FOG-ASSISTED CONGESTION AVOIDANCE SCHEME FOR INTERNET OF VEHICLES

by

Shumayla Yaqoob

Supervisor

Dr. Muhammad Akbar

Co-Supervisor

Dr. Ata Ullah

Submitted for partial fulfilment of the requirements of the degree of MSCS to the Faculty of Engineering and Computer Science

NATIONAL UNIVERSITY OF MODERN LANGUAGES, ISLAMABAD

DECEMBER 2018

CANDIDATE DECLARATION

I declare that this thesis entitled "*Fog-Assisted Congestion Avoidance Scheme for Internet of Vehicles*" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature	:
Name	: Shumayla Yaqoob
Date	: 28th December, 2018

ABSTRACT

Internet of Vehicles (IoVs) is an emerging research area. It has wide ranging applications such as traffic management, vehicle security and communication among vehicle etc. Most of these applications require vehicles to continuously update their information to a centralized repository or server in order to gain various services. IoV message dissemination schemes are identified with congestion issues due to large number of messages populated by vehicles in the area. However, frequent transmission of messages by a large number of vehicles may not only overwhelm a centralized server but also causes a congestion which may be dangerous in emergency situations. The aim of this research is to minimize congestion for smooth communication.

This work presents a fog-assisted congestion avoidance scheme for IoV named Energy Efficient Message Dissemination (E^2MD). To capitalize on the merits of fog computing and minimize delay, E^2MD uses a distributed approach by employing a fog server to balance services in IoVs. In E^2MD, vehicles continuously update their status to a fog server either directly or through intermediate nodes. In case of an emergency, the fog server will inform upcoming traffic to slow down the speed, dispatch rescue teams to provide necessary services, and coordinate patrolling missions to clear the road. Proposed scheme considers a reality based model having intercity highways as well as roads in urban areas. Each road consists of three lanes where left most is slowest and in the right lane vehicles are moving at high speed.

The performance of the proposed scheme is validated through NS 2.35 simulations. Simulation results confirm the performance supremacy of E^2MD compared to contemporary schemes in terms of delay, message overhead and packet delivery ratio. E^2MD consume 5 microseconds while contemporary schemes cause delays in milliseconds. E^2MD improves message delivery cost by 108% and decrease message overhead cost by 73% and 98% respectively than other schemes. In future need to work for the scenario if AV is blasted and unable to inform nearby vehicles.

Keywords—Internet of Vehicles, Fog Computing, Congestion avoidance, Latency.

Dedication

To belief, solemnity and freedom

To the soil of my motherland, Pakistan

To my beloved Parents, Mohammad

Yaqoob and Sakina Bibi

To my honourable teachers and

friends

ACKNOWLEDGEMENT

First of all, I wish to express my gratitude and deep appreciation to Almighty Allah, who made this study possible and successful. This study would not be accomplished unless the honest espousal that was extended from several sources for which I would like to express my sincere thankfulness and gratitude. I would extremely acknowledge the guidelines, encouragement and technical support from my Supervisor Dr. Muhammad Akbar and especially my research co-supervisor Dr. Ata Ullah, who whole heartedly guided me during my research journey. Yet, there were significant contributors for my attained success and I cannot forget their input like HoD Asst. Prof. Naveed Alam for providing us good learning facilities and special thanks to Mr. Gohar for providing support in installation and debugging for network simulator.

I shall also acknowledge the extended assistance from the administrations of Department of Computer Sciences who supported me all through my research experience and simplified the challenges I faced. For all whom I did not mention but I shall acknowledge their significant contribution, thanks for everything.

Table of Contents

List of Figures

List of Tables

List of Abbreviations

ACM	Adaptive Control Messages
AFCS	Adaptive Forwarding Messages & Cooperative Safe Driving
BSM	Beacon Safety Message
CANCORE	Context Aware Network Coded Repetition
CAM	Cooperative Awareness Message
CMP	Congestion Mitigation Process
DDA	Dynamic Data Aggregation
DDOS	Distributed Denial of Service
DEEP	Density Aware Emergency message Extension
E2MD	Energy Efficient Message Dissemination
ESM	Event-driven Safety Message
IoVs	Internet of Vehicles
RMFF	Reliable Model For Flooding
RSU	Road Side Unit
STNC	Space Time Network Coding
VANET	Vehicular Adhoc Network
VCC	Vehicular Cloud Computing
V2D	Vehicle to Device
V2G	Vehicle to Grid
V2V	Vehicle-to-Vehicle
V2I	Vehicle-to Infrastructure
V2X	Both V2V and V2I
LTV	Light Traffic Vehicle
HTV	Heavy Traffic Vehicle

CHAPTER 1

INTRODUCTION

1.1 Overview

This chapter includes an overview of research work. Research motivation, problem statement, research objectives and contributions are described briefly. A VANET is discussed that how vehicles form an adhoc network. Fog computing is explained. Its strengths and its utilization in our case. Motivation highlight that how our work distinguishes from others. Problem statement covers the existing issues in VANETs. Proposed scheme and its contributions are described briefly. Finally, organization of the thesis is given.

1.2 Vehicular Ad-hoc Networks (VANETs)

VANETs comprises of a set of vehicles that share messages for exchanging transportation related data with neighboring vehicles and servers. The vehicles have rich energy, storage, and communication capabilities [1]. VANETs can be divided into three scenarios in terms of vehicle positioning and communication: WLAN or cellular, ad-hoc and hybrid network as shown in Figure 1.1. WLAN involves a powerful Road Side Unit (RSU) with more transmission resources and communication range. It can also communicate to the base station (BS) for message transmission to servers [2,3]. Ad-hoc scenario involves the vehicle level communication for messaging. Hybrid is a combination of both scenarios. VANETs provide a solid base to setup IoV's where vehicles are considered to be smarter in terms of internet support and vast communication capabilities.

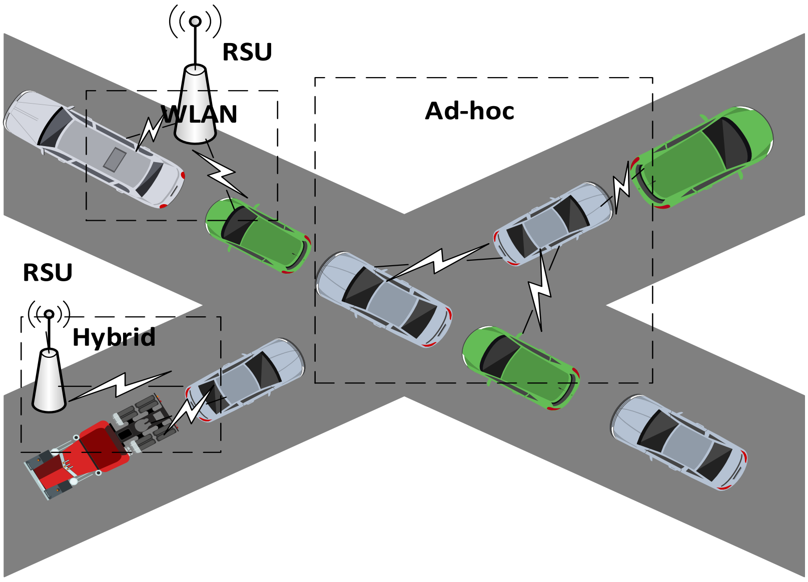

Figure 1. 1: VANET Architecture and Communication scenarios

VANET is a kind of wireless network that is an important part of the future transportation systems [2] to enable global connection among vehicles in the absence of any fixed infrastructure [3]. Vehicular networks provide driving safety, organize traffic and timely report accidents by exchanging useful information. VANET based applications for message dissemination among vehicles needs to focus on bandwidth of a network. Basically dissemination among vehicle means to pick information or distribute it to RSU or nearby vehicles [4]. Vehicles act as mobile nodes in VANET to collect and disseminate information such as travelling rate per unit time. Information dissemination is a major issue in VANETs [5] that results in message congestion. Message notification is major factor in message dissemination. High traffic density affects the performance of information dissemination models. Information dissemination may be in one hop or multi hops. In one hop case, messages are delivered to nearest neighbors only. In case of multi-hop, the messages will be forwarded to next neighbors. Multi hop VANET scenario is considered as a real road situation that is caused and also high vehicle density [6]. Efficient messaging need to avoid long delays during message dissemination [7].

VANETs were developed by using latest technologies such as cellular networks. This development has given rise to the requirement of data communication and computational ability. To meet this ever-growing requirement in communication and computational aptitude, VANET is an appealing idea. This growth leads to unsafe driving and hazards. To solve the communication and computational aptitude issues, techniques have been proposed, using third- (3G) and fourth-generation (4G) cellular networks [8] and roadside units [9]. However, these are not sufficient for cellular networks to give unlimited augmented communication, especially with ever growing number of vehicles. In 2010 number of vehicles in the world was estimated to be one billion [10]. Thus, it poses a great challenge for researchers and engineers to deal with VANET communication and computational requirements efficiently as VANET is the most widespread network. Vehicles behave as nodes full of rich energy, storage, and communication capability. Due to movement of vehicles network topology changes continuously. Therefore, it is difficult to find a vehicle's location for a message. Communication of vehicles is of two types: Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I). A combination of V2V and V2I is referred as V2X communication [11,12].

For V2V communication, the main problem is the distance between two vehicles. If it is shorter than the communication range, it may allow successful connection otherwise it would be difficult to establish connection. Network connectivity is the basic issue for enabling information transmission for V2V communication. V2V is considered as direct communication. In V2I scenario vehicles communicate to infrastructure in which vehicle sends information to the infrastructure. Reliability of communication depends on V2I sensors and internet availability. V2I sensors refer to the transmitter and receiver ability to communicate. V2X communication allow vehicles to collect information of moving vehicles and then help to warn possible about accidents or dangers ahead on the roads [13]. To meet rising transportation needs such as road safety and communication. IoV is an appealing idea, to be explore in order to achieve smooth traffic and road safety by handling several constraints such as congestion. Dissemination of Emergency messages (EMs) is a basic application and challenge of VANET [6] [14]. During the messaging between network devices, congestion may occur on some paths when a large number of packets are transmitted through certain intermediate or bridging nodes. Congestion may result in an overcrowded or blocked situation where smooth communication is not possible. It causes information loss and leads to poor communication. Hence, congestion control mechanism is very essential for reliable communication in a network. Moreover, message congestion in VANETs leads to poor road safety as message congestion leads to message loss. Driver intimation is not possible when messages drop due to congestion. It occurs when a vehicle broadcasts packets repeatedly. Repeated packets are inefficient for scalability and cause packet collisions [4] [7]. Packet collisions lead to packet loss that results in poor dissemination of EMs delivery. The problem has been handled previously in some schemes [15] [16] [17] [18] but it still needs to improvement for reliable communication.

1.3 Internet of Vehicles (IoVs)

Recent advances in sensing, automotive, and communication technologies have paved way for Internet of Vehicles (IoVs). IoV is a dynamic communication network that allows mobile communication between vehicles. A traditional VANET is growing into IoVs for the sake of an intelligent and efficient transportation system of future [19]. It is an emerging area that is the foundation for a smart traffic management, monitoring, mobile crowd sensing, accident reporting, weather alerts, parking alerts and audio and video streaming in vehicles. IoV supports communication in rural and urban areas where former deals with less traffic and later handles more traffic along with buildings and other hurdles in the area. In both cases, vehicle identifies commands, junctions, fuel stations and marts as per the trajectory between source and destination locations [20]. IoV allows communication between vehicle to vehicle (V2V), vehicle to grid (V2G), vehicle to device (V2D) and vice versa as depicted in Figure 1.2. In V2G system vehicles communicate with electric grids in order to cater for energy consumption [21]. V2D refers a scenario where vehicles communicate with devices like smartphones or smart bicycles. IoVs also helps to provide E-health applications in the terms of mobile hospitals [22].

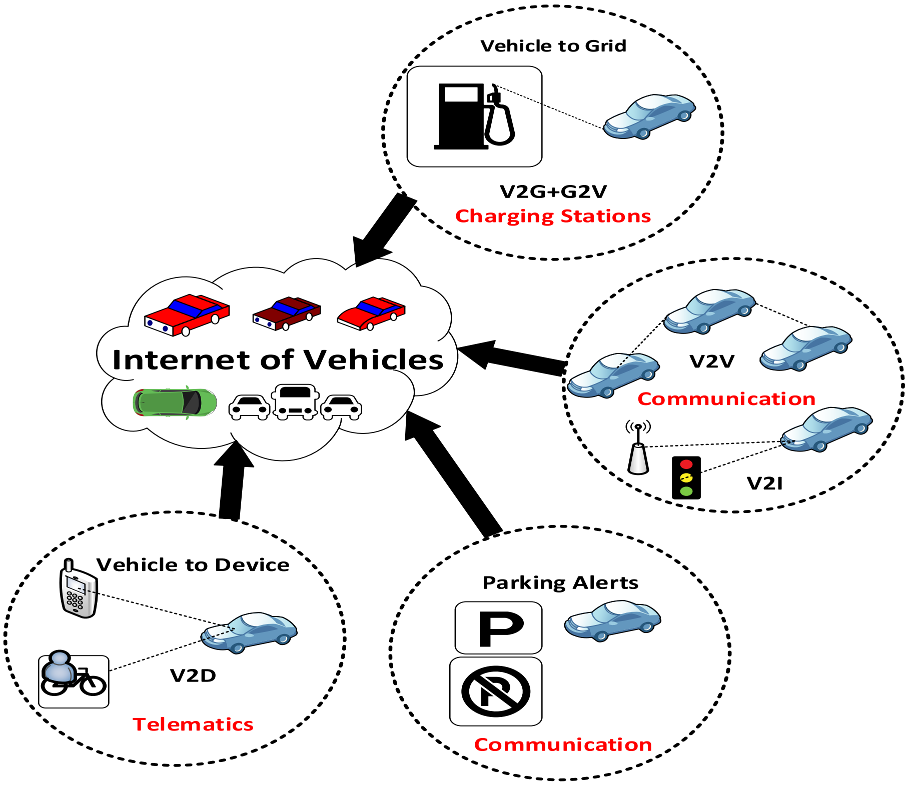

Figure 1.1: Internet of Vehicles Architecture

IoV is an important constituent of Intelligent Transportation Systems (ITS) to manage road safety and related transportation services by saving data at central online repositories for better decision making [14] [23]. In fact IoVs help to manage huge data transmission, computation and storage for users and owners [19]. Message congestion during information distribution is a main concern of VANET. To deal with the problem of congestion, some of the proposed schemes detect gradual blockage of message and timely decide about the alternate paths [12] [24]. Most of the existing congestion avoidance schemes deal with message storm in context of vehicular ad hoc network (VANET) [6] [16] [22].However, these schemes are not practical in context of IoV due to various reasons such as scalability and diversity of applications. Moreover, IoV-based schemes mainly rely on a centralized server to provide services, which is feasible for a large number of vehicles demanding for diverse applications.

1.4 Fog Computing

The term "fog computing" was invented by Cisco organization in 2012 [24] [25] [26]. Fog computing is the middle layer among clients and cloud. It is not a replacement of cloud but it is enhancement of cloud computing which is similar to cloud and gives data computation, data storage, and networking between end users and cloud servers. Fog computing - is an emerging domain that aims to resolve issues such as latency, mobility and location tracking and provide services to users. Fog computing computes data at the network edges by sharing computation workload [27]. Fog server act as local servers where it computes given tasks. In our case fog servers also process messages at local servers and help to take timely actions. Fog server actions include to inform upcoming traffic to slow down speed, as well also inform rescue teams for road clearance.

Fog based design presents an efficient resource allocation (ERA) architecture and algorithm on cloud in order to test the performance. It handles resources in an optimized way to improve overall round trip time, data transfer cost and bandwidth utilization. It has been shown in [28] that fog has a proficient algorithm including resources that is based on virtualization technique. It has also been proved that fog computing based approach allocates resources in an efficient manner and it is also better than previous algorithms in terms of response time, data transfer cost and bandwidth utilization. Fog computing in VANETs is known as Vehicular Fog Assisted VANET. The structure considers vehicles as permanent nodes and infrastructure acts as access points [29]. Fog assisted VANET consists of multi-hop and uses moving features of vehicles to send information from one location to another.

1.5 Problem: Message Congestion

In past several information dissemination and message congestion avoidance schemes have been proposed for VANETs. These schemes were identified some problems and limitations. Basically, most of these schemes have high message congestion and repetition rate [11,12] [30]. Message congestion arises due to repetition and leads to information loss. Delay in message delivery is also a major concern which needs to be focused for communication. Most schemes follow static approaches. Not only static but even dynamic approaches are not suitable in all cases. Some open research challenges are discussed here.

