PEMD: PRIORITISED EMERGENCY MESSAGE DISSEMINATION IN VEHICULAR SOFTWARE DEFINED NETWORKS

MADEEHA ZEREE FATIMA

NATIONAL UNIVERSITY OF MODERN LANGUAGES

THESIS AND DEFENSE APPROVAL FORM

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THESIS TITLE: PEMD: PRIORITISED EMERGENCY MESSAGE DISSEMINATION IN VEHICULAR SOFTWARE DEFINED NETWORKS

Madeeha Zeree Fatima	27/MS/CS/S19
Submitted By:	Registration #:
Master in Computer Science	Computer Science
Title of the Degree	Name of Discipline
	Signature:
Name of External Examiner	
	Signature:
Name of Internal Examiner	
Dr. Ata Ullah	Signature:
Name of Research Supervisor	
Dr. Sajjad Haider	Signature:
Name of Co-Supervisor	
Dr. Sajjad Haider	Signature:
Name of HoD (CS)	
Dr. Basit Shahzad	Signature:
Name of Dean (FE&CS)	
Prof. Dr. Muhammad Safeer	Signature:
Name of Pro-rector Academics	

July 6th , 2021

“I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of the degree of Master of (*Computer Science*)”

Signature : ____________________
Name : Assoc. Prof. Dr. Ata Ullah
Date : July 6th, 2021

Signature : ____________________
Name : Dr. Sajjad Haider
Date : July 6th, 2021

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MADEEHA ZEREE FATIMA

A thesis submitted in fulfillment of the
requirements for the award of the degree of
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Department of Computer Sciences
National University of Modern Languages

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DECLARATION

I declare that this thesis entitled "*PEMD: Prioritised Emergency Message Dissemination in Vehicular Software Defined Networks*" 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 : Madeeha Zeree Fatima
Date : July 6th, 2021

First I would be grateful to Allah Almighty for the completion of my MS-Thesis. This thesis work is dedicated to my parents and my teachers throughout my education career who have not only motivated me but whose continuous encouragement have taught me to work hard for the things that I aspire to achieve. Finally I would like to dedicate this thesis to my valuable friends for their contributions to my intellectual growth.

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ABSTRACT

Vehicular Software Defined Networking (VSDN) has attained implausible consideration because of their applications in traffic engineering, network intelligence and security services. However, due to high mobility, dense traffic and limited time of communication between vehicles, designing a reliable emergency dissemination strategy in VANETs that can minimize transmission delay to meet the needs of delay-sensitive applications is critical and challenging. Moreover, existing methods lack a reliable software-defined mechanism for scheduling and dissemination of emergency messages based on different severity levels. In this work, we propose a novel four class priority emergency packet scheduling method in VSDN named as prioritised emergency message dissemination (PEMD) to provide real-time data services in vehicular networks based on cooperative decisions. It mainly consists of four priority classes, medium, high, very high and extremely high. When a packet arrives at RSU, the policy based multifold classifier (PMF), classifies arrived packet as emergency or normal packet. Medium, high priority, very high priority, and extremely high priority data packets are considered as real-time, while normal packets are considered non-real-time data packets. The performance of the proposed method is analyzed by NS3.29 simulation which depicts upgrading in service delay, service ratio, deadline miss ratio, packet transmission, and network scalability as compared to state-of-the-art methods such as FCFS, EDF, ADPS, and SDN-controlled VNDN.

TABLE OF CONTENTS

CHAPTER **TITLE** **PAGE**

DECLARATION ii
DEDICATION iii
ACKNOWLEDGEMENT iv
ABSTRACT v
TABLE OF CONTENTS vi
LIST OF TABLES vii
LIST OF FIGURES viii
LIST OF ABBREVIATIONS ix
LIST OF SYMBOLS x

1 INTRODUCTION 1
1.1 Introduction 1
1.2 Motivation 1
    1.2.1 Architecture of VSDN 2
    1.2.2 Applications of VSDN 5
    1.2.3 Constraints of VSDN 9
1.3 Problem Background 11
1.4 Problem Statement 14
1.5 Research Questions 16
1.6 Aim of Research 19
1.7 Research Objectives 20
1.8 Scope of the Research Work 23

1.9 Thesis Organization 25

2 LITERATURE REVIEW 26
2.1 Overview 26
2.2 Emergency-based data dissemination in VANET 29
2.2.1 SDN-based Data Dissemination 31
2.2.2 Priority-based Data Dissemination 33
2.2.3 Data Dissemination in Heterogenous VANET 34
2.2.4 Routing in VSDN 36
2.3 Comparison of VSDN Schemes 42
2.4 Analysis of VSDN Schemes 43
2.5 Resarch Gap and Directions 43
2.6 Summary 44

3 METHODOLOGY 45
3.1 Overview 45
3.2 Operational Framework 46
3.3 Research Design and Development 46
3.3.1 Evolved Priority Packet at RSU 47
3.3.2 Policy-based Multifold Classifier 47
3.3.3 Priority-based EM Scheduling 48
3.3.4 Weight-based EMD selection 58
3.4 Simulation Framework 58
3.4.1 Priority-based Emergency Dissemination Model 59
3.4.2 Simulation Environment 50
3.4.3 Assumptions and Limitations 51
3.5 Summary 51

4 PRIORITY-BASED DATA DISSEMINATION 52
4.1 Overview 52
4.2 Priority-based data dissemination 52

4.2.1 Packet Classification 53
4.2.2 Packet Scheduling 53
4.2.3 Emergency Message Dissemination 54
4.2.4 Weight-base prioritized EMD selection 54
4.2.5 Conclusion 56
4.3 Summary 57

5 PERFORMANCE EVALUATION (PEMD) 59
5.1 Overview 59
5.2 Results and Analysis 59
5.3 Comparison with Benchmark Protocols 61
5.3.1 Service Ratio 61
5.3.2 Service Delay 62
5.3.3 Deadline Miss Ratio 63
5.3.4 Service Ratio w.r.t Vehicle Speed 65
5.3.5 Network Scalability 66
5.3.6 Packet Loss 67
5.4 Summary 67

6 CONCLUSION AND FUTURE WORK 68
6.1 Overview 68
6.3 Contribution and Future Work 68
6.3 Summary 69

REFERENCES 70

LIST OF TABLES

TABLE NO.	TITLE	PAGE
2.1	Summary of existing schemes for SDN based emergency data dissemination schemes	30
2.2	Analysis of emergency-based VSDN schemes	36
3.1	Simulation parameters	37
3.2	Limitations in benchmark schemes	40
4.1	Prioritized Classes of vehicles in abnormal conditions that needs pre-crash emergency support	42
4.2	Algorithm1: Policy based Multifold Classifier	45
4.3	Algorithm2: PEMS Scheme	46
4.4	Algorithm3: Modified TWG Scheme	48
4.5	Set of notations	50

LIST OF FIGURES

FIGURE NO.	TITLE	PAGE
1.1	V2V, V21 and I2I communication for VSDN	17
2.1	Fog assisted SDN-based data services	25
3.1	Evolved Interest Packet	32
3.2	Operational Framework of PEMD	35
3.3	SDN-controlled Priority-based Emergency Message Dissemination Model	37
3.4	Simulation Model Using SDN	39
4.1	Proposed system components	45

LIST OF ABBREVIATIONS

AdPS	-	Adaptive Priority Scheduling
CCDD	-	Context-aware cooperative data dissemination
CTDD	-	Cooperative temporal data dissemination
CS-VFC	-	Cooperative services in vehicular fog computing
ED	-	Emergency Dissemination
EMD	-	Emergency Message Disseminator
EM	-	Emergency Message
PEMD	-	Prioritised Emergency Message Dissemination
PEMS	-	Priority-based Emergency Scheduling
VSDN	-	Vehicular Software Defined Networking
FCFS	-	First Come First Serve
SDN	-	Software Defined Networks
SDN-VNDN	-	SDN controlled named-data networking
TWG	-	Trust-worthy weight graph scheme
SDMEV	-	SDN based multi-access edge computing
FAHDS	-	Fog-Assisted heterogeneous data services
PCD	-	Priority based content dissemination
LTE	-	Long-term evolution
AP	-	Access point
OVS	-	Open vSwitch

LIST OF SYMBOLS

V_st - Status info of vehicle in range of RSU

V_i - Speed of vehicle

Dest - Destination location of vehicle

TD - Traffic Density

Dmax - Maximum delay

D - Distance with RSU assisted SDN-controller

PE - Emergency packet

PN - Normal packet

PVE - Prioritised weight value of emergency packet

PVN - Prioritised weight value of normal packet

CHAPTER 1

INTRODUCTION

1.1 Overview

Vehicular Software-Defined Networking (VSDN) is quickly gaining traction as the latest technology to effectively replace conventional network-based approaches. VANETs based on SDN provide the ability to control network flow based on application requirements [1]. The data plane mechanism is isolated from the centrally managed control plane mechanism, which not only increases the amount of flow requests per second but also reduces the flow time for each flow request [2], [3]. Vehicles communicate with one another on an adhoc basis, and this may include needs and requests for safety or non-safety details. Safety information contains warning alerts in accidental situation and driver help to cope with the target area, whereas non safety information contains traffic information, weather condition and nearest parking spaces [4]–[6]. Vehicles have become prominent as they are furnished with a wide variety of sensors, built-in computers and different supporting devices for map-reading and communication. The rapid increase in number of traffic vehicles leads to several problems such as congestion avoidance for clear passage for emergency vehicles [7], [8].

