in this form of architecture.

2. **Flat-distributed**: Components in a distributed system are located on a network and use message passing to communicate and coordinate their activities. The key component of the framework is distributed in a flat structure on a collection of nodes in Flat distributed architecture, so there is no need for a central server. The machine continues to function even though one of the nodes fails. Fault-tolerant systems are the ones we're talking about.

3. **Hierarchical-distributed**: The system's main component is distributed in a hierarchical structure over many servers in this architecture. This architecture is used in the On-Street-Parking and IR-CAS ACN systems. On-Street-Parking is built on a three-tier architecture, with the OBU of vehicles in the first tier. The second tier consists of InfoStations, each of which is responsible for a specific parking zone. The service is provided by InfoStations located on the side of the road, which collects messages from vehicles requesting parking. An

InfoStationCenter (ISC) is the third tier, which tracks and coordinates all InfoStations. The architecture of the IR-CAS CAN is two-layered. The first layer is concerned with cars, and it is here that the seriousness of an accident is calculated. The RSU, which itself is responsible for informing emergence response centers and also the driver's family, makes up the second layer.

4. **Stand-alone:** This architecture has only one part and operates on a single computer device with no contact with other computers [51].

1.8 CHALLENGES OF VANETS

In ITS, which vary from traffic protection applications to infotainment applications, different applications are used. Such a set of applications presents different specifications for protocols for vehicular communication. Such requirements lead to new challenges:

- **Bandwidth limitations:** VANETs endure channel overcrowding, particularly in a high-density zone, because of the absence of a central controller that handles the use of restricted bandwidth and comfortable activity.
- **Delay constraints:** Applications for VANETs frequently have rigorous time rules. Hence, it is important to have a fair time delay to design effective vehicle transmission protocols.
- **Privacy rights:** Vehicular contact must resolve the tradeoffs between privacy and accountability. Each car has to believe the source of data it receives.
- **Cross-layering protocols:** In terms of time and place, real-time applications have rigorous limitations. The routes are often altered due to the complex topology. Thus, in such a situation, delivering reliable links via the transport layer is effective.
- **Security threats:** Because of the open environment of VANETs, vast amounts of attacks can be targeted. Therefore, it is a fateful problem to discover new incidents related to vehicular interaction and to protect the clustering protocols compared to such types of attacks.
- **High dynamic and disconnected topology:** The traffic conditions are changing at a very fast rate like at moment traffic is free flow and in other moment congestion can occur .Congestion detection algorithms in VANET are designed handle traffic

conditions in microscopic and macroscopic view.To deal with such conditions, a new research model is therefore implemented called Vehicular Delay Tolerant Networks.

- **QoS:** Maintaining QoS in a VANET is difficult due to high mobility, complex topology, frequent interruptions, out-of-range wireless connectivity, and other factors. Accessible bandwidth, transmission latency, delay jitter, throughput, and PDR are instances of QoS specifications. These parameters are nothing more than mathematical properties that can be categorized as an additive, multiplicative, or concave for evaluating consistency. Having the needed adaptability and using the existing resource for preserving QoS in VANET is a difficult research problem.

- **Standards:** The IEEE 802.11 specification fails to fulfill the requirement for reliable network access, and the IEEE 802.11p protocol's new MAC specifications are inefficiently optimized for a wide range of vehicles. As a result, further research on standards is needed.

- **Connectivity:** Building and maintaining communications and connection among vehicles with better delay execution is the main problem for VANET under circumstances like high vehicle speeds, geographical constraints, network dynamic topology, network bandwidths, and other factors.

- **High-speed wireless communication techniques:**To support high-speed vehicles in VANET, high-speed transmission techniques are also an essential issue in VANET. Many wireless systems, such as 2G, 2.5G, 3G, and 4G, may be used for connectivity because they have significantly enhanced communications infrastructure and throughput. Many wireless systems, such as 2G, 2.5G, 3G, and 4G, may be used for connectivity because they have significantly enhanced communications infrastructure and throughput.

- **Broadcasting:** Broadcasting protocols are useful in a variety of circumstances in the VANET, such as traffic data, weather updates, emergency information, being able to alert before a crash, notifying for abrupt brakes, road condition commercials, and so on. These protocols should be quick, reliable, and robust in VANET safety applications to supply essential information to drivers or other users on time. Interactions in messages and hidden node issues are just a few of the big difficulties that have been faced. Furthermore, the protocols should be able to broadcast security information across both low and high-intensity VANETs.

- **Scalability:** Nodes in a VANET represent vehicles that travel on highways, towns, and metropolitan areas of varying densities. In such circumstances, VANET is supposed to perform well.
- **Architectural design:** Flexible and dependable architecture will also be crucial when developing an integrated framework for VANET, as it will operate on a mix of different technologies in the future such as Wi-Fi, radio band 5.0, ZigBee, 3G/4G, and heterogeneous VANETs.
- **A different set of services:** Vehicular networks must be able to provide a different set of facilities. Low latency and high reliability are needed for security and road safety applications. On the other hand, packet drop and resource exploitation are general execution metrics for documentary applications. Given the variety of resources, it is essential to deploy entry, routing protocols, and resource allotment schemes that are well-adaptable.
- **Resources management**: To bring various lane applications in VANET, resource management approaches like storage management, bandwidth distribution, and packet management are required to ensure fairness in resource allocations [52].

1.9 ISSUES IN TRAFFIC MANAGEMENT SYSTEM

Over the last few decades, traffic management difficulties have worsened in most industrialized and developing nations throughout the world as the urban population has grown. Traffic congestion affects social, economic, and environmental issues on a huge scale [53]. In urban centers, traffic congestion, road accidents, and disruptions in traffic flow are all too prevalent. As a result of traffic management issues, fuel consumption and travel time have increased, as have air pollution levels [54][55]. The emergency health care trucks' ability to provide requested services on time is hampered by vehicular traffic congestion and flow issues. According to the World Health Organization's Global Status Report on Road Safety, the number of road-related incidents worldwide is estimated to be approximately 1.35 million per year [56]. According to the 2019 urban mobility study [57], the estimated time delay for a passenger traveling in the United States costs about 18.12 dollars per hour due to traffic congestion. People spent 6.9 billion extra hours traveling due to traffic congestion, resulting in a 160 billion dollar loss in the United States (US) and an additional 3.1 billion gallons of gasoline purchased and consumed[58][59]. According to the projected economic and environmental cost of congestion report[60], the cost of fuel and time spent during travel in the United Kingdom was $12,649 million in 2013 and is anticipated to rise to $20,937 million in 2030, a 66 percent increase from 2013 to 2030. In Germany, the cost of gasoline usage and travel time lost is predicted to reach 27, 702 million Euros in 2030, up from 21,684 million dollars in 2013. It is predicted to rise by 28% between 2013 and 2030, while direct costs linked to the value of fuel and time lost in France are expected to rise by 33% between 2013 and 2030. The total cost of gasoline consumption and travel time in four heavily populated cities, London, Paris, Stuttgart, and Los Angeles, is predicted to reach 42.71 billion dollars in 2030, up from 25.85 billion dollars in 2013.

According to a traffic congestion and reliability report by the US department of transportation, Federal highway administration [61], the causes of interruption in traffic flow are due to the following reasons. i) When the number of vehicles on a given road section is greater than the capacity of the road in terms of length and width. ii) Due to vehicular crashes and other traffic incidents the road traffic is jammed. iii) Due to construction on roads and lanes the highway environment is getting disturbed which affects the traffic flow. iv). Environmental conditions like snow, fog, and rain have a direct impact on traffic flow. v). Due to some special events and a sudden high volume of traffic on some of the days interrupts the traffic flow.

The congestion levels on roads and highways do not only increase from the past three decades but they are also volatile [62]. Due to the variety in the traffic on roads and the variety of traffic environment events the congestion levels vary from day today. To handle such huge traffic congestion and flow problems there is a need for new technologies like intelligent transportation systems (ITS).ITS focuses on the implementation of the operational strategies such as making lane incident response on road events more quick and effective, road event planning based on the weather events such as rain, fog, and snow, pre-planning and traffic control measurements information provided to the passengers on the road network in real-time like when and where congestion occurred and how to avoid it. In some cities around the world, some measures have been taken to manage the traffic problems such as carpooling and ridesharing where drivers are encouraged to share their drive with other passengers. The adaptive traffic light system is another good way to manage the traffic congestion on lanes of the roads[63][64]. Some companies have introduced drones to deliver the products to customers. In New Delhi (India) due to heavy traffic flow regularly the air pollution level has increased and to avoid this local administration has introduced an even-odd system where the vehicles with an even number plate run on one day and odd number plate vehicles run on other days. The adaptive speed limit signs on roadsides are also used in some cities to handle the traffic flow on a timely basis. Despite all the measures mentioned above the traffic flow problem has not decreased and is expected to increase exponentially in the future.

CHAPTER 2:LITERATURE SURVEY

2.1 LITERATURE STUDY

D. Mehta et al. (2020) [65]had researched to design a Multi-Objective Cluster Head based Energy-Aware Optimized Routing (MCH-EOR) algorithm in WSNs. In this routing mechanism, a multi-objective function-based Sailfish Optimizer (SFO) was used by the authors to select Cluster Head (CH) during route discovery to sustain energy efficiency in the network based on designed an effective fitness criteria with multiple objectives. MCH-EOR helps to minimize energy consumption in the network and also helps to reduce sensor nodes dying rate that helps to increase the network lifetime.

M. Elhoseny et al.(2020) [66]had researched to develop an energy-efficient optimal routing for communication in Vehicular Ad Hoc Networks (VANETs) by utilizing the concept of the clustering model. Here, the authors have proposed a K-medoid integration model to integrate an entire network of automotive sites, and thereafter, nodes or vehicles are designated as cluster heads to compelling communication in the network. They have also utilized the idea of the Enhanced Dragonfly Algorithm (EDA) to enhance the parameter as small power consumption on VANET in anticipation of achieving efficient power connections.

R. Kolandaisamy et al. (2020) [67]had presented a stream position performance analysis model based on the discovery of a Distributed Denial of Service (DDoS) attack on a detection-based route at VANET. The authors investigate the acquisition of cluster-based data aggregation attacks in which neighboring nodes contribute substantial information to the cluster's leader. Furthermore, the evidence accessible in the cluster head may be gathered by other vehicle nodes and used for a variety of tasks, such as data delivery decision-making. The existence of malicious nodes poses a risk of harmful data being sent, which may accidentally split VANET data and send huge volumes of packets to cars or the Road Side Unit (RSU). To combat this, the Stream Position Performance Analysis (SPPA) technique was created for writers, and it analyses the position of any field channel when publishing information to carry out DDoS assaults. **M. Saravananet al. 2020** [68] had researched to design a routing mechanism using reinforcement learning in VANETs. They suggested this job to meet a major issue of reducing transmission stability and resolving extra delivery delays. The whole research concentrated on identifying road and traffic selection by the number of cars grown by packet transfers at the time of the roadway's installation. This minimizes transmission delays and eliminates carrying-and-forwarding situations; but, owing to fast changes in traffic congestion, these techniques fail to identify accurate road congestion in real-time conditions. As a result, a model that correctly evaluates traffic congestion and helps VANETs in selecting the best route in an automated way with improved accuracy is required.

Guidoni et al. (2020)[69] propose a ground-breaking vehicle traffic control system focused on macroscopic flow-density traffic control methods. The four components of the proposed approach, called Re-RouTE, are Location Information, Network Representation, Network Classification, and Route Suggestion. To begin, the Location Information module gathers data on all of the network's cars' speeds and locations. The Network Representation creates a weighted graph representing the city map using the provided data. The Network Classification module uses traffic engineering theory and concepts to verify network congestion. This method reveals whether or not certain road segments have vehicle blockages and the severity of such bottlenecks. The system creates lower-cost routes for each automobile regularly by using the Route Suggestion module.

Ahmad et al.(2020) [70] had researched road traffic management using the concept of a cooperative heterogeneous vehicular clustering mechanism. The authors set out to create an integrated module that uses Vehicular Ad-Hoc Networks (VANETs) and heterogeneous type Long-Term Evolution (LTE) to offer seamless communication in intelligent transportation systems. Because a heterogeneous type LTE network was involved, resource cost reduction was taken into account when creating a traffic control system. The concept of vehicle clustering was utilized to tackle the traffic management problem since it is the most important method and helps to decrease data and LTE network use while also solving the problem of vehicle non-cooperation. A strategic game-theoretic-based clustering method is studied to tackle the cost issue caused by traffic, and the proposed technique is called Cooperative Interest-Aware Clustering (CIAC). The CIAC suggested by the authors in this study not only helps to balance costs but also helps to incentivize cars to engage in the data-sharing clustering mechanism. The selection of a Cluster Head (CH) utilizing the strategic game-theoretic approach was also employed to preserve the fair-use policy in this study.

EPK Gilbert et al.(2019) [71] proposed a cluster-based routing for WSN model with the concept of trust aware nature-inspired optimization method along with routing protocol, In this research, authors designed an optimized trust aware data aggregation and routing mechanism based on the clustering approach to divide the network into clusters for better transmission and network lifetime. To reduce the network overhead, authors also introduced the concept of compressed sensing method for data aggregation from sensor nodes and nature-inspired swarm-based optimization was implemented to transmitted data packets from source to destination using the most trusted route. **Al-Humidi et al. (2019)** [72]researched to solve the problem of a random selection of a sensor node as a cluster head through Energy-Aware Routing using Centralized Control Clustering (EACCC). The suggested EACCC routing system is based on a centralized control clustering approach, and each sensor node first communicated information about its energy to the base station, along with its position. The base station determines which section of the wireless network the sensor nodes will be deemed cluster heads based on the information it receives. EACCC runs in many rounds, with each round ending with the selection of a cluster head following the transmission of selection data. Finally, the authors assess and analyze the proposed EACCC routing mechanism's efficiency in terms of QoS metrics, emphasizing the importance of route optimization and security.**X Fu et al. (2019)** [73] had designed a model of cluster-based WSN using the concept of cascading approach and the authors also introduced the congestion-aware routing recovery mechanism. To develop a cascade model for cluster-based WSN, a load function was created on each sensor node based on data packet size, and overloading was decided depending on each node's congestion state. The network's overloaded sensor node may recover after a short amount of time and does not need to be permanently removed from the network area. The experimental results of the proposed model demonstrate that the network is immune to the overload tolerance phenomenon. Cluster size balancing and locating the sink node in the center of the deployment region may help the network reduce the risk of cascading failures. If a cluster-based routing recovery method is developed, the network will be able to recover the fail nodes after some time, and the recovery time will be reduced in the future.**R.Borawake-Sataoet al.(2019)**[74]

proposed a multi-objective strategy-based dynamic routing protocol for Wireless Multimedia Sensor Networks (WMSNs). The authors used the concept of adaptive mobility routing to improve the routing capacity of WMSNs as applications for the Internet of Things (IoT). The primary aim of the authors was to introduce the idea of multi-objective-based dynamic routing to enhance network capabilities in terms of QoS metrics. The experiment findings indicate that raising the mobility parameter increases network performance when compared to prior work in this period, however, the proposed model is not capable of multimedia-enabled smart cars.

Zahid Khan et al.(2019) [75] proposed a Cluster-Based VANET-Oriented Evolving Graph (CVoEG) Model and associated consistent robust Implementation for segmenting quickly networks into manageable clusters. By splitting the vehicular network into an optimal number of controllable groups, the proposed CVoEG model overcomes the constraints of the existing VoEG model. By removing superfluous control messages, substantially reduces time complexity. The suggested CVoEG model's primary advantage is its scalability since the necessary number of clusters (ONCs) can be determined for any vehicle design.

Pranav Kumar Singh et al.(2019) [76] have presented a model for detecting wormhole attacks in VANETs based on the idea of machine learning The authors' primary objectives are to identify wormhole attacks in VANET multi-hop communication using machine learning. They create a multi-hop communication scenario using the hybrid AODV routing protocol and the mobility traces given by the traffic simulator to identify the attack in the VANET model. The detection accuracy of various machine learning-based models is compared, and the results indicate that the detection rate is excellent but should be improved for safety reasons.**Y. Tang et al. (2019)** [77] Researchers used Machine Learning to investigate delay-minimization routing for heterogeneous VANETs to anticipate mobility. They developed this model to address the challenge of establishing and sustaining end-to-end connections in VANETs, which was made more challenging by higher traffic mobility, dynamic inter-vehicle spacing, and variable vehicle density. By enhancing routing architecture and total VANET performance is measured in terms of ongoing service availability, automobile mobility prediction may assist to address the aforementioned issue. The authors created a centralized routing approach for VANET that incorporates mobility prediction and is controlled by a software-defined network (SDN) controller powered by artificial intelligence. Because of a powerful artificial neural network approach, the SDN controller, in particular, can provide precise mobility prediction. Based upon mobility prediction and periodic network topology changes, the roadside units (RSUs) or base station may then evaluate both successful transmission probability and an average latency of each vehicle's request (BS). Vehicle arrivals are estimated using a stochastic urban traffic model using a non-homogeneous Poisson process. The SDN controller receives network information from RSUs and BSs, which are considered switches. Based on the global network information, the SDN controller calculates the best routing routes for switches (i.e., BS and RSU).**YousafSaeed et al. (2019)** [78] presented fuzzymodeling and an artificial neural network vehicle cognitive route decision making. They created a cognitive framework that allows cars to make autonomous choices based on route memories stored in the brain. By making it more realistic, the framework improves on current in-vehicle route-finding capabilities. The user has access to all route-related information required for the journey. For efficient route provisioning, route events also are learned, stored, and accessible inside cognitive memory. As a consequence of routeexperience, the vehicle learns about routes and improves over time. To accomplish cognitive route assessments, neural networks are also utilized to reduce learning error rates. The proposed cognitive framework for navigation outperforms the existing route-finding technique, which is both inefficient and stressful for drivers.**ValmikTilwari et al. (2019) [**79] conducted an assessment and comparison research of three routing protocols in a mobile network environment, using a series of simulations with different node speeds. The MRLAM multipath routing approach is suggested, which bases routing decisions on residual energy, connection quality, and network node mobility status. Furthermore, the MRLAM method employs the Q-learning process mechanics to integrate many variables into a single measure and generate an optimal routing choice. The proposed approach can assist other large-scale network deployments and common multi-hop wireless network circumstances, such as conventional WSN, VANETs, and MANET-IoT scenarios. Furthermore, when selecting routes, the queue length of network nodes should be considered to decrease network traffic congestion and packet overhead. The notion of a vehicle with the highest residual energy may be expanded in VANETs by utilizing AI methods to minimize data loss rate and transmission latency.

Saleem et al (2019)[80] developed a viable approach for IoT-based VANET architecture, where IoT is essentially the connecting of numerous things, as seen in Smart cities. The IoT and VANET routing standards have been pursued to change the transmission circumstances and utilize the mediator scheme to improve the routing schemes. The optimal routing path was determined by adhering to the cluster structure and routing standards. As a result of the use of IoT, vehicle communication inside a smart city is feasible. Finally, IoT deployment has been reduced by including competency and security elements in vehicle-to-vehicle communication.

Ahmad et al. (2019)[81] suggested an infrastructure-based approach for detecting vehicular congestion (IVCD) (using V2I communication). IVCD estimates the safety time (time headway) between cars using iterative content-oriented communication (COC) contents. On the other hand, the roadside sensor (RSS) provides an infrastructure for combining macro variables to predict traffic congestion and vehicle safety speed. In IVCD, RSS's primary duties were protecting privacy, collecting data, storing information, broadcasting a routing table, assessing safety speed, detecting traffic congestion, and creating vehicle session IDs (S-IDs). For ad hoc wireless vehicle networking in VANETs, V2V and V2I communications are used. VANETs are expanded by the Internet of Vehicles (IoV), which allows each vehicle to become a smart unit with its processing, storage, and internet connectivity.**Sousa et al. (2019)** [82] proposed a new V2V-based distributed and low-overhead traffic congestion control protocol (DisTraC). Because it solely utilizes V2V connections, DisTraC has a minimal communication overhead and is independent of external infrastructures. It lowers vehicle travel time while also lowering communication costs.

Zemmouri et al. (2019) [83]have proposed a distributed open-loop congestion forecasting protocol that enables each vehicle to estimate traffic density around it and utilize that knowledge to adjust beacon broadcast parameters depending on the network's current condition. Again, each automobile should do many calculations to reduce response latency, precision, effectiveness, and protocol dependability.

Zahedi et al. (2019) [84] presented a Connected Junction-based Routing (CJBR) technique for VANETs to improve routing mechanisms' communication performance in smart cities scenarios. The authors developed a new routing mechanism that employs the CJBR technique to improve network connection in urban environments.

The primary objective of the researchers is to reduce the routing mechanism's reliance on the path creation process based on traffic density inside road segments. CJBR achieves this goal by employing a multi-metric junction selection approach that is based on several factors and attempts to find the best path for data packet transmission via the junction. When compared to other current junction-based protocols at high and low connectivity, the CJBR mechanism's QoS performance was improved in terms of PDR and latency, but performance worsened when mobility was high.

Haider et al. (2019) [85] have looked into a reliable routing strategy for broadcasting warning messages in VANETs. The authors provide a Direction Aware Optimum Forwarder Selection (DABFS) routing mechanism in this research paper to improve network performance by picking the best path for data transmission in a dynamic environment. By employing the notion of Hamming distance, the DABFS routing mechanism evaluates the directions as well as the vehicle's relative geographical position to generate the optimum route based on the distance parameter to identify a vehicle's movement direction in the network. This routing technique can provide warning signals and best route discovery to the target cars via a neighbor. The network's simulation results show that the planned DABFS routing mechanism has a higher maximum throughput with a lower loss rate, as well as a lower transmission end-to-end time than other routing methods. However, the researchers in this study do not take into account the security concerns surrounding data packets.

In VANETs. **Ye et al.(2019)** [86] investigated the design of a Mobility Prediction based Routing (MPBR) mechanism for data packet transfer. Due to the type of changing or dynamic network behavior of vehicular nodes, the concept of position-based routing protocols in VANET has drawn the greatest interest in recent years. The authors of this study proposed a new routing paradigm known as MPBR, which is based on neighborhood detection, PDR, and path recovery in the network. The authors combine a predictive forwarding method and a recovery technique to discover neighboring vehicular nodes and transfer data packets using the nodes' or vehicles' predicted positions and angles. The authors compare the simulation results with existing protocols outcomes in terms of PDR, E2E delay, and average hops count in urban situations to evaluate the effectiveness and feasibility of the MPBR mechanism.

Abbas et al. (2019) [87] created a unique road-aware routing system for vehicular networks, two-level hierarchical Hybrid Road-Aware (THERA) routing for vehicle ad hoc networks. The proposed protocol is designed specifically for vehicle-to-vehicle communication. THERA's roads are split into non-overlapping path segments to save routing overhead. Unlike other protocols, the discovery method does not disseminate packets throughout the network. THERA's approach to exploration is built on the concept of Gateway Vehicle (GV). Additionally, since THERA just requires the road network ID and the target ID to communicate, the path from sender and receiver may be modified to accommodate changing topology. Routing that is aware of the road reduces traffic congestion, removes single points of failure, and makes network maintenance easier. A probabilistic approach for predicting journey time for each road segment is also provided by the highway mobility model.**R. Sugumar et al. 2018** [88] presented the Trust-based authentication method for cluster-based VANETs, and they developed a trust-based authentication scheme for cluster-based VANETs in this study. The vehicles are grouped for this, and the trust degree of each node is computed. The total of direct and indirect trust degrees is the trust degree. Cluster heads (CH) are chosen based on the degree of trust that is anticipated. Following that, each vehicle is monitored by a team of verifiers. The sender then digitally signs the communications, which are then encrypted using a public/private key provided by a reliable authority and decoded by the recipient. This authenticates the scheme by verifying the identities of both the sender and the receiver. The suggested method, according to simulation results, lowers authentication delay and keying costs while improving the packet delivery ratio.**YashAgarwal et al. (2018)** [89] presented a novel method based on localization for providing speed-based lane switching, TOA (Time of arrival), and avoidance of collisions in VANETs. TOA was designed to be used in situations when GPS signals are unavailable. The goal of TOA's design is to offer clear line sights for accurate placement and localization. The authors investigate collision avoidance using automated braking and webcam monitoring. Simulations in SUMO (Simulation of Urban Mobility) and NS-2 were used to assess the algorithms' feasibility and practicality (Network Simulator). The authors developed a mobile application interface (MAI) that allows onboard devices to more effectively and intelligently monitor distant traffic.

Mehdi Sookhak et al. (2018)[90] developed a unique strategy for resolving the problem of data sharing and data management. The authors accomplished this by utilizing computation as the key instrument for applying the utility computing hypothesis for storing massive volumes of data and effectively performing the re-encryption procedure. The major challenge for VANET is delivering important data across vehicles in a reliable manner. In a few cases, the data owner is unavailable and unable to oversee the data sharing procedure with the new user or by canceling the traditional user.

Hamrioui et al. (2018)[91] investigated IoT communications for smart cities to develop a smart and self-organized routing (SSR) mechanism. The authors of this study aim to address communication issues in smart cities by investigating IoT network performance degradation during communications and proposing a new routing method to improve network QoS. The proposed SSR mechanism employs the best path selection approach based on data packet needs, and it is capable of restructuring the found route during simulation to identify the best feasible path. That is, the authors suggested SSR mechanism is an adaptable technology that may enable a self-organizing routing method depending on the novel conditions encountered in an IoT network. To validate the routing method, the authors compare the SSR system to existing work on behalf of QoS parameters such as performance in terms of packet delivery rate (PDR), throughput, latency, and overhead packets with energy use. The SSR mechanism consumes more energy in smart cities, demanding energy consumption optimization as well as the consideration of extra QoS criteria for IoT connectivity in smart cities. Furthermore, by utilizing the artificial intelligence idea, the suggested SSR mechanism may be used for both basic and complex smart dwellings and cities.

Jhaveri et al. (2018) [92] presented a Trusted Routing Scheme (TRS) for pattern discovery utilizing several parameters. This technique, which looked at the behaviorand pattern of the packets, was used to identify the missing packets. Three distinct attack techniques were discovered using the trust idea, discovery mechanism, and routing mechanism. To preserve the QoS paradigm, the opponents were first divided. The findings show that after nesting, the cluster delivers the same amount of data and uses the same amount of energy as the best gaming model. The efficiency increases from 12.870 to 38.796 percent as the number of energy-saving nodes grows, demonstrating that collaboration benefits sensor nodes. This work has also demonstrated the optimal game model of energy consumption and cooperation for nodes with increased stability, resulting in more stable node collaboration. The authors concentrate on minimizing routing overhead while using the least amount of energy possible, but they need to expand on this work with IoT applications.

Guo et al. 2018 [93] provided a V2X communication-based method for predicting and sharing vehicle trip time, and also a real-time navigation algorithm to minimize traffic congestion. They split the estimated travel time for every road section into three parts: I for the straight lane, II for waiting for a traffic light, and III for avoiding the road junction. The authors used simulations to show that the proposed technique outperforms the fixed route planning method.