Message Congestion is one of the prime issues in IoV as it may lead to catastrophic consequences besides service degradation. Basically, all vehicles are required to send continuous updates to a central server i.e., beaconing messages [3]. Moreover, vehicles regularly communicate with the central server for safety and infotainment servicers. In the former case, vehicles may need to send emergency messages (EMs) about accidents, road blockages, foggy weather or storm ahead [11].

Internet of vehicles involve a number of moving vehicles connected with each other. They may communicate directly or through multi-hop communication. Vehicles exchange either normal message (*NMs*) for routine communication or *EMs* to inform about accidents and other alerts. These messages contain position of vehicle, velocity, heading information, and other emergency or safety based information [15]. We have assumed that vehicles maintain a list of one hop neighbors based on their communication range. It is also assumed that most of the vehicles on the road are smart vehicles, integrated with internet or V2I sensors but there may also be a few normal vehicles without internet to accommodate emergency service for legacy systems.

IoV also has applications in daily life such as safe driving, entertainment and map based guidance [16]. Safe driving means to reduce accidents and traffic blockage for reliable communication in VANET. To maintain reliable ITS, it needs traffic management, passenger information and public safety messaging [16]. There are two types of public safety messages including periodic safety (beacon) messages and event driven messages [17]. These messages are meant to be forwarded to other nodes. Event driven messages occur in the case of emergency like an accident. This message is considered important in order to deliver in multi-hop neighbors. There may be scenario where too many accidents are happening at the same time in same area. Emergency alerts are sent to the nearest server. It causes congestion as shown in Figure 1.3.

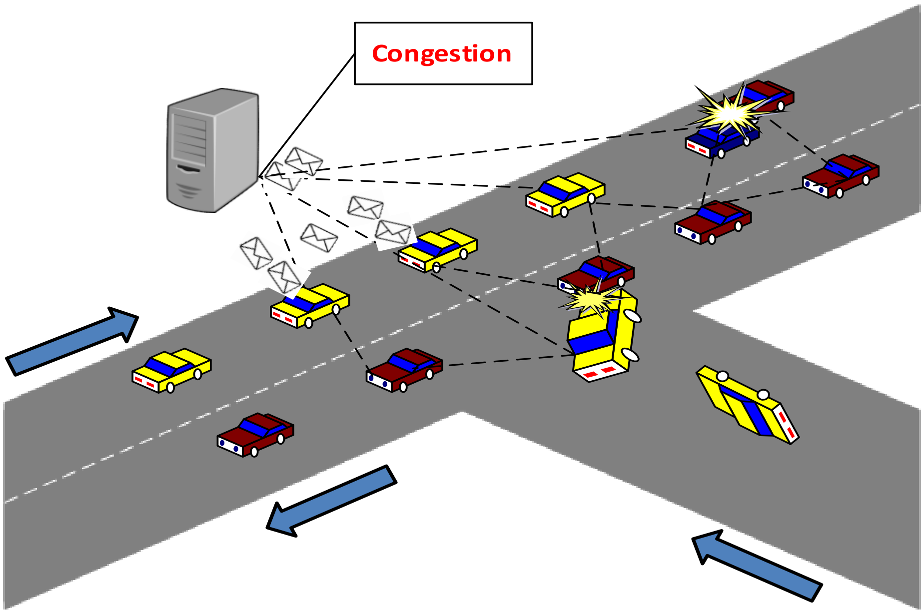

Figure 1.3: Message Congestion in IoVs

In V2X, frequent communication or repeated messages causes storm in the network. Broadcast storm also becomes severe in case of high vehicles density due to more packet delay and collisions [18]. To avoid this congestion, we have proposed fog based scheme. Fog computing means we may have a local server where requests are residing and processed.

1.6 Effects of Problem

In [11,12,18,21,30,31] message dissemination is performed through grouping or V2V communication in a specific area or limited environment. The grouping and V2V communication leads to more congestion in a real road scenario or congested environment. High message congestion rate leads to delay in message delivery and increases communication cost due to repetition. Existing schemes have tried to reduce congestion but still suffer from following limitations:

i. Each vehicle node sends messages to each other by using V2V concept and central units like RSU or BS before passing to the server [11] [12] [24] .
ii. More complex tree structure and clustering is implemented to make the groups in the form of hierarchal architecture [21] [18].
iii. Limited congestion is considered rather than real scenario by assuming specific road, two-way road or hotspot area [11] [30] [12].
iv. Limited known patterns are considered for information dissemination rather than unknown patterns of traffic [25].
v. Encryption and decryption cost of information for communication [15].

Timely delivery of safety messages is extremely crucial to avoid catastrophic consequences. However, direct communication with the server may not be possible due to limited communication range of vehicles. Therefore, vehicles may have to rely on multi hop communication (i.e., through intermediate vehicles) which may result in high communication cost and network congestion due to message storm. This may not only cause delay but also leads to packet drops. Therefore, congestion avoidance schemes are essential for IoVs. Major problem observed is that repeated messages occurs repeatedly on each transmission with in one hop based group. When the messages are transmitted continuously to the central server from various vehicles in IoV at the same time, it creates message storm and hence congestion. The vehicles entering into an area that is suffering from congestion may cause dropping of established sessions for audio, video streaming, monitoring or emergency reporting. This message congestion leads to packet drop, communication overhead and increase in delays due to unnecessary messaging in [11] [21] [18] [12] [24] as shown in Figure 1.4. These constraints are still tolerable in case of NMs but in the case of EMs packet drop and delay in message delivery during accident reporting may lead to loss of precious lives. In the above mentioned scenario, we can calculate established connection links between vehicles. Suppose total no. of vehicles in one hop = N and Established Connection Links = L. For Graph = (N, L) where L can be calculated as given in Equation 3.1. For example, we have 10 vehicles near AV, then L = $\frac{10(10-1)}{2} = \frac{10\times 9}{2} = \frac{90}{2} = 45$.

$$L = \frac{|N|\times|N-1|}{2} \tag{1.1}$$

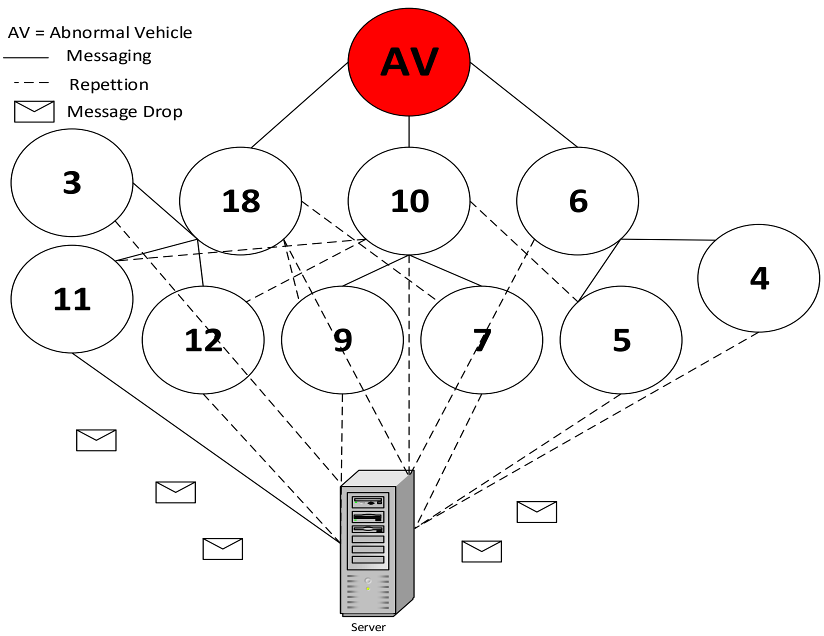

Figure 1.4: Un-necessary repetition of messages in IoVs

Repetition of messages also increases congestion as given in Equation 1.2 where L represents Established Connection Links, DM represents Dropped Messages and RM is Repeated Messages.

$$\text{Congestion} = L\times \frac{\sum_{i=1}^{n}(DM+RM)}{100} \tag{1.2}$$

Packet Delivery Ratio for the above mentioned scenario is given by Equation 1.3.

$$\text{Packet Delivery Ratio} = \frac{Recieved\ Packets}{Sent\ Packets} \times 100\ \% \tag{1.3}$$

1.7 Problem Statement

In existing schemes central units and neighboring vehicles causes delay in message delivery and repetition of messages. Message repetition is directly proportion to communication overhead and also increases communication cost. Duplicate messages results in message congestion. The message congestion varies from scenario to scenario that is in rural areas where less number of vehicles transmit few number of messages cause less congestion. In dense environment or urban areas large number of vehicles causes high congestion of messages. Message congestion increases packet loss ratio which may lead to loss of precious lives. We have figured out that static schemes and fixed small segment slots are not efficient approaches in VANET. These schemes are based on specific and limited areas. These static and small road segments disturb the actual situation on roads. Dynamic schemes are better and reliable to collect data in VANET, instead of predefined roads. A general and flexible scheme is required for congestion avoidance, management of traffic lights and detection of road conditions to reduce accident rate. When repeated messages are transmitted continuously to central server from various vehicles in IoV at the same time, it creates message storm and hence congestion. Congestion is one of the prime issues in IoV as it may lead to catastrophic consequences besides service degradation. Basically, all vehicles are required to send continuous updates to a central server for safety and infotainment services and emergency messages (EMs) about accidents, road blockage, foggy weather or storm ahead. In case of emergency vehicle does not stop broadcasting messages until a rescue has reached. It becomes worst because the nearby passing vehicles also keep on flooding the emergency information for a long distance that causes communication and energy overheads. Timely delivery of safety messages with less communication costs is extremely crucial to avoid catastrophic consequences and congestion that results into packet loss, poor communication, low latency, energy overheads and delay in propagating emergency messages.

1.8 Research Questions

i. How to control unnecessary flooding message to reduce energy consumption in the network?
ii. What is the overhead of sharing messages with V2I communication links?
iii. What is the effect if emergency messages travel to far distances to distant vehicles?
iv. When message type is identified during communication? Is it NMs (Normal messages) or EMs (Emergency Messages)?
v. How fog server is used in communication to control message storm?
vi. How to reduce message congestion to improve packet delivery ratio?

1.9 Research Objectives and Contributions

This work presents a Fog-assisted congestion avoidance scheme known as E^2MD. The scheme helps to avoid congestion and distribute all type of messages efficiently for effective communication. It also benefits transmission of emergency messages for safety alerts or accident reporting. Proposed scheme is based on fog computing that allows to process data locally and distribute it efficiently. Vehicles update fog server about their current status. Therefore, each fog server has the current location of vehicles in its range. Here, abnormal vehicle (AV) transmits messages to fog server directly and one hop neighbors only. Hence, fog server is responsible to inform upcoming traffic to slow down speed. Similarly, fog server is supposed to approach rescue teams for medical help and coordinate with police to remove accidented vehicles from the road. If a fog server is not in direct range of AV then, inform nearby vehicles in one hop and select a reliable vehicle that has the shortest path to the fog server and then transmit messages to the reliable vehicle. Reliable vehicle informs fog server in order to approach nearby vehicles. In case of emergency messages, rescue team and upcoming traffic could use nearby resources. In cases, where server is not in the range of AV, then messages reach to the server via V2V communication in IoVs. Our scheme resolves message congestion by avoiding duplicate messages which are only transmitted to reliable vehicle rather than all vehicles. End-to-end delay and less bandwidth consumption reduces communication cost. Less message congestion leads to following improved metrics:

i. Communication Overhead during Messaging
ii. Packet Delivery Ratio
iii. Packet Loss Ratio
iv. Message Transmission Delay
v. Throughput

1.10 Organization of Thesis

The thesis is organized as follows; Chapter 2 describes literature review and background knowledge in detail in order to highlight the strengths and limitations of each scheme. A detailed comparison of all schemes is given in the form of a table.

Chapter 3 highlights the problem statement in terms of problem effects and problem description. Problem statement is highlighted after technical review of problem with the help of a diagram according to simulation results of the existing scheme.

Chapter 4 includes proposed system model along with its advantages and challenges. Challenges of the proposed model will help the researchers in to explore future directions. Proposed E^2MD scheme along with an algorithm for message dissemination that manages the congestion as per different vehicle type is described. Data flow diagrams are drawn to understand the scheme easily.

Chapter 5 presents the results and analysis of the proposed and existing schemes along with simulation environment, scenario and parameters. Performance is evaluated on the basis of simulation results and it is represented in the form of graphs.

Chapter 6 concludes our work and outline the future directions. Future work is stated in simple words to help the researchers for future ideas, for the sake of more smooth and reliable communication in IoVs.

1.11 Conclusion

This chapter includes an overview of vehicular adhoc network and internet of vehicles. It also gives overview of fog computing and highlight how it can be helpful in solving the problem of message congestion. After identifying the problem, the chapter highlights effects of the problem and research questions.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

In this chapter, VANET architecture, its standards and challenges are discussed. Architecture is explained along with infrastructure linkage. The chapter also includes a detailed discussion and taxonomy on a VANET based messaging schemes. The schemes are categorized under different headings on the basis of their types. Congestion avoidance schemes of same types are under one heading like transmission control, transmission power control, segmentation and aggregation based schemes. These schemes give us related work about congestion avoidance. Finally, the chapter includes discussion about literature review in order to highlight strengths and limitations of each scheme.

2.2 VANET Architecture and Standards

VANET architecture consists of three groups: the WLAN or cellular, ad hoc and hybrid architectures as shown in Figure 2.1. WLAN is a wireless technology that acts as base in VANET. In Europe and Japan vehicle protocol stacks are specified for automotive industry. In USA IEEE 1609 WAVE (Wireless Access in Vehicular Environments) protocol stack built on IEEE 802.11p WLAN operating on seven reserved channels in the 5.9 GHz frequency band is used in VANET [26]. When infrastructure consists of WLAN/cellular or a WIMAX access point, the network will be taken as real WLAN/cellular. Cellular network covers large area and it is good for vehicular communication system [32]. In VANET permanent cellular gateways and access points are used at traffic intersections and interchanges in order to share information using internet. Permanent gateways around the road side help to connect mobile nodes (vehicles) but at a high cost [33]. WLAN (IEEE 802.11) is attractive and less expensive for its use is in wide range [34]. However, its communication range is limited. Ad-hoc network means there is no available infrastructure and the nodes communicate with each other without any central access point. Ad-hoc network is a temporary network where several access points are used for communication such as cellular gateways. In the absence of infrastructure communication is established in ad hoc environment.

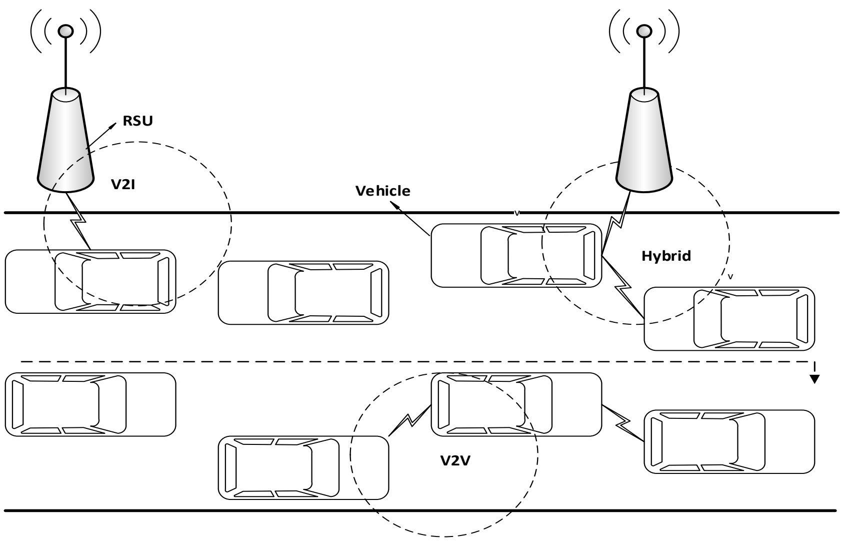

Figure 2.1: VANET Architecture

In a situation where nodes communicate using infrastructure or directly with each other it is called hybrid architecture. It uses both infrastructure and Ad-hoc environment with the capabilities of WLAN/Cellular and mobile network routers. The hybrid architecture was proposed to achieve minimum cost of IEEE 802.11p and maximum of the cellular technologies for low-latency communication [18]. This hybrid architecture has good coverage area but causes new issues such as communication transition between several wireless systems. The WLAN has capability to communicate throughout the world using internet.