Therefore, emergency message dissemination has gained major attention due to high traffic density as they are facing considerable challenges due to dynamic behavior of VANET [9], [10]. The more concerned challenges are broadcast storm, hidden node and packet interference. As a result, an effective and reliable mechanism for disseminating emergency messages (EMs) in the VANET environment is needed. Intelligent traffic lights, clustering, priority, the internet of things, software defined networks, 5G networks, and fog computing are some of the approaches used to disseminate emergency messages [11].

During the traffic congestion on thin roads the passage of emergency vehicles becomes difficult. Emergency vehicles requires immediate response for emergency services and a delicate delay during mobility of emergency vehicle on congested roads can results into financial and physical loss [12]. It is a critical requirement to ensure the dissemination of emergency messages on accurate time. Traffic lights are used to ease the passage of ambulances in busy areas by assimilating the model of IOT and VANET [13]. Dynamic scheduling algorithm is proposed for on-time traffic signaling and examines the intense traffic at interchange and enable the passing of heavy traffic on high priority [14]. Due to rapid development in Fog Computing, the concept of fog computing is solicited to dispatching emergency messages. A Fog assisted VANET architecture is suggested to refrain congestion at busy hours [15]. Enlarging SDN into VANET can provide optimization of network resources, streamlines of mobility and management of network heterogeneity. VSDN is a considerable solution as it reduces the impact of disconnectivity caused by high mobility of vehicles and escalates the trustworthiness of communication in VANET, upgrading the growth of intelligent mobility [16].

It is a critical requirement to ensure the dissemination of EMs on accurate time. Traffic lights are used to ease the passage of ambulances in cities by incorporating the idea of IOT and VANET [13]. The SDN can protect specific frequencies or channels to use them in the future when needed. Safety traffic or other high priority requests can consume that reserved frequencies. The safety messages such as cooperative awareness messages (CAM) can gain the advantage of the reserved frequencies. Appropriate vehicular emergency dissemination (AVED) approach is presented to avoid redundant broadcasting in the network which is supported by CAM [17], [18].

Vehicles can autonomously prioritize and schedule all the messages on its requirement. Each message is given a priority based on static and dynamic variables, as well as the message's size, using metrics such as weather and geographic location [19]. The Service Priority Adaptiveness for Emergency Traffic Using SDN (SPArTaCuS) shows how SDN can be used to prioritize emergency messages. The scheme is designed for smart cities that want to prioritize emergency services, which can be done using a priority management layer in SDN architecture. The model consumes a lot of system resources and is only suitable for locations with a large number of users [20]. W. Zhu et al. proposed a scheme known as SDN-Enabled Hybrid emergency message transmission (HEMT), which uses the principle of SDN to allow the dissemination of emergency messages fast and efficient while reducing the controller's overhead. However, the model is not ideal for high density traffic situations due to the message coverage ratio is not being maintained [21].

A cluster-based V2V MAC protocol called Priority-based direction-aware media access control (PDMAC) is proposed for prioritizing emergency messages dissemination in VANETs to avoid road accidents on two-way highway regimes. PDMAC presents inter-cluster clock synchronization in conjunction with intra-cluster synchronization, which helps to overcome communication overhead and enhances channel consumption [22].

1.2 Motivation

The efficiency of VANETs is limited by high traffic density due to the presence of a large number of vehicles in the Internet of things (IoT). Congestion disturbs the timely data processing of emergency applications during interchanging emergency or normal messages in traffic environment. Particularly, the emergency situations on roads like driver assistance, alert information (post-crash care) and warnings alerts through sensors (break failure, high temperature, accelerator condition, tire burst etc) requires SDN-controlled prioritised architecture that provides high consistency and low service delay. An irregular delivery of these serious and time-sensitive messages can be tragic and any human error can results into death and serious injuries. Therefore, vehicles need to be equipped with reliable emergency-controlled functionalities and there should be a real time effective solution that could disseminate emergency messages with high service ratio and reduced service delay.

1.2.1 Architecture of Vehicular Software Defined Network

A cooperative scheduling scheme assisting VSDN (VSDN-CS) is anticipated for data transmission in multi-hop traffic environment as shown in Figure 1.1. To cope up with the possible hindrances in data transmission the problem is formulated as considering deadline associated with data packets and sustainability of links, and cooperatively schedules V2V, V2I, I2V and I2I communications escalating efficient data dissemination [23].

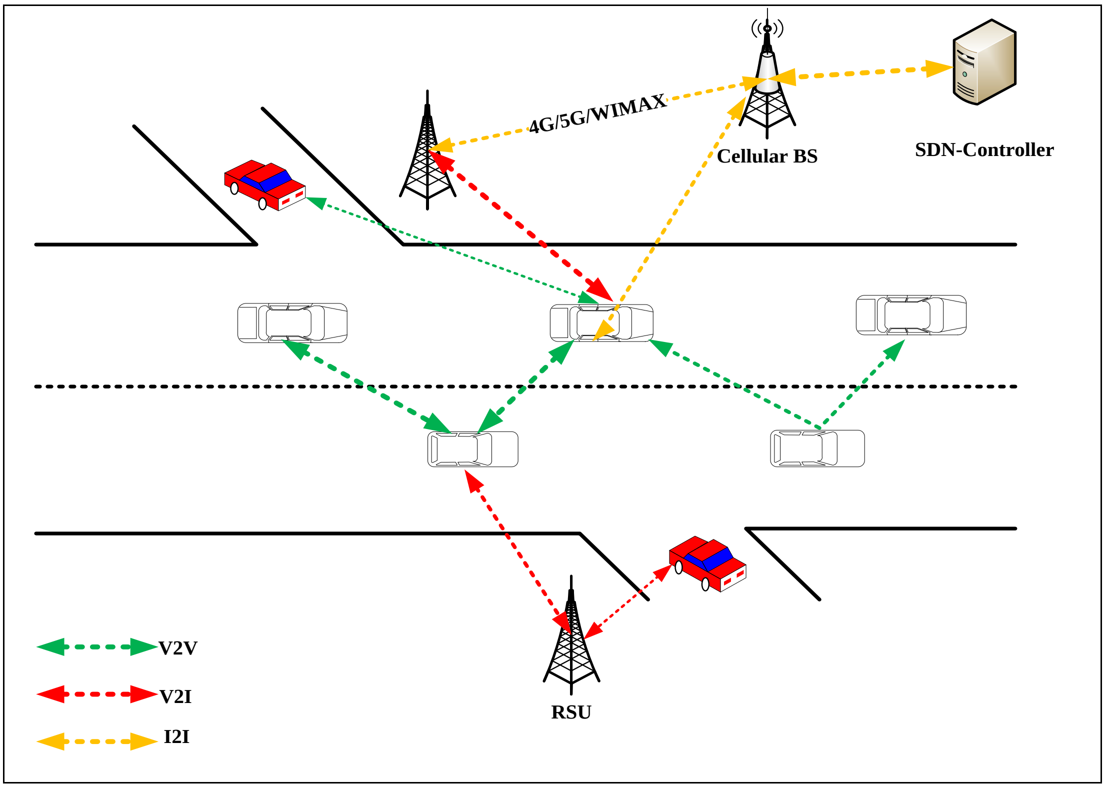


Figure 1.1: V2V, V21 and I2I communication for VSDN

There are numerous studies in the literature that concentrate on software-defined cooperative data sharing in VANETs. These researches, on the other hand, have paid less attention to the severity levels of emergency message dissemination in a real-time world of rapidly evolving network topology. However, emerging 5G-VANETs rely on secure data sharing and require a large amount of cooperative data sharing between vehicles and RSUs. Thus, priority-based emergency message dissemination for vehicular software-defined networks is needed for efficient data sharing services for emergency message dissemination.

1.2.2 Applications of Vehicular Software-defined Networks

VSDNs open a huge paradigm for various applications that supports the effective communications between vehicles and mitigates the challenges of broadcast storm problem, safety problems, congestion and the packet collision.

1.2.2.1 Intelligent City Application

Intelligent city applications are a progression of the Internet of Things (IOT), in which a large number of intelligent devices communicate with one another. The aim of the intelligent city application is to enhance traffic management in the smart and intelligent world from every aspect [24].

1.2.2.2 Safety to Non-safety Application

VANET supports excess of applications covering from safety to non-safety application through qualifying vehicles to interact with infrastructure (V2I) , with each other(V2V), and hybrid mode (V2X) [16].