Ahmad et al. (2018) [94] developed a microscopic congestion detection protocol (MCDP) to enable V2V communication to monitor vehicle density and identify traffic bottlenecks. Each car counts nearby vehicles and calculates vehicle time spacing by including the transportation control domain into the current network protocol header. Microscopically, MCDP offers a method for measuring vehicle density, flow, and average velocity that does not need any infrastructure.

Atallah et al., 2017 [95] proposed a brief survey for performance and modeling analysis of multi-hop Vehicle-to-Infrastructure (V2I) communications in VANETs. In lots of wireless networks, the concept of multi-hop communication was used to establish better connectivity between distant nodes but in types of vehicular networks requires more attention to solve the several challenging constraints like management of high mobility of nodes. The authors in this research focused on establishing a multi-hop connectivity path between source vehicle to destination vehicle or Roadside Unit (RSU). Here, the concept of a stochastic approach was formulated by the authors to consider the reliable connectivity path establishment between source vehicles to destination vehicles via RSUs. To solve the problem of dynamic changes in the mobile network topology, inherent contention-based Medium Access Control (MAC) protocol was used with several other limiting factors such as relay unavailability and hidden terminals. The simulation results of the proposed work show the significant impact of the developed path establishment approach between source and destination with minimum collision rate under a limited density of network but in the case of high vehicular densities, system-performance effect and need to utilize the better clustering approach to manage the network systematically.

Li et al. 2017 [96] proposed an analytical model based on the performance evaluation to provide better vehicle safety services using the concept of LTE. Because VANETs cannot able to operate in case of a traffic jam or dense environment and faces the problem of serious packet collisions. So, the authors try to solve these types of problems using the Third-Generation Partnership Project (3GPP) along with the LTE in VANETs. Here, Markov models with the concept of scheduling were used with two approaches like dynamic and semi-persistent scheduling (SPS) to evaluate the utility of LTE for the safety services purpose of users. Authors utilized the radio resources of LTE for vehicle safety services, which is known as (LTE-V) and in addition, the Weighted-Fair-Queuing (WFQ) algorithm is used for scheduling beacons for safety services. At the last, to evaluate the effectiveness of the proposed mechanism, a comparative analysis was proposed using the Quality-of-Service (QoS) under heavy traffic. But the model was not evaluated using the different number of inactive users and to improve the scheduling, integration of LTE-V and VANET would be a better option.

Bila et al. 2017 [97] had performed a survey to evaluate future vehicular network safety concerns The authors aimed to determine the effect of information and communication technologies (ICTs) on the present network scenario and future potential of cars for vehicles safety. A short discussion was held, along with a broad categorization of vehicular network regions for future study and development in the areas of vehicle detection, road detection, lane detection, pedestrian detection, sleepiness detection, and vehicle collision avoidance. The survey results lead the authors to the conclusion that future cars must be connected with mobile sensor platforms to improve vehicle knowledge and safety.**Sepulcre et al. (2016)** [98] presented the merging of congestion and awareness control approach for congestion control (INTERN). This study focuses on the channel busy ratio (CBR). Every vehicle's transmission characteristics are modified in such a way that load can be managed below the CBR threshold. It calculates the minimum power necessary for network packet transfer by measuring the transmission power of the vehicle device. The authors have included the proposed model to gain dynamically adaptability to changing vehicle formation at every second, channel Load Awareness, and the ability to maintain stable levels of channel load, all of which improve application efficiency. The INTERN model hasn't been proven in severely congested areas, and it doesn't use a load-balancing strategy to reduce traffic strain on a single link. Also, because it does not include any message compression or optimization methods, the existing model has been determined to be incapable of compression or optimization.

Taherkhani et al. (2016)[99] proposed a hybrid, centralized, and localized information congestion management system based on the K-means algorithm with RSUs at crossings to solve the problem of data congestion at junctions. The authors also suggested a distributed open-loop secure routing method that prioritized safety and services depending on message content and network status, then dynamically and heuristically organized signals in control and service channel queues. Regardless of network congestion, the taboo heuristic is constantly active on each vehicle, executing priority and scheduling duties.

Martuscelli et al. (2016)[100] created and developed four V2V protocols for delivering traffic information updates over defined routes were developed and tested. Due to their limited range and flexibility, other systems may use the protocols to provide traffic control services. The more advanced approach employs a well-known technique for lowering ad hoc network overhead.

Pan et al. (2016) [101] created a privacy-aware road traffic surveillance & reduction system that relies on V2V and cellular connection To determine the road density, the technique employs V2V communication (number of vehicleson the road). If the density reaches a particular threshold, this is most likely transmitted via a cellular network to a central server. In certain cases, the estimation technique isn't suitable (e.g., long roads). The central server uses the incoming density data to create a smoothed density map of the pathway. If the server detects traffic, this will send information to the most recently reported cars, sharing the information with other cars on the route. Automobiles will then be redirected to save time on the road.

Wang et al. (2016) [102] explored next-day road re-routing using an adaptive and VANETs-based system. Because unexpected road traffic congestion, which is a significant issue for research in contemporary urban road networks, maybe a major source of events such as car accidents, road repairs, unannounced parades, and so on. To address these concerns, the authors develop an extended Next Road Rerouting

(NRR) mechanism that uses a novel vehicle rerouting technique to handle fast changes in urban road traffic conditions. To accomplish this goal, VANET researchers used a sophisticated calibration of computational and functional parameters of NRR without involving traffic management. The coefficient of variation, the routing overhead, and the K-means technique for periodically permitting agents in networks are all taken into consideration in this instance. As a result, it's known as an Adaptive-NRR (a-NRR) method for VANETs technology, and simulation results show that the new model outperformed prior models with just one modification needed to solve the trip time reliability issue.

Jeong et al. (2016) [103] have developed a paradigm for traffic management in VANETs using cloud computing called Self-Adaptive Interactive Navigation Tool (SAINT). SAINT was developed by the authors to replace the existing network-wide navigation mechanism in this study for effective route navigation during peak traffic hours. SAINT was used to explore a path between vehicles and the cloud environment using the fundamental self-adaptive interactive navigation technique. The vehicular cloud gathered automobile navigation and route selection data to update real-time traffic congestion conditions for better routing guidance for other cars in the network. The authors developed a mathematical model to produce road segment congestion estimations for traffic management utilizing the vehicular cloud based on recorded traffic patterns and vehicle trajectories. The suggested approach provides each vehicle with a navigation path, which aids in the reduction of traffic jams on a particular road network. To validate the proposed scenario, the authors used an actual road network to replicate the model, showing that proposed SAINT outperforms existing navigation systems such as Dijkstra's algorithm and reduces travel time by 19% in crowded networks. When SAINT is combined with traffic signal control technology, however, improved management for dynamically adapted vehicular traffic may be achieved.

Katsaros et al. (2016) [104]proposed location-based routing in hybrid vehicle networks. As a consequence, the researchers developed a hybrid vehicular network design that separates data and signaling traffic on separate wireless networks and uses their location to enhance system performance. They propose a method for optimizing location-based routing in three distinct networking architectures: short-range ad hoc alone, cellular alone, and hybrid ad hoc/cellular network based on the stochastic upper limit of the end-to-end latency. This study's analytical approach shows the utility of the proposed model relying on a delay evaluation, but with a focus on the signaling issue during LTE routing.

Chen et al. 2016 [105]LTE-V, a vehicle LTE network related to time LTE, was created. The authors present a systematic and complete V2X solution based on TD-LTE, with the model concentrating on two modes: LTE-V-direct and LTE-V-cell are two different types of LTE. LTE-V-direct, unlike IEEE 802.11p, is a decentralized design with a physical layer modification that enables short-range direct communication, low latency, and high reliability. The model's central architecture, which includes native TD-LTE capabilities and improved LTE-V-cell support for V2I communication with radio resource management, is used. Combining LTE-V-direct with LTE-V-cell coordinate results in improved performance, according to simulations.

Garip et al. (2015) [106] developed a distributed congestion avoidance method based on V2V Cars that are routed between their originating location and their ultimate destination using checkpoints. When the vehicle gets close to the next target, it uses V2V communication to collect the average speed of vehicles ahead and use that information to calculate the optimal route to the next checkpoint. Despite its inability to provide traffic congestion data, the proposed system is one of the few in the available literature that candecrease vehicle travel time using just V2V communication.

Elbery et al. (2015) [107] created an eco-routing system that saves fuel and time by using vehicle-to-vehicle communication When a vehicle drives along with a road connection, it transmits information about fuel use to a traffic Command Center(TMC), which modifies routing data and assigns vehicles routes. One drawback is that the TMC does all computations in one location. This model was built using data from car sensors, which were also used to build an opportunistic fleet (a local vehicle mesh) (or partial mesh). The event detection system includes a variety of events, such as stop, start, and others, that are used to regulate the movement of the collective's following vehicles and help them in taking the necessary action to avoid traffic dangers as quickly as possible.

Gramaglia et al. (2014) [108] ABEONA, a V2V information exchange method for forecasting vehicle flow and along roadways, was proposed as a novel mechanism.

Aside from that, the method can forecast when traffic would switch from free-flow to synchronization. The authors do not indicate how expected events are distributed or how this information might be used to alleviate traffic congestion.

Padhariya et al. (2014) [109] E-VeT, a V2X-based economy-based/reward penalty approach for efficiently controlling vehicular traffic in road networks, was presented. There are two components to the system: a routing algorithm as well as a routing scheme. Longer-distance vehicles are rewarded, whereas those who use shorter-distance and wrongroutes are punished. The route allocation algorithm prefers shorter routes for cars that have made additional money via the RA program. The primary aim is to halve the average commuting time and reduce fuel usage.

Bellavista et al. (2014) [110] proposed V2X-based protocols for detecting traffic characteristics on crossings and delivering monitoring data for better traffic signal control They demonstrated that the protocols can give reliable forecasts of motor traffic and though this vehicle network penetration level is also reduced

Milojevic et al. (2014) [111] devised a distributed approach based on car-to-vehicle communication that enables each vehicle on the route to detect and measure traffic congestion To evaluate the degree of local congestion, every automobile records its speed and the duration it spends under or over a predefined threshold. Additionally, vehicles use data from theirneighbors to verify their local estimates, which are subsequently disseminated to nearby areas via a multi-hop broadcast. The data's usefulness in decreasing traffic congestion is not evaluated by the authors.

Berlin et al. (2014) [112] created dynamic rerouting to avoid many dangers and impediments The direction-based hazard routing protocol (DHRP) is based on the concept of a dispersed communications system among vehicles traveling in a certain direction or to a specific destination. As events unfold, different obstacles and hazards are recognized, including severe flooding, tree falling, terrain sliding, collisions, and so on, and proper action is made for the cars, which may be diverted to avoid the current situation.

Nafi et al. (2014) [113] proposed a centralized predictive road traffic control system It estimates future traffic intensity at different crossings and reroutes vehicles to reduce traffic congestion and overall trip time to use a modified linear predictive model. Each vehicle in this experiment transmits data to the RSU every 5 seconds. RSUs transmit automobile information to a central entity that predicts traffic flow once per minute.

Zhang et al. (2014) [114] a method was provided RTR (Road Topology-aware Routing) is a route discovery approach that enhances Ad hoc on Demand Distance Vector Routing (AODV) by discovering routing routes with two junction-disjoints. The source node selects one way of data distribution rather than all channels for a single packet forwarding to reduce traffic overhead. If both junction-disjoint routes are linked, the communication channel is chosen alternately. Connection failure & network congestion are reduced when two junction-disjoint channels are combined in a single routing route for data dissemination. When it comes to finding destinations, RTR has a higher control overhead than AODV. This is because the RREP is returned to the source through two distinct RTR routes from the destination.

Alsharif et al. (2014) [115] proposed the ideaiCARII, which assumes that all cars are outfitted with a GPS device. The suggested protocol enhances protocol performance by increasing the packet delivery ratio and utilizing one-hop broadcast of beacon packets to update driving conditions frequently while considering fixed infrastructure. Next hops selection, neighbor intersection selection, verity period computation, and segment evaluation are the four segments of iCARII. The protocol gathers real-time network information during the initial stage of segment evaluation. After receiving many control packets, the proposed protocol calculates the path life span for junctions and traversing segments in the second stage of the verity period estimate. The presence of an adjusted route is determined in the third step by the choice of a nearby junction. If a packet experiences a sudden path failure during the previous phase, the current vehicle sends a fresh request for a new path to the central location servers. The concept of "Gateway Nodes" isn't entirely original.

Wang et al. (2014) [116]introduced Next Road Rerouting which is a static central-server method (s-NRR). The V2I protocol is used to communicate between the TMS and cars, using TOCs located on the traffic light infrastructure. Induction Traffic operations centers use loop sensors to identify vehicles & calculate vehicle flow on the stretch of road in question. The central server should be notified whenever sensors on TOCs identify traffic jams. When the s-NRR gets traffic congestion information, it looks for alternate routes that are less congested. Traffic control centers are notified in this situation, and revised routes are provided to the afflicted vehicle.

Bazzan et al. (2014)[117] proposed an evolving traffic assignment method to reduce trip time and accomplish global system load balancing. The proposed evolutionary method computes distinct k-shortest alternative routes for each vehicle and chooses the optimal one to improve overall system efficiency. However, the method requires a thorough understanding of the whole traffic situation ahead of time.

Alsharif et al. (2013) [118] established the iCAR (intersection-based Connectivity Aware Routing) system for VANETs, which is based on location. It employs optimized broadcasting that takes into consideration both average packet delays at road segments as well as real-time traffic. For the next section, iCAR examines neighboring road segments with the highest traffic proportion, the shortest distance to a target, and the lowest rate of delay.

Pan et al. (2013) [119] created Dynamic Shortest Path (DSP), Random k Shortest Path (RkSP), and Energy Balancing k Shortest Path (EBkSP) .You may select from three different re-routing algorithms. When the network becomes congested, the suggested methods find alternate routes based on road segment travel times. The formula for calculating the travel time (Ti) of a road segment is Ti=Li/Vi, in which Li and Vi are the lengths and anticipated speed of lane I, respectively. The network was described using a directed weighted graph, with the weight of every edge equivalent to the journey time Ti of a road section.

Younes et al. (2013) [120]introduced ECODE, a V2X-based traffic congestion monitoring system. It uses multi-hop transmission and geographic routing techniques to collect and analyze vehicle data, presuming that each road junction is outfitted with an RSU.

Junior et al. (2013)[121], presented aDTraMS system that uses a decentralized architecture and V2X communication to monitor and share traffic statistics. RSUs are assumed to cover all regions, which may render the idea redundant.

Gupte et al. (2012)[122] introduced a VANET-based Autonomous Managing system that uses V2V communication to promote car-to-car data exchange on path planning, congestion, and traffic warnings, allowing vehicles to choose the optimal path. Each vehicle selects a beginning track and also a set of other paths in this method. The algorithm may recommend one of the optional paths as the optimal route to take based on the number of cars that have routes that are comparable to its present route. One disadvantage of this method is that it creates a lot of communication overhead.

M.G.H. Bell et al. (2012)[123] developed the hyperstar method, a one-of-a-kind approach for finding a fast and dependable route around heavy traffic. Based on the busy area, it analyzes in several ways. Average latency, bandwidth, data transfer ratio, and overhead ratio are the four measures it uses to evaluate network performance.

Hashemi et al. (2012)[124] proposes a technique for transferring vehicles from one route to another using the shortest path. To solve this issue, they offer a VANET Load Balancing Routing (VLBR) solution. VLBR maintains geographical data about automobiles on a centralized server and load balances by using the k-shortest path method when alternative routes are created.

Arbabi et al. (2011)[125] presented DTMon, one of the first V2X traffic management solutions that were proposed. The system, on the other hand, can only transmit traffic data in a free flow (i.e., non-congested) condition.

Bauza et al. (2010)[126]proposed which CoTEC is a cooperative technology that detects traffic congestions without the need of infrastructure sensors and is focused on vehicle-to-vehicle (V2V) communications. CoTEC provides a fuzzy theory-based traffic congestion quantification technique that uses traffic volume and vehicle speed for input parameters and outputs road congestion level or road traffic intensity. The personal capacity information is provided through multi-hop communication between cars, allowing data to be verified collectively and reducing transmission overhead. Vehicles only provide information when traffic congestion is detected locally.

Wischoff et al. (2003)[127] presented one of the earliest inter-vehicle connectivity traffic control systems,(SOTIS). By receiving data packets containing information from other cars, every SOTIS automobile does a constant traffic situation study. The information is available with cars in other regions via a store-carry-forward technique, and the result is transmitted to all nearby cars.

2.2 RESEARCH GAP

After studying the above mentioned research papers for smart vehicular networks, the following research areas are highlighted.

a. There is a need to work on congestion control, especially in smart vehicular networks. Traffic behaviour is dynamic, so there is a strong need for a congestion estimation mechanism that is adaptive, and also multiple factors need to be considered for analysing traffic conditions.
b. The existing models are practically impactful in their re-routing effectiveness. Re-routing decisions are a major concern in order to decongest vehicular traffic in the target area, which is one of the most important factors.
c. The existing models are certainly not designed to manage traffic flows to avoid the traffic jams and accidents described as road events while evaluating the behavior-aware vehicular fleets. The proposed protocols like vehicular fleet management and updating (VFMU) take account of the geographic location of the nodes and the vehicular events to keep the nodes updated, which will be travelling towards the location of the event. The current model has several flaws. It does not take into account the nodes that are out of range at first. It means that nodes that are out of range will not get (or will not be guaranteed to receive) the broadcast message regarding the event after joining an RSU. Such a concern must be considered to avoid endangering the lives of those travelling in vehicles that are out of reach during the message transmission. The failure of a node in an existing scheme might potentially result in dangerous circumstances. The failure of a node might result in a collision, traffic chaos, or other movement-related hazards. For any hazard event, node failures can be covered up via unicast query messages.
d. Although RSUs offer a viable and cost-effective solution for distributing road hazard warnings and a dependable alternative to V2V communication, particularly on roads with sparse vehicular traffic, there is still a need to expand the protocol for RSU deployment on highways with varying traffic.

CHAPTER 3:RESEARCH METHODOLOGY

3.1 MOTIVATION FOR RESEARCH WORK

The Tier-I, Tier-II, and Tier-III cities are struggling with the problems of massive traffic jams, which eventually increase the commute time for residents. It has been a major challenge for countries across the globe to decongest urban traffic. In this research, a solution is being proposed for the decongestion of vehicular networks. In the proposed model, vehicular congestion occurs as a result of a high random density of vehicles in one direction, collisions, natural hazards such as flash floods, and so on, and is handled by using effective and optimal vehicular re-routing for traffic moving in multiple directions.The geographical information of the current vehicular position and the destination is used to determine the alternative route for smooth mobility of the vehicular nodes across the city areas. The proposed model will be more adaptable to self-driving cars than the current one, which can drive themselves without human intervention.

3.2 OBJECTIVES

a. To design & develop traffic control mechanism to detect traffic congestion based on vehicle density estimation.

b. To design & develop adaptive traffic routing mechanism which provides re-routing decisions to vehicles to avoid traffic congestion.

c. To design a technique in order to improve the traffic flow in Smart Vehicular Network

d. To evaluate and compare the proposed work in the simulation environment with the existing techniques.

3.3 RESEARCH CONTRIBUTION

The smart vehicular ad-hoc network is a network made up of vehicles that allows for smoother mobility and better management of automobile connections throughout a particular network. Vehicular networks are always vulnerable to collisions for natural or unnatural reasons, which must be addressed before large-scale implementation of transportation systems. The newly created smart transportation movement control mechanism is based on the vehicle accident and traffic jam prevention schema, which may enable future smart city designs to become more resilient and error-prone. The suggested model focuses on developing a novel, vibrant, and dynamic hazardous route mechanism for smart vehicle networks in order to improve overall performance in a variety of ways. It is anticipated to reduce overall congestion on the road network.

Here, two mechanisms are proposed. The first one is MRGM (Multi-Metric Route Guidance Mechansim), which is an adaptive mechanism for congestion control in smart vehicular networks. The process is broken down into many phases, which constitute the approach. At the beginning of the process, the car is initialised by setting different parameters, including its id, its departure location, the lane it's in, and the route it's on. Next, the vehicle's data is gathered, including things like its average speed, emissions, and fuel usage. Analyze traffic conditions based on road and vehicle information, such as the width and length of the road, the number of cars on the road, and other traffic circumstances. The amount of congestion can be classified as low, moderate, or high using a function called the vehicle congestion index. In the next phase, a traffic study is performed to determine how congested the roads are likely to become. Congestion control kicks in at the next step, and if it detects congestion, it uses that information to figure out the best path to take to avoid it.

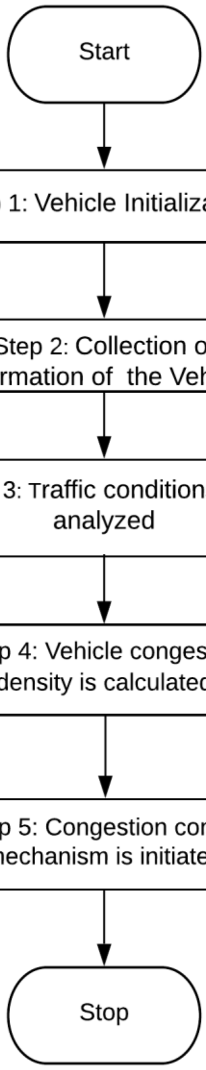

Figure 3. 1 MRGM Congestion control Mechanism

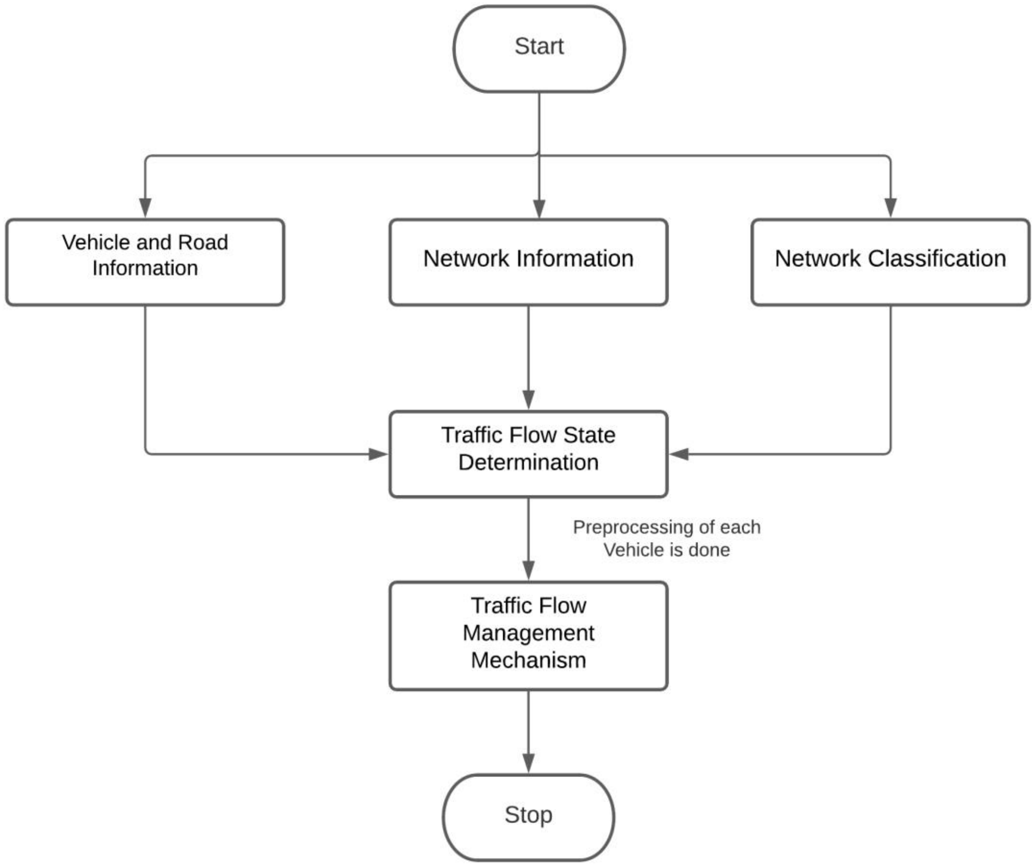

Figure 3. 2 PTFM mechanism

Another mechanism has been proposed, which is the PTFM (Pre-Processing-based Traffic Flow Mechanism), which is based on a pre method in order to enhance traffic flow in metropolitan areas. To begin, traffic data is gathered using a variety of multi-metric characteristics, such as vehicle identification numbers (VINs), arrival and departure lanes, speed, fuel consumption, vehicle length and breadth, and information about the lanes, as well as emissions of various gases. After that, there are three levels of traffic congestion: no congestion, moderate congestion, and heavy congestion. Pre-processing is done for each vehicle in this method, enhancing the efficiency of the route. The suggested system determines the distance between two cities and nodes and then travels through all of those pathways to find the shortest route. In a separate node known as a "shortcut node," the traffic information is kept. It saves time when a query for a given roadway is performed repeatedly if length and path information are pre-computed. After that, the acalculated rerouting technique aids the cars in avoiding congested areas, thus enhancing traffic circulation.

CHAPTER 4: STUDY OF EXISTING VEHICULAR TRAFFIC ALGORITHMS

4.1 INTRODUCTION

In the smart vehicular networks the traffic algorithms are important for finding effective paths for travelling vehicles especially in congestion conditions . The Traffic routing algorithms work on various parameters [Fig 4.1] which includes:

- Map of the city
- Traffic characteristics like the number of vehicles on the road, speed, size, etc.
- Road characteristics include road size, length, and number of lanes
- Traffic analysis
- Find an optimal route

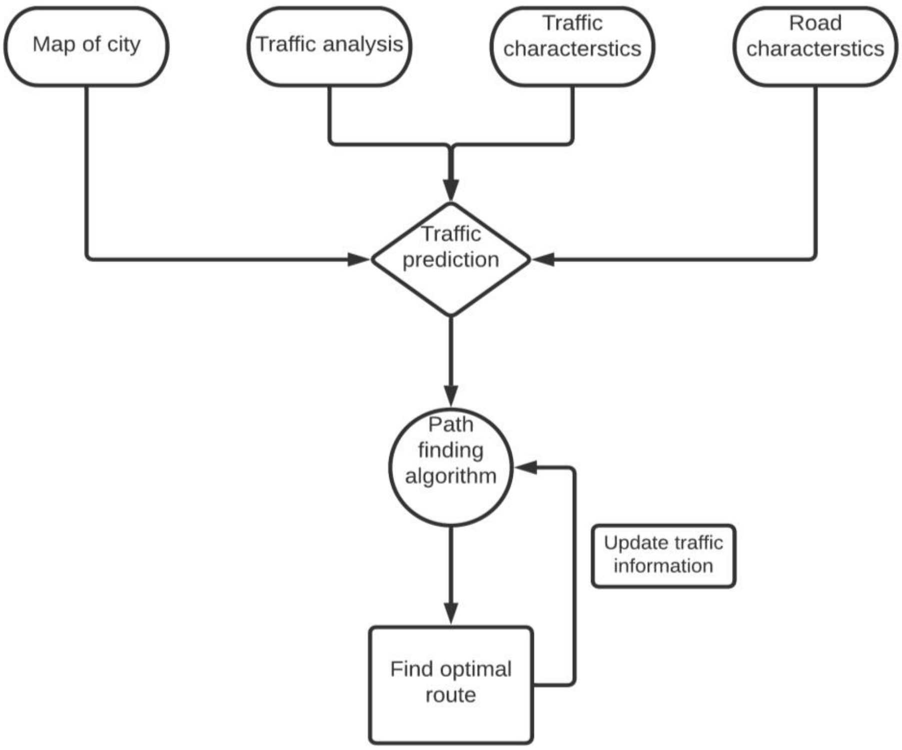

Figure4.1: Traffic routing algorithm

The road network is divided into edges and vertices. The vehicle moves on-road segments wanting a fast route to reach their destination The road weight is calculated as the time taken to reach from position A to Position B which is stored in the edge of the road segment. There are two types of path-finding problems that are available, static and dynamic. The static problems work on fixed graphs while dynamic works on the graph configuration where the number of nodes keeps on changing. so there is a need to update the graph on a subsequent basis. Real-time applications like traffic management systems require dynamic configuration.