Onboard Units (OBUs) with Global Positioning System (GPS) form a VANET [2] [9] [14] [35]. OBUs are integrated with sensors to detect accidents. Sometimes OBU called In-Vehicle equipment (IVE) for communication [32]. Generally vehicular networks consist of two types of nodes namely vehicles and RSUs. Vehicular communication is a component of the intelligent transport system. Its aim is to provide safety via intelligent transportation system by integrating different information. Vehicular communication includes Inter Vehicle communication (IVC) as V2V, Road Side vehicle communication (RVC) as I2V and Hybrid [32]. RSU acts as a router for vehicle communication [36]. Mostly RSUs are placed on the intersection of roads to cover more area and vehicles [34]. However, in VANET, RSU can also be placed alongside a road to transfer information from vehicles to server. Servers exist in upper layer while RSU and vehicles lies in lower layer. Providing efficient and continuous services by RSU is a challenging task under high vehicle's density [16]. Vehicles move at high speed on roads and communicate with RSU for a moment by staying in the RSU area for a while [4]. VANET is becoming more popular day by day in Intelligent Transport System and it provides good applications in daily life such as safe driving, entertainment and map based guidance etc [16]. Safe driving means to reduce accidents and traffic blockage by using VANETs. Entertainment includes reliable entertainment transmissions. Map based guidance is also based on VANET.

2.2.1 Vehicles and their Infrastructure Linkage

For V2V communication, Vehicles exchange information directly. The main problem in this case is distance between the two vehicles. If it is shorter than the communication range, it provides a successful connection. Network connectivity is a key issue for enabling information transmission for V2V communication. Thus, we go to the Fog assisted VANET, which takes moving vehicles as communication nodes in order to establish better network connectivity. V2V is considered as direct communication. In V2I vehicles send information to infrastructure, then it is sent to the server. In I2V infrastructure send information to vehicles and this infrastructure can be a Road Side Unit [16]. In I2V communication takes place between infrastructure and OBUs [32].

2.3 VANET Challenges

Although VANET has become popular in the world because of its advantages but still there are many challenges and open research areas. The challenges need to be explored in order to achieve smooth traffic and road safety. In smooth traffic it needs to avoid road blockage by using efficient traffic signals. Road safety needs to avoid accidents and inform rescue teams timely. VANET based applications for information distribution among vehicles needs to focus on bandwidth of a network. Some of the challenges such as latency, throughput, routing, security, availability, congestion, node mobility and time constraint can be improved using fog computing [25,29].

2.3.1 Latency

It is the basic issue in VANET which needs to be explore for node to node communication in an efficient way. Data latency means the time taken by a message to travel from one end (vehicle) to the another end (vehicle). It can be improved by using local servers of fog computing [37]. A key parameter in sending and receiving a data packet is transmission time. It is used to calculate throughput rate. To calculate transmission time delay Bit-Rate = Data Size/ Transmission Time Delay, Transmission Time Delay=Data Size/Bit-Rate and Data size = User Data + Header are used [38].

2.3.2 Throughput

It is based on the rate of communication per time unit. Basically it is the major point that is to be considered in packet forwarding. Several essential factors such as packet size, action range, mobility of nodes and cluster size affect it. Blind message broadcast is described as the 100% effect packet distribution [38].

2.3.3 Routing

In VANET routing is a hot topic of research area. It means to find out best path or route for traffic. It means less delay in packet delivery. It leads to optimal path by having limited hop connection in order to transfer data. Actually in routing data travels hop to hop. It consists of different protocols like SPIN and RUMOUR. Aim is to choose reliable routes. Reliable route is shortest and smooth path to the destination. Its sender already knows about routes then reliable one should be chosen instead of the shortest path which may lead to high maintenance overhead. Routing overhead means the number of packet transmitted per route, no matter broadcast or unicast per node. There are some choices such as the total number of packets received per node or the total number of routing bytes receives per node. Count sequence number of routing packets needs to be calculated per node instead of end-to-end [38].

2.3.4 Security

Security for VANET is important research area. It means to avoid attacks. There may be attacks such as Bogus attack on IVC [32]. One of the major problems of communication systems is secure communication for transmitted data. Security schemes lead to increased delay for message delivery in a VANET [6]. However, security schemes are common in wireless LANs but are not suitable for VANETs.

2.3.5 Availability

In safety applications as post-crash warning, the wireless broadcast signal has must reach other vehicles in order to receive the warning messages [6]. If the radio channel goes down (jamming), then the warning cannot be broadcast and the application becomes useless. Hence high availability of resources is essential.

2.3.6 Congestion

It can be categorized into two types one is physical congestion of vehicles on the road and other is network congestion which occurs during message reporting and V2V communication [6] [7]. Communication among vehicles is the major issue. Poor vehicle communication leads to road accidents and delay in identification of accidents. It may also lead to poor reporting about accidents for quick response.

2.4 Taxonomy of Messaging in VANET

This section describes messaging schemes for VANET and fog computing. During messaging, we have also to focus on congestion control and avoidance schemes. Fog computing supports geo-distribution, location awareness and support mobility to be relevant research field for vehicles. In VANET based schemes, we focus on three types of V2V communication, that is central access control, message transfer and group management. Several schemes have been studied for VANET and fog assisted VANET for providing efficient and smooth communication. Some of the schemes are discussed in this section. To provide a reliable Intelligent Transport System we need to manage few things such as traffic management, passenger's information and public safety messages [16]. There are two types of public safety messages are described in this section [17] [39].

2.4.1 Periodic Beacon Messages

Beacon known as basic safety message (BSM) in US and cooperative awareness message (CAM) in Europe [17] is transmitted to test the connectivity of devices in the network of vehicles. This messages ensures that a particular vehicle is in range of an RSU or other server level nodes. Beacon messages consist of current position, vehicle speed and its direction [9] [40] [41].

2.4.2 Event Driven Messages

Event-driven safety message (ESM) or decentralized environmental message (DENM) in Europe [17] are generated at the time of an event like query initiation, data collection, emergency reporting and accident alerts etc [42]. These messages can either be sent to RSUs via V2V or V2I. ESM has higher priority than periodic beacon messages.

2.4.3 VANET based Schemes for Messaging

A V2V Locality based broadcast communication protocol is presented in [35] where each vehicle produces emergency alerts at a fix rate. These emergency alerts and other messages may drop due to packet collision, channel fading, delay or congestion as shown in Figure 2.2. A scenario is considered where all vehicles are not equipped with wireless transceivers so urgent message transferring takes place in a lightly connected ad hoc network having highly mobile vehicles. When an abnormal event occurs, mostly there are many vehicles affected by the scenario. Multi-hop forwarding technique increases the reachable range for warning alerts. The author has focused on congestion control based on collision warning application and proposed a model to deal with emergency warning messages (EWM) [35]. It also discusses how to avoid the natural emergency situations. The paper focuses on congestion control among vehicles using Fog Computing. Congestion is a major constituent of Intelligent Transportation System for safety as highlighted in [39].

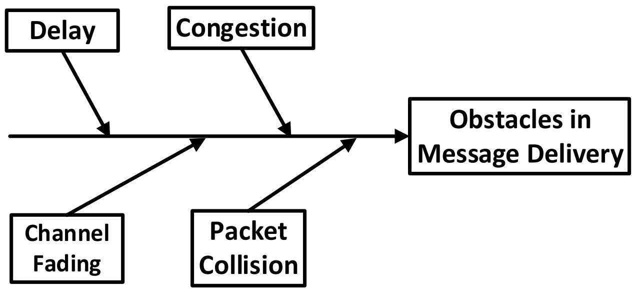

Figure 2.2: Message Congestion Metrics

Vehicular communication is a component of the intelligent transport systems. Its aim is to attain safety via intelligent transportation system by integrating different type of information. Communications in an active transport system takes place by using a combination of vehicle-to-vehicle and vehicle to- infrastructure communication. For V2V communication, vehicles exchange information directly where the main problem is the distance between the two vehicles.. Thus, go to the Fog assisted VANET, which takes moving vehicles as communication nodes in order to establish better network connectivity.

In VANET, nodes exchange EMs called beacons with their neighboring vehicles. A beacon message holds information about state of a vehicle such as position, velocity, heading information, and other emergency or safety based information [20]. Risky situations can be avoided through EM alerts. V2X communication allows vehicles to collect information of moving vehicles and then prevent possible accidents or avoid ahead dangers on the roads [13] [36]. Vehicles that are near to the abnormal vehicle (AV) where accident occurred, receive the EMs in real-time to react immediately, e.g. to slow down the speed.

A smartphone based protocol GoSafe to improve road safety and road management is introduced in [24]. The protocol is used to report warning messages about an accident by using voice commands to a server. It can send alert messages to emergency centers and can also receive EMs. Vehicle requests the server for nearby events regularly in order to get emergency alerts. In [43], a guidance system is proposed to detect accidents and ask for service of portable devices. It uses the GSM cellular network in to communicate among portable device and the central Server. It presents a system where information from the user is associated with a location using a GPS tracking system and generates an accident report [43]. It sends GPS coordinates of the person, displays the coordinates on a map and computes the shortest route to the accident site. The system also automatically detects an accident. The author proposed a new approach in [35] to improve vehicle communication by giving emergency alerts before collision of vehicles. Basically it focuses on the congestion of network which is determined by transmission rate and transmission power control methods. Many schemes improve latency in order to overcome this issue but still there are few aspects which need to be improved for the betterment.

This section presents a review of EM transmission schemes to distribute vehicular traffic information and safety messages among vehicles, in order to avoid message congestion. These schemes include transmission control, segmentation, encryption/decryption and aggregation. Analysis of each scheme brings out its strengths and limitations. Limitations identify future work. After analyzing individual scheme comparison is done to find new research areas. We have identified the schemes for EM forwarding efficiently, to reduce accidental life losses and ensuring timely intimation to rescue services. It will also help to reduce number of accidents by informing nearby vehicles. The scheme may also be helpful for industry by giving a good congestion control model e.g for emergency exit due to fire, toxic gases and other hazards. Congestion control system will allow to transmit a large number of messages efficiently. The work also highlights open research challenges about delay and bandwidth. Less delay and bandwidth avoids message congestion in VANETs.

2.5 Message Congestion Avoidance Schemes

Indirect message reporting involves V2I communication where vehicles under emergency inform a nearby server. When abnormal vehicle transmits an EM to nearby vehicles in order to inform a server then EM is repeated and congestion arises. Chris Thompson et al. proposed a scheme in which a smartphone is used to detect an accident by using acceleration and 3G data connection is used to transmit information to the main server [41]. The information is the processed by the server and the concerned authorities are informed. Congestion avoidance schemes can be sub divided into static and dynamic schemes. The former scheme uses fixed segment slots which are not suitable for VANET. Static road segments badly affect the actual situation on the roads because large segments result in accuracy loss while small segments result in high communication load. Therefore, dynamic schemes are preferred to collect data from vehicles. Dynamic schemes are accurate and reliable for collection of data in a VANET. A flexible design permits it to be used for several applications like management of traffic lights, detection of road conditions and accident avoidance. Dynamic schemes are divided into transmission control, transmission power control, security preservation, segmentation and aggregation based schemes that are further sub divided as shown in Figure 2.3. Congestion avoidance schemes along with their limitations are discussed in this section.

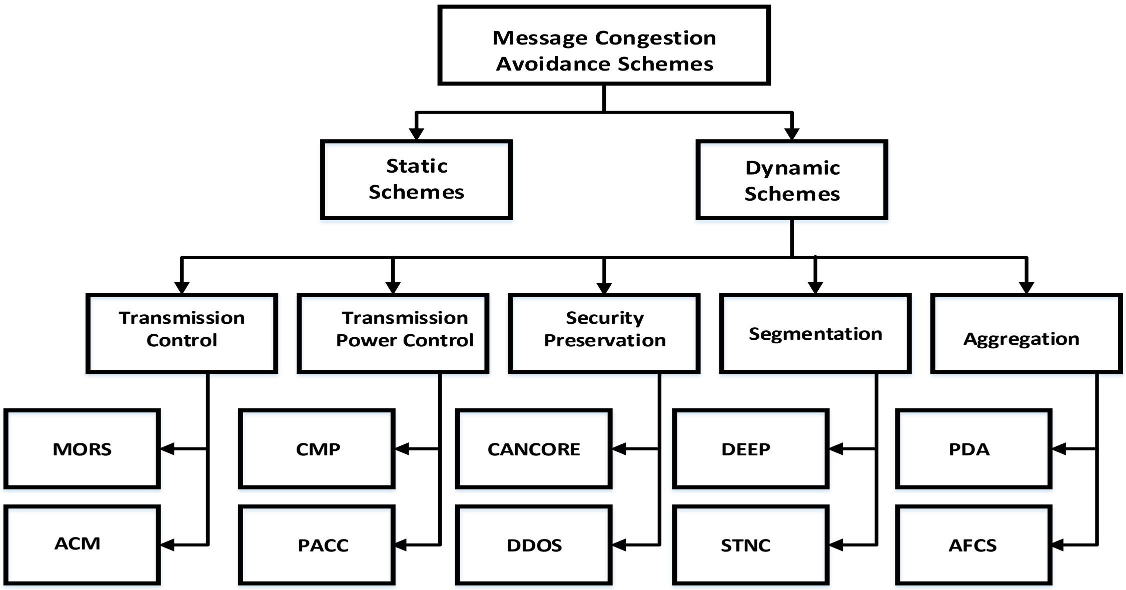

Figure 2.3: Taxonomy for Message Congestion Avoidance Schemes

2.5.1 Transmission Control-based Schemes

MORS discusses two main issues about VANETs; one is broadcast storms and the other is high speed of data transfer that causes disconnection problems for the network [44] . It reduces the amount of control messages locally, but this type of dissemination loss is related to vehicles velocities, badly affects delivery of safe messages. A reliable scheme RMFF based on restrictive flooding is proposed to overcome the message storm [45]. However, the scheme is still not efficient enough to control repeated message transmission. The scheme in [25] includes three types of mobility i.e., stationary nodes, nodes that move in arbitrary direction, and nodes which move in known paths. This scheme is based on mobility, Software Defined Network (SDN) and Fog server. Mobility information is required to minimize control message overhead for a known pattern. Therefore, this scheme is restricted because accidented vehicle only transmit *EMs* to stationary and predictable neighbor vehicles as given in Equation 2.1.

$$Cc = acc_t \rightarrow NbV \text{ and } StV \qquad (2.1)$$

Where,

Cc = Congestion Control

acc_t = Message transmission by accidented vehicle

NbV = Predictable nearby vehicles

StV = Stationary vehicles

2.5.2 Transmission power Control-based Schemes

Congestion Mitigation Process (CMP) is an approach to handle congestion of messages in [24]. It is stated that congestion is a result of higher transmission power that leads to higher number of neighboring nodes for a single channel like 802.11 network. Therefore, reduction in transmission power is proposed to reduce congestion. But it reduces limited congestion only, still we need to produce dynamic algorithms to control transmission power by reducing rate of repeated messages. In [46], a priority assignment, congestion detection and congestion control based scheme is presented. This scheme adjusts the transmission power with the rate of beacon transmission. The approach is based on three stages: Priority assignment to a message in order to transmit, detect the congestion created by several messages at a time and finally adjust the beacon messages load as given in Equation 2.2. Therefore, it is difficult to deploy.

$$Cc = min\{t_p\} \propto \min\{b_t\} \qquad (2.2)$$

Where,

t_p = power transmission

b_t = beacon transmission

2.5.3 Segmentation

Segmentation is a process of dividing large area into segments. Any small or specific area is considered as a segment. M.C.Chuang et al. has proposed a new segmentation based mechanism DEEP to broadcast messages in VANETs [30]. It is used to resolve the EMs broadcast storm issue, to reduce delay in distribution and improve reliability. The algorithm has shown good results but only for a specific area. In [14] X.Shen et al. has proposed a scheme STNC for message dissemination among vehicles. It is based on segments. It divides time slots along transmission to improve delay as shown in Equation 2.3. But it is also not suitable in a sparse environment.

$$Cc = Div(Time) \propto less(Delay) \tag{2.3}$$

Where,

Cc = Congestion Control

Div = Divide

2.5.4 Security Preservation based Schemes

H.Kang et al. has proposed a new scheme called Context-Aware Network COded REpetition (CANCORE) to improve effectiveness and security [15]. CANCORE has two major goals: First one is to broadcast the EMs from front vehicles only by using network coding. Second is to avoid unnecessary reporting growth caused by repetition of coded EMs. Beacon scores are updated regularly where each vehicle make a coded packet. These packets are based on two native beacons selected by two rules. Rule 1 is used to reduce overhead by permitting a large number of vehicles to have only one of P1 or P2 at the receiving time. Rule 2 is used to keep beacons as active as possible. As per first rule one simple packet is selected from each direction with highest score. While in case if there is same score of beacons, earlier arrived beacon will be preferred. If P1and P2 are far away from each other, probably receivers obtain beacons from above the transmission range of vehicles. So, CANCORE is bound by the distance among the sender and the source of a selected beacon in order to meet situation. In [40] the author detects the Distributed Denial Of service (DDOS) attack in the network and provides a good path for the safe V2V communication. Its objective is to reduce the communication delay and communication loss. The model creates the controlled clusters and applies the several limits based analysis to identify an attack. It ensures safe communication over the network.