1.2.2.3 Delay-sensitive Application

Congestion in VANETs influences the performance of time-sensitive applications when interchanging emergency or normal messages. Particularly, during emergency situations on roads like road accidents and security warnings require high consistency and low delay. An irregular delivery of these serious and time-sensitive messages can be tragic for the time-sensitive applications [25].

1.2.2.4 Smart Transport System

Smart transport System (STS) realized through Vehicular Adhoc Network (VANET) where vehicles share information and data with each other(V2V) and with the infrastructure(V2I), aspiring secure, reliable, and full of infotainment driving knowledge [13].

1.2.2.5 IoT enabled VANETs

The Internet of vehicles (IoV) has been considered as a rising standard that integrates the intelligent transportation system (ITS) with Internet of Things (IoT) technology. IoV enables vehicles to share data with its surroundings in order to improve the traffic safety and to offer intelligent services to road users [3]**.**

1.2.2.6 Autonomous Self-Driving Cars

Automakers have recently announced plans to release self-driving cars over the next few years. Sensors collect data that enable cars to drive independently on roads. The information gathered by fixed sensors cannot be sufficient to ensure an even and safe traffic flow in high-speed traffic situations. As a result, data from networks and other cars or vehicles on the road is critical [26].

1.3 Problem Background

Vehicular Software-Defined Networking (VSDN) meticulously brings versatility, programmability and wide-ranging evolution to vehicular networks. It helps to manage the global view of network based on vehicle requests and also establishes V2V and V2I communication. The effective communication between vehicles requires real-time applications which involve dissemination of emergency messages to approach vehicles in the target area with low service delay.

Numerous studies have been published in the literature that focuses on software-defined cooperative data sharing in VANETs. The severity levels of emergency message dissemination in a real-time environment are rarely focused on rapidly evolving network topology, according to existing studies. However, emerging 5G-VANETs need a large amount of cooperative data sharing between vehicles and RSUs and rely on efficient data sharing. Thus, ideal priority-based emergency message dissemination for vehicular software-defined networks that offers effective scalability of emergency data dissemination in terms of QoS metrics is needed for efficient data sharing services for EM dissemination [24].

The main problem is that priorities based on different emergency levels is less addressed that considers the reliance of safety and non-safety messages. Therefore, lack of concrete measures for the real-time EM dissemination based on different severity levels affect physical, emotional and environmental health of society. To address this gap, VSDN-enabled prioritised emergency message dissemination (PMED) architecture is presented that can prioritize emergency messages based on different severity levels.

1.4 Problem Statement

In the existing solution, emergency data dissemination starts off with packet classification. Interest packet includes an emergency type field, when received at RSU, policy-based bifold (PBF) classifier differentiate the emergency packets from normal packets. The emergency type field in evolved interest packet shows the severity of the message which is not further subdivided as per different level of emergency in the real-time scenario [24]. However , Robust Forwarder Selection (RUFS) scheme processes all the emergency packets with same priority that can cause delay during the propagation of severe emergency messages without defined EM priorities [27]. The proposed priority-based VSDN architecture ensures road safety by overcoming road hazards, controlling emergency situations based on severity levels in a practical traffic setting, and providing real-time data facilities with improved quality of service (QoS) for both emergency and normal messages.

1.5 Research Questions

Research questions for this work are identified based on research objectives and listed as below.

i. What are the possible specifications to differentiate between normal and emergency message?
ii. What are the possible procedures to disseminate emergency messages?
iii. What are the mechanisms to select best forwarder?
iv. What are possible thresholds values to calculate weight value to select best forwarder?

1.6 Aim of Research

It is expected to offer a large variety of applications for enhancing road safety, traffic management and road risks for vehicles encountering emergency situations. The performance VSDN can be improved in terms of QoS metrics. The emergency messages in VSDN can be disseminated in more efficient and timely manner and as a result scalability of emergency messages will be increased.

Congestion in VANETs influences the performance of time-sensitive applications when interchanging emergency or normal messages. Particularly, during emergency situations on roads like road accidents and security warnings require high consistency and low delay. An irregular delivery of these serious and time-sensitive messages can be tragic and leads to serious accidents. Therefore, deploying an effective scheme will minimize the delay and reduces financial and physical loss.

1.7 Research Objectives

The following objectives are defined to design and develop prioritised emergency dissemination method.

i. Efficiently disseminate the Emergency Data (ED).
ii. Efficiently prioritize the Emergency and Normal message.
iii. Efficiently identify the Emergency Data Forwarder in next hop.

1.8 Scope of Research Work

Vehicular Software defined networking is promptly appearing as the latest technology to effectively replace conventional network-based approaches. Enlarging SDN into VANET can provide optimization of network resources, streamlines of mobility and management of network heterogeneity. VSDN is a considerable solution as it reduces the effects of disconnectivity caused by rapid movability of vehicles and escalates the real-time data transmission in VANET, encouraging the improvement of smart mobility specifications. Furthermore, the traffic density has risen exponentially over the last decade and this densification is likely to increase due to population expansion and the number of vehicles that are involving in internet of vehicles (IoV). This high traffic density causes various problems, the most challenging of which is reducing average delay of EM dissemination and ensures their reliable delivery.

When looking at the dynamic features of VANETs, considerable challenges in disseminating the message across the network emerge. To tackle mentioned challenges, the proposed priority-based emergency data dissemination scheme will support efficient dissemination with reduced service delay, packet collisions and packet loss ratio that eventually increases the performance of VSDNs to allow timely dissemination of EM near mishap area.

1.9 Thesis Organization

The rest of thesis is organized as follows:

Chapter 2 will provide background on emergency-based data dissemination in VSDN. It illustrates literature review that includes brief discussion of all the existing literature being reviewed during present study. It also includes detailed comparison of the studied schemes, their research gaps and directions and categorical discussion.

Chapter 3 will present the methodology which includes the operational framework, research design and development and simulation framework. Extensive simulation is performed in NS3.29 to achieve effective results.

Chapter 4 offers detailed working and verification of proposed algorithm. Priority based emergency message dissemination (PMED) is a four-class priority emergency packet scheduling system introduced in VSDN to provide real-time data dissemination in vehicular networks based on cooperative decisions.

Chapter 5 will provide performance evaluation of Priority-based emergency data dissemination (PEMD) scheme comprehensively and interprets results and analysis performed in NS3.29 through extensive simulation.

Chapter 6 will give summary of contributions, future directions and gaps of the proposed architecture which are concluded to fascinate the innovative researchers to work in particular research area.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

In this section, different emergency dissemination schemes are explored through which emergency messages are disseminated efficiently. In vehicular networks, efficient data distribution has been extensively studied. Many studies have looked at network and connectivity problems in order to help heterogeneous data services such as SDN-based data dissemination, priority scheduling of emergency data, and data dissemination in heterogeneous vehicular networks. Numerous SDN-based data dissemination schemes are explored which includes priority-based data scheduling for data services and data dissemination in heterogeneous vehicular network and highlighted the gaps and improvements required in proposed methods. The current work could be expanded to allow for collaborative data service scheduling across heterogeneous network interfaces.

2.2 SDN-based Emergency Data Dissemination Schemes in VANET

In vehicular networks, there has been a lot of research on how to distribute data efficiently. Several studies have looked at network and connectivity problems in order to support heterogeneous data services via SDN-based data dissemination, priority scheduling of emergency data and data dissemination in heterogeneous vehicular networks.

2.2.1 SDN-based data dissemination

For SDN-based heterogeneous vehicular networks, Dai et al. proposed the cooperative temporal data dissemination (CTDD) problem. A priority-based task assignment (PTA) algorithm was developed to balance service load, relay performance, and service deadline among heterogeneous network interfaces, but the quality of service (QoS) for both emergency and normal messages was deficient [28].

Alowish et al. proposed software defined networking controlled named-data networking (SDN-VNDN) for packet classification and to facilitate trustworthy emergency message dissemination and data retrieval. Policy-based bifold classifier (PBF) classifier is implemented at RSUs to classify the evolved priority packet into emergency and normal packet. Trustworthy weight-graph scheme (TWG) is used to select best disseminator to disseminate emergency packets. It resolves the problem of packet flooding but it lacks scalability measures to disseminate emergency packets in dense traffic environment [24].

G. Luo *et al.* presented the Context-aware cooperative data dissemination (CCDD) by using edge computing to decouple contextual information from data dissemination. For efficient data transmission, a graph theory-based algorithm is proposed to formulate the maximum weighted independent set (MWIS) problem. For continuous and balanced content delivery, a balanced greedy algorithm is proposed. To make proper use of computational resources, integer linear programming (ILP) is proposed. As compared to other existing algorithms, the result indicated an improvement in terms of complexity and performance, but it failed to achieve maximum throughput over multiple channels [29].