To calculate the shortest distance various existing routing algorithms like dynamic routing Dijkstra, Dynamic Astar, and Modified Floyd Warshall are studied . These are the path finding algorithms which are used to find the optimal route for the vehicles .Here various dynamic algorithms and their functioning are defined.

4.2 DYNAMIC DIJKSTRA

The dynamic Dijkstra is used for finding the shortest path problem using a retroactive data structure. In this, the historical sequence of events is maintained which helps in deciding the futuristic events. The priority queue is used for solving the dynamic path problem [128]. Here the graph is made up of G(V,E, and W) where V denotes the nodes or vertex, and E defines the edges' is the weight of edges. Now the weight of the edges varies with increases or decreases with time and with insertion or deletion of nodes. Now there is a need for a retroactive priority queue in Dijkstra which allows performing operations at any point in time. The algorithm is defined below:

Algorithm4.1 Algorithm for Dynamic Dijkstra

```
Start(G, S)
distance[S]: = 0
For each node V in Graph:
    if V is not the equal source
distance[V]: = infinity
add V to Queue
Insert(x, t)
while Q is not empty:
    V: = node in Q with min disance[V]
remove V from Q
Invoke(Del_min(t))
for each neighbor U of V:
    alt: = distance[v] + Length(V, U)
if alt < distance[u]:
    distance[v]: = alt
```

```
else
    previous[v]: = u
return distance
End
```

4.3 DYNAMIC ASTAR

In a dynamic context, Astar algorithms perform effectively to identify the best answer. It is a best-first method whose goal is to discover the shortest and least expensive route to the next node. The cost is calculated based on the distance traveled or the amount of time spent traveling. A star's cost is calculated using the formula f(n)= g(n)+ h(n), where g(n) is the actual cost of the route from the beginning node to the nth node and h(n) is a heuristic function that determines the estimated cost of the cheapest path. The priority queue is used to pick nodes with the lowest cost. At each step of this method, the nodes are updated repeatedly, and the vertex with the lowest f(n) value is eliminated from the searching region. The values of g(n) and h(n) are updated appropriately. The Astar algorithm employs the LPA (Lifelong planning) technique, which allows it to reuse previously saved results for improved search[129][130].The algorithm for Dynamic A star is given below.

Algorithm4.2 Algorithm for Dynamic A star

```
Start(G, S)
distance[S]: = 0
For each node V in Graph:
    if V is not the equal source
distance[V]: = infinity
add V to Queue
Insert(x, t)
while Q is not empty:
    V: = node in Q with min disance[V]
remove V from Q
Invoke(Del_min(t))
for each neighbor U of V:
    alt: = distance[v] + Length(V, U)
if alt<distance[u]:
    distance[v]: = alt
```

```
else
   previous[v]: = u
return distance
End
```

4.4 DYNAMIC FLOYD WARSHALL:

Floyd Warshall's algorithm is another good example of dynamic pathfinding. The Floyd Warshall algorithm compares every possible combination of the path calculation process between all pairs of vertices. This algorithm is used to find the all-pair shortest path problem[131]. This shortest path is computed between all pairs of vertices. The graph is taken as a matrix and then updates the solution matrix by considering all vertices as an intermediate vertex. The algorithm for this algorithm is given below:

Algorithm4.3 Algorithm for Dynamic Floyd Warshall

```
Preprocessing (G, S) as a matrix :
   distance[S] := 0
Each vertice (v) in Graph:
    for each edge (s,k)
dist[s][k]←w(s, k)    (weight of path)
for each vertex k do
dist[k][k] ← 0
for x from 1 to |K|
  for u from 1 to |K|
   for v from 1 to |K|
    if distance t[u][v] >distance[u][k] + distance[k][v]
       distance[u][v] ← distance[u][k] + distance[u][j]
end
```

4.5 CH ALGORITHM

Contraction hierarchies (CH) is a speed-up technique to find the shortest path in a graph efficiently. The CH method exploits the graph for speeding up the traversing system. The CH routing algorithm avoids unimportant vertices and creates shortcut routes for vehicles[132]. The metric used in this algorithm is time travel which is used as the weight for path calculation on the road edges. The approach of CH consists of two phases:

4.5.1 Pre-processing Phase:

Consider that two large cities are connected through a network of roads (highway).The vehicle wants to reach from the source a to destination d. Throughout the highway, there are multiple junctions(edges) that lead to villages and small towns. The CH algorithm pre-processes the information of route calculation of all paths (vertices)that connect the two cities by traversing through all edges and vertices[4.2]. This information is stored in an additional edge which is called a shortcut edge. Now when the same highway is evaluating for traffic analysis again then pre-processing information that is already stored on the shortcut edge can be used which saves time during the path evaluation query. The working diagram is explained below in Figure 4.3

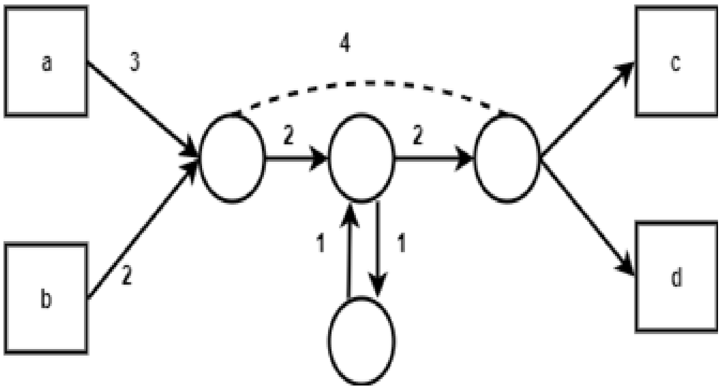

Figure4.2: Traversing in CH algorithm

The CH algorithm depends on the shortcut routes which are found during the pre-processing phase with fewer vertices as defined in the above diagram (shortcut path is represented with dotted lines).There are two approaches for traversing the graph.

The first one is bottom-up which does not know the order of the graph and selects the next node when the previous node is visited. Another approach is top-down which computes the node order in the graph before traversing starts. The computation time in the bottom-up approach is less as compared to the top-down approach.

4.5.2 Query Phase:

In this phase, a bidirectional search is done starting from the source node to the destination. The original graph is line [x,y,z,t,u,v]. To calculate the shortest path between x and t(Figure 4.3).The original distance is dist[x,y] +dis[y,z]+dis[z,t].Now the shortest path is the dist[x,y]+dist[y,t]. The path weights are calculated before choosing the path which includes less edges.The weight that is taken here is time travel and this information is stored at the end of each node.

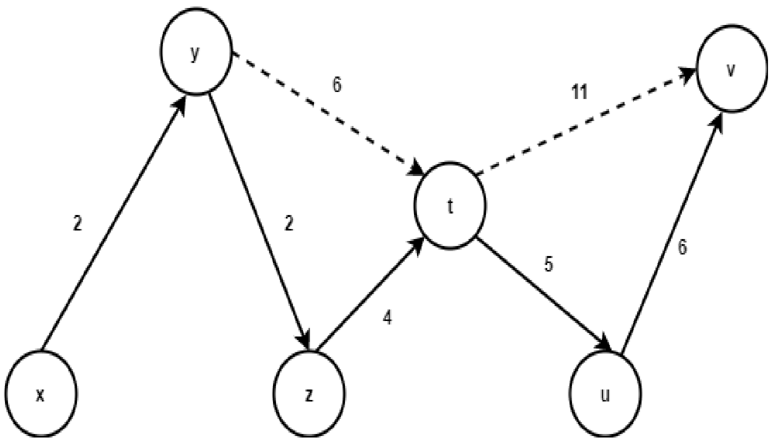

Figure4.3: Node order for query phase

The algorithm for CH is defined below.

Algorithm 4.4 Algorithm for CH

1: *Preprocessing (S, D, Distance [S] := 0)*

2: *Each node (x) in Graph:*

3: *Calculate shortest path value f(v)*

4: *Witness search for each pair {x, y}*

5: *s (x) : shortcut path value from starting node*

6: *h (x) = The heuristic of the value of the node*

7: *v: = vertex in Q with min dist[n]*

8: *Pre-compute and store information on edge node*

9: *Query for each neighbor x of y for shortcut path*

10: *path: = Dist[x] + Length (X,Y)*

11: *if path <dist [Y]:*

12: *update dist[y]:= path*

13: *else*

```
    previous[x]:= y
return distance
End
```

CHAPTER 5: CONGESTION DETECTION AND AVOIDANCE MECHANISM(MRGM)

5.1 INTRODUCTION

Traffic flow on roads has increased manifolds from the past few decades due to an increase in the number of vehicles and a rise in population. With fixed road infrastructure and more vehicles on traffic, routes lead to traffic congestion conditions especially in urban areas of developing nations. Traffic jams are normal in major cities which ultimately cause a delay in travel time, more fuel consumption, and more pollutionIn this chapter dynamic route guidance mechanism (MRGM)(Multi-metric route guidance mechanism is proposed which is an adaptive mechanism for congestion control in Smart Vehicular Network. MRGM usesmultiple metrics to analyze the traffic congestion conditions and based on the conditions effective optimal routes are suggested to the vehicles.

5.2 SYSTEM ARCHITECTURE FOR CONGESTION DETECTION AND AVOIDANCE

Vehicular ad-hoc networks make it possible for vehicles to communicate amongst themselves, thereby sharing important information like traffic congestions and accidents and ensuring timely response for the same. The traffic communication system consists of vehicles which include vehicles OBU (onboard units), vehicle to vehicle communication, vehicle to RSU communication, and RSU to cloud communication [Figure 5.1].The proposed model has been based upon the congestion detection and avoidance model, which is used to avoid the congestion conditions that occur due to an accident, road destruction, avalanche and traffic jams.

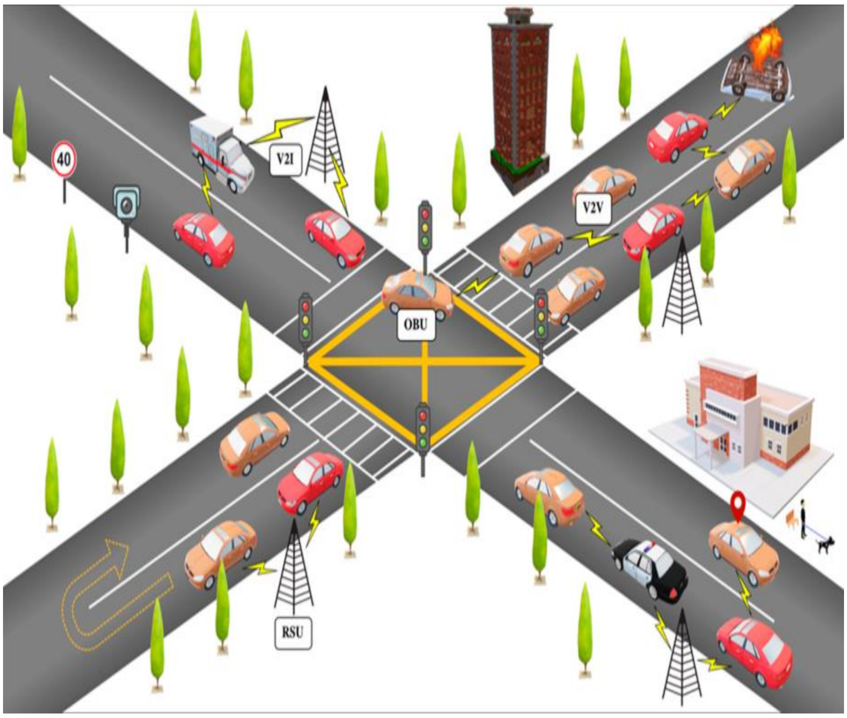

Figure5.1: Traffic System

In this system Multi-metric road guidance mechanism (MRGM) considers multiple metrics to analyze the traffic congestion conditions and based on the conditions effective optimal routes are suggested to the vehicles, if congestion based on VCD which is vehicle congestion index is found, then information is shared with other vehicles and RSU. Based on this congestion, a re-routing mechanism will check alternate routes available, based on the remaining number of available roads. $R_{rem.}\{R_{id-1,}\ R_{id-2,}\ R_{id-3,}\ R_{id-3....}R_{id-n,}\}$.Then the information is given to the other vehicles to re-route according to the optimal path. The sequence diagram of the MRGM is described in figure 5.2. In this, traffic information is collected through vehicles, and congestion is found through VCD (vehicle congestion density). The road weight calculation is done through PWC to find updated weights for finding the optimal path for vehicles.

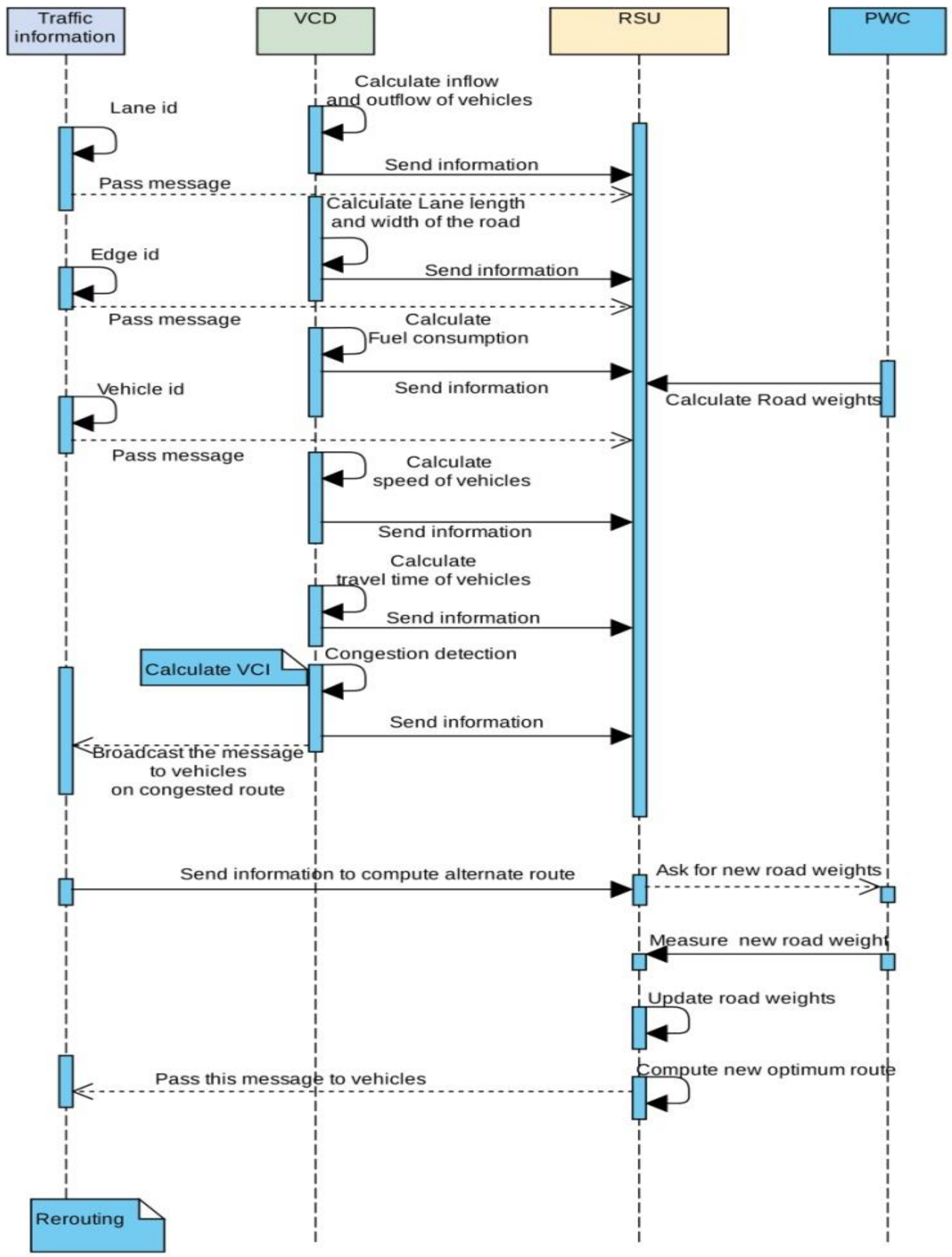

Figure5.2:Sequence diagram of MRGM

MRGM mathematical equations and algorithms are explained below. The methodology is defined with various steps. In step 1: vehicle initialization is done which defines the various parameters required to define the vehicle like vehicle id, its departure position, lane id, road id, etc. In step 2: the collection of information of the vehicle is done which includes the factors like vehicle average speed, emission data, and fuel consumption. In step 3: traffic conditions are analyzed, based on road states and vehicles information in which road measurement like its width and length is analyzed, number of vehicles on roads, and other traffic conditions. A function called vehicle congestion index will find the level of congestion like low congestion, moderate or high congestion. In step 4: traffic analysis is defined by which traffic congestion is predicted. In case congestion is found, then step 5 initiates the congestion control mechanism which provides the vehicle with information on finding the optimal route in case of congestion. Various notions have been used in explaining equations. It is defined in table 1.

Table 1: Notations

V_{id}: Vehicle id
V_{list}: Vehicle list
R_{id}: Road id
D_{Lane}: Departure lane of vehicle
D_S: Departure speed of a vehicle
A_{Lane}:Arrival lane of vehicle
A_S: Arrival speed of the vehicle
D_{Pos}: Departure position of a vehicle
A_{Pos}:Arrival position of a vehicle
AVG_t: Mean travel time of vehicle
F_C: Fuel consumption rate of vehicle
Q_t: Engine fuel consumption per unit hour
U_t:Running speed of a vehicle
E_V: Emission of gases
V_s: Maximum vehicle speed it can be achieved on-road segment

V_A: Actual vehicle speed it has achieved on-road segment
D_G: Gap between vehicles
L_R: Length of the segment of road
TT_P: Predicted time travel from source to destination of the vehicle
TT_A:Actual time travel from source to the destination of the vehicle
W_R: Width of the road
W_V: Width of the vehicle
D_Y: Distance between vehicles
S_{TAZ}: Traffic assessment Zone
L_V: Length of the vehicle
n : Number of vehicles on the road
AVG_S: Average speed of a vehicle
$Traffic_F$: Total flow of traffic at a particular time on the highway
T_V: Width of vehicle
PWC: Path weight calculation
VCD: Vehicle congestion Density
RSU: Roadside units

5.2.1 Vehicle Initialization: Each is vehicle is assigned with a vehicle id (Vid) which is used to identify the location of the vehicle on the road. This MRGM collects the information of vehicles which includes the current position of a vehicle, its destination preferences, its longitude, and latitude. The vehicle will travel along the predefined route initially. Vehicle attribute can be defined as vehicle information: $V_{id}|R_{id}|D_{Lane}|D_S|A_{lane}|A_S|D_{Pos}|A_{Pos}$. Rid defines the id of the road segment on which vehicle is going to travel alongside. D_{Lane},$D_{Pos}A_{lane}$ and A_{Pos}define the lane on which vehicle is departed and arrived and the position of its departure and arrival whereas D_S and A_S represents departure and arrival speed.

5.2.2 Collection of Information related to Vehicles:While vehicles travel on the roads, the MRGM collects the operational information from sensors deployed on vehicles, which includes average mean speed of the vehicle (AVGs), average mean travel time (AVG_t), Fuel consumption rate(FC) and Vehicle gases emission Value (Ev) which includes CO_2, CO and NOX values. The gases emitting from vehicles will help in determiningthe current state of pollution level on a particular segment of road.

5.2.3 Traffic states determination: To analyze the congestion condition MRGM mechanism uses the multi-metric parameter system which includes various factors of inclusion like Width of the road (WR), Length of the road(LR), Width of vehicles(WV), Length of vehicle(LV). Based on the above parameters, a report is generated which is defined as traffic flow report for n number for vehicles on a particular road segment TrafficF: n| AVG s| AVG t| Fc| Ev| WR| LR| WV| LV| is the concatenate of all values. Following the generation of the traffic flow report, the information is sent to all cars and roadside units (RSU) on the specific road segment.

Traffic flow rate can be determined with the average speed of the vehicle on a particular road segment which is calculated as

$$AVG_s \frac{1}{n} \sum_{i=1}^{n} v_s \quad (1)$$

Here n is the number of vehicles and $V_s$is the speed of each vehicle.

a) Vehicle density on a particular road segment is calculated with two formulas

$$\sum_{i=1}^{n} W_v + D_G \quad (2)$$

$$(\sum_{i=1}^{n} L_R) D_Y \quad (3)$$

Here D_G is the gap between vehicles and D_Y is the distance between vehicles.

b) The traffic condition in MRGM is calculated in two ways:

- **Bottleneck Condition**: The condition that occurs when the area(width) of the road is covered by multiple vehicles that want to pass from the road is defined as.

$$\propto=[\sum_{i=1}^{n} W_{V}+D_{G}]/W_{R} \quad (4)$$

- **Accidental or Jam Condition**: The traffic condition that occurs due to an accident or any type of jam that can happen on road from the last 300seconds is defined as

$$\emptyset=[\sum_{i=1}^{n} L_{R}+D_{Y}]/(L_{V}*n) \quad (5)$$

Here $\propto$ and $\emptyset$ two functions that define congestion conditions based on the width of the road and length of the road$\propto$and $\emptyset$.

c) Now the predicted time travel of vehicle on a particular lane of road on a given segment is calculated as:

$$TT_{P}=(L_{J}^{R})/V_{Vs}^{J} \quad (6)$$

Here L_{J}^{R} defines the length of road (R) with its road segment (J). V_{Vs}^{J}isthe speed of vehicle it can achieve on-road segment J Total time travel from source to destination of a vehicle which involves multiple roads is calculated as:

$$TT_{t}=\sum_{i=1}^{q} (\sum_{i=1}^{m} TT_{P}) \quad (7)$$

Where q represents the remaining number of roads and m represents the segments divided on the road on which vehicles are passing.

The actual time of the vehicle is TT_A which is calculated by using

$$TT_{A}=(L_{J}^{R})/V_{Vk}^{J} \quad (8)$$

Where $V_{Vk}^{J}$is the speed of a vehicle, it achieves actually during the travel

Now we define a function

$$\theta=\{\sum_{i=1}^{q} (\sum_{i=1}^{m} TT_{A})\}/\sum_{i=1}^{q} (\sum_{i=1}^{m} TT_{P})\} \quad (9)$$

It calculates the predicted time requires for a vehicle to travel and the actual time it has taken to travel on a given route. A stopwatch is used to calculate the actual travel time.The fuel consumption on a given road and particular segment can be calculated as:

$$F_C=\sum_{i=1}^{q} \left(\sum_{i=1}^{m} \frac{Q_f}{U_t}\right) \tag{10}$$

Where FCR is fuel consumption rate, $Q_f$is vehicle fuel consumption per unit hour(kg/h) and U_t is the ongoing speed of the vehicle in (Km/hr.).

5.2.4Traffic congestion analysis: In the MRGM, three parameters$\propto$,$\emptyset$ and θ are calculated for traffic states determination. Based on the following parameters, the following table is used to classify the vehicle classification index

Table 2: Vehicle congestion index

Vehicle Congestion Index(VCD)	Traffic state level
(0.0-0.3)	Free flow
(0.3-0.5)	Low congestion
(0.5-0.75)	Moderate congestion
(0.75-1.0)	High congestion

In MRGM, the cases are designed for traffic congestion analysis. The information collected is passed on to RSU nodes to analyze the traffic condition of an area which is called as (Traffic Assessment zones) TAZ.

- Congestion occurs when the width of the road is equal to or less than the number of cars traveling through the stretch of the route.

$$S_{TAZ}\{\propto<=\sum_{i}^{n} W_v+D_G]/W_R \} \tag{11}$$

- The congestion happens due to accidents or traffic jams the length of the road is occupied by the vehicles in a particular lane.

$$S_{TAZ}\{\emptyset<=[\sum_{i}^{n} L_R+D_Y]/(L_V*n)\} \tag{12}$$

- If the predicted travel time of vehicles is less than the actual time travel on the route,then this is the condition of congestion occurrence.

$$S_{TAZ}\{\theta <=\{\sum_{i}^{q} (\sum_{i}^{m} TT_A)\}/\sum_{i}^{q} (\sum_{i}^{m} TT_P)\} \tag{13}$$

The algorithm 4.5 to check vehicle flow density and congestion detection is explained below. In this various conditions are explained through which congestion can occur

Algorithm 5.1 Algorithm for congestion detection

Procedure for Congestion Detection
Graph ←Create of graph from road network
def get_trip(self, min_distance, max_distance, maxtries=100)
for all vehicle ∈ V ehicleList do
    $Lane_{Current} \leftarrow$ *vehicle.CurrentPosition()*
    $Lane_{Last} \leftarrow$ *vehicle.getLastRoad()*
    $Msg_{vehicle}$
def write_weights(self, fname, interval_id, begin, end)
    Calculating the Average Length and Width of vehicles
    Calculating the Width of Road
def buildTripGenerator(net, options)
    Calculating congestion condition 1
W_R *less than or equal to* $\sum_{i=1}^{n} W_v + D_G$
Calculating congestion condition 2
$(L_V)*n$ *less than or equal to* $(\sum_{i=1}^{n} L_R) + D_Y$
Calculate congestion condition 3
Travel time of vehicle Actual and predicted:
TT_A / TT_P
Measure Traffic assessment Zone S_{TAZ}
Calculate vehicle congestion density(VCD)

End

5.3 CONGESTION CONTROL:

If congestion is detected based on conditions equations 11,12, and 13then a congestion control mechanism is initiated. The RSU calculates the Traffic assessment zone(TAZ) of an area. After this number of the route(K) will be calculated. Each road constitutes edges and lanes. These are assigned with edge id and lane id. The weights are assigned to each segment of the road. The RSU determines the shortest optimal path for vehicles. RSU will calculate the PWC (Path weight calculation) of the road network. The PWC is calculated as

$$(PWC)=W_{ij}(\propto,\emptyset,\theta) \quad (14)$$

It calculates the weight between the edges of roads. If congestion is found then to find an alternate short route the equation is written below

$$W_{ij}=\min(W_{ij},W_{ik}+W_{kj}) \quad (15)$$

Adaptive traffic routing is defined as the mechanism that would instantly communicate vehicles about the congestion on the path and would suggest them according to various methods that would help to avoid Traffic Congestion.