2.5.5 Aggregation

The Rakesh et al. has introduced a probability based framework to manage EMs broadcast storm [21]. It reduces broadcasting rate by minimizing repeated EMs. Less bandwidth rate leads to improved data dissemination. Proposed framework is local knowledge based in order to save the decisions for data aggregation. But it increases communication overhead. In [11] and [12] author has tried to resolve message storm by introducing an aggregation or grouping based scheme. The scheme is based on two segments i.e., adaptive forwarding message (AFM) and AFM including cooperative active safe driving (AFM-CSD) where message is sent to group leader only. The leader is responsible to forward message by using V2V communication in a hop as given in Equation 2.4. But it improves congestion slightly for CSD-Vehicles, considered as smart vehicles only. It does not handle NON-CSD vehicles.

$$Cc = GL \rightarrow \sum_{i=1}^{1hop} V \propto \min(bandwidth, delay) \tag{2.4}$$

Where,

Cc = Congestion Control $\quad\quad$ $\sum_{i=1}^{1hop} V$ = Vehicles in one hop

GL = Group Leader

The major limitations observed in the schemes are as follows:

(i) Congestion control only for a specific area rather than a real scenario. It means reduced message storm for smaller dense areas rather than large dense area.

(ii) Increased communication overhead, due to several intermediate nodes for communication and the messages.

(iii) Most of researchers have assumed smart vehicles only. Therefore, their solutions are limited to smart vehicles integrated with V2I sensors and internet only. It leaves out normal vehicles which are very important in real world scenarios.

2.6 Comparison of Congestion Avoidance Schemes

Message congestion avoidance schemes are reviewed here to identify gaps in the current research. In this section, we have categorized the existing schemes in table 2.1 in order to analyze the strength and weakness of the schemes as per the metrics. The metrics use for the comparison are congestion, delay and bandwidth of each scheme. The limitations in schemes lead to possible gaps. To cater for a real world scenario, the congestion avoidance schemes must be in multi-hop environment because single-hop is not enough in urban areas. Single-hop schemes may be not useful in urban areas because there is dense environment of vehicles. Beaconing frequency is also a challenging future work for traffic aware networks [3]. Message forwarding load and accuracy of destination also needs to considered. In this section we highlight open research challenges to provide reliable communication for VANETs by analyzing several EM transmission schemes.

Table 2.1: Comparison of congestion avoidance schemes

Technique	Methods	Strength	Limitation	Congestion	Delay	Bandwidth	Remarks
DEEP: Density-aware Emergency message Extension Protocol [30]	Segmentation (fixed length and width of block size)	Control broadcast storm of EMs	Deliver EMs to a specific area.	M	H	H	Needs QoS Needs to extend for Complex environment.
CANCORE: Context-Aware Network COded REpetition scheme based [15]	Coding & Decoding	Broadcast the EMs. Avoid unnecessary reporting growth caused by repetition of coded EMs.	Increased computation cost. Limits the distance.	L	H	L	high delay due to coding /decoding. Needs to be generalized without distance limitation.
ACM: Adaptive Control Messages [25]	Fog, SDN & 5G	Reporting frequency can be reduced for known mobility pattern and quasi-stationary nodes.	Unknown mobility pattern nodes report their mobility information frequently.	L	L	H	Needs to control Frequent EMs for unknown mobility patterns.
CMP: Congestion Mitigation Process [24]	Transmission Power control	EMs congestion control	Structural congestion control scheme	M	H	L	Needs to develop a suitable algorithm.
DDA: Dynamic	Data Aggregation	Congestion control dynamically	Less Throughput	M	H	M	Need to disseminate data

Data Aggregation [21]							efficiently to achieve maximum throughput.
AFCS: Adaptive Forwarding message & Cooperative Safe driving [12]	Grouping/Data Aggregation. Identify group leader	Efficient messaging for mobile society & 5G world by controlling message storm.	Needs to improve speed synchronization interval. Absence of ITS.	M	M	L	Needs to communicate with ITS. Needs to synchronize speed dynamically in order to control message congestion rate.
RMFF: Reliable Model For Flooding [45]	Transmission control by using restrictive flooding	Less delay during message transmission	Message overhead due to repetition of messages.	M	L	H	Needs to avoid repetition of message transmission in order to gain less packet drop ratio and message overhead.
PACC: Priority Assignment for Congestion Control [9]	Adjustment of transmission power along message transmission rate.	Congestion detection and handle it for efficient messaging	Difficult to deploy	M	M	M	Needs dynamic algorithms for integration to reduce delay and easy to deploy in real scenarios.

STNC: Space Time Networking Coding [14]	Scheduling: Made transmission frames.	Safe message dissemination. Avoid Collision.	Not good in sparse environment. Random access leads to issue of interaction among vehicles.	L	L	M	Needs to improve interaction for message distribution and sparse environment.

**** Congestion, Bandwidth and Delay quantities are represented as L: Low, M: Medium, H: High***

The scheme DEEP reduces message congestion using small segments but it is useful in rural areas only. It needs to be extend to urban areas. ACM scheme is also used to avoid message congestion but only for fixed and known mobility patterns. It needs to be extended for unknown mobility pattern also. CANCORE is used to control message storm but with the limitation of high cost due to encryption and decryption. CMP highlights a message congestion avoidance scheme but it needs a dynamic algorithm. DDA avoid message storm by using data aggregation but it reduces data throughput

2.6.1 Optimize Energy

In VANET, Energy or power is an important aspect which needs to be improved for reliable vehicle communication. It means that the network is not able to send the data in given or specific time so the energy needs to be increased [1]. It includes delay, routing and throughput in order to improve energy efficiency. Basically research for latency, delay and throughput is in progress just to gain optimized energy.

2.6.2 Delay

For vehicle communication time delay needs to be improved. Low delay rate is preferable for the sake of reliable communication. It is an important aspect of mobility in VANETs. Here nodes can be vehicles or road side units. DEEP [30], CANCORE [15], CMP [24] and DDA [21] are used for message congestion avoidance by reducing congestion rate but all these schemes have high delay. DEEP has segments that leads to high delay. CANCORE has encryption/decryption which will leads to high delay because of encoding/decoding of packets. CMP controls message transmission power which leads to delay by sending packet in limited power. Limited power leads to high delay in order to reach the destination. DDA also has a higher delay because of aggregation of the data.

2.6.3 Bandwidth

ACM and DEEP reduce message congestion to some extent but they need more bandwidth. ACM [25] also needs higher bandwidth for unknown mobility pattern because it has to send frequent messages repeatedly. DEEP [30] also needs a high bandwidth because of high transmission rate.

2.6.4 Throughput

It is based on rate of communication per time unit. Throughput or packet delivery ratio is the ratio of the number of packet received by the destination to the number of packet sent by the sender. Basically it is the major point that is to be considered in packet forwarding. Several essential factors such as packet size, action range, mobility of nodes and cluster size affect it. DDA [21] has low throughput due to dynamic data aggregation. It needs to achieve high throughput by using better dynamic algorithms.

2.7 Conclusion

This chapter has reviewed current literature on congestion avoidance schemes. After describing architecture of VANET and its challenges, a highlighted that how congestion is a major challenge in internet of vehicles. Brief description about messaging and its types is included before explaining of existing message congestion avoidance schemes. After comparison and various of schemes few more challenges are highlighted which can be improved by using the proposed scheme.

CHAPTER 3

METHODOLOGY: FOG ASSISTED ARCHITECTURE FOR VANET

3.1 Overview

In this chapter proposed fog assisted architecture for VANETs is described under the headings of opportunities and challenges for fog assisted VANET architecture. The role of fog computing in VANET is discussed briefly. Opportunities of fog assisted VANET explains the use of fog computing is useful for VANETs. Under heading of challenges of fog assisted VANET architecture limitations of fog computing in VANET are discussed. in detail.

3.2 Proposed Fog-assisted Architecture for VANETs

Fog assisted VANET is a structure that considers vehicles as permanent nodes and infrastructure acts as access points. The main difference between Fog assisted VANET and Vehicular Cloud Computing (VCC) is that it gives real-time and distributed services for a geo location. Vehicles as infrastructure in Fog assisted VANET reduces the extra cost of main infrastructure. Fog assisted VANET consists of multi-hop and moving features of vehicles to transfer information from one location to another. Moving vehicles provide good message carriers to transmit information by making new connections continuously. Fog assisted VANET have features like geo distribution and local decisions to connect with each other [46,47]. Particularly, when some vehicles act as communication hubs, they establish connection among the nearby vehicles. Due to these communication hubs, the fog is shaped to share communication resources locally, instead of sending data to cloud servers. It includes both localdecision making and geo distribution characteristics to reduce delay. Resultantly Fog assisted VANET provide better communications than VCC with less time delay and less cost for geo related vehicles [29]. Fog server is a local server that carries out computations locally. There are different ways to access fog server like smart devices access servers via internet while vehicles access fog servers by using wireless access points as shown in Figure 3.1. Fog server use the concept of distribution for load balancing and task sharing among different local fog servers (answer to (v & vi) research question).

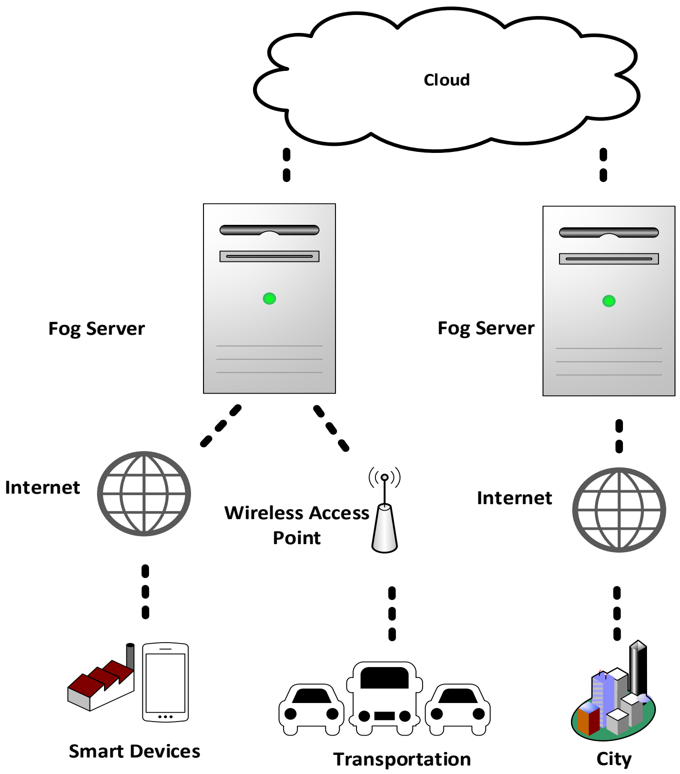

Figure 3.1: Proposed Fog Assisted Architecture

3.3 Opportunities for Proposed Fog assisted VANET Architecture

This section explains use of fog servers in VANETs. Fog assisted VANET opportunities highlight the usage of fog servers for communication among vehicles, production of novel vehicles, mobility strength and storage. Communication includes computation time by the vehicles. Mobility pattern means whether the vehicles are parked or moving. Uses of fog servers in VANETs are briefly discussed in this section.

3.3.1 Connectivity

Fog assisted VANETs provide very good connection among vehicles. Fog computing has resolved the major issue of connectivity in vehicular networks [17]. In fog environment router and vehicles act as nodes in order to provide better network connectivity [31]. It helps to avoid collision and data loss by using the concept of V2X.

3.3.2 Computation

Basically the concept of fog assisted VANET or vehicular fog computing is to compute tasks at edges, that is near to the source (vehicle) that results in less energy consumption (answer to (i) research question). Computation task at edges refers to edge computing where data is processed on network edges [37]. Computational nodes are many and distributed [37] [49]. Edge network consists of smart devices, base stations, internet and RSUs. Edge computing in VANETs results in shorter communication paths which leads to less delay and faster response.

3.3.3 Virtual server

Fog assisted VANETs provides virtual server opportunity rather than central servers [50]. It provides local computing, storage and processing of data. It leads to secure environment because it has hidden paths for communication. It also provides dynamic allocation means easy to access servers.

3.3.4 Energy Consumption

Fog assisted VANET reduces energy consumption by reducing traffic in the network [50]. Basically less traffic conserves less energy at the nodes (answer to (i) research question). It is especially useful in scenarios where devices have limited battery support.

3.3.5 Novel Applications

Fog assisted VANET not only offers internet based multimedia services but it also has provision for new internet applications referred to Intelligent Transportation System [51] [31]. Basically Fog assisted VANET focuses on end users and maintains data locally without involvement of third party. It leads to reduced latency and improved quality to perform storage and computational tasks (answer to (iii) research question)..

3.3.6 Mobility

Fog assisted VANET handles mobility of nodes (vehicles) such as track the vehicle location, control the expected traffic lights and give EMs alert to nearby vehicles dynamically [27]. It provides high mobility support [50] [49]. Actually fog server in VANETs helps to manage traffic using traffic signals, and sending EM alerts.

3.3.7 Vehicle Security

Fog server has ability to recognize an object and track it. Fog assisted VANET is also capable of providing vehicle security by recognizing the secret numbers and tracking features. Fog servers can act as sink for storing secured information from different vehicles scattered in large areas to provide real-time sensor readings. Fog server can also play the role of a central certification authority to assist in cryptographic operations.

3.3.8 Storage

Fog assisted VANET gives sufficient storage space for captured video streams to identify traffic violations and accidents. It also interprets video frames for the tasks like data mining and tracking. Fog server keeps the record of collected data that can be used for several novel applications. Fog server is also directly linked with a cloud that allows a much large storage capacity for VANET related information.

3.3.9 Low Latency

Fog assisted VANET reduces the latency by processing tasks on the edges [49] [50] . Basically it leads to low latency because of accessibility of cloud from RSU or the cellular network. Vehicles can access cloud services for availing live feedback regarding weather, global positioning and tracking the fellow vehicles. Fog server reduces the latency to access the data of these services by maintaining local backup.

3.3.10 Scalability

VANET researchers were focusing on scalable data dissemination by avoiding information repetition [6]. Fog assisted VANET supports high scalability instead of waiting for new updates in the system [50]. Being fog nodes vehicles are capable to form highly scalable and distributed fog environment [37] [49].

3.3.11 Hardware/Software Up-gradation

Without fog servers' vehicles needed experts to install recent software packages which lead to heavy cost [52]. This type of software/hardware updating was also limited due to delay and other constraints of cloud. Fog assisted VANET provides software /hardware updating on edges without facing delay and bandwidth constraints.

3.3.12 Vehicles as Infrastructure

Fog assisted VANET employs vehicles as infrastructure in order to avail best usage of communication and computational resources [29]. Basically it enhances the available resources for the sake of best usage.

3.3.13 Geographic Distribution

Fog assisted VANET provides best features for slow and stationary vehicles for geographic distribution like clustering and distribution on site [29]. Clustering is commonly used to resolve message storm [18]. Its deployment provides real scenario of interactions like V2V and V2I [53]. Fog components gives ideal platform to provide services for safe mobility and geo distribution. This allows to communicate with nearby vehicles.

3.3.14 Local Decision Making

Fog assisted VANET introduces local servers for decision making instead of remote server. It utilizes resource of nearby vehicle by using the concept of V2V communication e.g traffic lights. Fog nodes collect the data and process it in real time by sending data to a cloud.

3.3.15 Smart Traffic Lights

The traffic light nodes communicate with each other locally by using sensors, to identify the presence of cycles and pedestrians [53] [17]. Fog assisted VANET gives the opportunity of traffic light management in order to avoid accidents and smooth traffic flow. Video cameras and sensors are used to sense an emergency situation like an ambulance. After sensing emergencies fog nodes control traffic lights in order to clear the road.

3.4 Challenges

Fog assisted VANETs is a novel idea. It provides many opportunities but still there are some limitations that needs to addressed. These limitations may be used for future research work.

3.4.1 Structural Issues

In fog assisted VANETs, edge based network is used as computing infrastructure. These components consist of various processors that are general purpose which is a challenge [37]. Here, selection of nodes (vehicles) and resource configuration needs to be focused such as normal vehicle look for smart vehicle. Smart vehicles have ability to transfer message to fog server with in no time.