A logical SDN-based multi-access edge computing (SDMEV) scheme is introduced for vehicular networks, combining SDN and multi-access edge computing principles. To boost data dissemination of V2V and V2X messages to move into vehicles in indented areas, efficient data dissemination (EDD) scheme is proposed. A fuzzy clustering algorithm is used to nominate cluster head node to disseminate messages and enable direct communication between vehicles. The OpenFlow algorithm is used to update the flow table that is responsible to transmit packets to vehicles. The proposed algorithms assure the delay requirements of V2X services but lacks proper allocation of computing resources over SDMEV [30].

Xiao et al. formulated a Fog-Assisted Heterogeneous Data Services (FAHDS) which intends to deal with the heterogeneities of data services and reduces the service delay. A greedy algorithm is deployed at the SDN controller, which makes intelligent decisions for cloud nodes and broadcasts the collaborative data services between fog nodes and vehicles. In comparison with previous research, the findings showed an improvement in service delay and broadcast efficiency of diversified packets, but they did not address the dynamic behavior of rapidly evolving heterogeneous network interfaces [31].

The Cooperative Service in Vehicular Fog Computing (CS-VFC) problem is formulated to enable collaboration between SDN-based cloud services and distributed fog services, and to optimize the bandwidth efficiency of vehicles between cloud nodes (V2C) and fog nodes (V2F). An online scheduling algorithm is proposed that enables policy-driven scheduling decisions at SDN controller and deployed inter and intra cooperative services at the fog layer to enhance the overall network performance but fails to lower service delay in high workload environments [32].

Fog Assisted Cooperative Service (FACS) problem is formulated with clique searching based scheduling (CSS) algorithm for software-defined heterogeneous VANETs. It supports collaborative data compression, caching and dissemination among V2V, V2C and V2F communications to improve bandwidth efficiency as illustrated in Figure 2.1. Graph transformation scheme is implemented that assists diverse data rates, radio coverage and mobility of vehicles. The proposed algorithm proved its superiority in simulations results as compared to already existing algorithms [33].

SDN is combined with the intent-based networking (IBN) technology to present intelligent data dissemination method for VANET using edge computing. It handles huge amount of data intelligently during the busy hours, decreases the bandwidth consumption level and overcomes the service delay. The proposed scheme can be further improved in terms of energy-efficient data dissemination [34].

SDN-based QoS-aware and location-aware content dissemination scheme is presented in VANET to enable efficient geographic data dissemination in perspective of QoS requirement such as delay. SDN-based routing algorithm is implemented to define the Content Delivery Area (CDA) that enables to cope up with the application requirements. By taking into consideration criticality of real-time applications more efficient functionalities can be added to further enhance the proposed scheme [35].

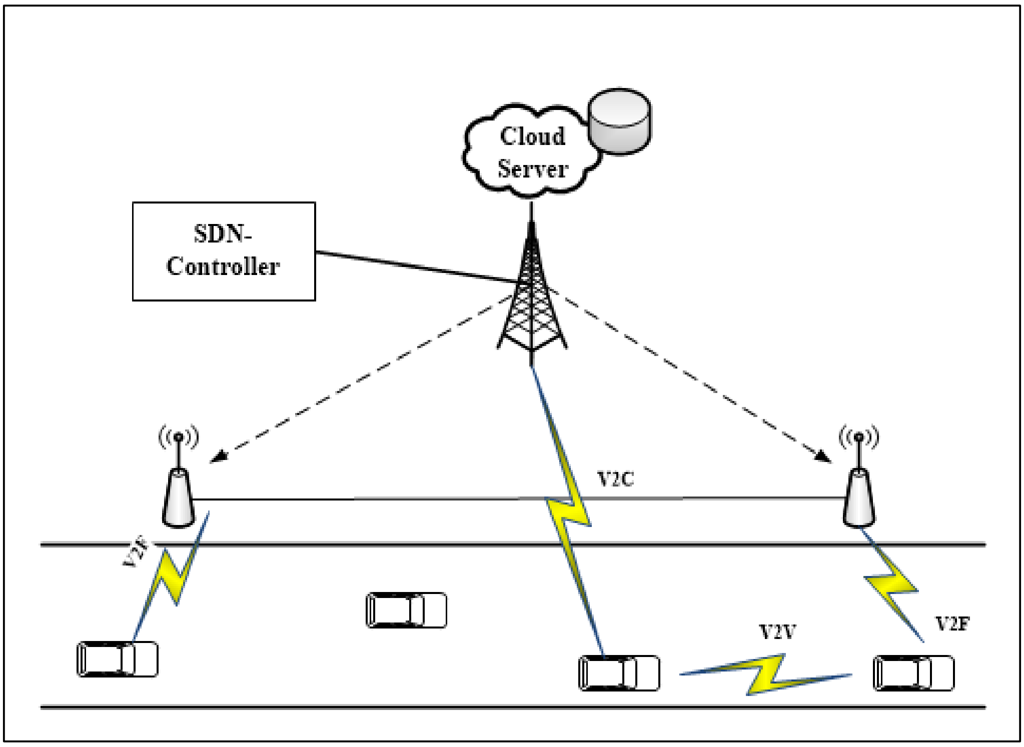


Figure 2.1: Fog assisted SDN-based data services

2.2.2 Priority based data dissemination

In context of the data urgency, a priority-based content dissemination (PCD) scheme is proposed, in which data items are classified as urgent or non-urgent data items in order to ensure reliable data dissemination, boost secure drive application, and shorten the time it takes to obtain frequently requested data items. In comparison with existing systems, the scheme improved the information forwarding fabrics of the Content Centric Vehicular Network (CCVN) and also improved data dissemination. [36].

S. Park et al. proposed the reinforcement learning data scheduling (RLDS) algorithm for SDN-based VANETs, to reduce the number of services that fail to deliver on time. Each time slot has a deadline for services. Choose the service with the shortest deadline, the most requested service, or the least requested service to determine the action space. When compared to previous algorithms, the proposed algorithm generated progressive results in various environments [37].

A priority-based efficient data scheduling (D*S/P) scheme was introduced, which takes into account requests that are dropped due to a short deadline and are no longer covered by RSU. On the basis of request collection priority, request priority, and popularity of requested data, the scheduling for the requested information was performed. It is primarily concerned with the availability of data to the greatest number of vehicles within the RSU's coverage area. The scheme worked well in both urban and highway situation, according to simulation results on data ratio, service ratio, and deadline miss ratio metrics [38].

In CCN-based VANET, the preference value was equally distributed to each property which affects emergency data dissemination in the network [27]. First Come First Serve (FCFS) and EDF (Earliest Deadline First) are two scheduling algorithms that cause delays in processing requests and lack fairness among users. [39], [40]. Dynamic and heuristic (DySch and TaSch) scheduling strategies were proposed by N. Taherkhani et al., which assign priorities based on content size, static and dynamic variables. The simulation results of proposed algorithms showed that they were more efficient than current algorithms [41].

There is a suggestion for a better delay management technique. A. Sharma et al. proposed a novel adaptive priority data service scheduling (AdPS) algorithm for providing real-time data services in heterogeneous traffic scenarios that uses fuzzy logic for data scheduling. The prime focus is to minimize service delay through prioritizing the requests of vehicles based on dynamic factors and type of service of the requested content. The evaluation results proved that the proposed algorithm is superior among related proposed algorithms [42].

A novel cooperative scheduling scheme assisting VSDN is proposed for data transmission in multi-hop traffic environment. The problem is constructed as an ILP problem to deal with potential data transfer bottlenecks. The proposed scheme cooperatively schedules V2V, V2I, I2V, and I2I communications, escalating efficient data dissemination while taking into account data packet deadlines and connection sustainability. It also prioritized the incoming data packets to overall minimize the delay of the network. The scheme comparatively showed improvement on significant parameters from existing studies [23].

2.2.3 Data dissemination in Heterogeneous vehicular networks

In VANETs, data dissemination has become a significant research area that has sparked the interest of both industry and academia [43]. With the aid of RSUs and drop-box, Xing et al. [44] devised a utility-based maximization problem to incorporate a carry and forward strategy in crowded traffic situations for multimedia data dissemination. Based on an evolutionary fuzzy game, Liu et al. [45] consider real-time cooperative data dissemination for more efficient data sharing among neighboring vehicles. Heterogeneous wireless networks, such as DSRC, WiFi, 5G, and LTE, are dominant in modern mobile communication networks. As a result, data dissemination in heterogeneous networks has been assessed [43]–[45].

In D2D-based LTE-V2X networks, Gu et al. [46] solves the content sharing issue. During the link scheduling of V2V and V2I communications, the dynamic nature of data and link quality are also taken into account. In an advanced hybrid architecture comprised of VANET and LTE networks under the coverage of V2I communication, Zhioua et al. [47] proposed a cooperative traffic transmission algorithm. The algorithm uses fuzzy logic to decide which gateway to use to link the sending node to the LTE infrastructure. Ucar et al. [48] proposed the VMaSC-LTE hybrid architecture, which incorporates IEEE 802.11p-based multi-hop clustering with a 4G-cellular system to achieve a high packet delivery ratio (pdr) and low transmission time while reducing cellular system use.