The system would predict (detect) the congestion for various time intervals, then later would communicate regarding it and assures its presence in the following ways:

i. Predicted Data Communication: After predicting congestion on path, for a particular time system would verify it legitimately by sending location (Latitude and Longitude) to GPS feed, which would further assure the detection.

ii. GPS Feed Communication: Once the Global positioning system got the particular Latitude and Longitude it would detect the chances of congestion on the road and would send its report mentioning levels of congestion (HIGH, MODERATE, LOW), depending upon the Intensity of congestion over the area it would further communicate to RSU regarding Congestion level. I would also provide various backup routes and backward re-routes information to us.

iii. RSU Communication: Local RSU then works on the detected (Latitude and Longitude) by populating the message towards the smart vehicles in the suspected area and would get the assurance of intensity of congestion and the percentage of vehicles jammed over a road that need support.

Once the assurance of the Congestion ata particular time for a particular area with its level of congestion and percentage of congestion, avoidance and rerouting mechanisms starts to work on.

STEP1: Those vehicles that are under the HIGH CONGESTION area would be divided among 4 Quarters depending upon their percentage of Congestion.

REROUTED: Quarter 1 vehicle of the same lane would be rerouted towards Route 1

REROUTED: Quarter 2 vehicle of the same lane would be rerouted towards Route 2

REROUTED: Quarter 3 vehicle of the same lane would be rerouted towards Route 3

ROUTED: Quarter 4 vehicle of the same lane would be passing from the same Path

STEP2: Those vehicles that were in MODERATE LEVEL would be shown 3 backward routes to get re-routed and MODERATE LEVEL also divided among 4 Quarters depending upon their chances of Congestion.

REROUTED: Quarter 1 vehicle of the same lane rerouted towards Backward Route 1

REROUTED: Quarter 2 vehicle of the same lane rerouted towards Backward Route 2

REROUTED: Quarter 3 vehicle of the same lane rerouted towards Backward Route 3

ROUTED: Quarter 4 vehicle of the same lane would pass from the same Route.

STEP3: Besides to it simultaneously those vehicles were in LOW-LEVEL area would be populated with the message of congestion. LOW LEVEL is also divided among 2 Quarters depending upon their Congestion chances.

Table 3: Reroute Strategy

ADAPTIVE REROUTE STRATEGY				
LEVEL OF CONGESTION	QUARTERS	DETECTED CONGESTION	CONGESTION CHANCES	SAFEGUARD MECHANISMS
HIGH LEVEL	QUARTER 1	100%	100%	Route 1
	QUARTER 2	75%	100%	Route 2
	QUARTER 3	50%	100%	Route 3
	QUARTER 4	25%	100%	Same route
MODERATE LEVEL	QUARTER 1	0%	95%	Backward reroute 1
	QUARTER 2	0%	75%	Backward reroute 2
	QUARTER 3	0%	50%	Backward reroute 3
	QUARTER 4	0%	25%	Same route
LOW LEVEL	QUARTER 1	0%	10%	Congestion information and shown congestion-free routes
	QUARTER 2	0%	5%	Congestion information

The algorithm 4.6 for congestion control is defined below:

Algorithm 5.2 Algorithm for congestion control

```
Create a graph of the road network (R_id1 , R_id2....R_idn)
whereas SIMULATION
if  time of simulation is  600 s  then
Pause Simulation
def buildTripGenerator(net, options)
def is_vehicle_attribute(attr):
    for cand in ['depart', 'arrival', 'line', 'Number', 'type']:
        if cand in attr:
            return True
  else
        return False
S_TAZ(t)  ← ZoneCongestion (subgraph)
Send a message to S_TAZ(t) to RSU to calculate PWC
for each Road_Lane
    Calculate VCD
   If congestion found
     Calculate new path
   Shortest path ← ( Subgraph)
    W_ij = min(W_ij , W_ik + W_kj)
 for all vehicles in the vehicle in V_List do
    Current_Pos ← Current position of the vehicle on the road
     Last_pos ← Last position of the vehicle on the road
    Shortest- Paths(subgraph,Current, last)
Message(Current_Pos, Last_Pos)
New_Path ←Set new path
Message new path to vehicles on congested roads
End
```

CHAPTER 6: TRAFFIC FLOW MANAGEMENT MECHANISM (PTFM)

6.1 INTRODUCTION

The traffic flow is getting disrupted due to traffic jams, congestions, collisions, and various other hazards. As a result of this the average fuel consumption, travel time, and pollution level is rising at a faster rate. The average speed of travel for vehicles slows down, especially in urban areas. This section proposes a mechanism (PTFM) that is based on the pre-processing of information on an additional node which is called a shortcut node for managing the vehicular flow data. For every vehicle data and road, information is processed by using this node and saved for future use. This information is used in the future to guide the vehicles to follow better routes. First of all the traffic information is collected using multi-metric parameters which include the information of the vehicle like vehicle id, its arrival and departure lane, vehicle speed, fuel consumption, length and width of the vehicle, lane information, and emission of gases, etc. Then traffic congestion and flow conditions are defined as a) No traffic congestion b) Moderate traffic congestion c) Heavy traffic congestion. This technique performs pre-processing for each vehicle that is under consideration, thus increasing the routing efficiency. The proposed system calculates the distance between two cities or nodes and traverses all paths. The parameters of traffic information calculated are stored in an additional node which is called a shortcut node. Pre-computing distance and path information saves time when a query is processed for the particular highway again and again. Then a rerouting strategy helps the vehicles to avoid the traffic congestion conditions thus improving the traffic flow.

6.2 PRE-PROCESSING BASED TRAFFIC FLOW MECHANISM (PTFM)

In PTFM traffic information is collected using multi-metric parameters which include the information of the vehicle like vehicle id, its arrival and departure lane, vehicle speed, fuel consumption, length and width of the vehicle, lane information, and emission of gases, etc. Then traffic flow conditions are defined as a) No traffic flow condition b) Moderate traffic flow condition c) Heavy traffic flow condition. This technique performspre-processing for each vehicle that is under consideration, thus increasing the routing efficiency. The proposed system calculates the distance between two cities or nodes and traverses all paths. The parameters of traffic information calculated are stored in an additional node which is called a shortcut node. Pre-computing distance and path information saves time when a query is processed for the particular highway again and again. Then a rerouting strategy helps the vehicles to avoid the traffic congestion conditions which improvesthe traffic flow.

6.2.1 Vehicle and road information: During the trip, the vehicle moves from many streets roads, lanes, and highways to reach its destination. The vehicle attributes can be defined as:$V_i|R_i|D_L|D_{speed}|A_L|A_{speed}|D_P|A_P$[21]. Each vehicle traverses along the lane of the section of the road. Each lane has a unique id $R_i$which is used to identify vehicle location and information of the road like the length of the road($L_{R)}$ and its width($W_{R)}$.

6.2.2Network information: Every road network can be defined as a graph g(V, E) where V are vertices or nodes and E are the edges. The edges are the road segment which is connected with the vertices at both ends. The structure is defined below:

6.2.3Network Classification: This is the most important part of the traffic flow management system. The traffic flow can be affected by various reasons like accidents, road jams, or other road hazards. So to define traffic flow it has to be considered in three levels. a) Microscopic level b) macroscopic level c) macroscopic level. The microscopic level is the communication between two vehicles. The macroscopic level defines the interaction of a group of vehicles and the macroscopic level consists of the vehicle's traffic flow at the city level.

The traffic engineering and management system investigate the traffic flow at the macroscopic level. The proposed system (PTFM) represents the traffic flow at the macroscopic level. The algorithm for traffic measurement is

---

Algorithm 6.1 Algorithm for traffic measurement

---

1. *Traffic flow measurement procedure*
2. *def is_vehicle_attribute(attr):Vehicle and lane attributes($V_i|R_i|D_L|D_{speed}|A_L|A_{speed}|D_P|A_p$)*
3. *def buildTripGenerator(net, options):*
4. *try:*

max_length = 0
for edge in net.getEdges():
if not edge.is_fringe():
max_length = max(max_length, edge.getLength())
Predicting the count of the vehicle after every 300 seconds.
$S_{TAZ}(t)$ ← ZoneCongestion (subgraph)
Calculate congestion condition 1
W_R *less than or equal to* $\sum_{i=1}^{N} W_v + G$
Calculate congestion condition 2
$(L_V)*N$ *less than or equal to* $(\sum_{i=1}^{N} L_R) + Y$
Calculate congestion condition 3
Travel time of vehicle Actual and predicted:
T_A / T_P
Calculate $FUEL_{c.}$
Calculate vehicle traffic flow

End

6.2.4 Traffic flow state determination: Based on algorithm 4.7 and parameters thetraffic flow assessment is done which is defined in the table given below:

Table 4: Vehicle traffic flow index[133]

Vehicle Traffic Flow (VTF)	Traffic State Level
(0.0 – 0.3)	Free Flow
(0.3 – 0.5)	Low Traffic
(0.5 – 0.75)	Moderate Traffic
(0.75 – 1.0)	High Traffic

6.2.5Traffic flow management mechanism: The proposed mechanism (PTFM) performs separate pre-processing for every vehicle class that is encountered, thereby increasing routing efficiency. The algorithm calculates all the paths that are connecting the two cities. This information is stored in an additional edge node which is called the shortcut edge node. Now when the same highway or lane is evaluating for traffic analysis then the shortcut edge node will provide the information of traffic route data to the vehicles thus avoid calculation of path again .this saves time in query processing. After that rerouting mechanism is activated which will reroute the traffic to different paths. The algorithm for PTFM is given below:

Algorithm 6.2 Algorithm for PTFM

```
Preprocessing(S,D):
Vehicle information{V1-------VN}
Distance [S] := 0
Each Node Vx{1----N} in the  Graph
def is_vehicle_attribute(attr):
    for cand in ['depart', 'arrival', 'line', 'Number', 'type']:
        if cand in attr:
            return True
else
        return False

Calculate shortest path value f(v)
Search for each pair {x, y} vertices
S(x) : Path value from the start node
V:  vertex in Q with min dist[n]
Store Information on shortcut node
The query for each neighbor x of y for shortcut path
route f(v): = Dist[x] + Length (x,y)
if route <dist [y]:
    update dist[y]:=route
else
    previous[x]:= y
return distance
End
```

4.2.6 Vehicle Updation: To keep the car information up to date, The ballistic technique is used to update the location of vehicles. Energy Saving Implicit Method is used which is defined with the equation below

$$X_{pos+1=} X_{pos}h[V_{A+1}, d(V_{Acc})/d(t)] \quad (16)$$

Here Xpos is the vehicle's current location andV_{A+1} is the vehicle`s speed. $d(V_{Acc})/d(t)$ is the acceleration rate of change.

CHAPTER 7: SIMULATION AND RESULTS

7.1 INTRODUCTION TO SIMULATOR

(SUMO) is an open-source and highly portable tiny road traffic simulation program. It is designed to handle large-scale simulation scenarios. SUMO includes a plethora of support applications to aid in the creation of sophisticated microscopic traffic simulation models. Vehicle characteristics (for example, vehicle type, acceleration, length, maximum speed, and so on), vehicle route and flow parameters, right of way, traffic signals, and so on, are all very customizable. A range of vehicle following and overtaking models are available via SUMO distribution. A rapid open GL-based graphical user interface, high execution speed, run-time compatibility with other programs through the TRACI interface, and edge level, vehicle level, and detector level outputs are among the appealing characteristics. Figure 7.1 shows a GUI snapshot of traffic simulation using SUMO.

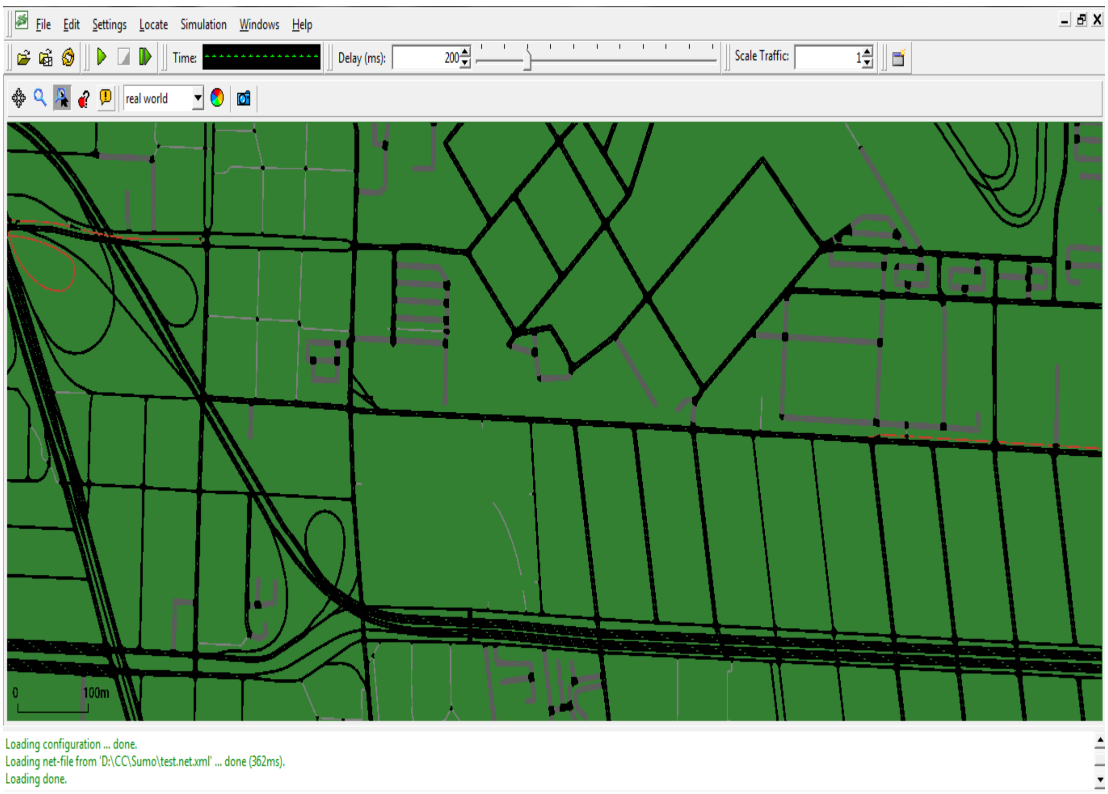

Figure 7.1:GUI interface

7.2 BUILDING THE NETWORK

For building a road network in SUMO open street maps are used in XML format. Then through the net convert command, the networks of cities are imported to the sumo interface.

Net-Convert imports and creates digital road networks from open street maps which includes

- Aim: Import road networks and conversion to the compatible format .
- System requirement: (Linux or Windows to run on the command line).
- Input:Road network definition.
- Output: A road network generated in SUMO.
- Programming Language: Python.

7.3 VEHICLE AND ROUTE INFORMATION

The vehicle and route information defines the type of vehicle, its width and its length. The route of the vehicle is defined as

```
</routes>

<vType id="type1" accel="0.7" decel="4.7" sigma="0.4" length="4"
maxSpeed="80"/>

<route id="route1" color="1,2,0" edges="beg middle end rend"/>

<vehicle id="1" type="type2" route="route1" depart="3" color="1,0,1"/>

<vehicle id="1" type="type3" route="route2" depart="2" color="1,1,1"/>

</routes>
```

The route table inside every vehicle stores the information which includes id, depart speed, depart position, depart lane, color, arrival speed, arrival lane, and reroute information(in case of traffic congestion).

7.4 TRAFFIC FLOW INFORMATION

The traffic flow can be measured according to lane which consists of number of vehicles on the particular route which is defined below

```
<flow id="type2" color="0,1,0"  begin="0" end= "7000" period="800" type="CAR">
<route edges="beg middle end rend"/>
<stop carStop="station1" duration="20"/>
</flow>
<route id="route1" edges="beg middle end rend"/>
<flow id="type3" color="1,1,1"  begin="0" end= "6000" period="800" type="CAR"
route="route2">
<stop carStop="station3" duration="40"/>
</flow>


</flow>
<route id="route3" edges="beg middle end rend"/>
<flow id="type3" color="1,1,1"  begin="0" end= "6000" period="800" type="CAR"
route="route2">
<stop carStop="station3" duration="40"/>
</flow>
```

7.5 RESULT ANALYSIS OF ROUTING ALGORITHMS

To simulate the various routing protocols the Sumo Simulator is used. The Simulator is an open-source urban mobility simulator. The Python script is used for writing the code for simulation. The open street map Los Angeles is used with an area of 10 square km.The diagram of the simulation of the Los Angeles map is shown in Figure 7.2.Figure 7.3 is showing the running status of vehicles in the streets of an urban city. The vehicle parameters are shown in Table 5.This includes the length of vehicles, their emission standards, maximum speed, and minimum gap between the vehicles, acceleration, and deceleration of the vehicles.

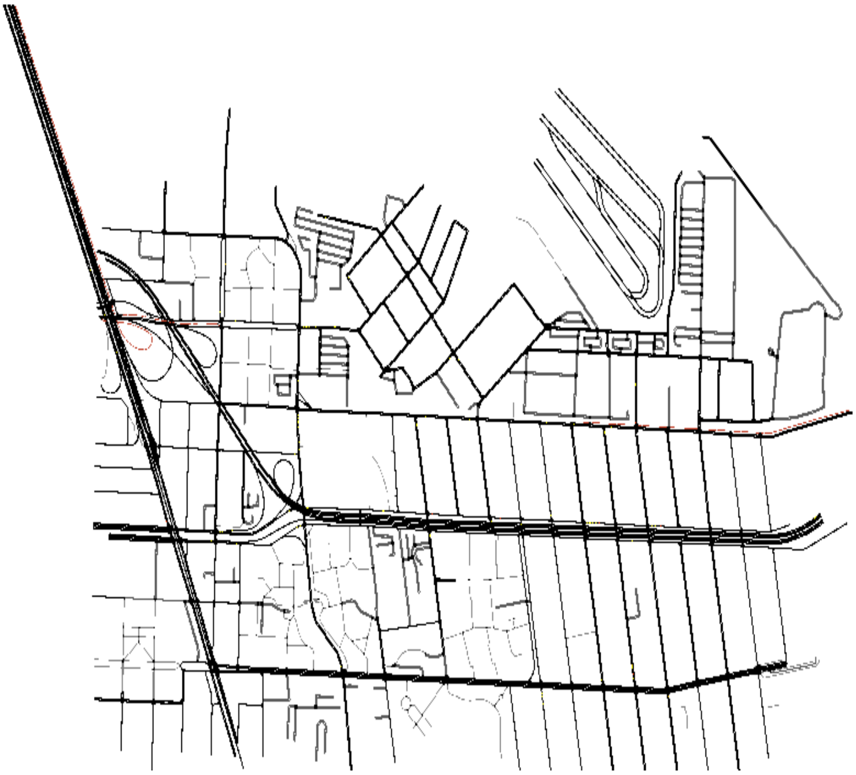

Figure 7.2: Simulation Los Angeles map of 10km

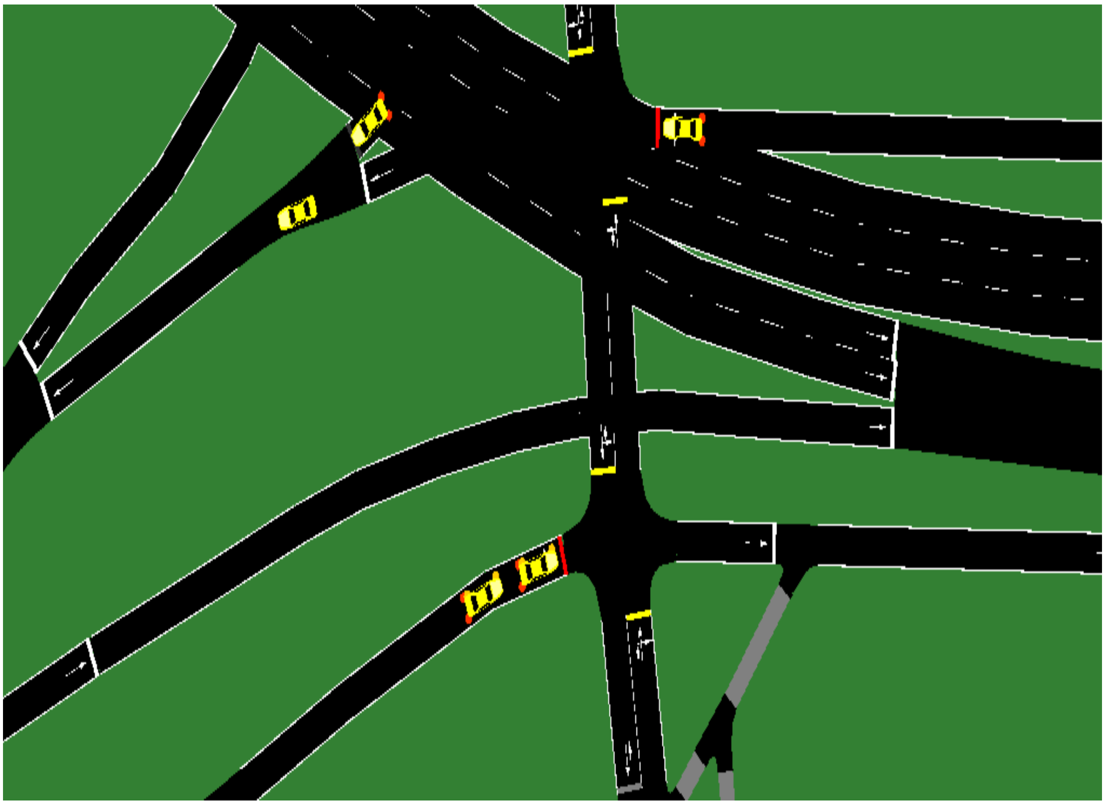

Figure 7.3: Los Angeles map simulation

Table 5: Parameters of vehicle used for simulation

Acceleration	Deceleration	Min gap	Length of vehicle	Emission class	Max Speed
2.60ms^{-2}	4.50 ms^{-2}	2.50m	5m	HBEFA3/PC_G_ EU4	55.31 Km/hr

The comparative analysis of Dynamic Astar, Dynamic Dijkstra,FloydWarshall, and CH routing algorithm is done based on the various attributes. The travel time average and average travel distance of the CH algorithm are calculated based on the Top-down approach and bottom-up approach [See figure 7.4 and figure 7.5]. It has been found that the Top-down approach is better optimized in terms of traveldistance and time. This is due to the calculation of the path. The top-down heuristics computes the whole node order of the graph before the contraction of the graph. This yields better results. The bottom-up heuristic does not compute the node order in advance; it selects the next node for contraction during traversing.

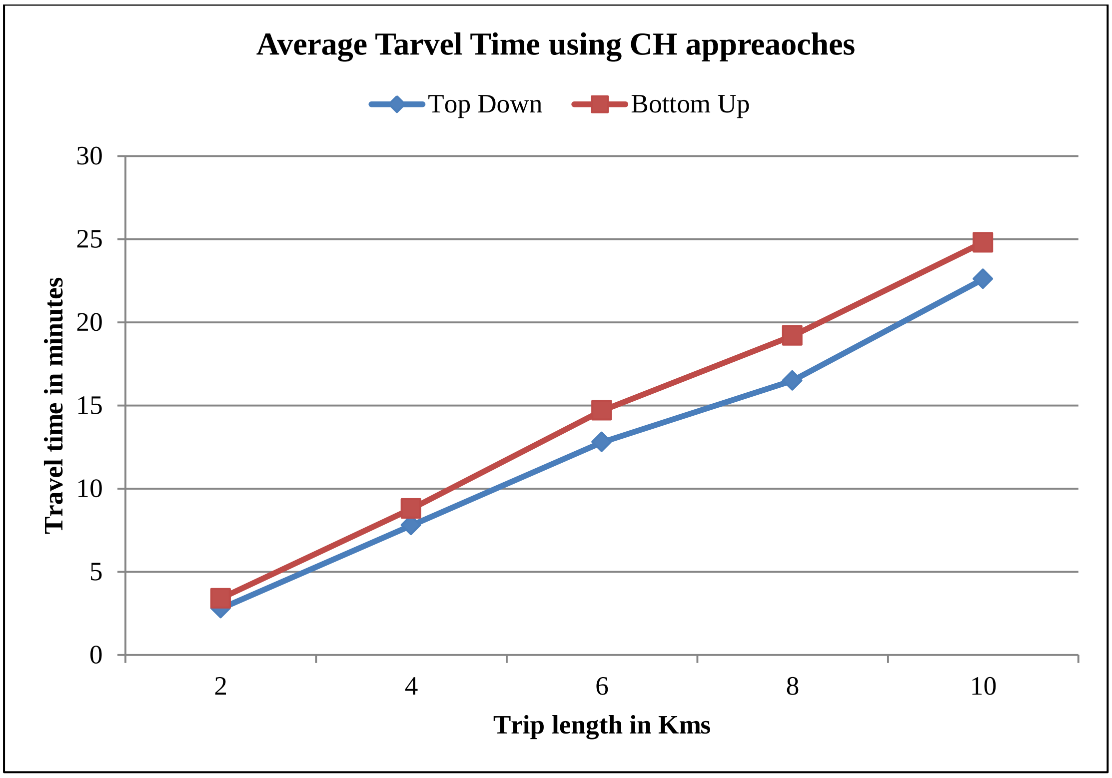

Figure 7.4: Average Travel time with CH approaches

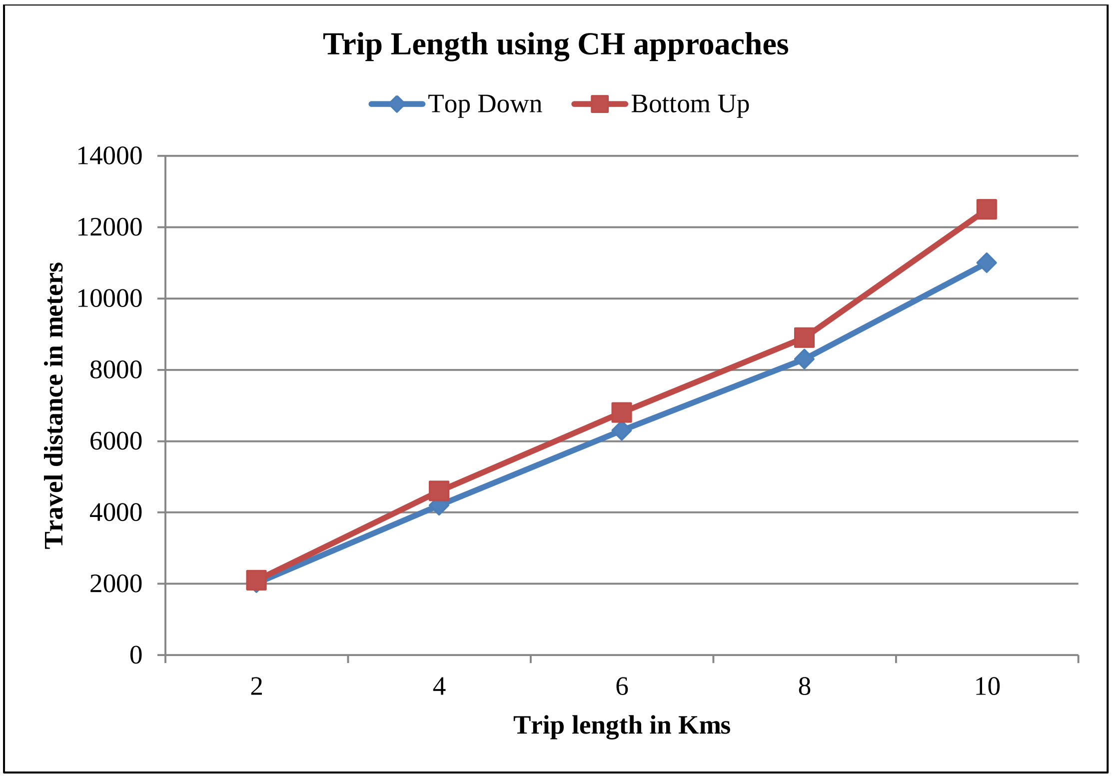

Figure 7.5: Travel distance with CH approaches

The various routing algorithms are compared based on the parameters like route length, average travel time, average waiting time, and average speed of vehicles. Figure 7.6 shows the average route length covered by vehicles using various routing algorithms. The comparison of the vehicles for a distance of two to ten kilometers is considered. There is no significant difference in route covered by using routing algorithms when the distance is small. As the travel distance is increased, it has been found that the CH algorithm covered less distance (route length) as compared to other algorithms. The route length becomes an important parameter especially in case of congestion when rerouting is needed for the vehicles. Figure 7.7 describes the average travel time comparison of vehicles. The travel time of the CH algorithm is less as compared to other algorithms. Figure 7.8 represents the average waiting time of different algorithms used for simulation. The Astar algorithm is found to be effective, as waiting time is less during the travel of the vehicles as compared to other algorithms.