3.4.2 Detection/Sync

In fog assisted VANETs, run time applications may need a central server for communication. For this purpose, detection and synchronization of nodes is a challenging task [31].

3.4.3 Security Aspects

Fog assisted VANETs are considered as weak in security aspect. Basically fog computing is based on distributed concept, therefore it's difficult to manage security for several servers to authenticate the data on different gateways [17]. Security implementation is directly proportional to QOS of fog communication. It may affect services of fog communication [37] [48]. So that, it is difficult to deal with real time applications like VANET communication. Fog computing cannot decrypt data while privacy applications need encrypted data.

3.4.4 Resource Management

Fog assisted VANET needs to manage resources in order to utilize computation nodes and storage resources [50]. Nodes can be vehicles, base stations, RSU or a router. Computation nodes need to be cheaper in cost for V2V communication in order to send message to nearby vehicles. Several protocols and algorithms are needed to detect available resources and utilize them efficiently among vehicles. However, future research needs to explore new algorithms and techniques to share resources among nodes efficiently.

3.4.5 Capacity

We have seen that fog assisted VANET provides computation by using load balancing concept. However, vehicles need more storage capacity in order to process data in a real time environment [29]. In this context research can be used to explore dynamic algorithms and simulations for vehicle capacity improvement.

3.4.6 Storage Space

Fog assisted VANET gives the concept of local server for computation and communication. For the sake of reliable communication and computation enough storage space is required in a fog server [29]. In fact, storage space and time is basic constraint for any network. Less space may lead to high packet loss ratio. However, in this era dynamic techniques and algorithms are needed in future.

3.4.7 Deployment

Fog assisted VANET deployment for dynamic situations is quite a challenging tasks because it is based on several fog nodes or components. Fog nodes or components include servers, base stations, RSUs and vehicles [37].

3.4.8 Quality of Service

Quality of services is a challenging task in Fog assisted VANET in order to fulfill expected requirements [50]. As it is the key parameter in any communication network. VANET topology provides reliable communication for highly mobile vehicles. Delay should be minimized by retransmission in order to manage quality. Fault tolerance with QoS requirements is also a challenging task in this environment [37].

3.4.9 Mobility

Fog assisted VANET introduce mobility among vehicles by using geo distribution concept for known pattern of vehicles. Mobility for random patterns needs to be explored in future research work as highlighted in table 2.1.

3.4.10 Connection

Fog assisted VANETs based on fog servers provide connection among vehicles and other central units. Stored information in central units through fog server is used to inform nearby vehicles without repetition of data [37]. If fog server link goes down it will affect the entire network. Therefore, this area needs to be explored in future.

3.5 Conclusion

In this chapter fog based methodology for research work is discussed. Uses of fog computing are discussed in detail where it is highlighted how fog computing based architecture can be helpful to meet recent challenges. Challenges for fog computing are discussed to identify research areas and future work.

CHAPTER 4

PROPOSED ENERGY EFFICIENT MESSAGE DESSIMINATION SCHEME ($\boldsymbol{E^2}$MD)

4.1 Overview

In this chapter proposed solution is presented in the form of Energy Efficient Message Dissemination (E^2MD) scheme. The scheme is based on fog computing. This section includes headings as system model, proposed protocol and algorithms and fog based VANET opportunities and challenges. System model covers the proposed technology and fog based model for efficient messaging. In proposed protocol heading an efficient algorithm is explained step by step for messaging in a real time. Finally, it is highlighted that how fog computing is useful. Challenges fog based VANETs are also mentioned.

4.2 Energy Efficient Message Dissemination ($\boldsymbol{E^2MD}$) Scheme

Message Congestion has significant influence on information dissemination in IoVs and VANET. Several schemes have been proposed for information distribution in VANET but none of these provides the efficient approach to resolve congestion in

IoVs. Indeed, information dissemination schemes in VANETs are not sufficient in this modern era of life. This work has proposed a fog based model in IoVs scenario, for quick exchange of messaging among vehicles and fog servers smoothly by avoiding congestion. Basically it helps to avoid repeated messages when large number of messages are generated. In fact E^2MD helps to deliver messages timely which may help to save precious lives in the cases of emergencies. A list of notations used in E^2MD is given in table 4.1.

Table 4.1: List of Notations

AV	Abnormal Vehicle
EmT	Emergency Message Transmission
EMs	Emergency Messages
N	"number of" Packets
N	Nodes
NMs	Normal Messages
RL	Right Lane
SN	Sink Node
ML	Middle Lane
M_T	Total Messaging Cost
LL	Left Lane
V_{mn}, V_{mx}	Minimum and Maximum Velocity
V_c	Current Velocity
P_{size}	Packet Size
$R_{Packets}$	Received Packets
R_{ltv}, R_{htv}	Communication Range of LTV and HTV traffic
k	Constant
Cc	Congestion Control
GH	Group Head
GL	Group Leader

t_p	Transmission Power
Sv	Smart Vehicle
Bv	Basic Vehicle
Iv	Intelligent Vehicle
BU	Base Unit
acc_t	Accident transmit message
NbV	Nearby Vehicle
b_t	Beacon transmission
Div	Division for time
VS	Vehicle Selection

Major advantage of this research work is that EM^2D is based on real time scenarios where vehicles are acting as mobile nodes. Proposed scenario consist of fog server along one way roads, having three lines, fast, middle and slow respectively. Fog server helps to cater for normal or emergency events timely in order to avoid potential losses. In case of an emergency, to avoid more possible accidents, the urgent alert sent by AV is needed to be delivered to the nearby vehicles and reporting server in order to arrange quick response. Movement of vehicles provides good message carriers to transmit information by making new connections continuously. Due to these communication hubs, the fog server is used instead of sending data to cloud servers. Fog server shares communication resources locally, by local decision making and geo distribution characteristics in order to reduce delay. Basically Fog server acts as a local server in different manners.

4.3 System Model

In this scheme, the network consists of three distinct types of nodes. First one is SN (Sink Node) which is a fog server. SN has higher energy, memory, speed and computation power compared to other types of nodes. SN is responsible to inform upcoming traffic and police to clear the road. Second one GH (Group Head), has more energy, computation power and range than ordinary nodes. Basically, GH is a group leader which is selected on the basis energy and computation power. Third one is a simple Node (N) that has less energy, computation power and range than GH. The network is based on priority and groups as shown in Figure 4.1. Group is either controlled by GH or by both SN and GH. Simple nodes N have the ability to communicate with GH and neighboring nodes. GH acts as intermediate node between SN and N. There are three possible scenarios. In first case communication takes place through intermediate node GH. In Second case communication is made through normal nodes while in the third case GHs communicate with each other. In third case GHs are responsible for communication. AV sends message to a GH and the GH is responsible to find a fog server. Therefore, GH transfers message to another GH until a fog server is found. Here SN is the fog server.

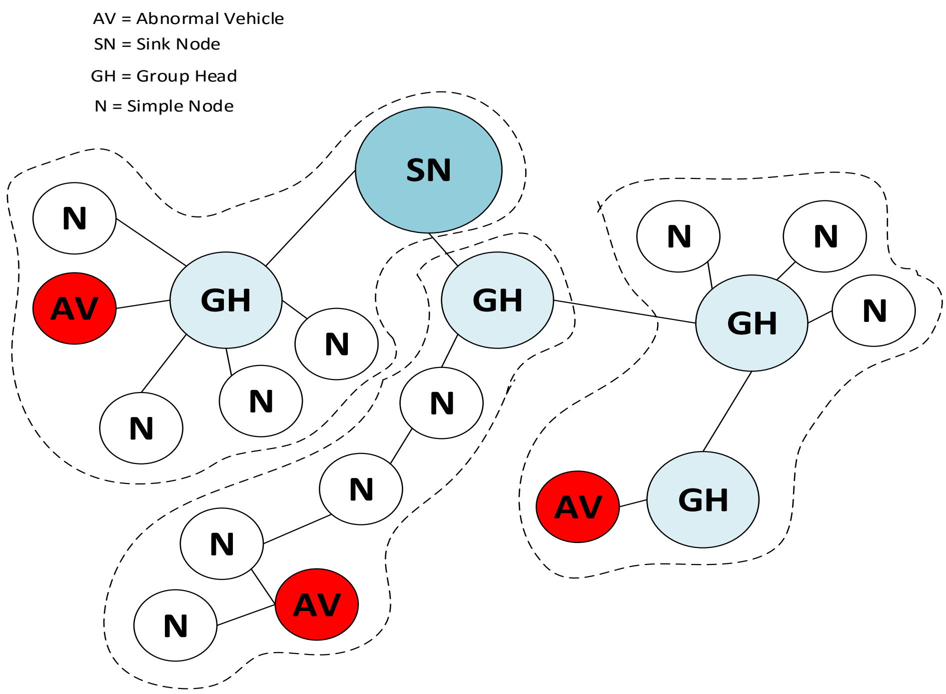

Figure 4.1: Proposed Model

In addition, the model is based on three cases. In first one AV informs SN through GH and SN stops AV and informs upcoming traffic through GH. In second case communication takes place through V2V concept while in third case GHs communicate with each other to forward the message until reach to SN. Hence all communication take place with the involvement of GH. The proposed scheme is dynamic and considers real scenario with multi hop communication to provide reliable communication. The scheme is based on fog computing, which helps to reduces bandwidth and delay by avoiding message repetition. Fog computing is used to support the mobile devices used by humans for communication for example, augmented reality and connected vehicles [52]. Fog computing gives a virtual platform that computes data on its edges. Fog computing has the concept of local server that brought cloud to the edges [31]. It is used to reduce latency and act as backbone for bandwidth saving in order to achieve better quality of service. In Figure 4.2 vehicles integrated with smart phones and internet, approach fog server directly. Vehicles with only mobile phones first access base unit and then communicate with fog server. Normal vehicles without any smart device or internet approach fog server through road side units, firstly send message to RSU then it sends it to fog server. Basic purpose of this architecture is to provide reliable communication. If road side units are not available in the area, then the messages can be sent through other vehicles by using V2V concept. Suppose there is no RSU in the range of a normal vehicle then it gives message to nearby vehicles in one hop only. Then the message is sent to fog server and it gets the response back from fog server. When the message reaches to fog server it contacts the abnormal vehicle with in no time in order to stop further messaging. Fog server replies at the same moment to the smart vehicle to inform abnormal vehicle. Fog server is considered as a local server as it computes the issue and contacts with in no time. In general fog assisted VANET gives better communications with less time delay and less cost for geo related vehicles.

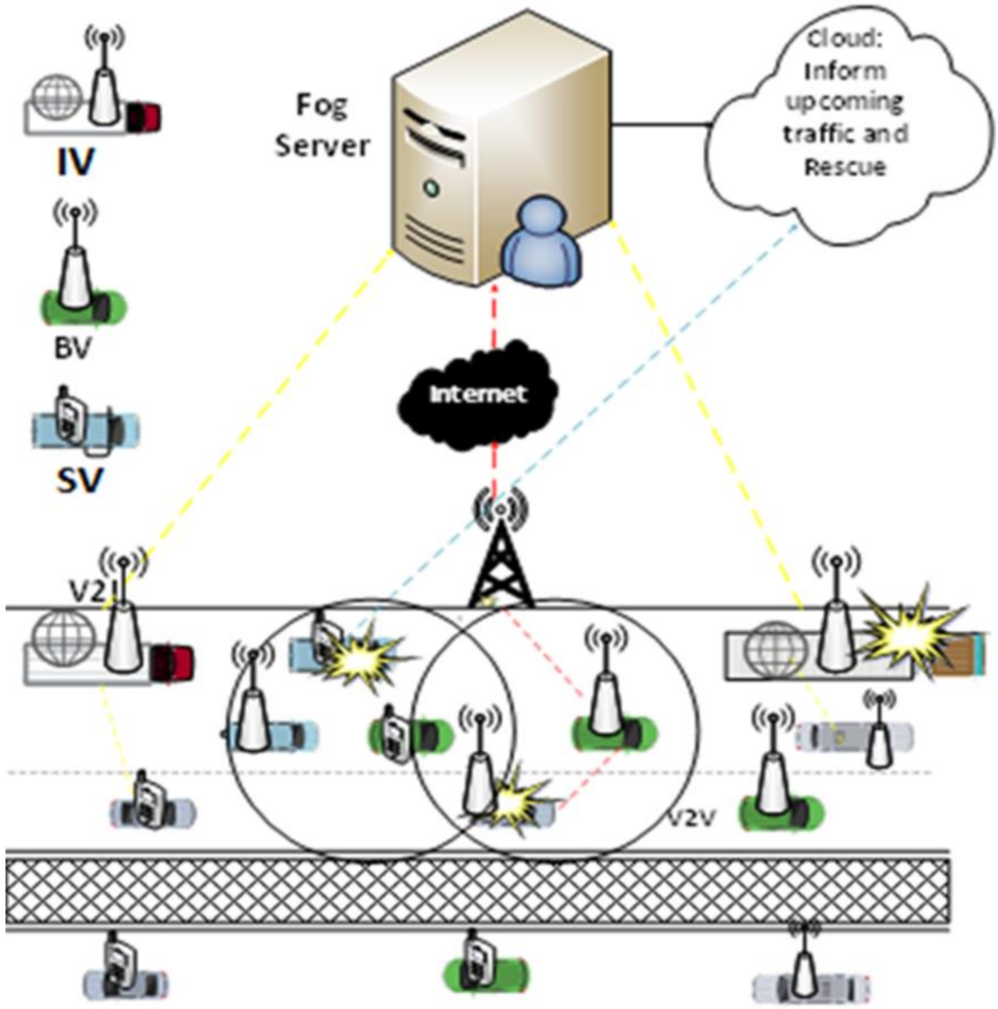

Figure 4.2: Proposed scenario for E2MD

4.4 Proposed E2MD Protocol

The proposed E2MD protocol is used to reduce congestion and provide efficient communication for IoVs. E2MD considers three types of vehicles based on their capabilities and availability of resources. First one is an Intelligent Vehicle (Iv) that can detect the obstacles and speed of vehicles by utilizing attached sensors. It can identify an accident and report to fog server directly by using internet and V2I sensors. It can maintain the history of driving on different tracks and also warns about fuel, temperature, water and oil level etc. In case of emergency, Iv can contact fog servers quickly as these are located on edges. Fog server calls rescue team for medical help and coordinates with police for road clearance. This to avoids more accidents. Second one is a smart vehicle (Sv) which contains wireless sensors that provide data to an application that is either vehicle embedded or interfaced with driver's smartphone. It uses internet to contact fog server directly. Third one is a Basic Vehicle (Bv) that transmits the data via V2I communication. In this case RSUs are involved to approach base station and then communicate with fog server because of unavailability of internet. An Sv with poor internet conditions is also forced to act as a Bv in case of emergency. Moreover, in case of the absence of nearby RSU, both type of vehicles can perform V2V communication until a vehicle is approached that can perform V2I communication as shown in Figure 4.2. Proposed solution is presented in two sub sections to discuss messaging by utilizing vehicle type support. A novel algorithm is also proposed to provide a stepwise solution for managing messaging in this section.

4.4.1 Vehicle Type based Messaging

Identify normal and abnormal condition of vehicle and activate communication unit for message dissemination. A vehicle node may act abnormally on the road, when excessive speed (velocity) or sudden change or tilt (angle) in moving direction is sensed. It can be categorized as an Abnormal Vehicle. A vehicle can turn into an AV because of its own mechanical breakdown or due to unexpected road hazards. When vehicle transmits message firstly it will be identified that whether it is normal message or emergency message by ordinary vehicle or AV respectively (answer to (iv) research question). If abnormal vehicle is Iv or Sv it can directly send message to a fog server for medical help and remove accidented vehicles from the road. If abnormal vehicle is BV, then it selects the most reliable vehicle from one hop neighbors instead of blind broadcasting which saves a lot of cost. Priority for the selection of reliable vehicle for next hop in the path is Iv > Sv > Bv as shown in Figure 4.3. Iv has the highest priority as it has direct path to fog server as it is equipped with V2I sensors and internet. GL is responsible to inform other vehicles in its range R in order to reduce the speed. Fog server is also supposed to approach medical servers for requesting medical help for rescue. It also informs auto recovery services to remove accidental vehicles from the road in order to avoid more collisions. It should also be ensured that all vehicles are secured near accident area. GL can transmit message in its range but cannot ensure that all upcoming traffic is informed about the danger. Every vehicle has its own storage, velocity and acceleration capabilities to affect the communication due to mobility. By using these steps proposed solution save the bandwidth by reducing transmission of repeated messages. AV should not transmit same message for help again because it sends it via a reliable route or vehicle to server. Similarly, GL transmits in its range to nearby vehicles by using V2V concept and all other vehicles are informed by server until congestion is cleared or the region with congestion is crossed. Therefore, it helps to avoid congestion by saving bandwidth and reducing delay.