2.2.4 Routing in vehicular software-defined networks

Vehicular Software-defined networking (VSDN) is broadly agitated [46] which exhibit the benefits of centrally managed intelligent controller. Gao et al. proposed a hierarchical geography routing protocol for load balancing for VSDN to enhance packet transmission performance. The protocol is divided into three phases. In first phase the protocol equally segregates a bulky locality in to several undersized sections as maintained by geographical location and diagnoses a sequence of sections with well connection oriented integration based on vehicle concentration in that specific section and past vehicle transfer probability between sections. In second phase, an effective path cost function with load balancing is constructed that keeps two paths with nominal costs from the chosen sections. Lastly in the third phase, a sequence of dispatching nodes on each selected path is refined for routing according to node service.

Y.Gao et al. mainly focused on the routing mechanism for urban scenario. The unicast routing mechanism under expressway environment is suggested for the future work. Expressway is specified by high vehicle concentration with high vehicle mobility, which is a great challenge for reliable routing. To ensure that the SDN central controller's predetermined routing does not disrupt the rapidly evolving network topology on the expressway, each vehicle must transmit its coordinates, speed, and buffer space in a timely and precise manner. The central controller translates these specific network values into arguments that machine learning and artificial intelligence can use to rapidly make forwarding routing for the expressway's moving vehicles. VANETs make it easier to use on-road applications that rely on multi-hop communications [47].

VSDN introduced a number of futuristic features, as well as improved performance and lower computational overhead. The majority of current VSDN routing schemes focus solely on finding the shortest path that results in significant computational overhead. Few current routing protocols pay attention to abrupt changes in vehicle motion. These concerns are addressed, and Yang et al. proposed a widely used flexible route and proactive updating (FR-PU) mechanism which takes three factors into account for each connection and proceeds to examine the route direction. An effective path is determined by three factors: relative distance between the transmitting node and the destination, desired connection stability length, and efficient reception capacity. The proactive updating scheme helps the SDN controller to be held responsible for the entire duration of the application while also mitigating the effects of a vehicle's sudden change of motion [47].

While designing an SDN-enabled routing protocol [48] the dynamic topology of VANETs is not considered, this result in ineffective resource utilization and congestion. In VANETs, there are currently problems with how a central SDN controller can contribute ineffective resource allocation and sustain QoS. When routing data packets on road parts, the SDN controller is used to reduce congestion in V2V communications. This is accomplished by making effective use of bandwidth on different road sections. The proposed SDN controller implements a novel routing mechanism that takes into account existing routing paths that are already transmitting data while also addressing new routing requests, ensuring that no road section is congested by multiple crossing routing paths. M. Rayeni et al. proposed an Optimal Resource Utilization Routing Scheme (ORUR) routing mechanism that incorporates load balancing and congestion avoidance.

H.Ghafoor et al. proposed a routing scheme named as SDN based On-Demand Routing Protocol (SVAO) that segregates data layer and control layer of network [49] to improve data dissemination efficiency inside VANETs. The RSU performs its part of Local Controller to select vehicular nodes to forward packet within a road section. All the vehicular nodes positioned in the road used two-level design. The Global Level is widely disseminated and uses a ranked query scheme to collect vehicular node information and determine which road segments a message should be routed along. The local level, on the other hand, is in charge of selecting forwarder vehicular nodes in each road section determined by the global level. This scheme focuses on redesigning the control layer and data layer of network in VANETs with the help of SDN. The relation between two adjacent links is mainly focused as a future work to optimize the SVAO scheme, and how to achieve the equilibrium between number of nodes in a link and link stability will be a challenging future path.

K. Sudheer proposed a novel packet routing framework [50] which explore the dynamic behavior of wireless links. The shortest path and the constancy of the route is mainly focused in finding the best possible paths. The packet routing problem is formulated as a minimum cost capacitated flow problem with the goal of finding several paths that are even enough to successfully transmit a certain number of packets with minimal delay. The scheme identifies the dynamic behavior of links while routing the packets in SDVN and considers the network globally that allows SDN controller to work efficiently. The routing framework has limitation with respect to the architecture to minimize the quantity of messages exchanged between the control and data planes to retrieve communication cost and high delay.

2.3 Comparison of VSDN Data Dissemination Schemes

This section categorizes different ED schemes where we present advantages and limitations in Table 2.1. It has been determined that the majority of current schemes depend on efficient information dissemination, but due to the unique existence of vehicular networks, numerous challenges remain.

Table 2.1: Summary of Existing Schemes for SDN-based Emergency Data Dissemination Schemes

Scheme	Basic Idea	Mechanism	Advantages	Limitations
CCDD [51]	SDN-based 5G VANET and edge	Decoupling of contextual information sensed	Improves efficiency and complexity.	Less throughput. Need

	computing	from data dissemination.		validation of model at MAC layers and physical layers.
CTDD [28]	SDN and heterogeneous VANET.	Balances the service load between heterogeneous wireless interfaces.	Unifies allocation ratio, broadcast efficiency and service deadline.	Need quality of service (QoS) for both safety and non-safety data.
SDN-VNDN [24]	SDN-VANET using Vehicular named-data networking (VNDN).	To select the best data disseminator depending upon highest weight value.	Control Broadcast storm problem, minimizes bandwidth consumption. Secure EM dissemination.	Deliver EMs with same priority. Need QoS.
VSDCD-MEC [52]	Software-defined content delivery for MEC systems.	MEC search strategy for V2V and vehicle level caching for V2I communications.	Dissemination of MEC services with reduced latency. Better QoS.	Need Security and storage capabilities. Need support for V2X services.
SDMEV [30]	SDN-VANET using multi-access edge computing (MEC).	Selects the head vehicles to carry out V2V or V2I communication and OpenFlow algorithm to update the forwarding tables.	Improve latency among V2X services.	Need to improve allocation ratio.
(RLDS) [37]	SDN & Fog computing based on RL.	Minimize number of services that could not meet deadlines.	Reduces average delay for scheduling period.	Not suitable for sparse environment.
VNDN-	VANET & NDN	Content naming, named based routing,	Efficiency, security and	Need integration of

EDD [53]		network caching and security.	scalability.	new technologies to extend for complex situations.
FAHDS [31]	SDN & Fog computing	Coding decisions for V2F and V2C nodes.	Satisfy service delay among V2F and V2C nodes.	Need customized algorithms for better cooperative data services.
CS-VFC [32]	SDN & Fog computing.	Collaboration between SDN based services at the cloud layer and fog layer.	Maximizes the bandwidth efficiency of V2C and V2F data transmission.	Need effective cooperative services solution for coding decisions.
SDVN-NDD [54]	SDN & heterogeneous VANET.	Network selection and Data distribution.	Improve pdr and average end-to-end delay	Use limited number of decision making factors.
FACS [33]	SDN & Fog computing.	Collaborative data compression, caching and dissemination among V2V, V2C and V2F communications.	Improves bandwidth efficiency among V2V, V2C and V2F communications.	Difficult deployment for complex environment.
SDN-CD [35]	SDN-IoV based Pub/Sub middleware.	QoS awareness and mobility management.	Low latency, control overhead.	Need support for inter-SDN controller exchanges.
VSDN-CS [23]	SDN & VANET	Scheduling and routing V2V, V2I, I2V, and I2I interactions in a cooperative manner.	Minimize service delay. Avoid packet collisions.	Need reduction in computational complexity.

SDN-IBN [34]	SDN & VANET using edge computing.	IBN technology intelligently operates tasks and provides coordination among data services.	Decreases bandwidth consumption, less service delay.	Needs to focus on energy-efficient data dissemination.

SDN-based heterogeneous data dissemination schemes mainly considers diversities of traffic environment for a better dissemination of data [28], [31], [33], [54] SDN-based cooperative data dissemination schemes involves cooperative behavior of services among V2V, V2I, I2I and V2F, V2C to cooperatively maximize data delivery and improves link connectivity for efficient data dissemination [23], [30], [32], [35], [51], [52]. SDN-based named data networking enables trustworthy communication by named data to improve scalability and resilience in the network [24], [53]. SDN-based intelligent data dissemination consider learning procedure to efficiently disseminate data within deadline [34], [37].

CCDD is proposed to make proper use of computing resources and as a result it reduces the service delay. Similarly, CS-VFC problem is formulated to deliver cooperative data services by minimizing delay during emergency hours. Also, FACS problem cope up with the heterogeneities of network and reduces the tendency of delay. VSDN-CS escalates the efficient data dissemination. Furthermore, CTDD aims to maximize the service ratio (SR) and supports cohesive management of heterogeneous resources but lacks quality of service (QoS) for data dissemination. Similarly, FAHDS deals with heterogeneous data services and intends to improve end to end delay and transmission time. In the context of SDN-controlled efficient data dissemination, EDD integrates named data networking (NDN) to boost up the network scalability. In the same way, SDN controlled VNDN framework facilitates trustworthy emergency message dissemination through TWG scheme, that selects the best disseminator based on highest weight value to disseminate emergency messages aiming to minimize delay and bandwidth consumption.