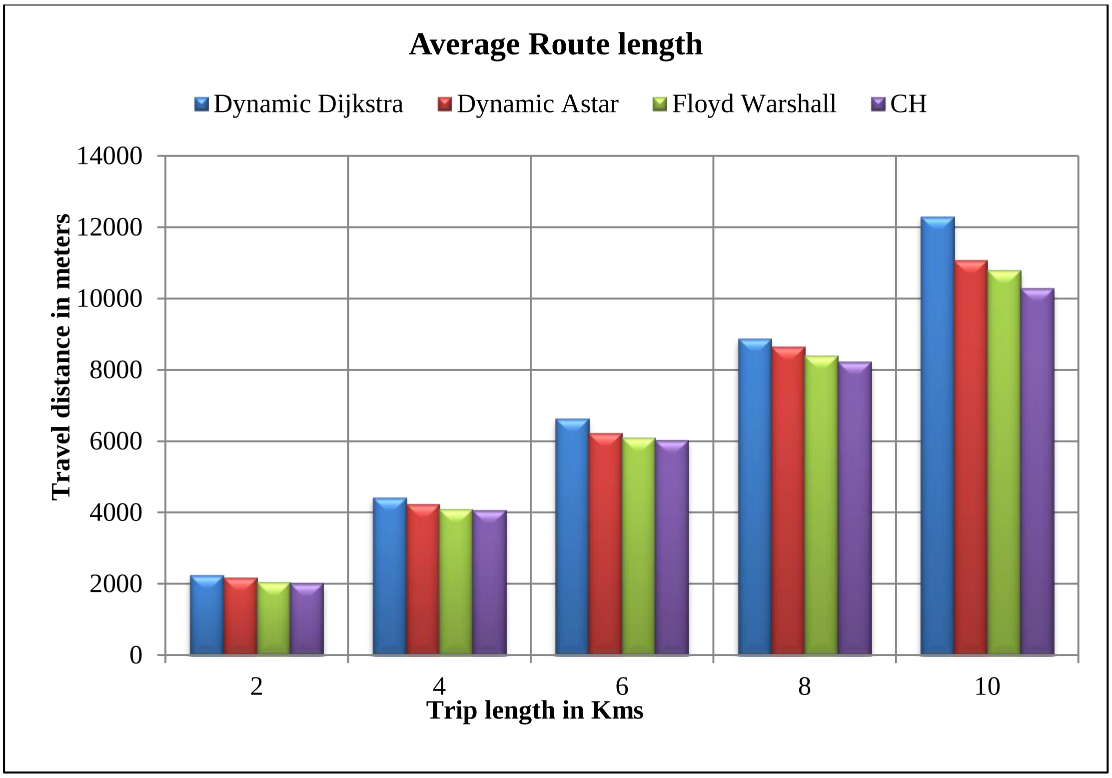

Figure 7.6: Average route length comparison of algorithms

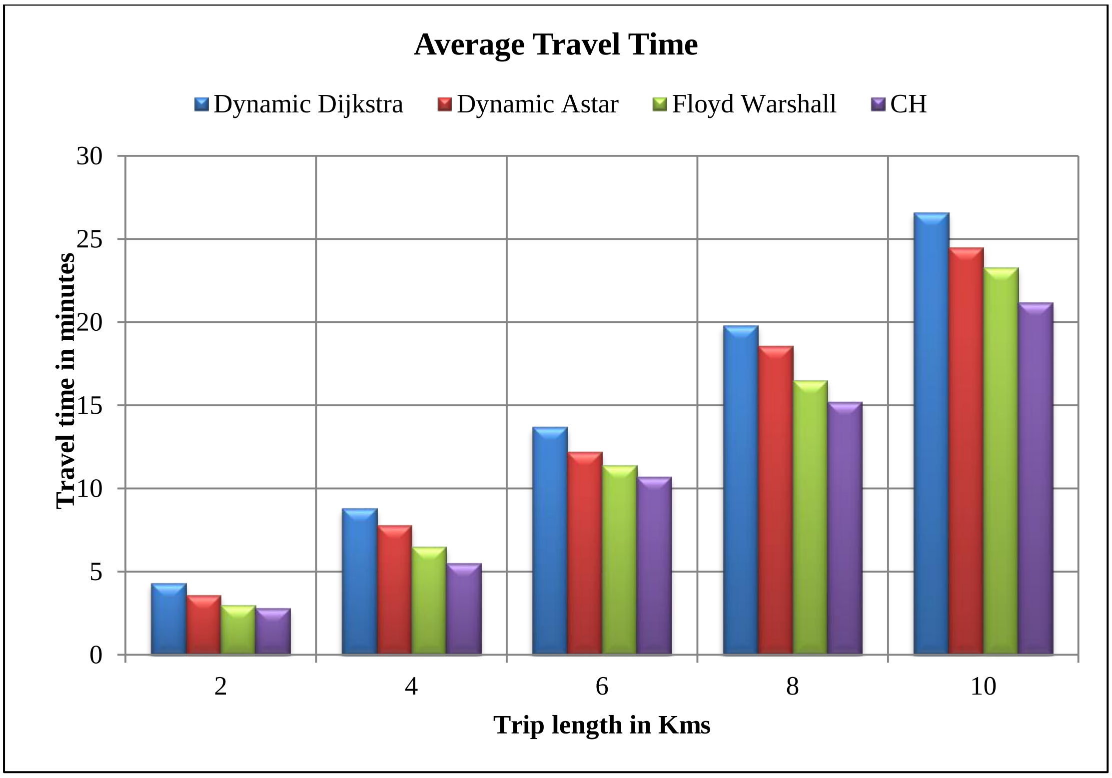

Figure 7.7: Average travel time comparison of algorithms

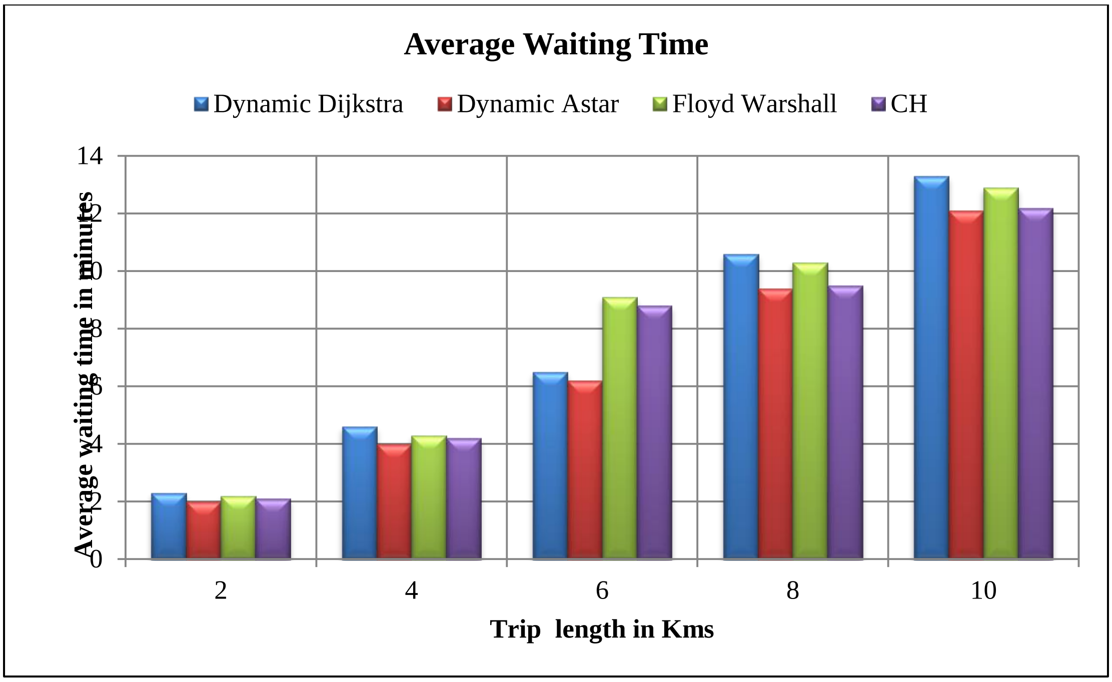

Figure 7.8: Average waiting time comparison of algorithms

Figure 7.9 represents the speed comparison of vehicles using four different routing algorithms. The speed of vehicles using the CH algorithm is found to be good as compared to other algorithms. The various statistics of routing algorithms according to trip length, route length, average waiting time, average travel time, and average travel speed of vehicles are described in table 5.2, table 5.3, and table 5.4 for the four algorithms.

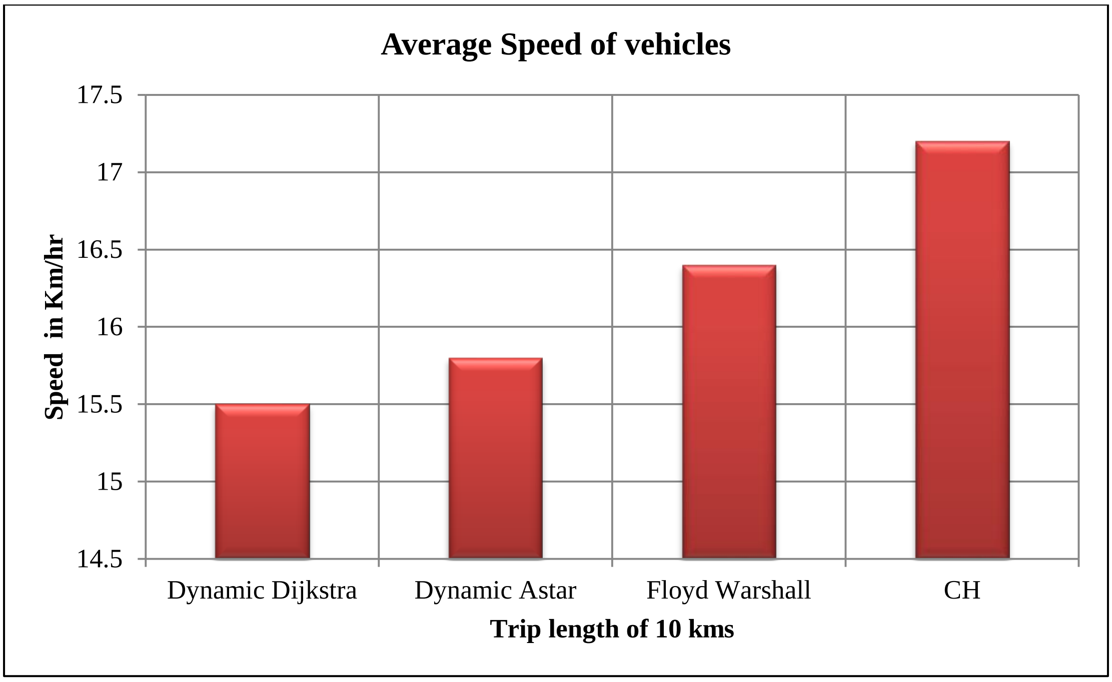

Figure 7.9: Average speed comparison of algorithms

The statistics are prepared according to the route trip length of 2 km and 10 km.

Table 6: Statistics for trip length for 2 Kms

Parameters / Algorithms	Route length in meters	Average Waiting time in minutes	Average Travel Time in minutes
Dynamic Dijkstra	2240	2.3	4.3
Dynamic Astar	2182	2	3.6
Floyd Warshall	2050	2.2	3
CH	2012	2.1	2.8

Table 7: Statistics for trip length for 10 Kms

Parameters / Algorithms	Route length in meters	Average Waiting time in minutes	Average Travel Time in minutes
Dynamic Dijkstra	12300	13.3	26.6
Dynamic A-star	11076	12.1	24.5
Floyd Warshall	10800	12.9	23.3
CH	10300	12.2	21.2

Table 8: Statistics for average speed for 10 Kms

Algorithm	Dynamic Dijkstra	Dynamic Astar	Floyd Warshall	CH
Average Speed km/h	15.5	15.8	16.4	17.3

7.6 RESULT ANALYSIS OF MRGM

Multi-metric road guidance mechanism(MRGM) considers multiple metrics to analyze the traffic congestion conditions and based on the conditions effective optimal routes are suggested to the vehicles. To simulate MRGM mechanism SUMO simulator is used which is an urban mobility traffic simulator with python script.To analyze the mechanism, open street maps of Downtown Los Angeles in the USA, Melbourne region in Australia, and Manhattan in the USA are analyzed. The communication radius of RSU is 500 m. The simulation diagram for Los is shown in figure 7.10

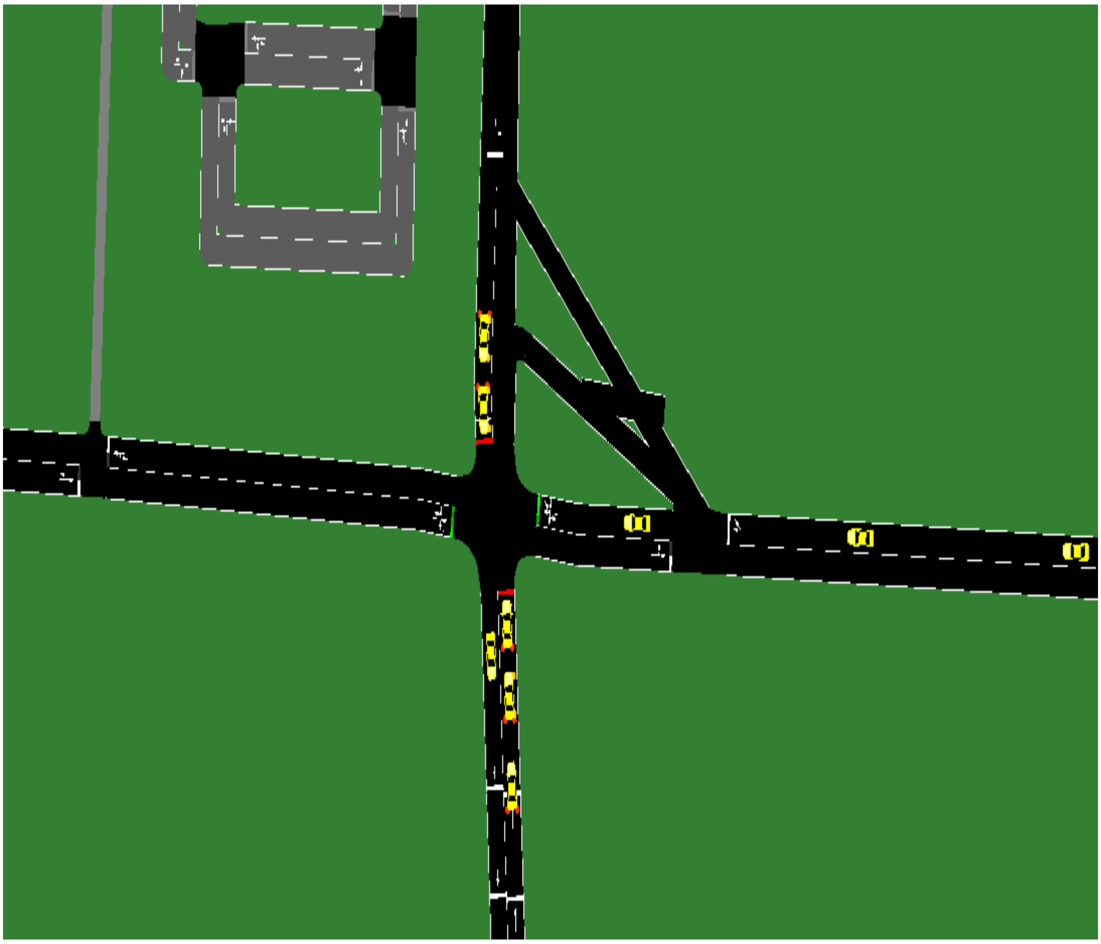

Figure 7.10: Simulation diagram

The HBEFA3/PC_G_EU4 is a gasoline-powered Euro norm 4 passenger car model for emission of pollution. The duration of the simulation is 600s. Figure 7.11 defines the average travel time for vehicles in Melbourne, Los Angeles, and Manhattan cities in minutes by using the VCD (Vehicle congestion density) function which varies from 0 to 1. As the value of VCD increases, travel time also increases. It means when congestion increases, then the average travel time also increases.

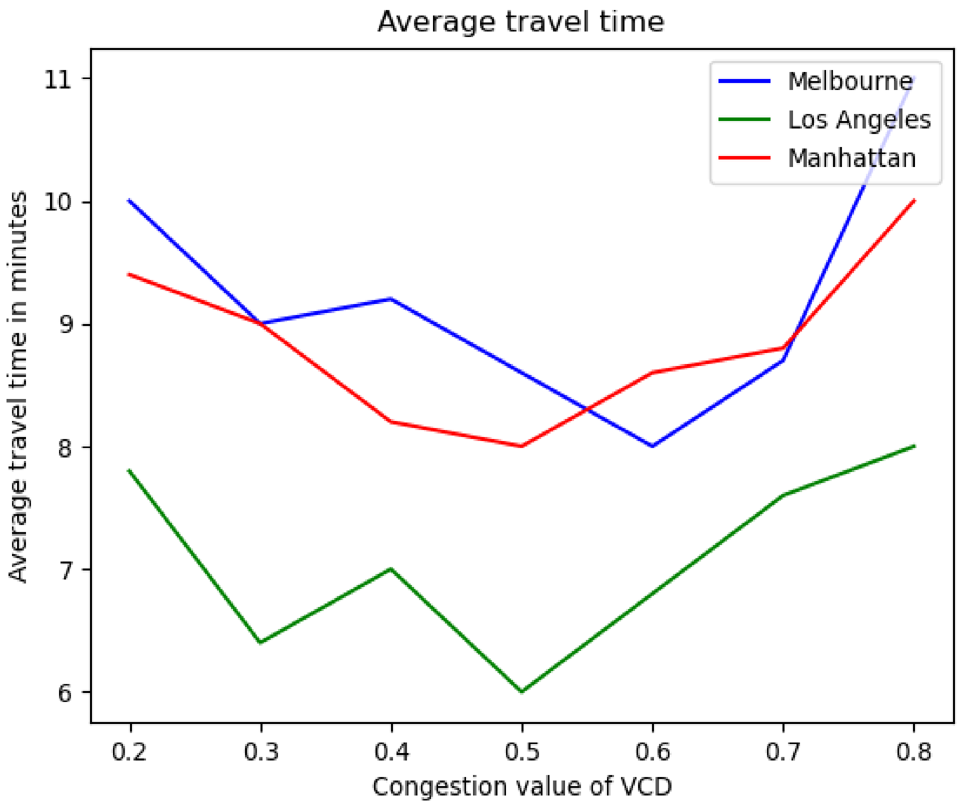

Figure 7.11: Average Travel time

In Figure 7.12 the effect of the average speed of the vehicle with VCD is defined. With the increase in traffic density, the speed of vehicles decreases. In Figure 7.13 average CO_2 emission level is calculated. In figure 7.14 average fuel consumption of vehicles is measured for VCD. The fuel consumption is calculated by the speed of vehicles and the length of the road on which vehicles are running.

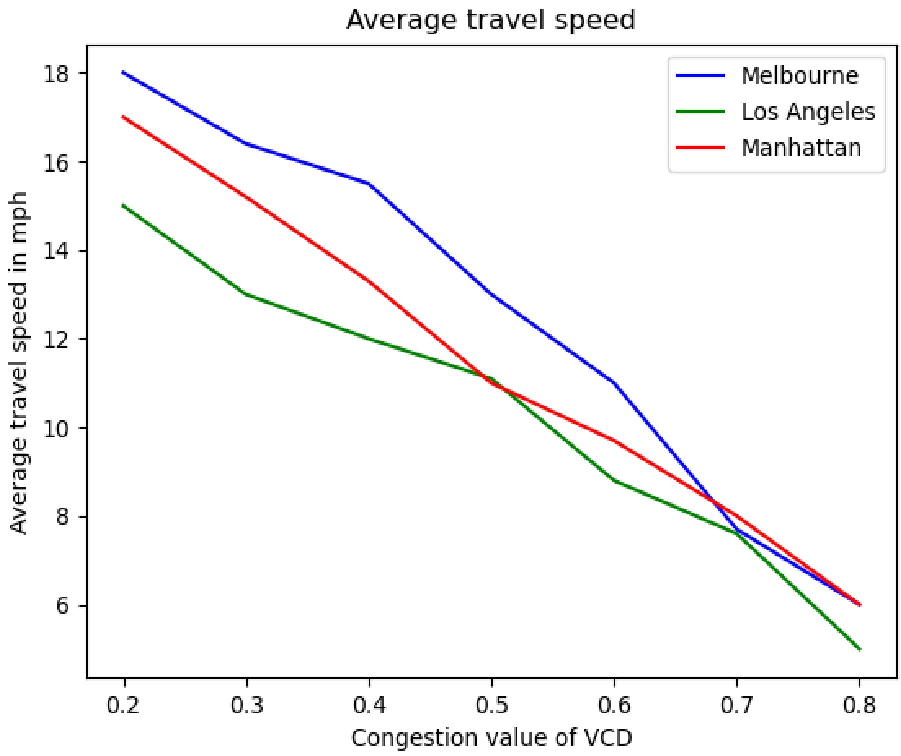

Figure 7.12: Average speed of vehicle

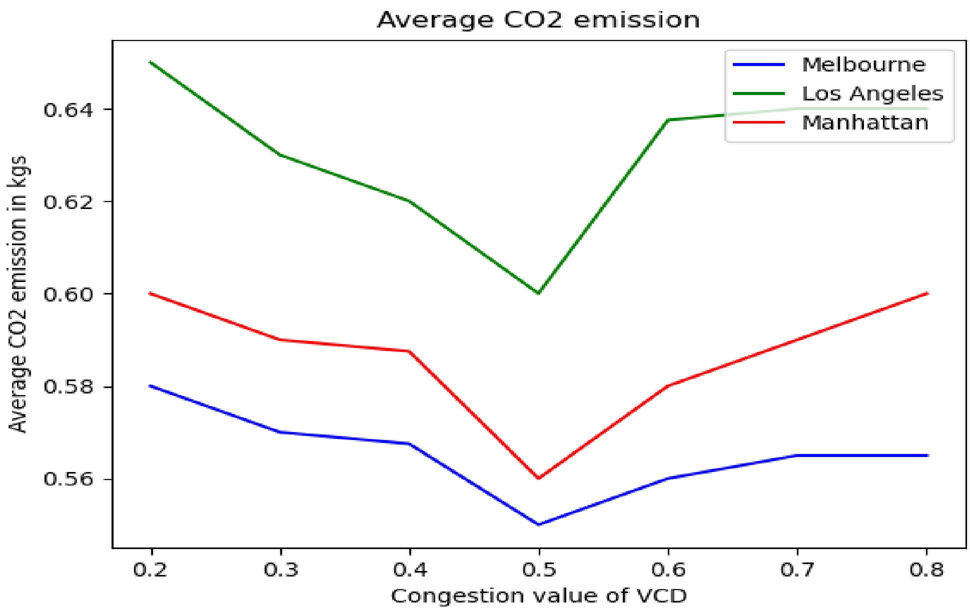

Figure 7.13: Average CO_2 emission

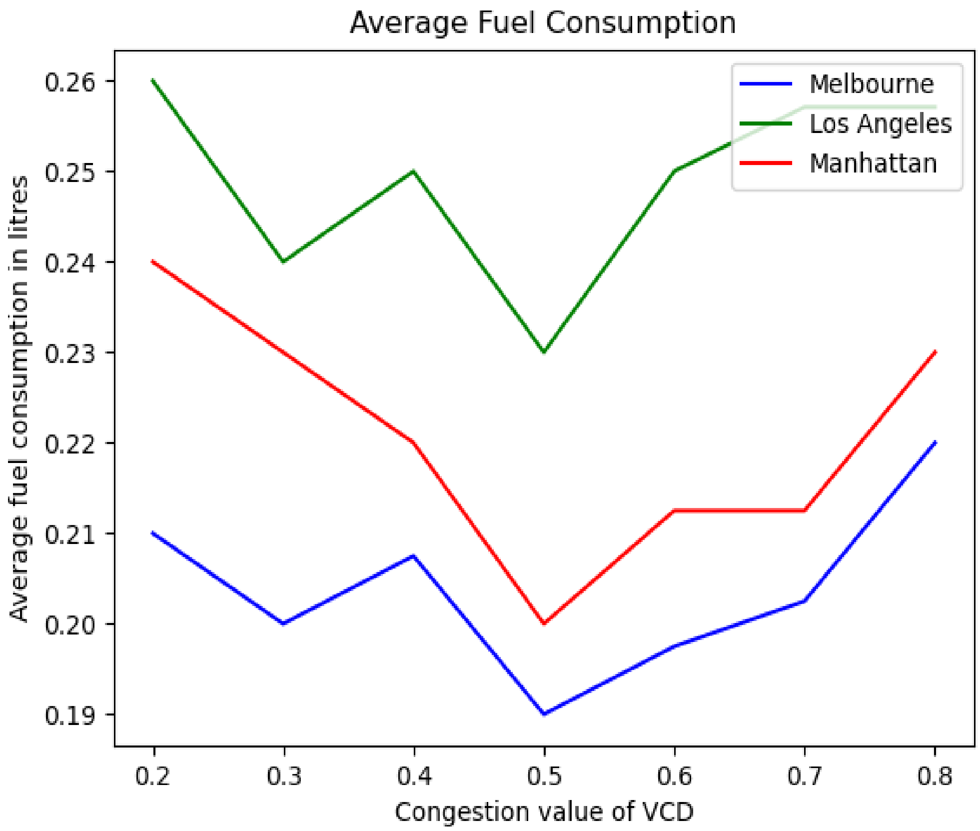

Figure 7.14: Average Fuel consumption

In Figure 7.15 the travel speed of vehicles is showed on the Los Angeles map using MRGM. It has been found that when MRGM mechanism is used, then the average speed of vehicles in the urban area of Los Angeles is increased which reduces the travel time. Figure 7.16 shows the CO_2 emission on the Los Angeles map. The CO_2 emission is less as there arefewer traffic jams and congestion occurs. Figure 7.17 shows the average fuel consumption by vehicles