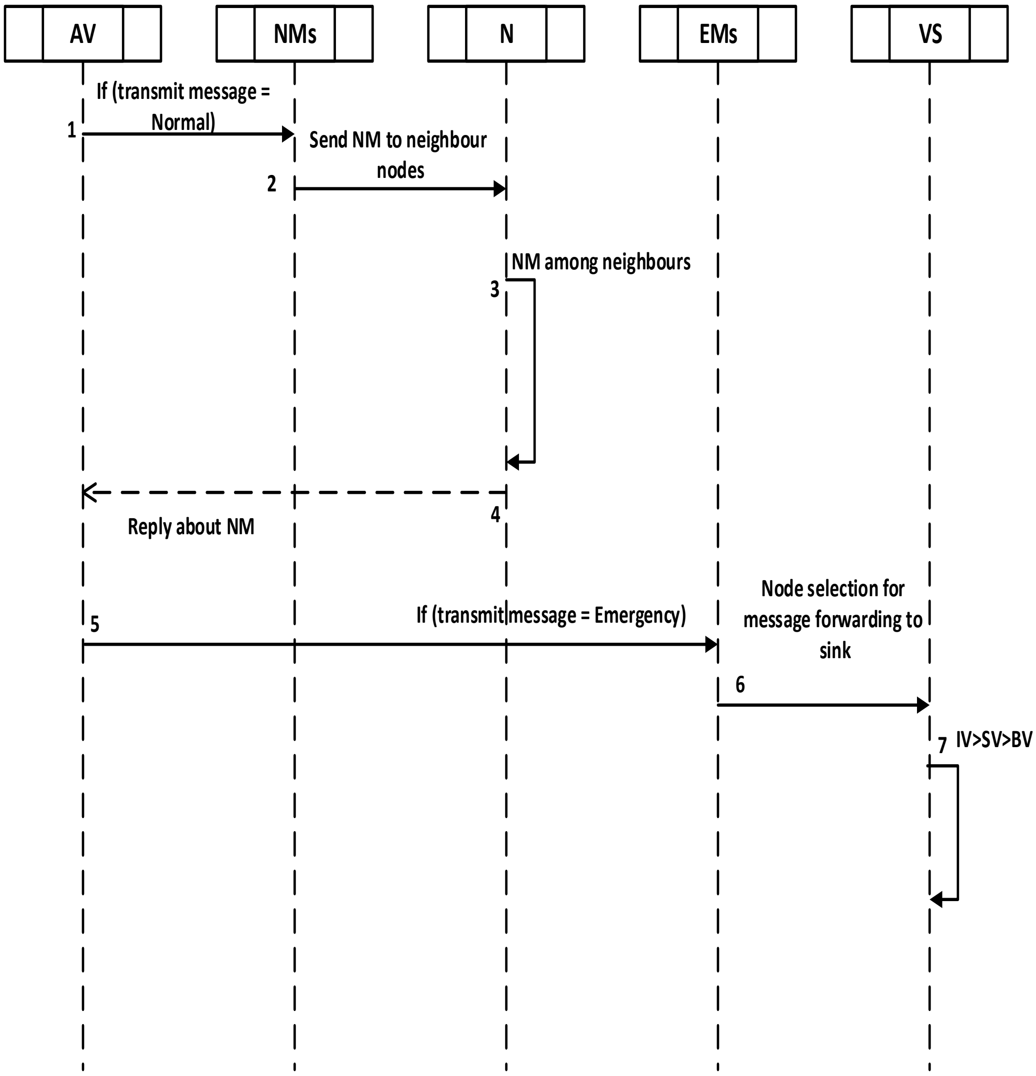

Figure 4.3: E2MD during messaging

4.4.2 Message Dissemination Algorithm

We have developed an algorithm to disseminate messages dynamically by utilizing the available capabilities of a vehicle. A stepwise description is given in Figure 4.4 and the algorithm is given below.

Algorithm for Message Dissemination (AMD)

```
// Accident occurred
If autoVehFlag is 1 AND inetFlag is 1 then
  Set V_TYPE = I_V
Else if inetFlag is 1
  Set V_TYPE = S_V
Else if RSUFlag is 1 then
  Set V_TYPE = B_V
End if
If V_TYPE equals I_V OR S_V AND inetFlag is 1 then
  Send_Message (Pkt) to fog server
Else
    Set SevConditionFlag to ON
    For i =1 to NeighborCount
      If NeighborList[i]equals I_V OR S_V
        Send_Message (Pkt) to fog server
        Set SevConditionFlag to OFF
        Break loop
      End If
    End For
    If SevConditionFlag is ON then
    Set SentMsgFlag to ON
     For k =1 to NeighborCount
      If NeighborList[k]contains RSU at one hop
        Send_Message (Pkt) to RSU
        Set SentMsgFlag to OFF
        Break loop
      End If
     End For
   End if
   If SentMsgFlag is ON then
    Send_Message (Pkt) to Neighbor ->Next_Vehicle
```

31. End if

32. End if

Steps (1) – (7): When accident occurs *autoVehFlag* and inetFlag is activated. A V2I sensors and internet are available to transmit messages, then select vehicle type as *Iv*. If only internet is available and there is no v2I sensors, then select vehicle as *Sv*. Finally, if *RSUFlag* is activated then select *Bv*, it shows absence of internet. Selection of vehicle is done on the basis of priority.

Steps (8) – (18): If the vehicle is *Iv* or *Sv* and internet is available then send message to fog server in order to approach rescue team for medical help and removal of accidented vehicle from the road. It helps to avoid more accidents. If the vehicle is *Bv* then severe condition flag IS activated and *NeighborCount* starts in order to count nearby vehicles having *Iv* and *Sv*.Then send message to the fog server through *Iv* or *Sv* and deactivate *SevConditionFlag.*

Steps (19) – (28): Check severe condition flag if it is activated then *SentMsgFlag* is turned on and find a vehicle nearest to RSU (one hop only). In this way message will reach to RSU through V2V communication. When messaged reaches to its destination then deactivate the *SentMsgFlag*.

Steps (29) – (32): Untill *SentMsgFlag* is activated keep sending message to nearby vehicles unless it reach a server.

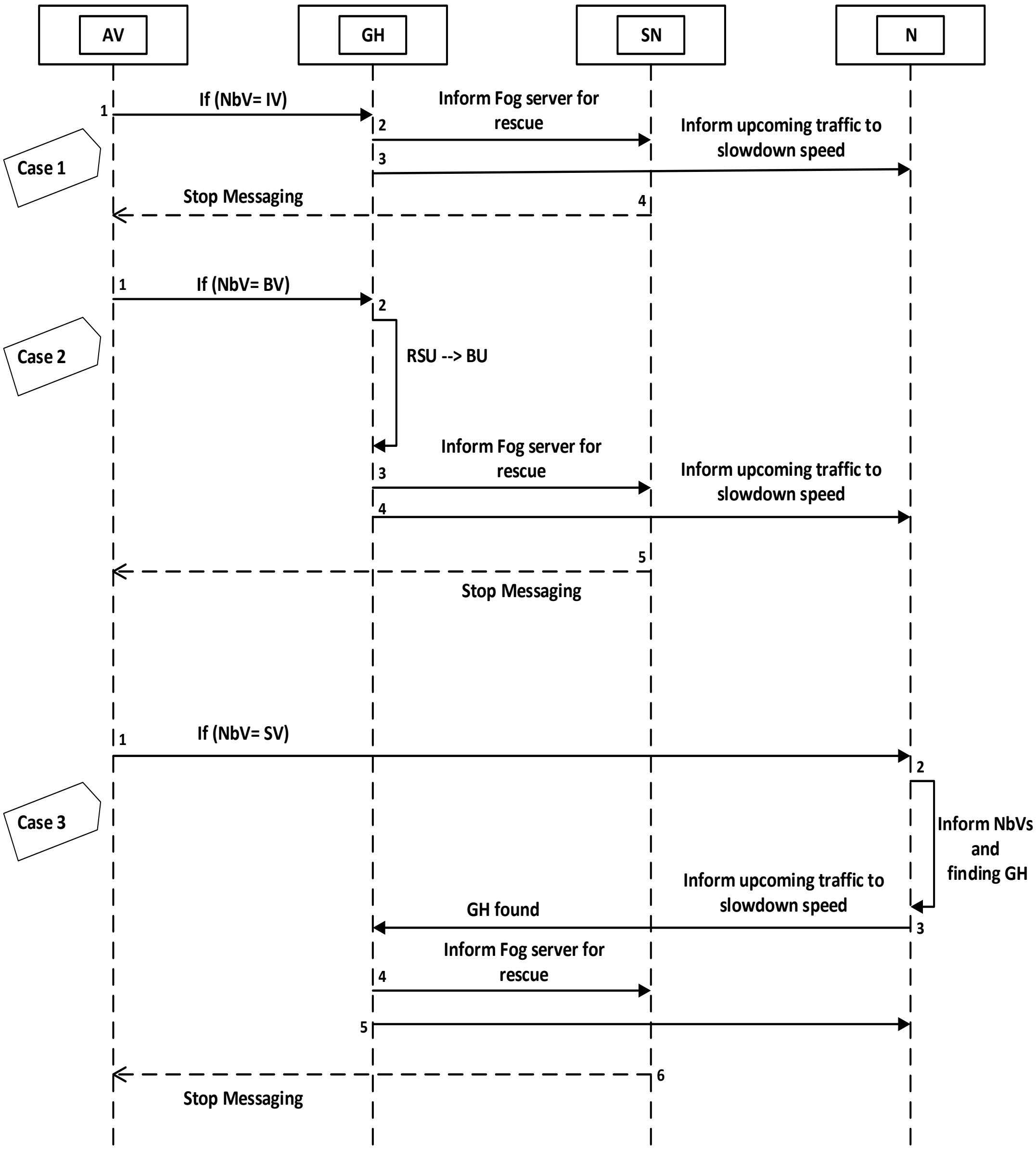

Figure 4.4: Flow diagram for AMD

4.5 Conclusion

In this chapter proposed scheme has discussed in detail by using algorithm and flow diagrams. Firstly, model for proposed scheme is discussed. And then model for proposed algorithm is explained.

CHAPTER 5

RESULTS AND ANALYSIS

5.1 Overview

This chapter includes comparison of existing schemes with the proposed scheme. Simulation is used for analysis and comparison of results. Comparison is based on strengths and limitations of existing and proposed algorithms. This section includes the simulation environment which is based on a real time scenario. It also presents curves for communication overhead and delay for comparison. Parameters used for the curves are sent messages and received messages. These parameters are used to compare packet drop ratio, packet delivery, delay and throughput.

5.2 Simulation Environment

NS2.35 has been used for proving efficiency of the proposed scheme. We have used Tool Command Language (TCL) and Practical Extraction and Report Language (PERL) for comparison the results. Both of these are scripting languages. TCL files are used for deployment and PERL script file is used for extracting results from trace files. There is another file similar to PERL file, known as awk file. This scripting language is used to read and write scripts. For simulation script of relevant formulas is written in awk file which extracts the results from the trace file. Trace file is produced after running the simulation, it has relevant information about all parameters like sent and received packets along with its specifications. LTV and HTV are two types of vehicles. LTVs are considered to have less energy consumption and transmission range than HTV. Transmission range of LTV and HTV is assumed to be 30 meters.

Deployment region for nodes is set to 100 x 2000 meters and sensing area to 120 m. A real time scenario is taken where all types of vehicles like *Iv*, *Sv* and *Bv* are moving. The vehicles are within allowed speed limits and range according to their type like LTV and HTV. Communication time among vehicles is set to 3 minutes. Within this communication time vehicle are supposed to send and receive messages. Configured nodes in simulation consist of three different sizes to represent vehicles and fog server. Simulation parameters are tabulated in Table 5.1.

Table 5.1: Simulation Parameters

Simulation Setup	
Parameters	***Values***
Deployment Region	100 x 2000 meters
GL Tx Radius	400 m
Sensing Radius	120 m
Tx Power at Node	0.819 µJ
Receiving Power	0.049 µJ
Queue Type	Queue/DropTail/PriQue
Antenna Type	Omni Directional
Routing Vehicles	*Iv, Sv and Bv*
Agent Trace	ON
Router Trace	ON
Neighboring Vehicles	05 – 30

We have simulated proposed E^2MD scheme and its performance has been compared with AFCS [12] and RMFF [45]. AFCS is the approach where vehicles are in a lane during communication. AFCS is not good approach because vehicles are considered in a lane which becomes worse from congestion perspective in a real scenario. RMFF is not good because in this scheme repeated messages are not handled properly. During message forwarding RMFF produces a large number of repeated messages. This repetition of messages increases average of message loss. Simulation results vary from situation to situation as the per the number of messages transmitted. Number of transmitted messages is directly proportional to the congestion which affects simulation results.

5.3 Performance Metrics

Under mentioned metrics are used to assess the performance of proposed E^2MD scheme. These metrics are used to highlight the strengths of the proposed scheme. Less communication overhead, delay and packet loss ratio makes any network more reliable, while high packet delivery ratio and throughput allows smooth communication in IoVs. In fact, smooth communication is only possible when there is less delay in packet delivery and less chance of packet drop.

i. Communication Overhead during Messaging
ii. Packet Delivery Ratio
iii. Packet Loss Ratio
iv. Message Transmission Delay
v. Throughput

5.3.1 Communication Overhead during Messaging

Communication overhead means transmission overhead during messaging. Transmission overhead refers to the total number of messages in network [54]. Communication cost is analyzed for the transmission of messages from the vehicle to the servers and then reply received by the initiating vehicle. Total messaging cost M_T

is sum of all costs as given in Equation 5.1 where M_{α} represents messaging cost for direct transmission by A_v to passing by vehicles. M_{β} represents messaging cost for EMs from passing by vehicles to their neighbors. M_{γ} represents the cost of indirect messaging to vehicles in the opposite direction and M_{ω} represents their forwarding cost.

$$M_T = M_{\alpha} + M_{\beta} + M_{\gamma} + M_{\omega} \tag{5.1}$$

Figure 5.1 shows communication overhead in terms of message count as a function of number of neighbors. The results clearly demonstrate that E^2MD incurs far less communication overhead compared to AFCS and RMFF. This is mainly because there is no chance of repeat messages due to good vehicle selection for reporting to fog server and upcoming traffic.

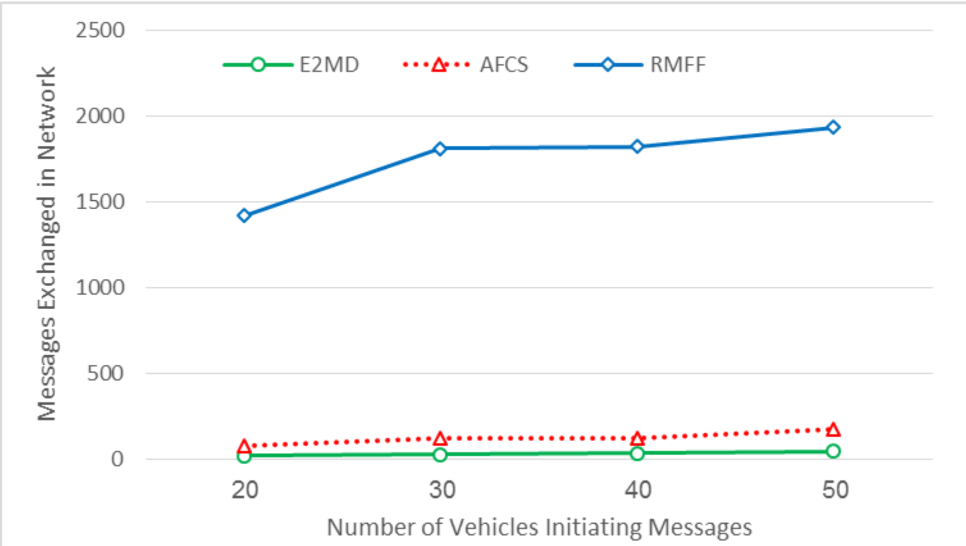

Figure 5.1: Communication Overhead during Messaging

The messaging overhead increases with the increased number of neighbors and more message sharing by multiple sources via internet. It is worth noting that E^2MD significantly reduces the communication overhead in congested networks as well. On the other hand, RMFF incurs highest messaging overhead for the dissemination of messages due to restricted flooding. In case of 5 vehicles in neighborhood in AFCS, A_v informs head node in one message then head node informs 4 other vehicles in the group so $M_\alpha = 5$. These 4 vehicles inform 2-hop away neighboring vehicles which means that $M_\beta = 5 * 4 = 20$ messages. Messages are also exchanged with vehicles in the opposite direction so $M_\gamma = 5$ when there are 5 vehicles in neighborhood. Then the messages are transmitted to further neighbors which means $M_\omega = 5 * 5 = 25$ messages. Therefore, $M_T = 45$ messages are exchanged. It will be worse if more number of vehicles are present as shown in Figure 5.1 where 20,30,40 and 50 vehicles are considered. Similarly, large number of messages are transmitted in case of RMFF but although vehicles drop repeated message but it adds to transmission cost. The proposed scheme sends message to one vehicle only and neighbors in one hop means $M_\alpha = 5$ messages are transmitted to vehicles in direct range. Messages are not forwarded to vehicles coming from opposite direction. Meanwhile server inform other upcoming traffic and hence dominates as compared to counterparts.