SDN-IBN and RLDS [34], [37] applies learning and intelligently disseminate the data with the intent to decrease bandwidth consumption and transmission time. In the context of reliable content delivery, VSDCD-MEC supports reliable content delivery between interconnected vehicles and SDN-CD defines content delivery area (CDA) to improve QoS of geographic data dissemination [35], [52]. In the context of cooperative data dissemination, a logical SDMEV scheme intends to improve data dissemination of V2V and V2X messages with low delay. SDN-NDD scheme in heterogeneous wireless interfaces aims to improve bandwidth consumption and delay for the delivery of cooperative data services. CTDD provide the best solution for better content temporal data dissemination. It adaptively assigns the dissemination jobs and balances the service load among wireless interfaces but lacks quality of service (QoS) for data dissemination. The explored schemes entail to tackle some challenging aspects which are illustrated in Table 2.2.

Table 2.2: Analysis of SDN-based Emergency Data Dissemination Schemes

Scheme	**Scalability**	**Single point Failure**	**Heterogeneity**	**Protocol Standards**	**Dynamic Topology**	**Service Delay**	**Security**	**Sustainability**
CCDD [51]	Yes	Yes	Yes	No	Yes	Yes	No	No
VSDN-CS [23]	Yes	Yes	No	No	Yes	Yes	No	No
CS-VFC [32]	Yes	Yes	No	No	Yes	Yes	No	No
SDN-CD [35]	Yes	Yes	No	No	Yes	No	No	No
VSDCD-MEC [52]	Yes	Yes	No	No	Yes	No	No	No
SDMEV [30]	No	Yes	No	No	Yes	Yes	No	No
FAHDS [31]	Yes	Yes	Yes	No	Yes	No	No	No
SDN-NDD [54]	Yes	Yes	Yes	No	Yes	Yes	No	No
FACS [33]	No	Yes	Yes	No	Yes	No	No	No
CTDD [28]	Yes	Yes	Yes	No	Yes	Yes	No	No
VNDN-EDD [53]	Yes	Yes	No	Yes	Yes	Yes	Yes	No
SDN-VNDN [24]	Yes	Yes	No	Yes	Yes	Yes	Yes	No
RLDS [42]	No	Yes	No	No	Yes	No	No	No
SDN-IBN [34]	No	Yes	No	Yes	Yes	No	No	No

There is dire need to investigate scalability, security and sustainability aspects of VSDNs. The changing needs of society and technological advancements has arisen a number of research opportunities in this area. One such challenge is to effectively tackle with the scalability, sustainability, single point of failure and security issues. The privacy of data and location of a specific vehicular application is neglected to be addressed in all schemes expect [24], [53].

The problem of scalability is roughly addressed in entire schemes but only some schemes [30], [33], [34], [37] are not scalable to be implemented in realistic traffic environment due improper resource allocation and high computational overhead. As SDN-controllers are centrally managing the whole network so there is always a threat of single point of failure in VSDN environment. They should be equipped with sustainable features or provide backup functionalities in case of any collapse. The SDN-based heterogeneous vehicular network schemes cope up with the diverse traffic issues [28], [31], [33], [51], [54] but other schemes needs to address the diversities of network traffic more precisely. The standardization of protocols needs to be integrated in VSDNs for efficient routing of diverse traffic. All schemes have successfully tackled the delay-constraint contents but some schemes (e.g. [24], [28], [30], [51], [54]) needs to reduce bandwidth consumption and proper allocation of resources to further decrease the tendency of delay in the network. Moreover the energy-efficient data dissemination is needed to be emphasized and practiced in all schemes with respect to software sustainability.

2.4 Research Gaps and directions

Scalability of existing VSDNs is a major concern due high density of traffic on roads. The possibility of unforeseen obstacle and unexpected changes are uncertain. There are many aspects such as updating the network based on new technology, multiplex road topologies, link breakage or failure of node to communicate can affect the performance of VSDN. The rapidly increasing traffic density followed by dense data transmissions leads to scalability issue of VSDN. Moreover, architecture should capable to efficiently deal with popular data requests and diverse weather alerts [55], [56]. Another main concern is to deal with traffic environment in case of any possible disaster. due The broken links because of the disaster are not capable of disseminating emergency messages, so there is a needs of more efficient SDN controllers that could dynamically allocate different functional features to sustain the QoS specifications [16].

Integrating Software defined networking (SDN) and vehicular named data networking (VNDN) there comes a scalability issue which could be further improved to bring more efficiency across the entire network [24]. Reliable assessment of the cooperating vehicles in VANET is an open challenge. Delicate misconceptions in assessing mobile nodes can results into physical and financial loss. Therefore solid measures for deciding a right and trusty vehicle are still lacking. Researchers have presented different techniques for misconduct detection, [57] but no techniques are proposed to carry out practical demonstration. There are no strict measures defined for harmful mobile nodes. Moreover, there is a lack of non-repudiation schemes to be implemented if any mobile node is performing misconduct in the traffic environment.

2.4.1 Scalability and real-time data sharing in VSDN

The data scheduling is considered only within the range of RSU, which results into scalability issue and large volume of data cannot be shared [29]. For the assurance of reliable temporal information and real-time distribution of data services in case of emergency applications which enforce strict timing requirements on completion of data services is a challenge. The design of an efficient scheduling strategy in a heterogeneous vehicular environment is a challenge as temporal data of vehicles is updated occasionally. The traditional distributed scheduling approaches cannot solve the problem of cooperative data sharing via different wireless interfaces. The efficient data scheduling is hindered because the traditional network architecture only makes non real-time scheduling decision with the assistance of internal information of network environment. Due to rapid change of position the data services information of vehicles like vehicle speed, density and real time traffic flow is needed to be updated periodically [28].

Long Term Evolution Device to Device (LTE-D2D) can be used to efficiently transmit V2X emergency data services based on SDMEV. The challenge of large volume of data distribution with minimal cost, balanced content distribution and real-time emergency data sharing requires competing strategies that can efficiently cope with these challenges [51]. Furthermore, need of improvement is observed to escalate efficiency of effective emergency message dissemination across the traffic environment with the assistance of efficient software defined controllers.

2.4.2 SDN into VANET as a single point of failure

Proper measures of integrating SDN into VANET are not defined yet. As the SDN-controllers are centrally managing the entire network, there is chance of software vulnerabilities. Such centralized system can cause single point of failures. Also in chaotic traffic conditions, when the number of user requests increases abruptly, there is a chance of broadcast storm problem in disseminating the emergency messages and consequently the performance of SDN-controllers suffers a lot. The infrastructure layer of VANET is separated from the control plane layer of SDN, so there is a need of designing improved strategies that could take rapid and intelligent decisions to overcome and resolves the significant problems occurs during chaotic traffic environment and proposes a dynamic path selection measure [16].

Proper monitoring of a chaotic traffic environment can determine which control layer component has to be removed from the infrastructure layer to take the maximum benefit of VSDNs. However, the existing systems lack such measures to be implemented in real-world which affects the performance evaluation of VSDNs. Therefore, adequate attention should be set for the improvement of real-world implementations for emergency message dissemination [58].

2.4.3 Standardization of protocols in VSDN

Traditional routing protocols lack efficient functionalities to deal with dynamicity of VSDNs. Therefore, requirement of proper mechanism is observed that can dynamically respond to delay and resource usage particularly in real-time emergency applications. Due to chaotic traffic situations, the routers encounter congestion and delay across the network increases which affect the emergency data delivery and leads to financial loss. Therefore, VSDN can consider the delay parameter in each path of network to give prioritization to links based on low delay and reserve them for real-time emergency messages dissemination. This allows real-time emergency messages to reach the destination with reduced delay. While, the non-real time messages could use paths derived from traditional routing protocols such as routing information protocol and inter gateway routing protocols etc [1]. In the future, new protocols are required to deploy based on the centralized control logic to improve the degree of compatibility of VANET into SDN for the better delivery of emergency data services [16].

2.4.4 Heterogeneities of VSDN

VSDN is growing to collaborate with new devices mounted with updated technologies that belong to different vendors; as a result there is a need to standardize the technologies so that communication between the vehicles may not suffer. Moreover, due to chaotic traffic situations in the urban environment, VSDN architecture requires many innovations about the network topology to improve its computing capabilities at respective RSUs. Whereas, to implement VSDN in highway scenario is not challenging as the prediction of the network topology is not as much difficult. In the city environment there is less aggressive traffic, hence there should be a mechanism deployed at RSUs to adjust its computing capabilities according to the traffic environment for the efficient delivery of emergency data [16]. Some application enforces strict timing requirements so there is a need to retrieve and share data timely. An irregular transmission of real-time emergency messages can be tragic for safety applications [28].