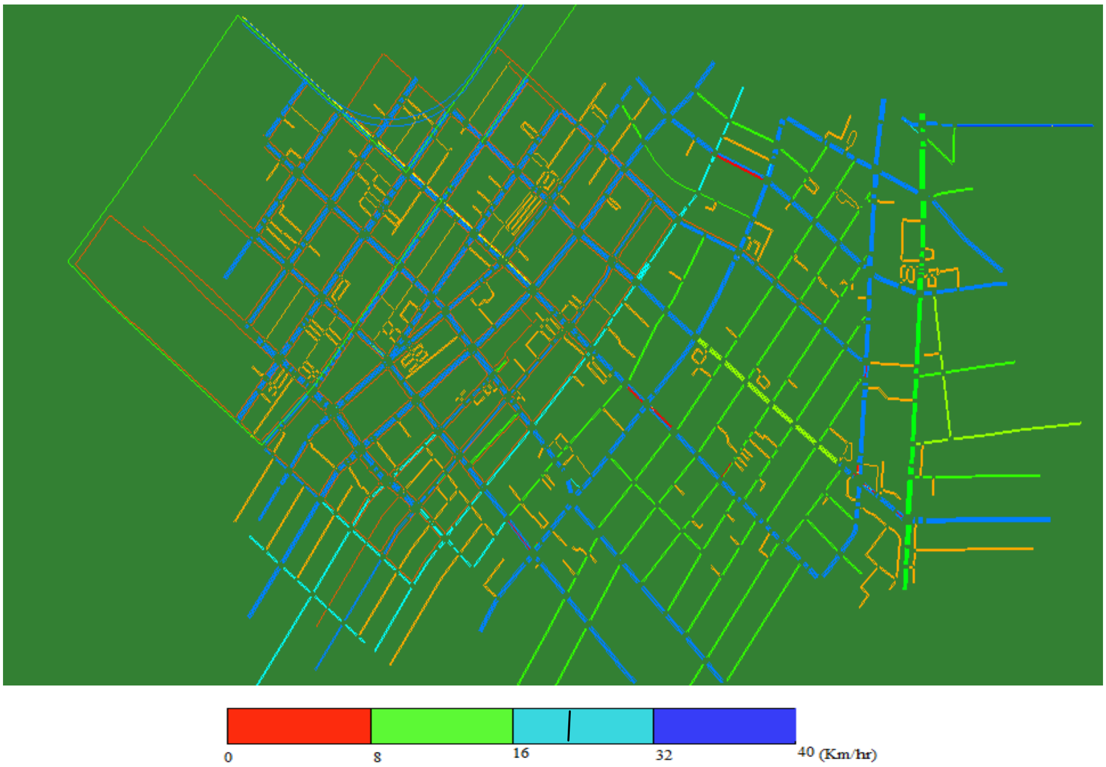

Figure 7.15: Average speed of vehicle on Los Angeles map

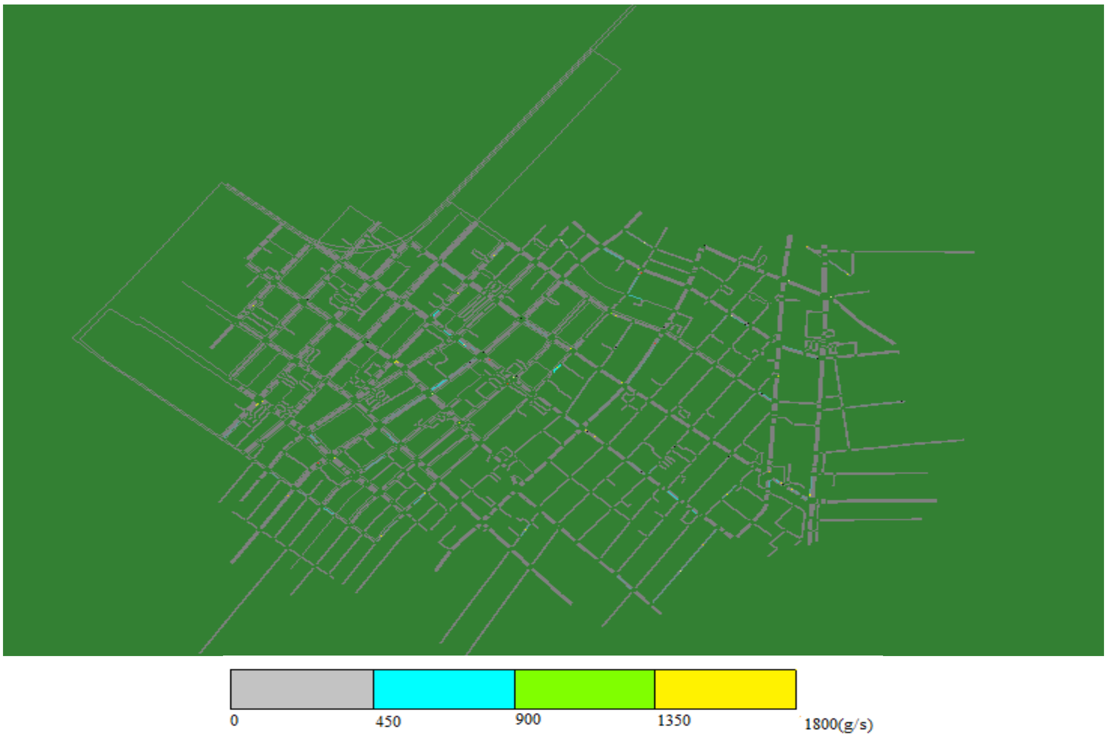

Figure 7.16:CO_2 Emission levels on Los Angeles map

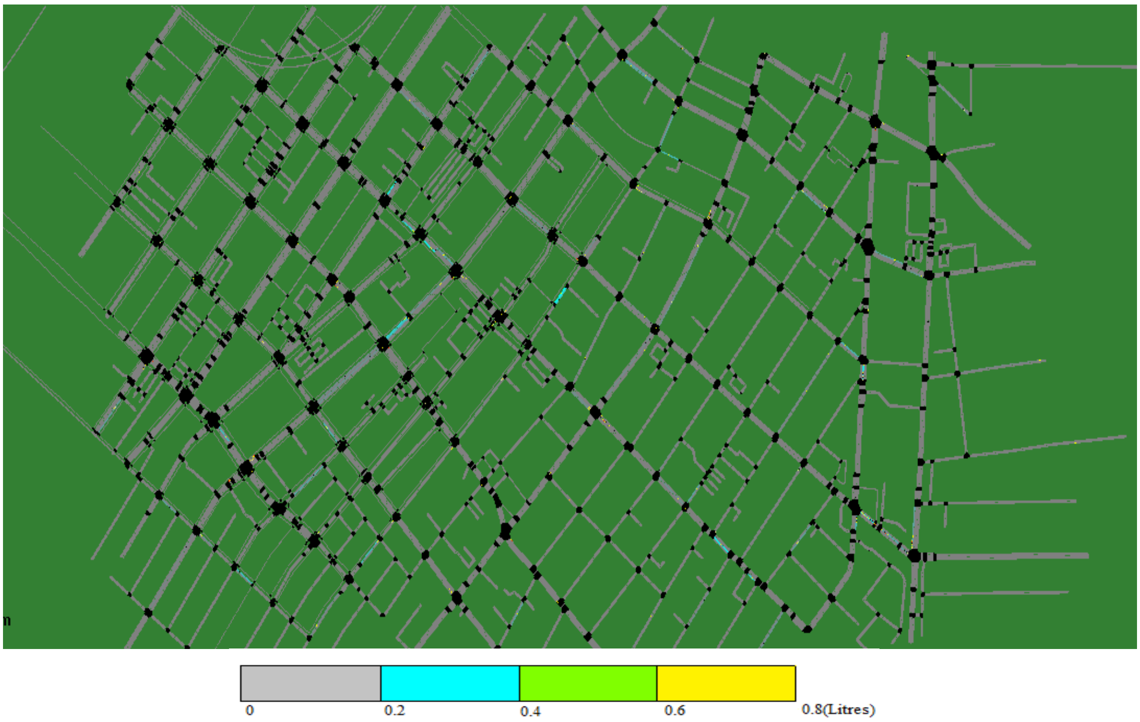

Figure 7.17: Average fuel consumption on Los Angeles map

The working of MRGM is compared with existing mechanisms like RTS, SSRGS, and Refocus over three different urban areas. The comparison is done based on average fuel consumption, CO_2 emission levels, and average travel time. The results show that MRGM has shown improved and promising results over these existing techniques and mechanisms. Figure 7.18 shows that level of emission of CO_2 is reduced by using MRGM as compared to other mechanisms. Figure 7.19 shows the average fuel consumption which is reduced by using MRGM. The travel time for vehicles has also been reduced which is shown in figure 7.20. This is due to the congestion detection and avoidance mechanism used by MRGM using the functions VCD and PWC for optimal route finding.

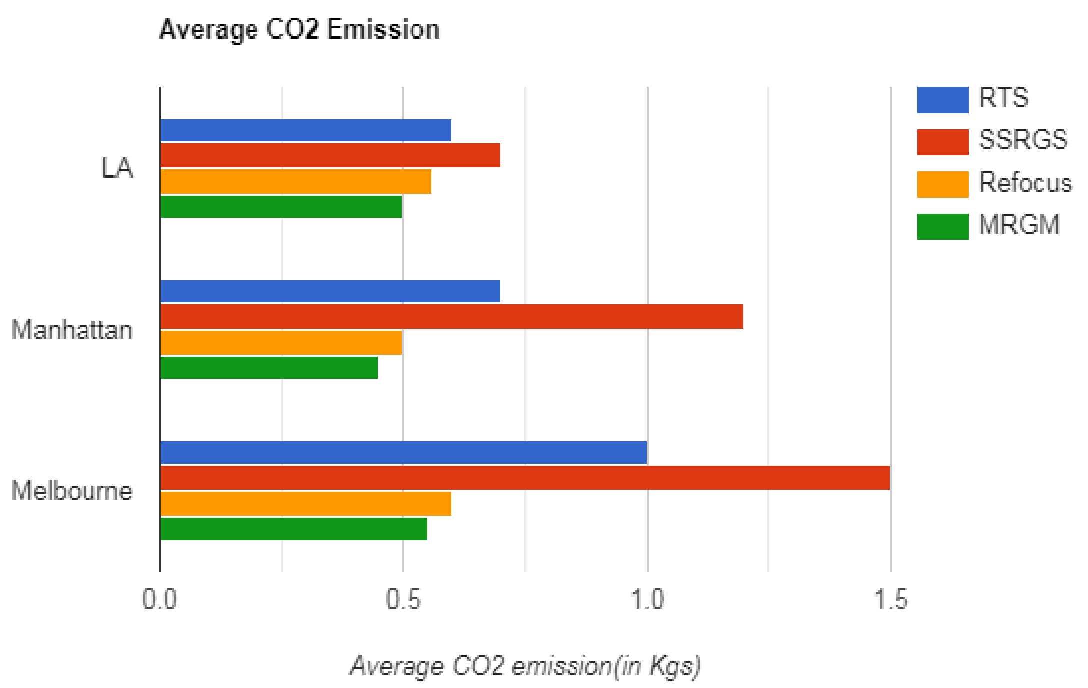

Figure 7.18: Average CO_2 emission

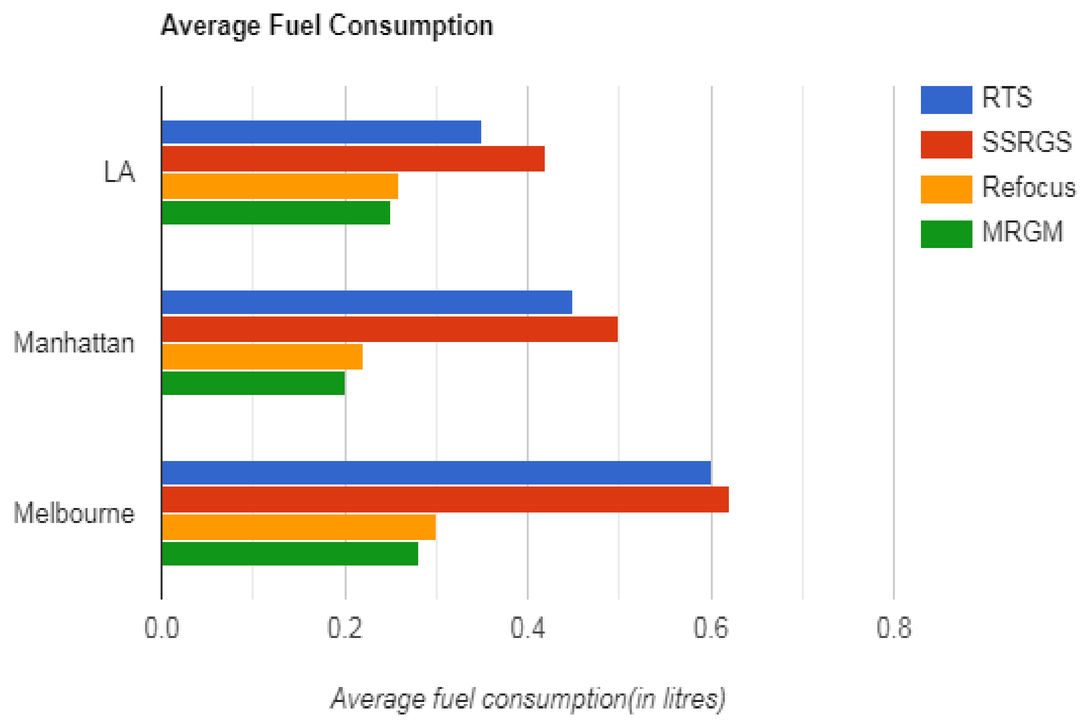

Figure 7.19: Average fuel consumption

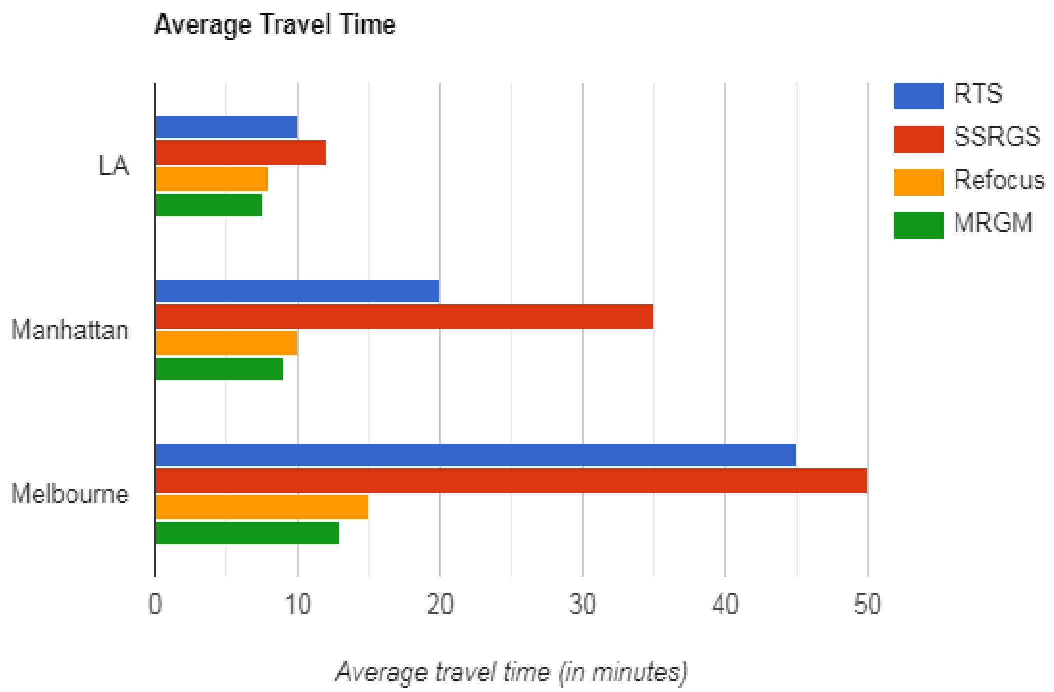

Figure 7.20: Average travel time

7.7 RESULT ANALYSIS OF PTFM

To simulate the PTFM mechanism SUMO simulator is used. The Python code is used to implement the mechanism and to create the trips in the cities. For the comparison, the PTFM is compared with other existing mechanisms like NRR, DIVERT, and Re-route. The simulation map diagram is shown below[figure 7.21]

Figure 7.21: Simulation Map

Figure 7.22 is showing the running traffic environment with vehicles on the Paris map. Similarly, the traffic scenario is created for Los Angeles also. The communication radius between vehicles and shortcut nodes is 500 m.

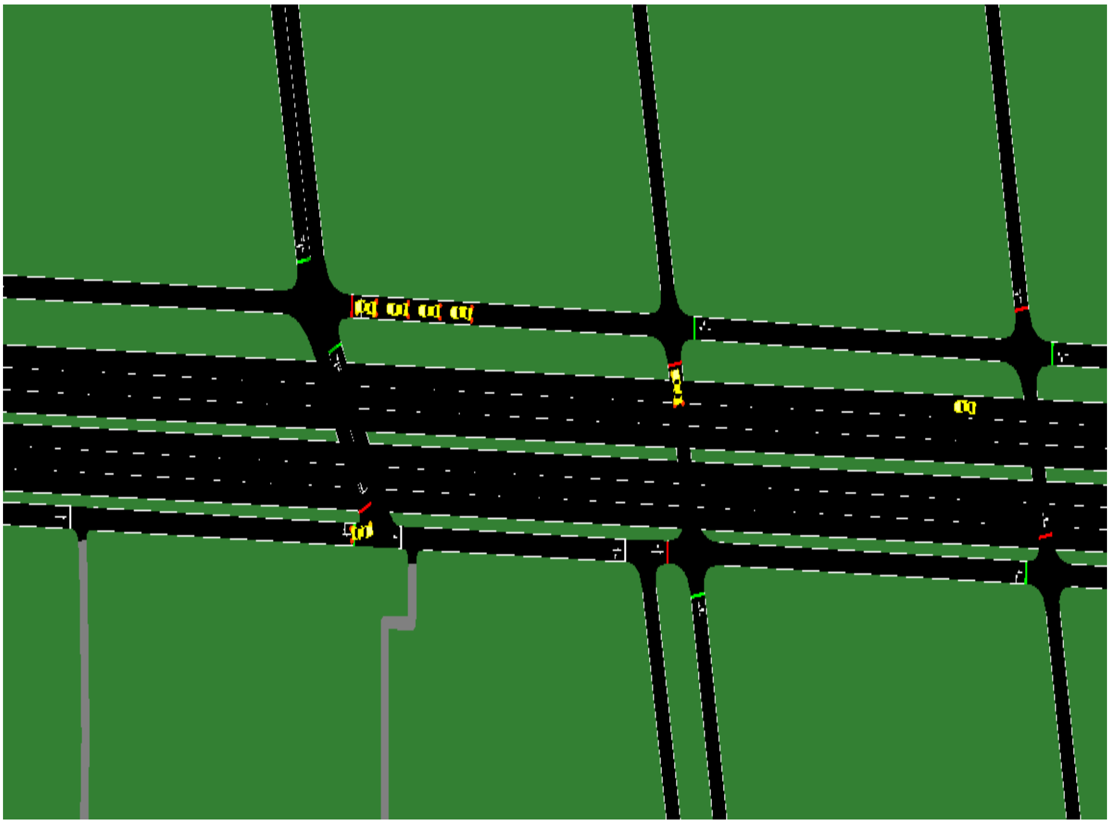

Figure 7.22:Simulation with traffic

The HBEFA3/PC_G_EU4 is a car model which is gasoline-powered as per European emission standards for emission of pollution. The duration of the simulation is the 2000s.Figure 7.23 illustrates the average CO_2 emission level for LA and Paris cities based on travel distance in Kms by using the PTFM mechanism. As the travel distance increases the carbon emission levels also increase. Figure7.24 shows the travel distance in meters by using PTFM for LA and Paris.

In figure 7.25 average fuel consumption for the two cities is compared. The fuel consumption varies according to the distance traveled and flow level. In figure 7.26 the important parameter which is travel time is shown using PTFM. The travel time is measured in minutes. As per the analysis, it has been found that average carbon emission levels, average travel time, average fuel consumption, and travel distance are more when vehicles move in Los Angeles as compared to Paris which means the traffic flow is more congested in LA as compared to Paris.