5.3.2 Packet Delivery Ratio

Packet delivery ratio (PDR) is a measure of packets received to the number of packets transmitted [55]as shown in Equation 5.2. Proposed scheme gives good packet delivery ratio than the existing schemes due to utilization of fog server. Fog server helps to reduce congestion caused by repetition of messages. E^2MD selects a reliable vehicle to pass messages to fog server. Fog server is used to inform rescue teams and upcoming traffic. AFCS and RMFF inform server and upcoming traffic through neighbouring vehicles. It causes congestion due to repetition of messages. To calculate PDR, proposed scheme and AFCS divide number of received packets by the number of sent packets. In RMFF received packets are divided by sum of received and dropped packets due to flooding as shown in Equations 5.2 and 5.3 respectively.

$$PDR = \frac{\sum(R_{packets})}{Sent\ Packets} \times 100 \tag{5.2}$$

$$PDR_{(RMFF)} = \frac{\sum(R_{packets})}{\sum(Dropped+R_{Packets})} \times 100 \quad (5.3)$$

Figure 5.2 shows PDR in terms of message transmission among number of neighboring vehicles successfully. This research has considered real scenario where vehicles transmit different number of messages like 20, 30, 40 or 50. Number of messages depends upon number of vehicles. For example, dense areas have large number of vehicles so that number of messages is also large. When there is sparse environment with less vehicles, then automatically it will cause less message congestion. Less message congestion leads to good packet delivery. Basically there is less chance of packet loss in limited congestion. Dense environment has move message congestion than sparse environment. In AFCS messages are forwarded through nearby vehicles, that is, each vehicle transmits same messages in its range which results in higher congestion. RMFF schemes creates a flood of repeated messages which results in higher congestion. As we have seen high congestion leads to lower PDR. However, proposed scheme handles repeated messages by introducing three distinct types of vehicles and uses fog server. It helps to avoid repeated messages by sending message through a reliable vehicle only. The results clearly demonstrates that E^2MD has significantly higher PDR compared to AFCS and RMFF.

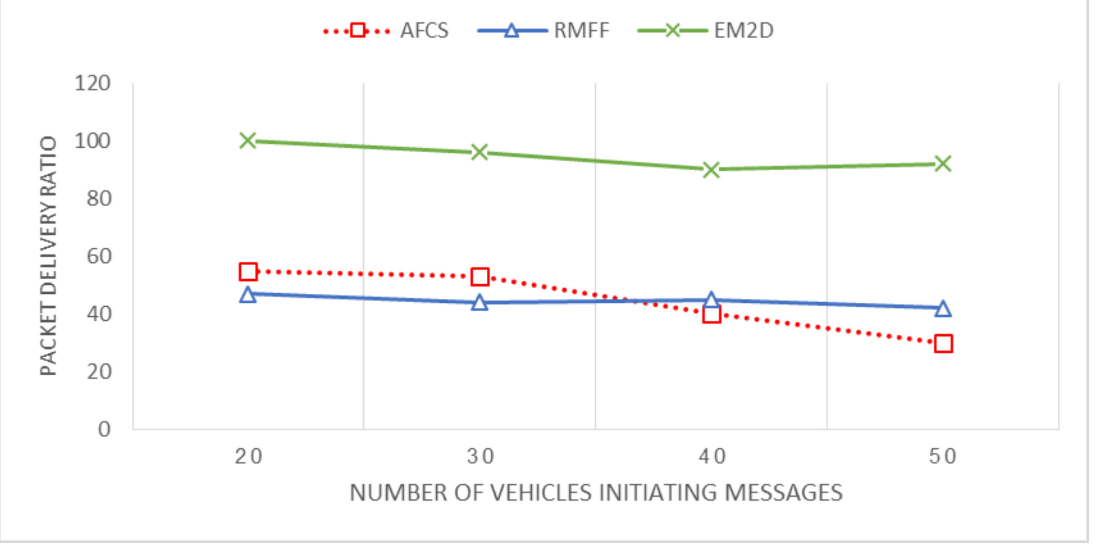

Figure 5.2: Packet Delivery Ratio for Emergency Messages

5.3.3 Packet Loss Ratio

Packet Loss Ratio (PLR) is a measure of dropped messages during packet transmission from source to destination. Proposed scheme E^2MD provides less packet loss ratio than the existing schemes AFCS and RMFF. In existing schemes repeated messages causes congestion and higher message congestion leads to a higher packet loss. Packet loss is very critical in the case of emergency messages. If EMs are not delivered in time it may result in more deaths due to accidents. E^2MD provides less PLR due to intelligent use of fog based scenario and by having three types of vehicles. The proposed scheme helps to reduce the amount of congestion due to less number of repeated messages. Figure 5.3 shows PLR in terms of messages lost during packet transmission. To calculate PLR, we need to subtract received messages from the sent packets. In fact, number of dropped messages is used to calculate average of packet loss. This research has considered a real scenario having different number of messages like 20, 30, 40 or 50 sent from source to destination. Results vary according to transmitted number of messages as small number of packets gives less PLR than large number of transmitted packets. The results clearly demonstrate that $\mathrm{E}^2\mathrm{MD}$ incurs far less PLR compared to AFCS and RMFF.

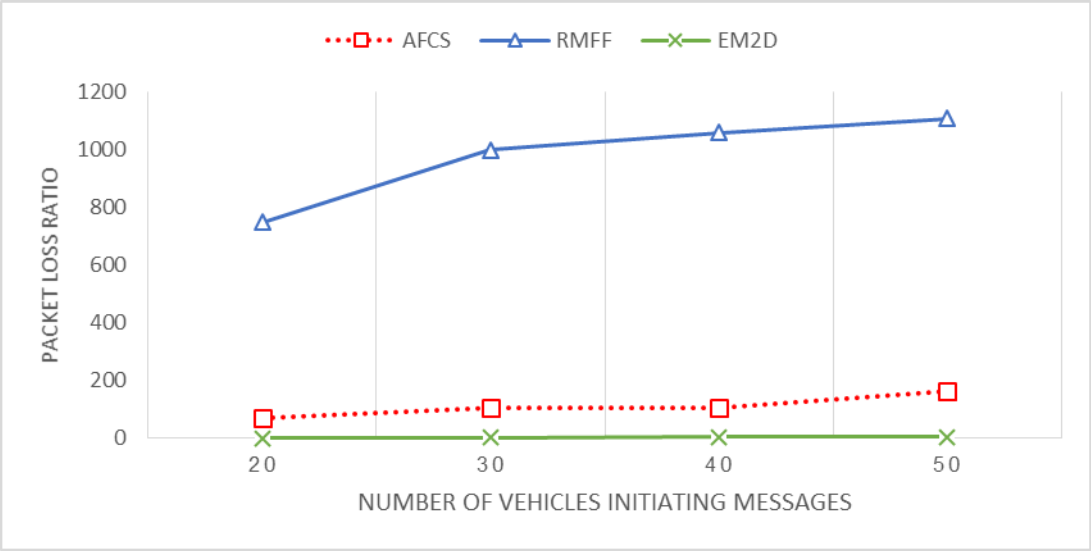

Figure 5.3: Packet Loss Ratio during Message Dissemination

5.3.4 Message Transmission Delay

Message Transmission Delay is the average time taken by n messages to reach the destination. End to End delay is the amount of time taken from source node to the destination [56] as shown in Equation 5.4. With respect to a real time scenario with following limitations $V_{mn} \leq V_c \leq V_{mx}$ where RL is from 100 to 150mph, ML is from 70 to 100mph and LL is from 10 to 70mph. According to these equations speed of vehicles must be with in limit and as per traffic to rules, neither more nor less. In right lane LTV traffic having small cars may travel at a fast speed. In middle lane vehicles can travel with normal speed while in left lane HTV traffic with large vehicles comprising of trucks and loaders can travel. Communication range of LTV vehicles must be less than HTV like $R_{ltv} \leq R_{htv}$. Speed of vehicles should not exceed the limits as $Acc \leq k\{(V_{mx})^2 - (V_C)^2\}$. Figure 5.4 shows the average delay during messaging transmission from AV to the server. Average delay for proposed scheme and AFCS is calculated using Equation 5.4. While average delay for RMFF [40] is calculated as $Delay_{avg} = \frac{n}{2r}$.

$$Delay_{avg} = \frac{\sum(End-to-End\ delay)}{\sum(R_{Packets})} \tag{5.4}$$

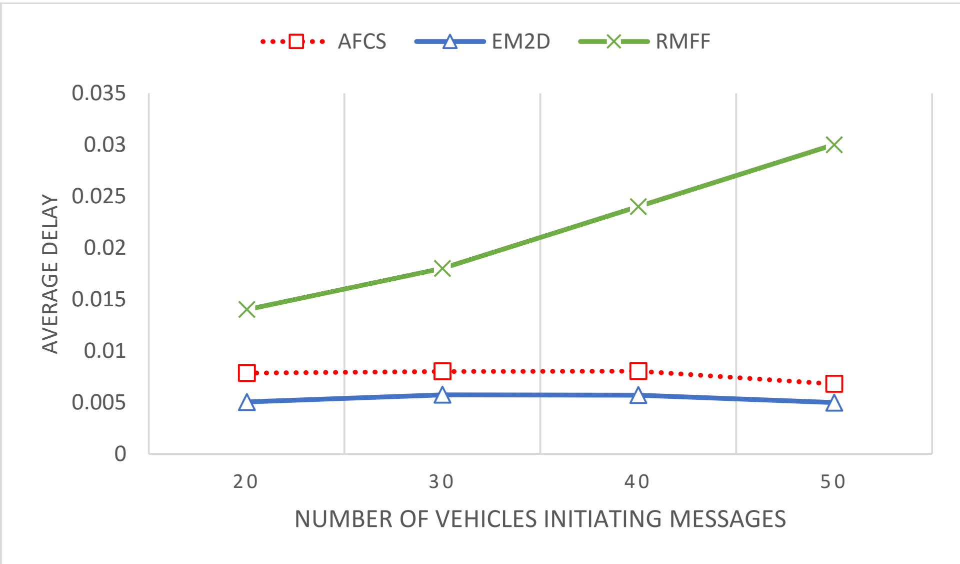

Figure 5.4: Average Delay for Message Dissemination

We use different formula for delay calculation of RMFF scheme. Number of sent packets is divided by twice the number of received packets (2r). In different cases when there are distinct neighbors around the AV then average time delay varies in milliseconds as shown in Figure 5.4. Our scheme is the best with only 0.005 millisecond delay.

5.3.5 Throughput

Throughput is a measure of received packets at the destination per unit time. It helps to analyse the performance of a network. Figure 5.5 shows the throughput in terms of message delivery in a given time. This research has considered a real scenario having different number of messages like 20, 30, 40 or 50 sent from source to the destination. Average throughput is calculated by using Equation 5.6 [2] [56]. The results clearly demonstrate that E^{2}MD shows better throughput compared to AFCS.

$$Throughput_{Avg} = \frac{R_{Packets}}{Delay_{avg}} \times \frac{P_{size}}{1000} \quad (5.6)$$

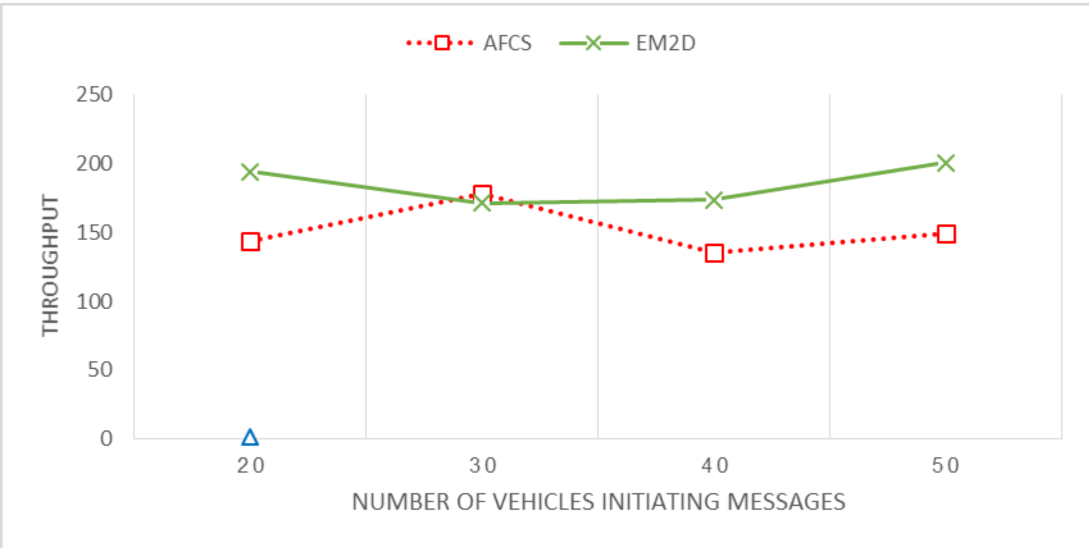

Figure 5.5: Throughput for the Emergency Message Transmission from Vehicles

5.3.6 Energy Consumption

Energy consumption highlights the consumed energy during messages dissemination. It leads to analyse the efficiency of a network. Figure 5.6 shows the energy consumption in terms of message delivery. Energy consumption is measured in micro joules. This research has considered a real scenario having different number of messages like 20, 30, 40 or 50 sent from source to the destination. The results clearly demonstrate that E^2MD consumes less energy compared to AFCS and RMFF.

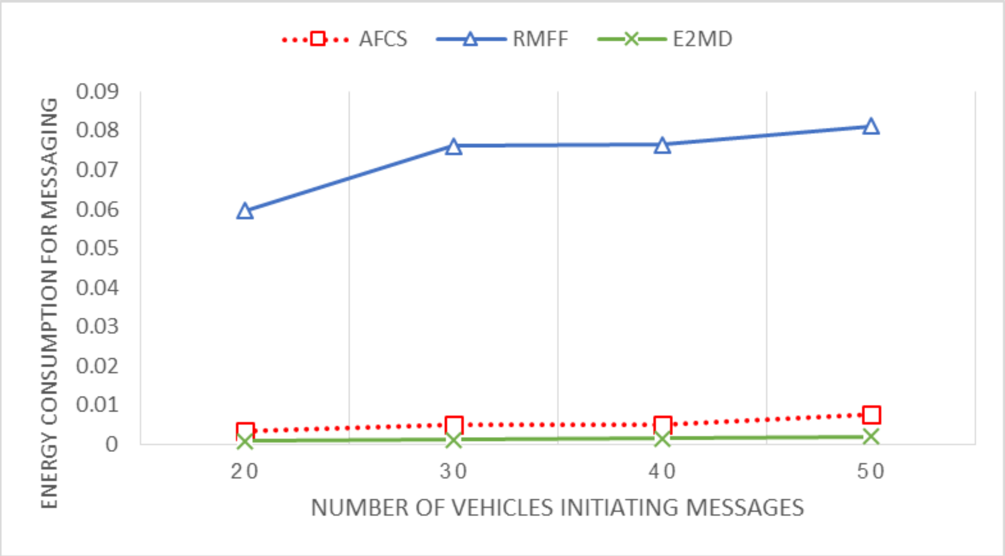

Figure 5.6: Energy Consumption for Messages

5.4 Conclusion

Initially simulation environment and performance metrics were describing in this chapter. Simulation environment give details about the platform for simulation. Performance metrics are specified to highlight the strengths of the proposed scheme. After comparison of proposed scheme and other schemes, it is concluded that our proposed scheme is better than AFCS and RMFF schemes on the basis of PDR, PLR, communication overhead and message delay time.