Once a packet associated with a definite network detects a match in the routing table, the switch intelligently predicts to tackle with the remaining packets of the same service type. SDN controller escalating the traffic redirecting efficiency of the switch, but it develops problems due to mobile nature of nodes, which leads to inconsistency of the forwarding table rules that eventually hinders the timely-processing of emergency data. Hence, it becomes difficult for controller to manage the dissimilarities among the physical network topology and global network topology which results into low emergency packet delivery ratio (pdr) [3].

2.4.5 Minimizing service delay

Delay is very unpredictable constraint in software defined vehicular networks. In view of to its wireless nature, it cannot be assured that after how long the data will be received by the destination. Delay relies upon efficient resource management. Due to the abrupt increase in traffic density the use of cloud computing to disseminate emergency messages in VANETS becomes costly. The costly functions like transferring user urgent-requests to cloud server, gathering user urgent-requests related to link settings, computational overhead encounters in cloud servers, QoS measures and monitoring of location, all services introduces delay in the network [59].

Proper resource allocation over SDMEV is required to be investigated to reduce the service delay of emergency data dissemination [30]. Moreover, there is a need to design more efficient protocols at VSDN controllers that could balances the load and minimize the service delay of emergency data by idealizing the resource utilization among RSUs and user applications [60].

The tendency of delay in the network depends upon the optimized resources so its control can be achieved through optimizing the resource usage of emergency data across the network. Therefore , there is a need to focus on delay control in future works [16]. With the evolving VANET technology exclusive vehicles are mounted with built-in intelligent sensing devices for reliable communication of emergency data, fast computation and optimal resource utilization to realize profusion of VANET-based smart applications. Therefore, the network designers are influenced to deploy smart algorithms that maximizes the network performance in terms of effective emergency data delivery[61].

2.4.6 Dynamic Topology of VSDN

One major concern for SDN-based VANET is large voids among heterogeneous data services. The problem of mutual capability of heterogeneous data services for emergency data delivery with new technological innovation is a major concern as it leads to link breakage among vehicles. Due to chaotic traffic conditions there is a chance of high packet loss and packet interference [56]. As a result, existing heterogeneous data services for emergency data demands improved techniques and capacity generation of network topologies must be enhanced.

In [62] VSDN , challenges related to the high mobility of nodes still apply as they make problems that should be properly tackled to attain desired improvements of SDN concepts for the purpose of emergency message dissemination. Also, vehicles are changing their respective positions rapidly that creates architectural design challenges and suggested to examine dynamic distributed control based on diverse traffic environment [60]. There are more chances of link disruptions due to unstable VSDN topology, as a result to deploy efficient SDN-controllers mounted with improved functionalities can become costly [16]. Furthermore, it is difficult to uphold emergency data due to frequent trafficking of beacon messages that causes emergency message interferences.

2.4.7 Security and privacy with VSDN

Security Network Model with enhanced capabilities to offer secure emergency services is a challenge. Software Defined Network and Cloud Computing can be integrated to offer essential protection in vehicular network from cybercriminal attacks [63]. When an intruder breaks into the system, reliance in the system may not be formed if the information is manipulated by the intruders and before sent to the recipients. As a result, it is crucial to retain system availability and to maintain reliance in traffic environment [64].

Data request is accepted and acknowledged in few seconds using MEC applications and allows the vehicle to respond instantly. The MEC could host different virtual network functions (VNFs) to enable secure and reliable emergency data transmission between V2V and V2I. However, the MEC encounter several issues that is concerned with secure service chaining of VNFs mounted in the MEC, the authorization of VNFs at the MEC, and to propose different machine learning algorithms for interruption exposure such as bogus information attack at MEC to decrease the blockage and bandwidth utilization of emergency vehicles [65].

SDN is exposed to DDoS attacks due to low bandwidth of transmission link between SDN-controllers and switches and fixed size of routing tables [3]. Moreover, the unavailability of compact emergency data among data plane bodies due to directly programmable feature of SDNs, and valuable policies concerned with functionality of SDN are the major bottlenecks in a way of adopting VSDN in real time environments.

2.4.8 Sustainability in VSDN

Sustainability in VSDNs generally refers to two aspects; it may concerns with the long lasting existence of software-based emergency services or software that is developed under consideration of environmental aspects, social aspects and economical aspects to disseminate emergency messages [66]. Vehicular software defined networking (VSDN) needs to focus on software sustainability aspects to enable a networking software to sustain over the long time for reliable emergency data delivery. As VANETs are evolved and integrated with SDN-based technology and becomes software controlled to centrally manage the emergency traffic network. Therefore more energy-efficient SDN-controllers are required to be designed with optimal algorithms and energy efficient coding schemes for sustainable emergency data dissemination [34].

The prime focus is to assist software developers to make use of optimal coding and less energy consuming codes to help SDN-controllers to be operated as environment friendly controllers that can contribute towards a sustainable environment. Moreover SDN-controllers should be equipped with reliable and energy-efficient features to enhance the longevity of SDN-controllers so that the challenge of single point of failure can be minimized. However, there is a need to investigate whether the existing working architecture of VSDN adequately address the aspects of sustainability in deliverance of emergency data services.

2.4.9 Hidden vehicle attack and Broadcast Storm in VSDNs

Another challenge that appears in SDN-based emergency message dissemination is the hidden vehicle attack. During the broadcast warnings of accidental vehicle , some vehicles are not warned on time because they do not lies in coverage range of RSUs [11]. The intruder even thwarts the real situation by transmitting fake location information to nearby cars. The attacker deceives nearby vehicles by claiming to be in a better place to warn them of the crash. The attacker either sends fake accident notifications to other nodes or remains quiet after receiving the safety messages [64].

Disseminating emergency communications in a congested traffic area often creates a broadcast storm problem, in which redundant transmission of the same messages induces communication delays and decreases traffic network throughput. Additionally, to tackle the challenges induced by hidden nodes and broadcast storm problems, the SDN-controllers should run techniques that use more effective optimization models for allotting distinct frequencies to each vehicle [3].

2.4.10 Lack of QoS for emergency services in VSDNs

Since it is close to the vehicular nodes, the fog server may play an important role in the transmission of emergency messages. It can help with the collection of emergency data in a timely manner. With the aid of wired connections, a fog server connects to the cloud or other fog devices. It helps to reduce operational costs by conserving network bandwidth by refining only selected data at the local level rather than sending the data to the central cloud for evaluation. As a result, increasing the efficiency of VSDNs requires equipping fog servers with high intelligence capable of finding a suitable destination for emergency messages by offering location-based services [28].

Furthermore, in an emergency, the vehicle must broadcast emergency signals to surrounding vehicles and RSUs. The range of an emergency message's dissemination varies depending on the form of mishap. Some mishaps are broadcasted to a small region, while others, depending on the severity of the incident, are broadcast to a large area of several kilometers. To prevent more casualties, event forms such as auto crashes and traffic congestion must be disseminated over a greater distance. However, the propagation range of emergency messages can be influenced by other variables, such as environmental conditions, necessitating a more complicated rationale to determine an appropriate propagation range. As a result, more efficient machine learning algorithms in fog servers are needed to minimize packet loss, delay, and jitter on the traffic network [60].

2.5 Summary

SDN-based heterogeneous data dissemination coordinates with diverse wireless interfaces such as cellular communication, dedicated short range communication (DSRC), Wi-Fi and Bluetooth etc., to support versatility of intelligent transport systems (ITS). The gaps and improvements needed in proposed methods for priority-based data scheduling for data services and data distribution in heterogeneous vehicular networks have been highlighted. The existing works are perpetuated to assist collaborative data service scheduling across heterogeneous network interfaces. It is ascertained that the most of the existing schemes recon upon efficient information dissemination but still numerous challenges are imposed due to distinct nature of vehicular networks.

CHAPTER 3

METHODOLOGY

3.1 Overview

Software-defined system architecture has been provided to endorse emergency message dissemination among V2V, V2I and VX communications. A novel SDN controlled priority-based emergency messages dissemination (PEMD) scheme is proposed. At RSU, policy-based multifold classifier (PMF) is deployed to classify packets into multiple folds. After that the packets are sent to SDN-controller that also acts as fog server for EM priority scheduling. Furthermore, weight of the prioritized packets is calculated using modified TWG scheme to select best emergency message disseminator (EMD). Due to high mobility, dense traffic and limited time of communication between vehicles, it is important and challenging to design a reliable dissemination strategy in VANETs that can minimize the transmission delay to meet the needs of delay-sensitive applications. Therefore, the existing work lacks reliable software-defined mechanism for scheduling and dissemination of emergency messages based on different severity levels. A four class priority emergency packet scheduling method in VSDN is presented to provide real-time data services in vehicular networks based on cooperative decisions of mounted sensors in vehicles to control the emergency situation. It mainly consists of four priority classes, medium, high, very high and extremely high. Evolved priority packet is introduced for immediate EM dissemination; PMF performs packet classification into multiple folds based on optimal policies. The best EM disseminator is selected by modified TWG scheme.