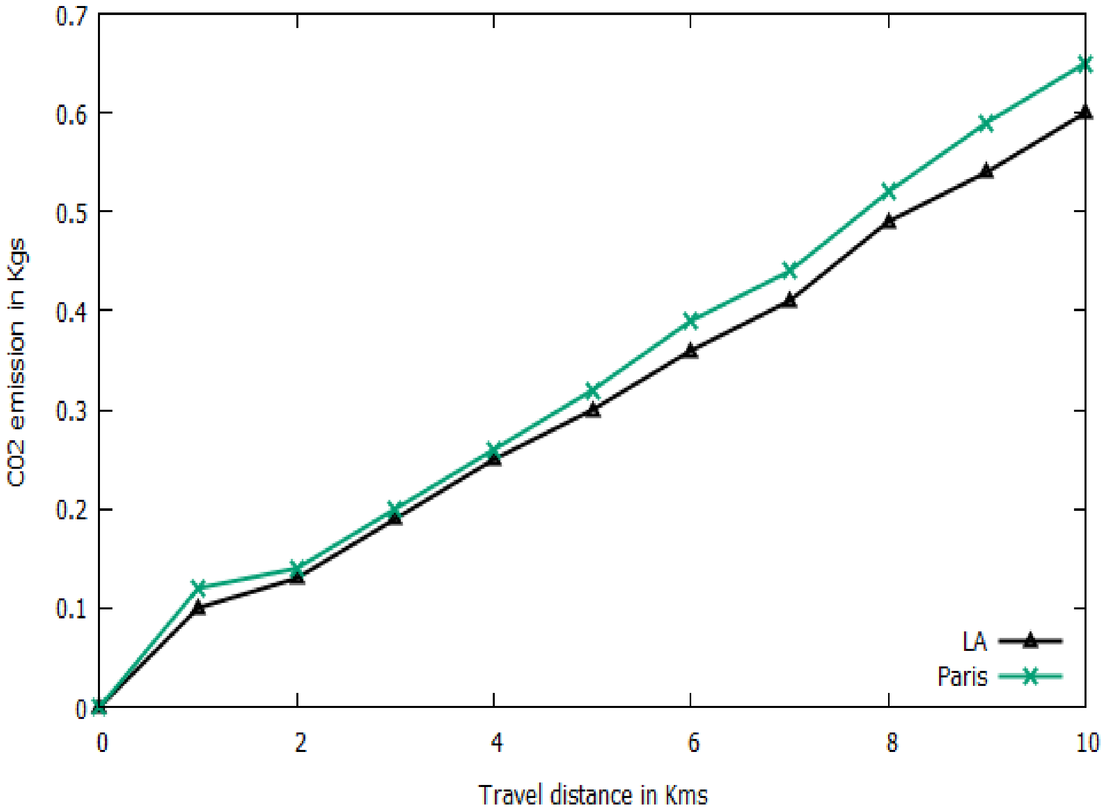

Figure 7.23: Average CO_2emission

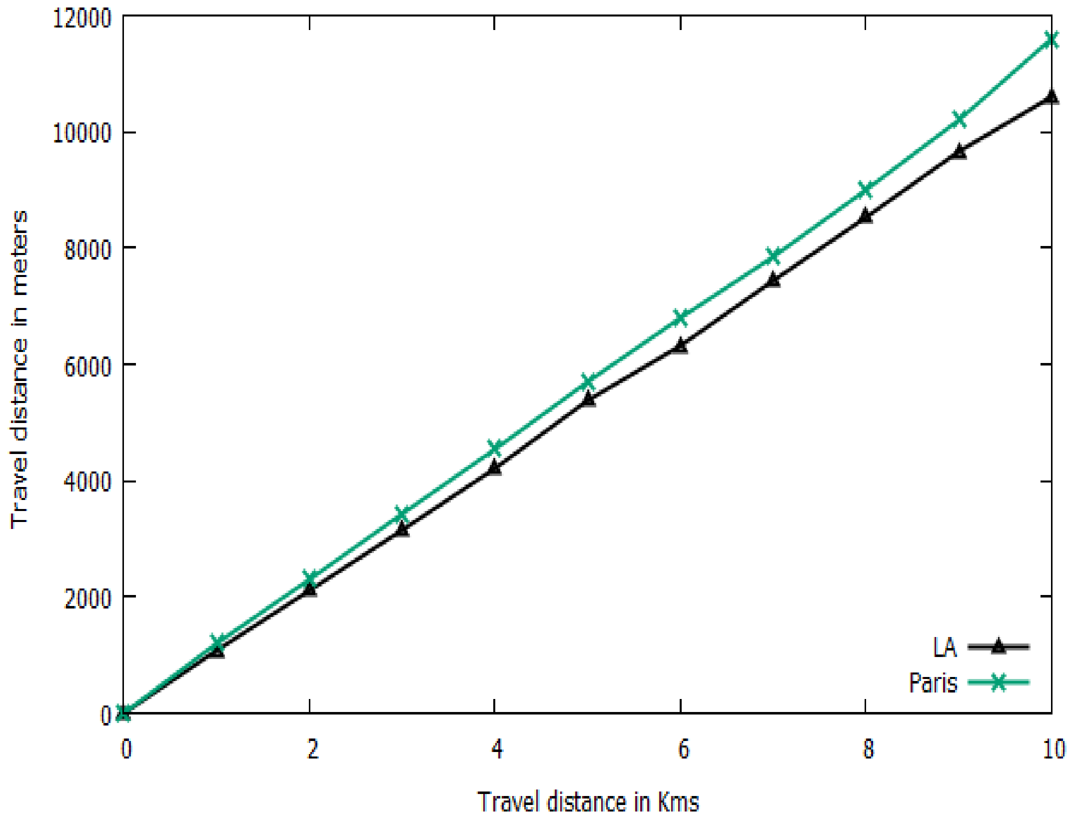

Figure 7.24: Average travel distance

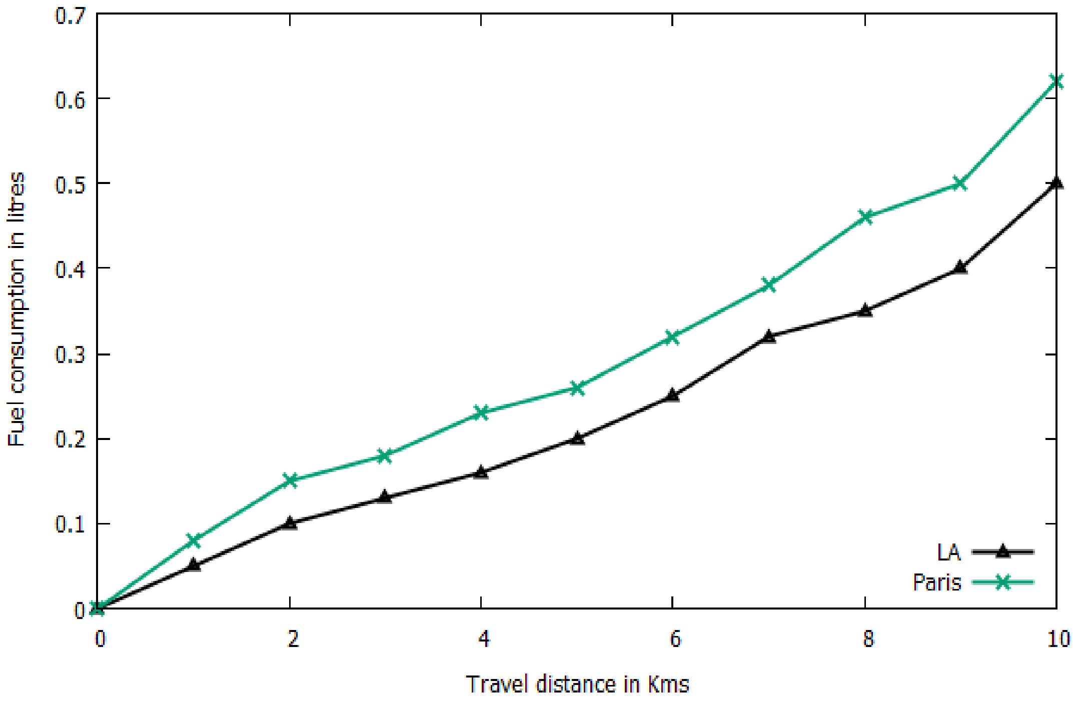

Figure 7.25: Average fuel consumption

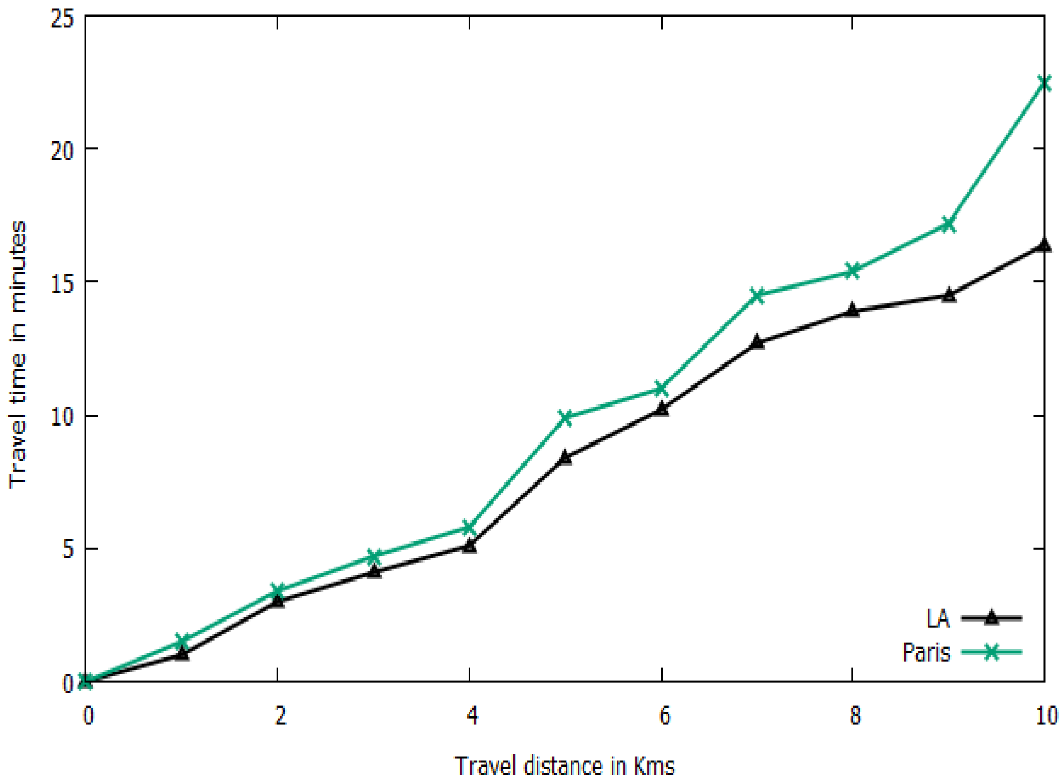

Figure 7.26: Average travel time in minutes

The average time travel for the PTFM is compared with an existing mechanism like DIVERT, NRR, Reroute, and PTFM for LA. [figure 7.27] and Paris in [figure 7.28] according to the number of vehicles on the roads. It has been found the average travel taken by vehicles using PTFM is less as compared to other mechanisms. So PTFM is found to be effective in this case.

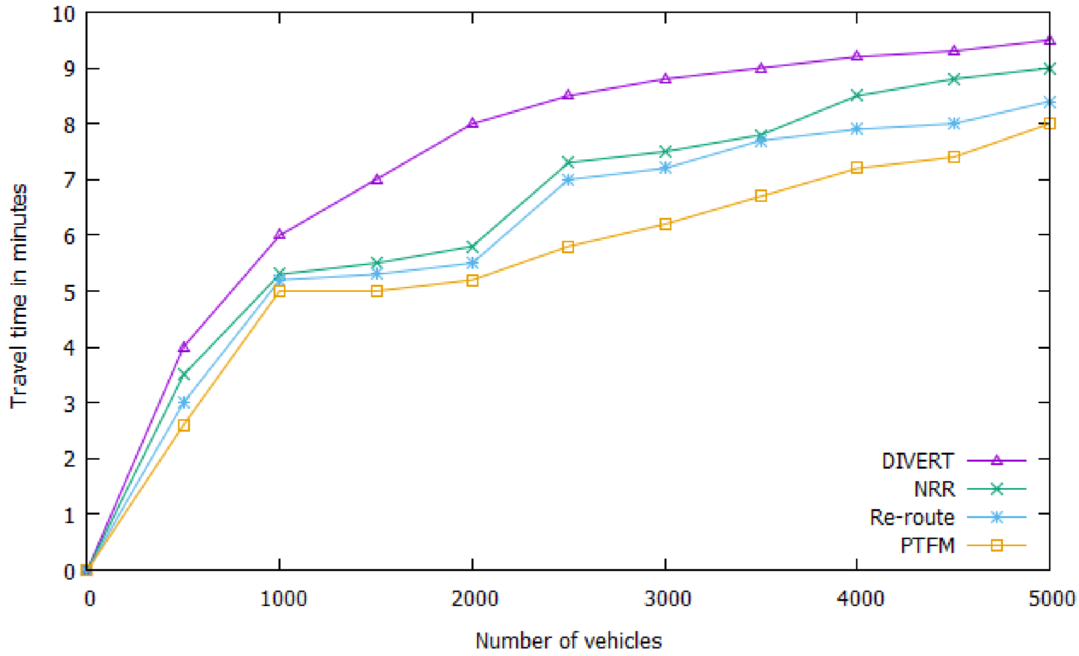

Figure 7.27: Average time travel for LA

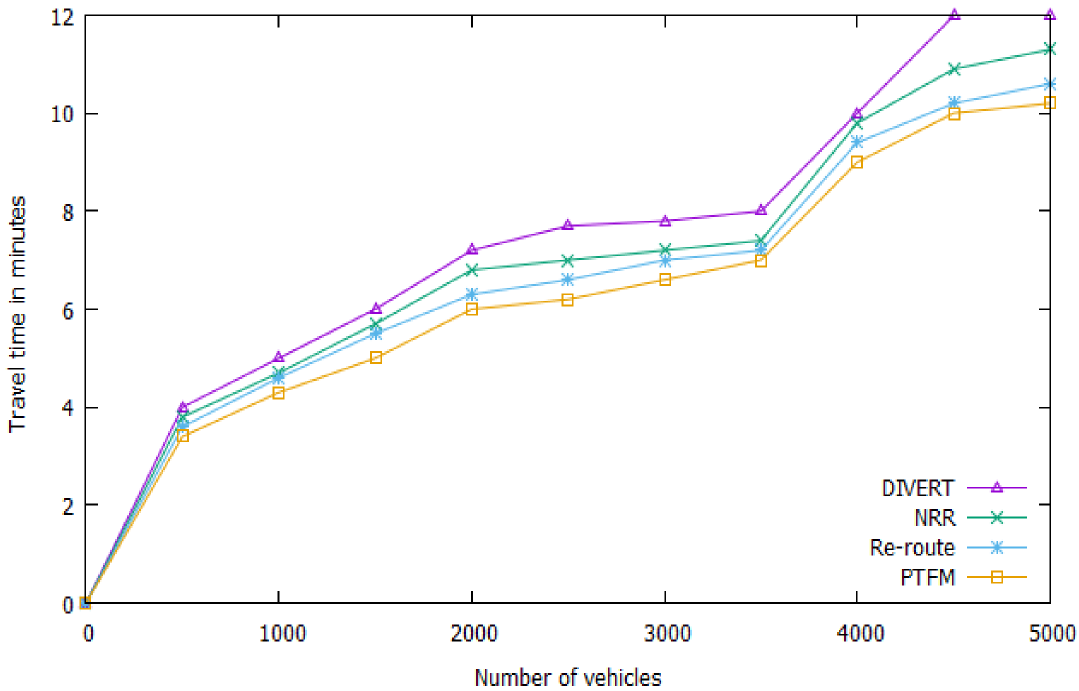

Figure 7.28: Average time travel for Paris

The average speed of vehicles in both cities is also compared [See figure 7.29 and figure 7.30].Again PTFM performs better in this parameter as compared to other algorithms. The average speed of the vehicle is more as compared to other mechanisms. It means traffic flow is getting better by using PTFM.

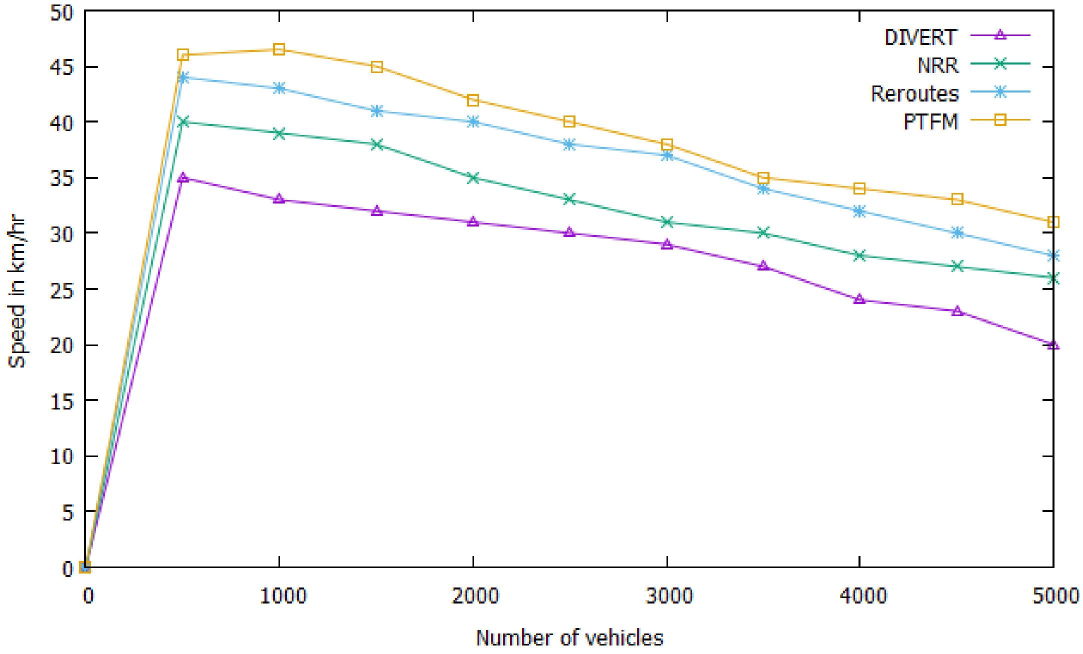

Figure 7.29: Average speed of vehicles in LA

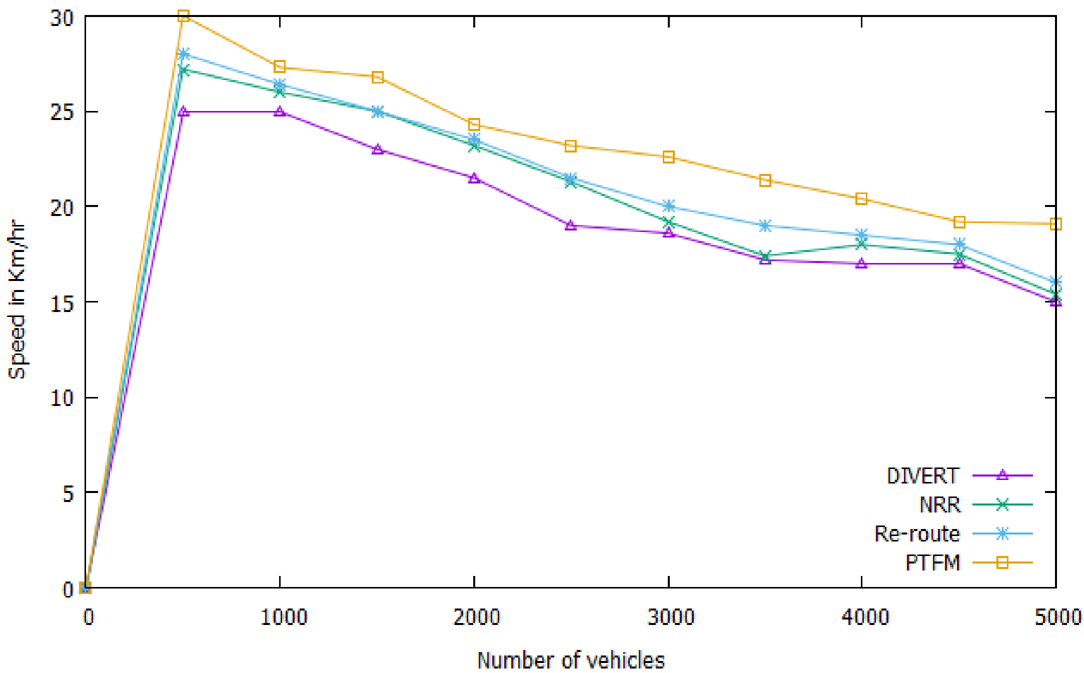

Figure 7.30: Average speed of vehicles in Paris

Table 5.5 and Table 5.6 define the statistics of vehicular data for 5000 vehicles on the LA and Paris map. The two parameters that are taken to consider are speed and travel time

Table 9: Statistics for 5000 vehicles in Los Angeles map

Parameters **Mechanism**	**Speed in Km/Hr**	**Travel time in minutes**
DIVERT	21.2	9.5
NRR	36.7	9
Re-route	29.5	8.5
PTFM	32.6	8

Table 10: Statistics for 5000 vehicles on Paris map

Parameters **Mechanism**	**Speed in Km/Hr**	**Travel time in minutes**
DIVERT	15.1	13
NRR	15.5	10
Re-route	15.8	9.8
PTFM	18.8	8.2

CHAPTER 8: CONCLUSION AND FUTURE SCOPE

8.1 CONCLUSION

The smart vehicular Adhoc network gained popularity in the last few years to manage traffic-related problems like traffic flow, jams, and accidents in a better way. The congestion detection and avoidance with optimal pathfinding need attention to manage traffic in urban areas. Transportation jams, congestion, accidents, and other dangers impede the flow of traffic. Fuel economy, journey time, and pollution are all increasing more rapidly as a result. In this research,the comparative study of fourpathfindingalgorithms(CH,FloydWarshall, Dynamic Astar, and Dynamic Dijkstra)is done using SUMO simulator. The performance of algorithms is measured using an open street map of Los Angeles with a 10-kilometer radius, the average route length covered, the average waiting time of cars, the average speed of vehicles, and the average journey time of vehicles. The python script is used to implement the algorithms.Contraction hierarchiessimulation results are found to be good in finding the shortest path, it reduces travel time and the average speed of the vehicle is also improved. CH algorithm is analyzed with two approaches of navigation one is top-down and the bottom-up approach.The performance of the top-down approach is found good as compared to the bottom-up approach in terms of finding the optimal pathfindingsolution.This is due to the pre-computation of the path in advance in the top-down approach. The average waiting time of CH is found to be a little more than other algorithms.In the future, work needs to be done to reduce the computational time of the algorithms so that quick decisions can be made for the traffic management system.The traffic congestion problem is very serious in urban areas. Another concern is the nature of the traffic flow which is dynamic.This poses lots of challenges for existing traffic management systems, So adaptive mechanism MRGM is proposed for the detection of congestion and finding the optimal routes. MRGM is a multi-metric traffic congestion detection and avoidance method for traffic situations in metropolitan areas. Here a function (VCD) which is vehicle congestion density is used for measuring the traffic density based on which congestion conditions are defined. The PWC is a path weight calculation that is used for understanding the conditions of roads, lanes, and edges on a regular time basis. With this mechanism, the average travel time on roads for vehicles has been reduced, fuel consumption is significantly lessened and CO_2 emission levels are also controlled. This mechanism detects congestion and also provides rerouting for vehicles with optimal paths by setting new paths to vehicles. The Simulation results show that it has improved over existing mechanisms like RGS, Refocus, and SSRGS in terms of vehicle fuel consumption, vehicle travel time, and emission of gases.In case of CO_2 emission the carbon emission is reduced by 3.92 % by using MRGM when compared to Refocus mechanism , it is reduced by 9.76% when compared to RTS mechanism and it is further reduce by 27.45% when compared to SSRGS technique. To manage the traffic flow in the city area where traffic management is a big concern, another mechanism PTFM is proposed which is based on the pre-processing of traffic route and vehicle information bystoring it on an additional node which is called a shortcut node for managing the vehicular flow data. For every vehicle data and road, information is processed by using this node and saved for future use to guide the vehicles. So when the next time route query is initiated, the data can be picked from the shortcut node, thus saves time in processing again. This mechanism will help in guiding the routes to vehicles in advance before traffic congestion occurs.The metrics which is used for the proposed mechanism are fuel consumption, travel time, vehicle dimensions, road dimensions, emissions, and speed of vehicles. Based on these parameters vehicle traffic flow is detected and a rerouting mechanism is activated which will divert the traffic to a different route. Further, the proposed mechanism is compared with the existing ones which are NRR, DIVERT, and Reroute mechanisms. The two mega-cities that have been taken into consideration are Los Angeles and Paris. In case of LA the average travel time using PTFM mechanism is reduced by 11.11% when compared with NRR mechanism, it is reduce by 15.78% when compared with DIVERT and further it is reduced by 5.55% when compared with Reroute.The results show that PTFM outperforms the existing algorithms in terms of the speed of vehicles and travel time.

8.2 FUTURE SCOPE

- Smart traffic management in poor nations confronts considerable hurdles that must be addressed if the technology is to be broadly used. There is, however, a global shortage of research on cost-effectiveness.The traffic management system needs to be more responsive, as in a fraction of seconds the situation of traffic scenario changes.In future technologies like edge computing and fog computing can be used in order to take quick actions on changing traffic scenario especially for microscopic view.

- In the future, work needs to be done to reduce the computational time of the routing algorithm for finding the optimal routes so that quick decisions can be made for the traffic management system, especially for emergency cases.This will help is reducing the congestion and travel times alongside with reduction in Green house gases emission.
- The data processing technologies for traffic can be further improved in the future to reduce congestions and accidents on roads based on real time scenario. In order to make roads safer, authorities should use data management systems to gather and evaluate systematic information on traffic events.For this big data technology can be used . The success of smart traffic system depends on significant advances in this area.
- Further internet of things is transforming vehicular systems by utilizing communication, sensing, and data processing units. So more work needs to be done in this direction to make traditional traffic systems smarter and effective for future use. The most difficult challenges in a smart transportation system are safety and privacy, and both should be studied.

REFERENCES

[1] Pojani, D., & Stead, D. (2015). Sustainable urban transport in the developing world: beyond megacities. *Sustainability*, *7*(6), 7784-7805.

[2] Singh, S. K. (2012). Urban transport in India: issues, challenges, and the way forward.

[3] Mitra, S. (2012). Operational efficiency of freight transportation by road in India. *TCI-IIMC Joint study report*, 1-36.

[4] Nellore, K., &Hancke, G. P. (2016). A survey on urban traffic management system using wireless sensor networks. *Sensors*, *16*(2), 157

[5] Cai, C., Wang, Y., &Geers, G. (2013). Vehicle-to-infrastructure communication-based adaptive traffic signal control. *IET Intelligent Transport Systems*, *7*(3), 351-360.

[6] Xiong, G., Wang, K., Zhu, F., Cheng, C., An, X., &Xie, Z. (2010). Parallel traffic management for the 2010 Asian Games. *IEEE Intelligent Systems*, *25*(3), 81-85

[7] Rawal, T., &Devadas, V. (2015). Intelligent transportation system in India—A review. *J. Dev Manage Commun*, *2*, 299.

[8] Mandhare, P. A., Kharat, V., &Patil, C. Y. (2018). Intelligent road traffic control system for traffic congestion a perspective. *International Journal of Computer Sciences and Engineering*, *6*(07), 2018.

[9] Dubey, P. P., &Borkar, P. (2015, February). Review on techniques for traffic jam detection and congestion avoidance. In *2015 2nd International Conference on Electronics and Communication Systems (ICECS)* (pp. 434-440). IEEE

[10] Hsiao, M. H., Kuo, H. P., Wu, H. C., Chen, Y. K., & Lee, S. Y. (2004, March). Object-based video streaming technique with application to intelligent transportation systems. In *IEEE International Conference on Networking, Sensing and Control, 2004* (Vol. 1, pp. 315-320). IEEE

[11] Vanajakshi, L., Ramadurai, G., &Anand, A. (2010). Centre of excellence in urban transport IIT Madras. *Intell. Transp. Syst. Synth. Rep. ITS*, 1-58.

[12] Xiaofei, L. (2009, March). A new fast hybrid algorithm of background extraction suitable for the DSP platform. In *2009 WRI World Congress on Computer Science and Information Engineering* (Vol. 7, pp. 1-4). IEEE.

[13] Awan, R., & Rani, F. (2007, November). Video based effective density measurement for wireless traffic control application. In *2007 International Conference on Emerging Technologies* (pp. 99-101). IEEE

[14] Lien, C. C., & Tsai, M. H. (2011). Real-time traffic flow analysis without background modeling. *Journal of Information Technology and Applications 5*(1), 1-14

[15] Puntavungkour, S., &Shibasaki, R. (2003, October). Vehicle detection from three line scanner image. In *Proceedings of the 2003 IEEE International Conference on Intelligent Transportation Systems* (Vol. 1, pp. 785-788). IEEE.

[16] Abbas, N., Tayyab, M., &Qadri, M. T. (2013). Real time traffic density count using image processing.*International Journal of Computer Applications*,*83*(9), 16-19.

[17] Krause, B., von Altrock, C., &Pozybill, M. (1996, September). Intelligent highway by fuzzy logic: Congestion detection and traffic control on multi-lane roads with variable road signs. In *Proceedings of IEEE 5th International fuzzy systems* (Vol. 3, pp. 1832-1837). IEEE.

[18] Cherrett, T., Waterson, B., & McDonald, M. (2005, August). Remote automatic incident detection using inductive loops. In *Proceedings of the Institution of Civil Engineers-Transport* (Vol. 158, No. 3, pp. 149-155). Thomas Telford Ltd.

[19] Rekha, R., &Karthika, R. (2013). Fuzzy based traffic congestion detection & pattern analysis using inductive loop sensor. *International Journal of Scientific & Engineering Research*, *4*(6), 1149-1152.

[20] Liepins, M., &Severdaks, A. (2013, November). Vehicle detection using non-invasive magnetic wireless sensor network. In *2013 21st Telecommunications Forum Telfor (TELFOR)* (pp. 601-604). IEEE.

[21] Gholve, M. H., &Chougule, S. (2013). Detection for Highways UsingWireless Sensors.*International Journal of Electronics and Communication Engineering*,*6*(3), 0974-2166.

[22] Barbagli, B., Magrini, I., Manes, G., Manes, A., Langer, G., &Bacchi, M. (2010, July). A distributed sensor network for real-time acoustic traffic monitoring and early queue detection. In *2010 Fourth International Conference on Sensor Technologies and Applications* (pp. 173-178). IEEE.

[23] Hussain, S. R., Odeh, A., Shivakumar, A., Chauhan, S., &Harfoush, K. (2013, December). Real-time traffic congestion management and deadlock avoidance for vehicular ad Hoc networks. In *2013 High Capacity Optical Networks and Emerging/Enabling Technologies* (pp. 223-227). IEEE

[24] Gupta, A., Choudhary, S., & Paul, S. (2013, September). DTC: A framework to Detect Traffic Congestion by mining versatile GPS data. In *2013 1st International Conference on Emerging Trends and Applications in Computer Science* (pp. 97-103). IEEE.