CHAPTER 6

CONCLUSION AND FUTURE WORK

6.1 Overview

This chapter concludes of this research work and gives ideas about future research. Achievements of our work and its impact on society are discussed. Future work highlights future possible enhancements in the role of fog computing for different VANET scenarios. These future directions are expected to help the researchers to explore this area further.

6.2 Summary of Research Work

IoVs is a collection of vehicles that are connected via internet. IoVs consist of thousands of vehicles, supposed to communicate with each other for a variety of reasons. Message Congestion is a major challenge in vehicle communication which may lead to more accidents. Message congestion occurs when same messages are transmitted repeatedly in case of accidents. The repeated messages lead to packet drop accidents which results in poor communication and may cause in more accidents. To address this problem, E^2MD scheme has been proposed for efficient message delivery and to reduce congestion. Proposed work is based on fog computing which gives a sense of local servers for information processing and distribution. The scheme helps to reduce accidents in a real scenario. It not only caters for smart vehicles but also takes care of normal vehicles where internet is not available. These vehicles do not have the ability to transmit and receive data. The proposed solution also works in scenario where server is not in the range of vehicle.

This work also explains about fog architecture its opportunities and challenges. Several messaging schemes in VANET and Fog scenario have been presented. We have also focused on congestion avoidance and congestion control based schemes. A taxonomy of related schemes maintained that is subdivided into static and dynamic schemes where the latter is suitable for VANET due to its mobility support. Schemes have been compared in tabular form to highlight the strengths and limitations of each scheme. Proposed Fog assisted VANET architecture is well suited for efficient messaging as compared to existing VANET based communication architectures. The proposed architecture also efficiently achieves congestion avoidance and control. Moreover, a number of possible opportunities are explored that facilitate the V2V and V2I communication. It explores the role of smart vehicles which are equipped with synchronized cellphones and internet facility in addition to RSUs. It also explores the level of various metrics including delay, bandwidth and transmission range that are a must for optimal performance. Research work is based on multi hop and complex urban environments. We have performed simulation in NS2.35 in order to prove efficiency of the proposed scheme. Tcl files are used for deployment and PERL script file is used for extracting results from trace files. Performance of the scheme has been compared with AFCS and RMFF to gain highlight its achievements (in section 6.2) .

6.3 Achievements

Achievements of this research work is the improvements made in various metrics. It has improved the overall VANET communication system. Following metrics have improved to reduce message congestion during communication.

i. Communication Overhead

ii. Packet Delivery Ratio
iii. Packet Loss Ratio
iv. Average Delay
v. Throughput

Simulation results have shown highly improved performance for PDR, PLR, delay, bandwidth and transmission overhead. E^2MD has improved the message delivery cost by 108% than AFCS and RMFF while decrease messages overhead cost by 73% and 98% than AFCS and RMFF respectively.

6.4 Future work

A number of new open challenges have been discussed in the research work for the researchers to work in this area Some of the research areas are as follows.

i. It need to work on the measurements of several entities for more reliable communication like measure the impact on variations of queue size interface during congestion due to emergency message dissemination.
ii. Needs to work for a scenario where AV has been damaged and it is unable to inform nearby vehicles and other central units.
iii. Work may be done on weak areas for different algorithms mentioned in table 2.1.

References

[1] F. Domingos, D. Cunha, A. Boukerche, L. Villas, A. Carneiro, A. Viana and A. F. Loureiro, "Data Communication in VANETs: A Survey, Challenges and Applications," *(Doctoral dissertation, INRIA Saclay; INRIA),* 2014.

[2] M. S. Khabazian, A. M. Aissa and Mehmet-Ali, "“Performance modeling of message dissemination in vehicular ad hoc networks with priority," *” IEEE J. Sel. Areas Commun ,* vol. 29, no. 1, pp. 61–71,, Jan. 2011.

[3] K. Ghafoor, Zrar, J. Lloret, B. Kamalrulnizam, Safa, A. S. Sadiq, Ali and B. Mussa, "Beaconing Approaches in Vehicular Ad Hoc Networks: A Survey," *Wireless Personal Communication,* vol. 73, no. 3, pp. 885-912, 2013.

[4] W. Sushama, P. S. Choudhary and M, "Data Dissemination in Software Defined Vehicular Ad hoc Network: A Review," *International Research Journal of Engineering and Technology (IRJET),* vol. 4, no. 1, pp. 1-4, 2017.

[5] S. Panichpapiboon and W. Pattara-atikom, "A Review of Information Dissemination Protocols for Vehicular Ad Hoc Networks," *IEEE Communications Surveys & Tutorials,* vol. 14, no. 3, pp. 784-798, 2012.

[6] M. Chaqfeh, A. Lakas, "A survey on data dissemination in vehicular ad hoc networks," *Vehicular Communications,* vol. 1, no. 1, pp. 214-225, 2014.

[7] A. Julio, M. Sanguesa, P. Fogue, F. Garrido, J.Martinez and C. T. Cano, "A Survey and Comparative Study of Broadcast Warning Message Dissemination Schemes for VANETs," *Mobile Information Systems,* vol. 2016, pp. 1-19, 2016.

[8] G, K. L. Hampel, J. D. Clarkson, A. P. A. Hobby and Polakos, "“The tradeoff between coverage and capacity in dynamic optimization of 3G cellular networks,”," in *Vehicular Technology Conference, 58th, vol. 2, pp. 927-932. IEEE*, 2003.

[9] W. Kuo, Y. Tung and S. Fang, "A node management scheme for R2V connections in RSU-supported Vehicular ad-hoc networks," in *Computing, Networking and Communications (ICNC) IEEE PP. 768-772*, 2013.

[10] Sousanis, "World vehicle population tops 1 billion units," *in WardsAuto,* pp. 99-102, 12 Aug 2011.

[11] Ben-Jye, Y. H. Chang, A. Y. D. Liang and Huang, "Efficient Emergency Forwarding to Prevent Message Broadcasting Storm in Mobile Society via Vehicle-to-X

Communications for 5G LTE-V," *International Computer Symposium (ICS),* pp. 479-484, 2016.

[12] Ben-Jye, Y. H. Chang, A. Y. D. Liang and Huang, "Adaptive message forwarding for avoiding broadcast storm and guaranteeing delay in active safe driving VANET," *Wireless Network*, vol. 21, no. 3, pp. 739-756, 2015.

[13] S. Schwarz and M. Rup, "Society in motion: challenges for LTE and beyond mobile communications," *IEEE Communications Magazine,* vol. 54, no. 5, pp. 76-83, 2016.

[14] X. Shen, X. Cheng, L. Yang, R. Zhang and B. Jiao, "Data Dissemination in VANETs:A Scheduling Approach," *IEEE Transactions on Intelligent Transportation Systems,* vol. 15, no. 5, pp. 2213-2223, 2014.

[15] H. Kang, H. Yoo, D. Kim and Y. Chung, "CANCORE: Context-Aware Network COded REpetition for VANETs," *IEEE Access,* vol. 5, pp. 1-9, 2017.

[16] S. Asad-Hussain, M. Iqbal, A. Saeed, I. Raza and H. Raza, "An Efficient Channel Access Scheme for Vehicular Ad Hoc Networks," *Hindawi Mobile Information Systems,* vol. 2017, pp. 1-11, 2017.

[17] M. Xiaomin, K. Gabe and S. T. Kishor, "Application-level Scheme to Enhance VANET Event-driven Multi-hop Safety-Related Services," in *Workshop on Computing, Networking and Communications (CNC). pp. 860-864,* Durham, 2017.

[18] S. Ucar, S. Ergen, Coleri and O. Ozkasap, "Multihop-Cluster-Based IEEE 802.11p and LTE Hybrid Architecture for VANET Safety Message Dissemination," *IEEE Transactions on Vehicular Technology,* vol. 65, no. 4, pp. 2621-2636, 2016.

[19] W. Xu, H. Zhou, N. Cheng, F. Lyu, W. Shi, J. Chen and X. Shen, "Internet of Vehicles in Big Data Era," *Journal of Automatica Sinica,* vol. 5, no. 1, pp. 19-35, 2018.

[20] Y. Fangchun, S. L. Jinglin, L. Zhihan and S. Qibo, "An Overview of Internet of Vehicles," *China Communications,* vol. 11, no. 10, pp. 1-15, 2014.

[21] Rakesh, M. Kumar and Dave, "A Framework For Handling Local Broadcast Storm Using Probabilistic Data Aggregation In VANET," *Wireless Personal Communication,* vol. 72, no. 1, pp. 315-341, 2013.

[22] D. Lin, Y. Tang, F. Labeau, Y. Yao, M. Imran, V. Athanasios and Vasilakos, "Internet of Vehicles for E-Health Applications: A Potential Game for Optimal Network Capacity," *IEEE Systems Journal,* vol. 11, no. 3, pp. 1888-1896, 2017.

[23] J. Wan, J. Liu, Z. Shao, V. Vasilakos, Athanasios, M. Imran and K. Zhou, "Mobile Crowd Sensing for Traffic Prediction in Internet of Vehicles," *IEEE Sensors,* vol. 16, no. 1, pp. 1-15, 2016.

[24] B. Munir, M. Asif, A. Wagan and H. Hasbullah, "Efficient Congestion Control in VANET for Safety Messaging," *In Information Technology Simposium (ITSim),* vol. 2, pp. 654-659, 2010.

[25] S. Park and Y. Yoo, "Network Intelligence Based on Network State Information for Connected Vehicles Utilizing Fog Computing," *Hindawi Publishing Corporation,* vol. 2017, pp. 1-9, 2017.

[26] A. Malathi and N. Sreenath, "A Comparative study of clustering protocols in VANET," *International Journal of Emerging Trends & Technology in Computer Science (IJETTCS),* vol. 6, no. 1, pp. 11-20, 2017.

[27] S. Yi, C. Li and Q. Li, "A Survey of Fog Computing: Concepts, Applications and issues," in *Proceedings of the 2015 Workshop on Mobile Big Data ACM. (pp. 37-42).*, 2015.

[28] P. Kukreja and D. Sharma, "A Detail Review on Cloud, Fog and Dew Computing," *International Journal of Science, Engineering and Technology Research (IJSETR),* vol. 5, no. 5, pp. 1-9, 2016.

[29] X. Hou, Y. Li, D. Wu, D. Jin and S. Chen, "“Vehicular Fog Computing: A Viewpoint of Vehicles as the Infrastructures”," *IEEE Transactions on Vehicular Technology,,* vol. 65, no. 6, pp. 3860-3873., JUNE 2016.

[30] M. C. Chuang and M. Chang Chen, "DEEP: Density-Aware Emergency Message Extension Protocol for VANETs," *IEEE Access,* vol. 5, no. 10, pp. 3504-3512, 2013.

[31] R. Merino, L. Vaquero "Finding your way in the fog: Towards a comprehensive defininition of fog computing.," *SIGCOMM Computer Communication Review,* vol. 44, no. 5, pp. 27-32, 2014.

[32] L. Sichitiu and K. Maria, "Inter-Vehicle Communication Systems:A Survey," *IEEE Communications Surveys & Tutorials,* vol. 10, no. 2, pp. 88-105, 2008.

[33] R. Kumar and M. Dave, "A Comparative Study of Various Routing Protocols in VANET," *International journal of computer science,* vol. 8, no. 4, pp. 643-648, 2011.

[34] L. Long, B. Roberto, S. Pablo, F. Andreas and Z. Wenhui, "Performance Evaluation of Beacon Congestion Control Algorithms for VANETs," in *Global Telecommunications Conference (GLOBECOM), pp. 1-6.*, Europe, 2011.

[35] X. Yang, J. Liu, F. Zhao and N. H. Vaidya, "A Vehicle-to-Vehicle Communication Protocol for Cooperative Collision Warning," in *MOBIQUITOUS. First Annual International Conference. pp.114-123*, 2004.

[36] B. Bihari, N. Dubey, P. Chauhan and Kumar, "A Survey on Data Dissemination Techniques used in," *International Journal of Computer Applications,* vol. 10, no. 7, pp. 5-10, 2010.

[37] R. Mahmud, R. Kotagiri and R. Buyya, "Fog Computing: A Taxonomy, Survey and Future Directions," *In Internet of Everything,* pp. 103-130 Springer Singapore, 2018.

[38] K. Rakesh and Kumar, "VANET Parameters and Applications: A Review," *Global Journal of Computer Science and Technology* , vol. 10, no. 7, pp. 1-6, 2010.

[39] M. Yusof and K. B. Darus, "A Review of Congestion Control Algorithm for Event-Driven Safety Messages in Vehicular Networks," *International Journal of Computer Science Issues,* vol. 8, no. 5, pp. 49-53, 2011.

[40] S. Grover and P. Mittal, "A Novel Model based on Group Controlled Observation for DDOS Attack Detection and Prevention in VANET," *Indian Journal of Science and Technology,* vol. 9, no. 36, pp. 1-6, 2016.

[41] C. Thompson, J. White, B. Dougherty, A. Albright and Douglas, "Using Smartphones to Detect Car Accidents and Provide Situational Awareness to Emergency Responders," in *International Conference on Mobile Wireless Middleware, Operating Systems, and Applications pp. 29-42 Springer Berlin Heidelberg.*, 2011.

[42] P. Roma and J. Gayatri, "Traffic Congestion Detection and Management Using VANET," *International Journal of Advance Research and Innovative Ideas in Education,* vol. 2, no. 3, pp. 1274-1280, 2016.

[43] A. Fanca, A. Puşcaşiu and H. Vălean, "Accident Reporting and Guidance System with automatic detection of the accident", in *ICSTCC pp.150-155,* Siania Romania, 2016.

[44] S. A. C. Omar, "Enhancing Safety Messages Dissemination over 802.11p/DSRC," in *User Mobility and Vehicular Networks,* Canada, 2013 (pp.179 - 187).

[45] S. Sattar, H. Khaliq - Qureshi, M. Saleem, S. Mumtaz and J. Rodriguez, "Reliability and energy-efficiency analysis of safety message broadcast in VANETs," *Computer Communications,* pp. 1-9, 2018.

[46] S. Djahel and Y. Ghamri-Doudane, "A Robust Congestion Control Scheme for Fast and Reliable Dissemination of Safety Messages in VANETs," in *IEEE Wireless Communications and Networking Conference: Mobile and Wireless Networks pp. 2264-2269,* France, 2012.

[47] M. Li, K. Zeng and W. Lou, "Opportunistic broadcast of event-driven warning messages in Vehicular Ad Hoc Networks with lossy links," *Computer Networks,* vol. 55, pp. 2443-2464, 2011.

[48] I. Stojmenovic and S. Wen, "The Fog Computing Paradigm: Scenarios and Security Issues," in *Federated Conference on Computer Science and Information Systems, pp. 1–8*, 2014.

[49] Amir, Vahid, H. Dastjerdi, R. Gupta, N. Calheiros, Soumya and B. K. Ghosh, Fog Computing: Principles,Architectures, and Applications, arXiv preprint arXiv:1601.02752, 2016.

[50] G. Varun and Menon, "Moving From Vehicular Cloud Computing to Vehicular Fog Computing:Issues and Challenges," *International Journal on Computer Science and Engineering (IJCSE),* vol. 9, no. 5, pp. 0975-3397, 2017.

[51] B. Yuanguo, "Neighboring vehicle-assisted fast handoff for vehicular fog communications," *Peer-to-Peer Netw. Appl.,* pp. 1-11, 2017.

[52] M. Chiang and T. Zhang, "Fog and IoT: An Overview of Research Opportunities," *IEEE Internet of Things Journal,* vol. 3, no. 6, pp. 1-11, 2016.

[53] F. Bonomi, R. Milito, J. Zhu and S. Addepalli, ""Fog computing and its role in the internet of things"," in *Proceedings of the first edition of the MCC workshop on Mobile cloud computing pp. 13-16 ACM.,* 2012.

[54] K. H. Han, Y. B. Ko and J. H. and Kim, "A Novel Gradient Approach for Efficient Data Dissemination in Wireless Sensor Networks," in *IEEE Vehicular TechnologyConference,* 2004.

[55] Vegni, S. Anna Maria, A. N. Alessio and Enrico, "SRB: A Selective Reliable Broadcast Protocol for Safety Applications in VANETs," in *International Conference on Selected Topics in Mobile and Wireless Networking*, France, 2012.

[56] Y. Saleh and F. and Mahmood, "Performance of beacon safety message dissemination in VANET," *Journal of Zhejiang University science A,* pp. 1990 - 2005, 2007.

[57] P. Fazio, D. Floriano and T. M. Rango, "Prediction and QoS Enhancement in New Generation Cellular Networks With Mobile Hosts: A Survey on Different Protocols and Conventional/Unconventional Approaches," *IEEE Communications Surveys & Tutorials,* vol. 19, no. 3, pp. 1822-1841, 2017.