[25] Wang, Z., Lu, M., Yuan, X., Zhang, J., & Van De Wetering, H. (2013). Visual traffic jam analysis based on trajectory data. *IEEE transactions on visualization and computer graphics*, *19*(12), 2159-2168.

[26] Mohan, P., Padmanabhan, V. N., &Ramjee, R. (2008, November). Nericell: rich monitoring of road and traffic conditions using mobile smartphones. In *Proceedings of the 6th ACM conference on Embedded network sensor systems* (pp. 323-336).

[27] Bhoraskar, R., Vankadhara, N., Raman, B., &Kulkarni, P. (2012, January). Wolverine: Traffic and road condition estimation using smartphone sensors. In *2012 fourth international conference on communication systems and networks (COMSNETS 2012)* (pp. 1-6). IEEE.

[28] Kim, S. S., & Kang, Y. B. (2007, November). Congestion avoidance algorithm using extended Kalman filter. In *2007 International Conference on Convergence Information Technology (ICCIT 2007)* (pp. 913-918). IEEE.

[29] Asif, M. T., Dauwels, J., Goh, C. Y., Oran, A., Fathi, E., Xu, M., &Jaillet, P. (2012, September). Unsupervised learning based performance analysis of n-support vector regression for speed prediction of a large road network. In *2012 15th International IEEE Conference on Intelligent Transportation Systems* (pp. 983-988). IEEE.

[30] Hu, W., Wang, H., & Yan, L. (2014, October). An actual urban traffic simulation model for predicting and avoiding traffic congestion. In *17th International IEEE Conference on Intelligent Transportation Systems (ITSC)* (pp. 2681-2686). IEEE.

[31] Wedel, J. W., Schünemann, B., &Radusch, I. (2009, December). V2X-based traffic congestion recognition and avoidance. In *2009 10th International Symposium on Pervasive Systems, Algorithms, and Networks* (pp. 637-641). IEEE.

[32] Soylemezgiller, F., Kuscu, M., &Kilinc, D. (2013, September). A traffic congestion avoidance algorithm with dynamic road pricing for smart cities. In *2013 IEEE 24th Annual International Symposium on Personal, Indoor, and Mobile Radio Communications (PIMRC)* (pp. 2571-2575). IEEE.

[33] Desai, P., Loke, S. W., Desai, A., & Singh, J. (2013). CARAVAN: Congestion avoidance and route allocation using virtual agent negotiation. *IEEE Transactions on Intelligent Transportation Systems*, *14*(3), 1197-1207.

[34] Balaji, P. G., Sachdeva, G., Srinivasan, D., &Tham, C. K. (2007, September). Multi-agent system based urban traffic management. In *2007 IEEE Congress on Evolutionary Computation* (pp. 1740-1747). IEEE

[35] Ezzat, A. A., Farouk, H. A., El-Kilany, K. S., &Moneim, A. F. A. (2014, January). Optimization using simulation of traffic light signal timings. In *Proceedings of the 2014 International Conference on Industrial Engineering and Operations Management Bali, Indonesia*

[36] Cheng, S. T., Li, J. P., Horng, G. J., & Wang, K. C. (2014). The adaptive road routing recommendation for traffic congestion avoidance in smart city. *Wireless personal communications*, *77*(1), 225-246

[37] Lu, Z., Qu, G. and Liu, Z. (2018). A survey on recent advances in vehicular network security, trust, and privacy. *IEEE Transactions on Intelligent Transportation Systems*, 20(2), 760-776

[38] Abdel-Halim, I.T. and Fahmy, H.M.A. (2018). Prediction-based protocols for vehicular Ad Hoc Networks: Survey and taxonomy. *Computer Networks*, 130, 34-50.

[39] Tripp-Barba, C., Zaldívar-Colado, A., Urquiza-Aguiar, L. and Aguilar-Calderón, J.A. (2019). Survey on routing protocols for vehicular ad hoc networks based on multimetrics. *Electronics*, 8(10), 1177

[40] Katiyar, A., Singh, D. and Yadav, R.S. (2020). State-of-the-art approach to clustering protocols in vanet: a survey. *Wireless Networks*, 26(7), 5307-5336.

[41] Bitam, S., Mellouk, A. and Zeadally, S., 2013. HyBR: A hybrid bio-inspired bee swarm routing protocol for safety applications in vehicular ad hoc networks (VANETs). *Journal of Systems Architecture*, 59(10), 953-967.

[42] Park, J. S., Lee, U., Oh, S. Y., Gerla, M., &Lun, D. S. (2006, September). Emergency related video streaming in VANET using network coding. In*Proceedings of the 3rd international workshop on Vehicular ad hoc networks*(pp. 102-103).

[43] Nandan, A., Tewari, S., Das, S., Gerla, M., &Kleinrock, L. (2006, January). AdTorrent: Delivering location cognizant advertisements to car networks. In *WONS 2006: Third Annual Conference on Wireless On-demand Network Systems and Services* (pp. 203-212

[44] Intanagonwiwat, C. (2000). A scalable and robust communication paradigm for sensor networks. In *Proc. 4th ACM Int. Conf. on Mobile Computing and Networking, 2000* (pp. 56-67).

[45] Lee, U., Magistretti, E., Zhou, B., Gerla, M., Bellavista, P., &Corradi, A. (2006, March). Efficient data harvesting in mobile sensor platforms. In *Fourth Annual IEEE International Conference on Pervasive Computing and Communications Workshops (PERCOMW'06)* (pp. 5-pp). IEEE.

[46] Papadopouli, M., &Schulzrinne, H. (2001, October). Effects of power conservation, wireless coverage and cooperation on data dissemination among mobile devices. In *Proceedings of the 2nd ACM international symposium on Mobile ad hoc networking & computing* (pp. 117-127).

[47] Moustafa, H., & Zhang, Y. (2009). *Vehicular networks: techniques, standards, and applications*. Auerbach publications.

[48] Toor, Y., Muhlethaler, P., Laouiti, A., & De La Fortelle, A. (2008). Vehicle ad hoc networks: Applications and related technical issues. *IEEE communications surveys & tutorials*, *10*(3), 74-88.

[49] Olariu, S., &Weigle, M. C. (Eds.). (2009). *Vehicular networks: from theory to practice*. Crc Press.

[50] Rawashdeh, Z. Y., & Mahmud, S. M. (2008, January). Intersection collision avoidance system architecture. In *2008 5th IEEE Consumer Communications and Networking Conference* (pp. 493-494). IEEE

[51] Vahdat-Nejad, H., Ramazani, A., Mohammadi, T., &Mansoor, W. (2016). A survey on context-aware vehicular network applications. *Vehicular Communications*, *3*, 43-57.

[52] Nandan, A., Das, S., Zhou, B., Pau, G., &Gerla, M. (2005, July). Adtorrent: Digital billboards for vehicular networks. In *Proc. of IEEE/ACM International Workshop on Vehicle-to-Vehicle Communications (V2VCOM), San Diego, CA, USA.*

[53] J. Wang, L. Chi, X. Hu, and H. Zhou, "Urban Traffic Congestion Pricing Model with the Consideration of Carbon Emissions Cost," *Sustainability*, vol. 6, no. 2, pp. 676–691, 2014.

[54] F. Armah, D. Yawson, and A. A. Pappoe, "A Systems Dynamics Approach to Explore Traffic Congestion and Air Pollution Link in the City of Accra, Ghana," *Sustainability*, vol. 2, no. 1, pp. 252–265, 2010.

[55] A. Nayyar, R.S Batth,D.B Ha, G.Sussendran, "Opportunistic Networks: Present Scenario- A Mirror Review," International Journal of Communication Networks and Information Security 10 (1)(2018).

[56] "Global status report on road safety 2018," *World Health Organization*. [Online].Available:https://www.who.int/publications/i/item/9789241565684. [Accessed: 05-Mar-2021].

[57] "Urban Mobility Scorecard and Appendices—Urban Mobility Information 2017,".[Online]. Available:https://mobility.tamu.edu/um

[58] D. Schrank, B. Eisele, T. Lomax, and J. Bak, “2015 Urban Mobility Scorecard,” *TRID*, 31-Jul-2015. [Online]. Available: https://trid.trb.org/view/1367337. [Accessed: 05-Mar-2021].

[59] G.S Shahi, R.S Batth, S. Egerton, “A Comparative Study on Efficient Path Finding Algorithms for Route Planning in Smart Vehicular Networks,” International Journal of Computer Networks and Applications, vol. 7, no. 5, pp 157-166., 2020.

[60] “The future economic and environmental costs of gridlock in ...” [Online].Available:https://time.com/wpcontent/uploads/2015/05/inrix_costs-of-congestion_cebr-report_v5_final.pdf. [Accessed: 05-Mar-2021].

[61] “Traffic Congestion and Reliability: Trends and Advanced Strategies for Congestion Mitigation,” *Traffic Congestion and Reliability: Trends and Advanced Strategies for Congestion Mitigation: Executive Summary*. [Online].Available:https://ops.fhwa.dot.gov/congestion_report/executive_summary.htm. [Accessed: 05-Mar-2021].

[62] C. Wang, R.S.Batth, P. Zhang, G.S Aujla, “VNE solution for network differentiated QoS and security requirements: from the perspective of deep reinforcement learning”. Computing (2021).

[63] F. sun, A. Dubey, and J. White, “DxNAT - Deep Neural Networks for Explaining Non-Recurring Traffic Congestion,” *arXiv.org*, 30-Jan-2018. [Online]. Available: https://arxiv.org/abs/1802.00002. [Accessed: 05-Mar-2021].

[64] R.S Batth, M. Gupta, K.S. Mann, S. Verma A. Malhotra “Comparative Study of TDMA- Based MAC Protocols in VANET: A Mirror Review”, In International Conference on Innovative Computing and Communications, Advances in Intelligent Systems and Computing, vol. 1059, Springer, Singapore.(2020).

[65]. Mehta, D., &Saxena, S. (2020). MCH-EOR: Multi-objective cluster head based energy-aware optimized routing algorithm in wireless sensor networks. Sustainable Computing: Informatics and Systems, 28, 100406.

[66]. Elhoseny, Mohamed, and K. Shankar. "Energy efficient optimal routing for communication in VANETs via clustering model." In Emerging Technologies for Connected Internet of Vehicles and Intelligent Transportation System Networks, pp. 1-14. Springer, Cham, 2020.

[67]. Kolandaisamy, Raenu, RafidahMd Noor, IndraahKolandaisamy, Ismail Ahmedy, Miss Laiha Mat Kiah, MohdEmranMohd Tamil, and TarakNandy. "A stream position performance analysis model based on DDoS attack detection for cluster-based routing in VANET." Journal of Ambient Intelligence and Humanized Computing (2020): 1-14.

[68]. Saravanan, M., and P. Ganeshkumar. "Routing using reinforcement learning in vehicular ad hoc networks." Computational Intelligence 36, no. 2 (2020): 682-697.

[69]. Guidoni, D. L., Maia, G., Souza, F. S. H., Villas, L. A., &Loureiro, A. A. F. (2020). Vehicular Traffic Management Based on Traffic Engineering for Vehicular Ad Hoc Networks.*IEEE Access*, *8*, 45167–45183. https://doi.org/10.1109/access.2020.2978700

[70]. Ahmad, I., Noor, R. M., Zaba, M. R., Qureshi, M. A., Imran, M., &Shoaib, M. (2020). A Cooperative Heterogeneous Vehicular Clustering Mechanism for Road Traffic Management. International Journal of Parallel Programming, 48(5), 870–889. https://doi.org/10.1007/s10766-019-00629-y

[71]. Gilbert, E. P. K., Baskaran, K., Rajsingh, E. B., Lydia, M., &Selvakumar, A. I. (2019). Trust aware nature inspired optimised routing in clustered wireless sensor networks. International Journal of Bio-Inspired Computation, 14(2), 103-113.

[72]. Al-Humidi, N., &Chowdhary, G. V. (2019). Energy-aware approach for routing protocol by using centralized control clustering algorithm in wireless sensor networks. In Computing, Communication and Signal Processing (pp. 261-274). Springer, Singapore.

[73]. Fu, X., Yao, H., & Yang, Y. (2019). Modeling and analyzing cascading dynamics of the clustered wireless sensor network. Reliability Engineering & System Safety, 186, 1-10.

[74]. Borawake-Satao, R., & Prasad, R. (2019). Mobility aware multi-objective routing in wireless multimedia sensor network. Multimedia Tools and Applications, 78(23), 32659-32677.

[75]. Khan, Zahid, Pingzhi Fan, Sangsha Fang, and Fakhar Abbas. "An Unsupervised Cluster-Based VANET-Oriented Evolving Graph (CVoEG) Model and Associated Reliable Routing Scheme." IEEE Transactions on Intelligent Transportation Systems (2019).

[76]. Singh, Pranav Kumar, Rahul Raj Gupta, Sunit Kumar Nandi, and Sukumar Nandi. "Machine learning based approach to detect wormhole attack in VANETs." In Workshops of the international conference on advanced information networking and applications, pp. 651-661. Springer, Cham, 2019.

[77]. Tang, Yujie, Nan Cheng, Wen Wu, Miao Wang, Yanpeng Dai, and XueminShen. "Delay-minimization routing for heterogeneous VANETs with machine learning based mobility prediction." IEEE Transactions on Vehicular Technology 68, no. 4 (2019): 3967-3979.

[78]. Saeed, Yousaf, et al. "In-Vehicle Cognitive Route Decision Using Fuzzy Modeling and Artificial Neural Network." IEEE Access 7 (2019): 20262-20272.

[79]. Tilwari, Valmik, KaharudinDimyati, M. H. D. Hindia, AnasFattouh, and IrajSadeghAmiri. "Mobility, residual energy, and link quality aware multipath routing in MANETs with Q-learning algorithm." Applied Sciences 9, no. 8 (2019): 1582.

[80]. M. A. Saleem, Z. Shijie, & A. Sharif, “Data Transmission using IoT in Vehicular Ad-Hoc Networks in Smart City Congestion,” Mobile Networks and Applications, vol. 24 no. 1, pp. 248-258, 2019.

[81]. Ahmad, M.; Chen, Q.; Khan, Z.; Ahmad, M.; Khurshid, F. Infrastructure-based vehicular congestion detection scheme for V2I.*Int. J. Commun. Syst* 2019, *32*, e3877.

[82]. de Sousa, R. S., Boukerche, A., &Loureiro, A. A. (2019, June). DisTraC: A distributed and low-overhead protocol for traffic congestion control using vehicular networks. In *2019 IEEE Symposium on Computers and Communications (ISCC)* (pp. 1-6).

[83]. Zemouri, S., Djahel, S., & Murphy, J. (2019). An altruistic prediction-based congestion control for strict beaconing requirements in urban VANETs. *IEEE Transactions on Systems, Man, and Cybernetics: Systems*, *49*(12), 2582-2597.

[84]. Zahedi, Khalid, Yasser Zahedi, and Abdul Samad Ismail. "CJBR: connected junction-based routing protocol for city scenarios of VANETs." Telecommunication Systems 72, no. 4 (2019): 567-578.

[85]. Haider, Shahab, Ghulam Abbas, ZiaulHaq Abbas, and Thar Baker. "DABFS: A robust routing protocol for warning messages dissemination in VANETs." Computer Communications 147 (2019): 21-34.

[86]. Ye, Mao, Lin Guan, and Mohammed Quddus. "MPBRP-Mobility Prediction Based Routing Protocol in VANETs." In CommNet, pp. 1-7. 2019.

[87]. Abbas, M. T., & Song, W. C. (2019). THERA: Two-level hierarchical hybrid road-aware routing for vehicular networks. *KSII Transactions on Internet and Information Systems (TIIS)*, *13*(7), 3369-3385.

[88]. Sugumar, Rajendran,AlwarRengarajan, and ChinnappanJayakumar. "Trust based authentication technique for cluster based vehicular ad hoc networks (VANET)." Wireless Networks 24, no. 2 (2018): 373-382.

[89]. Agarwal, Y., Jain, K., &Karabasoglu, O. (2018). Smart vehicle monitoring and assistance using cloud computing in vehicular Ad Hoc networks. International Journal of Transportation Science and Technology, 7(1), 60-73.

[90]. Sookhak, M., Yu, F. R., & Tang, H. (2017). Secure data sharing for vehicular ad-hoc networks using cloud computing. In Ad Hoc Networks (pp. 306-315). Springer, Cham.

[91]. Hamrioui, Sofiane, Camil Adam Mohamed Hamrioui, Jaime Lioret, and Pascal Lorenz. "Smart and self-organised routing algorithm for efficient IoT communications in smart cities." IET Wireless Sensor Systems 8, no. 6 (2018): 305-312

[92]. R. H. Jhaveri, N. M. Patel, Y. Zhong, & A. K. Sangaiah, "Sensitivity analysis of an attack-pattern discovery based trusted routing scheme for mobile ad-hoc networks in industrial IoT," IEEE Access, vol. 6, pp. 20085-20103, 2018.

[93]. Guo, C., Li, D., Zhang, G., &Zhai, M. (2018). Real-time path planning in urban area via vanet-assisted traffic information sharing. *IEEE Transactions on Vehicular Technology*, *67*(7), 5635-5649

[94]. Ahmad, M.; Chen, Q.; Khan, Z. Microscopic Congestion Detection Protocol in VANETs. *J. Adv. Transp.* **2018**, *2018*, 1–14.

[95]. Atallah, R., Khabbaz, M., &Assi, C. (2017). Multihop V2I Communications: A Feasibility Study, Modeling, and Performance Analysis. IEEE Transactions on Vehicular Technology, 66(3), 2801–2810. https://doi.org/10.1109/TVT.2016.2586758

[96]. Li, W., Ma, X., Wu, J., Trivedi, K. S., Huang, X. L., & Liu, Q. (2017). Analytical Model and Performance Evaluation of Long-Term Evolution for Vehicle Safety Services. IEEE Transactions on Vehicular Technology, 66(3), 1926–1939. https://doi.org/10.1109/TVT.2016.2580571

[97]. Bila, C., Sivrikaya, F., Khan, M. A., &Albayrak, S. (2017). Vehicles of the Future: A Survey of Research on Safety Issues. IEEE Transactions on Intelligent Transportation Systems, 18(5), 1046–1065. https://doi.org/10.1109/TITS.2016.2600300

[98]. M. Sepulcre, J. Gozalvez, O. Altintas, and H. Kremo, "Integration of congestion and awareness control in vehicular networks," *Ad Hoc Networks*, vol. 37, pp. 29–43, 2016

[99]. Taherkhani, N., & Pierre, S. (2016). Centralized and localized data congestion control strategy for vehicular ad hoc networks using a machine learning clustering algorithm.*IEEE Transactions on Intelligent Transportation Systems*,*17*(11), 3275-3285

[100]. Martuscelli, G., Boukerche, A., Foschini, L., &Bellavista, P. (2016). V2V protocols for traffic congestion discovery along routes of interest in VANETs: a quantitative study.*Wireless Communications and Mobile Computing*,*16*(17), 2907-2923.

[101]. Pan, J., Popa, I. S., &Borcea, C. (2016). Divert: A distributed vehicular traffic re-routing system for congestion avoidance. *IEEE Transactions on Mobile Computing*, *16*(1), 58-72.

[102]. S. Wang, S. Djahel, and J. McManis, "An adaptive and VANETs-based Next Road Re-routing system for unexpected urban traffic congestion avoidance," *IEEE Veh. Netw. Conf. VNC*, vol. 2016-January, pp. 196–203, 2016, doi: 10.1109/VNC.2015.7385577.

[103]. Jeong, J., Jeong, H., Lee, E., Oh, T., & Du, D. H. C. (2016). SAINT: Self-adaptive interactive navigation tool for cloud-based vehicular traffic optimization. IEEE Transactions on Vehicular Technology, 65(6), 4053–4067. https://doi.org/10.1109/TVT.2015.2476958

[104]. Katsaros, K., Dianati, M., Tafazolli, R., &Guo, X. (2016). End-to-end delay bound analysis for location-based routing in hybrid vehicular networks. IEEE Transactions on Vehicular Technology, 65(9), 7462–7475. https://doi.org/10.1109/TVT.2015.2482362

[105]. Chen, S., Hu, J., Shi, Y., & Zhao, L. (2016). LTE-V: A TD-LTE-Based V2X Solution for Future Vehicular Network. IEEE Internet of Things Journal, 3(6), 997–1005. https://doi.org/10.1109/JIOT.2016.2611605

[106]. Garip, M. T., Gursoy, M. E., Reiher, P., &Gerla, M. (2015, January). Scalable reactive vehicle-to-vehicle congestion avoidance mechanism. In *2015 12th Annual IEEE Consumer Communications and Networking Conference (CCNC)* (pp. 943-948). IEEE

[107]. Elbery, A., Rakha, H., Elnainay, M., Drira, W., &Filali, F. (2015, September). Eco-routing using v2i communication: System evaluation. In *2015 IEEE 18th International Conference on Intelligent Transportation Systems* (pp. 71-76). IEEE

[108]. Gramaglia, M., Calderon, M., &Bernardos, C. J. (2014). ABEONA monitored traffic: VANET-assisted cooperative traffic congestion forecasting. *IEEE vehicular technology magazine*, *9*(2), 50-57

[109]. Padhariya, N., Wolfson, O., Mondal, A., Gandhi, V., &Madria, S. K. (2014, July). E-VeT: Economic reward/penalty-based system for vehicular traffic management. In *2014 IEEE 15th International Conference on Mobile Data Management* (Vol. 1, pp. 99-102). IEEE

[110]. Bellavista, P., Foschini, L., &Zamagni, E. (2014, September). V2x protocols for low-penetration-rate and cooperative traffic estimations. In *2014 IEEE 80th Vehicular Technology Conference (VTC2014-Fall)* (pp. 1-6). IEEE

[111]. Milojevic, M., &Rakocevic, V. (2014, June). Distributed road traffic congestion quantification using cooperative VANETs. In *2014 13th annual Mediterranean ad hoc networking workshop (MED-HOC-NET)* (pp. 203-210). IEEE

[112]. M. Berlin, S. Anand, " Direction based Hazard Routing Protocol (DHRP) for disseminating road hazard information using road side infrastructures in VANETs," April 2014 Springer plus 3(1):173

[113]. Nafi, N. S., Khan, R. H., Khan, J. Y., & Gregory, M. (2014, November). A predictive road traffic management system based on vehicular ad-hoc network. In *2014 Australasian Telecommunication Networks and Applications Conference (ATNAC)* (pp. 135-140). IEEE.

[114]. Zhang, H., & Zhang, Q. (2014, September). A Novel Road Topology-aware Routing in VANETs. In*Asia-Pacific Web Conference* (pp. 167-176). Springer, Cham

[115]. Alsharif, N., &Shen, X. S. (2014, June). iCARII: Intersection-based connectivity aware routing in vehicular networks. In *2014 IEEE International Conference on Communications (ICC)* (pp. 2731-2735). IEEE

[116]. Wang, S., Djahel, S., &McManis, J. (2014, October). A multi-agent based vehicles re-routing system for unexpected traffic congestion avoidance. In *17th International IEEE Conference on Intelligent Transportation Systems (ITSC)* (pp. 2541-2548). IEE

[117]. Bazzan, A. L., Cagara, D., &Scheuermann, B. (2014, December). An evolutionary approach to traffic assignment. In *2014 IEEE Symposium on Computational Intelligence in Vehicles and Transportation Systems (CIVTS)* (pp. 43-50). IEEE.

[118]. Alsharif, N., Céspedes, S., &Shen, X. S. (2013, June). iCAR: Intersection-based connectivity aware routing in vehicular ad hoc networks. In *2013 IEEE international conference on communications (ICC)* (pp. 1736-1741). IEEE

[119]. Pan, J., Popa, I. S., Zeitouni, K., &Borcea, C. (2013). Proactive vehicular traffic rerouting for lower travel time. *IEEE Transactions on vehicular technology*, *62*(8), 3551-3568.

[120]. Younes, M. B., &Boukerche, A. (2013, June). Efficient traffic congestion detection protocol for next generation vanets. In *2013 IEEE international conference on communications (ICC)* (pp. 3764-3768). IEEE

[121]. Júnior, J. G. R., Campista, M. E. M., & Costa, L. H. M. (2013, November). A decentralized traffic monitoring system based on vehicle-to-infrastructure communications. In *2013 IFIP Wireless Days (WD)* (pp. 1-6). IEEE

[122]. Gupte, S., &Younis, M. (2012, June). Vehicular networking for intelligent and autonomous traffic management. In *2012 IEEE international conference on communications (ICC)* (pp. 5306-5310). IEEE.

[123]. Bell, Michael GH, et al. "Time-dependent Hyperstar algorithm for robust vehicle navigation." Transportation Research Part A: Policy and Practice (2012).

[124]. Hashemi, H. T., &Khorsandi, S. (2012, May). Load balanced VANET routing in city environments. In *2012 IEEE 75th Vehicular Technology Conference (VTC Spring)* (pp. 1-6). IEEE.

[125]. Arbabi, H., &Weigle, M. C. (2011, January). Monitoring free flow traffic using vehicular networks. In *2011 IEEE Consumer Communications and Networking Conference (CCNC)* (pp. 272-2760). IEEE.

[126]. Bauza, R., Gozalvez, J., & Sanchez-Soriano, J. (2010, October). Road traffic congestion detection through cooperative vehicle-to-vehicle communications. In *IEEE Local Computer Network Conference* (pp. 606-612). IEEE.

[127]. Wischoff, L., Ebner, A., Rohling, H., Lott, M., &Halfmann, R. (2003, April). SOTIS-a self-organizing traffic information system. In *The 57th IEEE Semiannual Vehicular Technology Conference, 2003. VTC 2003-Spring.* (Vol. 4, pp. 2442-2446).

[128]. Sunita, &D.Garg, (2018). DynamizingDijkstra: "A solution to dynamic shortest path problem through retroactive priority queue". Journal of King

Saud University - Computer and Information Sciences. doi:10.1016/j.jksuci.2018.03.003

[129]. Huang, Bo, Q.Wu, and F. B. Zhan. ”A shortest path algorithm with novel heuristics for dynamic transportation networks.” International Journal of Geographical Information Science 21.6 (2007): 625-644.

[130]. Koenig, Sven, Maxim Likhachev, and David Furcy. ”Lifelong planningA*.”Artificial Intelligence 155.1 (2004): 93-146.

[131]. Ramadiani, D.Bukhori, Azainil, &N.Dengen, (2018). Floyd-warshall algorithm to determine the shortest path based on android. IOP Conference Series: Earth and Environmental Science,144, 012019. doi:10.1088/1755-1315/144/1/012019

[132]. Fu, Liping, D. Sun, and Laurence R. Rilett. ”Heuristic shortest path algorithms for transportation applications: state of the art.” Computers & Operations Research 33.11 (2006): 3324-3343.

[133]. F. He, X. Yan, Y. Liu, and L. Ma, “A traffic congestion assessment method for urban road networks based on speed performance index,” Procedia Eng., vol. 137, pp. 425–433, Feb. 2016.