3.2 Operational Framework

In this proposed model, software-defined system architecture has been presented to support emergency message dissemination among V2V, V2I and VX communications.

SDN controlled priority-based emergency messages dissemination architecture is proposed. It consists of four system units: (1) vehicles, (2) RSUs, (3) SDN controller and (4) cloud server. The vehicles can communicate via V2V and V2I interfaces through wireless communications. RSUs lies in the coverage area interconnected through wireless or wired links. The evolved priority packet is depicted in Figure. 3.1. It involves packet fields which includes source coordination, service flag and Emergency level. The packet features represents data name, Dmax and priority preference which are considered in PMF classifier.

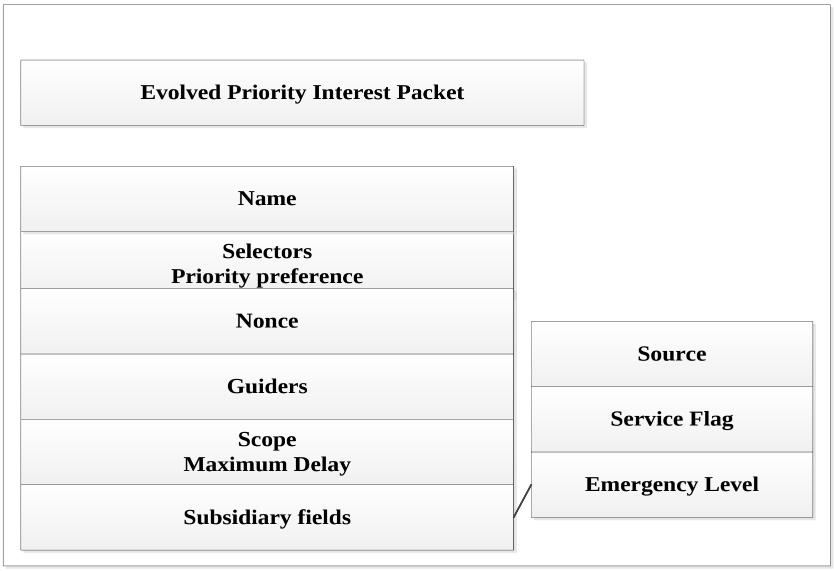


Figure 3.1: Evolved Priority Interest Packet

SDN-controller is mounted centrally to support efficient routing for emergency message dissemination by maintaining a global view of entire network. RSUs can synchronize data among them as illustrated in Figure 3.2. RSU contains emergency and normal data items that are classified by using optimal indexes. When a request packet from passing vehicle arrived at RSU, it is classified into emergency packet and normal packet through policy-based multifold classifier implemented (PMF) at RSU. PMF classifier makes use of packet features associated in request packet. The requested packet is associated with following fields: (1) source address, (2) service flag and (3) request deadline. Here, the service flag represents the packet type (i.e. if this flag set to 1, the packet is an emergency type and if it is set to 0, the packet is normal.

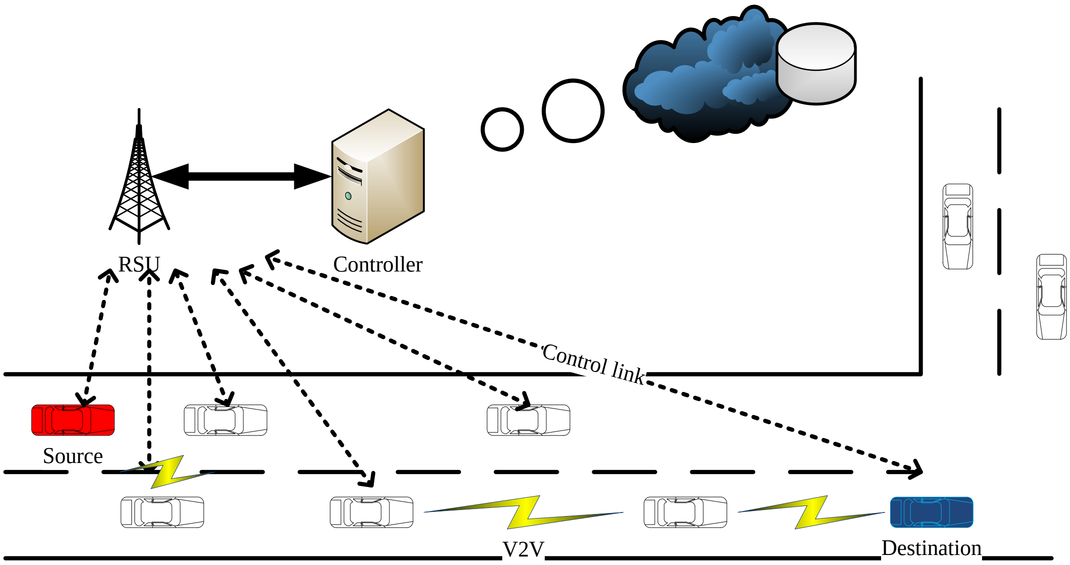


Figure 3.2: Operational Framework of PEMD

3.3 Research Design and Development

In CCN-based VANET, the preference value was equally distributed to each property which affects emergency data dissemination in the network. [27]. In SDN-controlled VNDN, emergency data dissemination starts with packet classification. Interest packet includes an emergency type field, when received at RSU, policy-based bifold (PBF) classifier differentiate the emergency packets from normal packets. The emergency type shows the severity of the message which is not further subdivided as per different level of emergency in the real-time traffic environment. The system processes all the emergency packets with same priority that can delay the propagation of severe emergency messages without segregating them into different emergency packets. To ensures the road safety and overcomes road risks our proposed novel priority-based VSDN architecture controls the emergency situations according to severity levels in realistic traffic environment [24]. Thus, it is necessary to improve EM dissemination in VANET, considering priorities of EMs with a novel SDN-based architecture.

3.3.1 Evolved Priority Interest Packet at RSU

At RSU, the process begins with the evolved priority packets. Name, maximum delay, service flag, and emergency level are necessary fields in the evolved interest packet to reduce delay in an emergency for instantaneous data transmission. The evolved interest packet arrives at RSU, where the packets are further classified into multiple folds.

3.3.2 Policy-based Multifold Classifier

At RSU, a novel policy-based multifold classifier (PMF) is deployed at RSU to classify packets into multiple folds. The evolved interest packet is classified into emergency packet and normal packet. If the service flag is set to 1, it is emergency packet and if service flag is set to 0, it is labeled as normal packet. After that the packets are further processed at RSU assisted SDN-controller for EM priority scheduling.

3.3.3 Priority-based EM Scheduling

The emergency packet is further classified into 4 emergency level , in the first fold the emergency packet is categorized as medium emergency level with maximum delay (D_{max}) of 20ms and a priority value (Pri) 4, in second fold as high emergency level (EL) with maximum delay (D_{max}) of 15ms and a priority value 3, in the third fold as very high emergency level with maximum delay (D_{max}) of 12ms and a priority value 2 and in the forth fold as extremely high emergency level with maximum delay (D_{max}) of 8ms and priority value 1. Here the (D_{max}) is considered as threshold value (TH).

3.3.4 Priority-based EMD Selection

Weight of the classified packets is calculated on the basis of velocity (V), number of neighbors (N_{Nei}), traffic density (TD) and distance with RSU (D). The best disseminator will be selected through modified trustworthy weight graph (TWG) scheme with highest weight value of the node in the road section.

3.4 Simulation Framework

The simulation model was built in conjunction with the stated priority-based emergency message propagation in VSDNs, and the results were evaluated. The simulation model was built using the device model. To simulate communication between vehicular nodes and the local RSU assisted SDN-controller and regional SDN-controller, the network simulator (NS-3.29) is operated. The RSUs have been positioned at junctions and are evenly dispersed along the roads.

Packets are arrived at RSU, which is then sent to the SDN-controller for real-time data scheduling. The SDN-controller keeps a global view of the entire network. Vehicles and ambulances are among the diverse traffic. The interaction between vehicles, RSUs, and the SDN-controller has been investigated. SDN-controller maintains a database of 500 data packets, 400 of which are emergency packets and 100 of which are normal packets. Data packet sizes were supposed to be restricted.

The data packets were meant to be the same size all the time. Important simulation parameters have been tabulated and used in the implementation of data distribution of emergency messages in the VSDN, as shown in Table 3.1. Simulation begins after setting up all of the simulation parameters in order to test the proposed work.

Table 3.1: Simulation Parameters

Parameters	Value
Simulation time	1000s
Number of vehicles	20-100
Number of RSU	4
Number of SDN-controller	2
RSU range	300m
SDN-controller range	500m
Vehicle range	100m
Number of data packets	500
Emergency Packets	150
Normal Packets	300
Channel Type	Wireless
Network Field	1200x1200metres
Packet Interval	10ms
Initial Energy	1000J
Receiving Power	0.049J
Maximum vehicle speed	10 to 100 m/s

The communication between 100 vehicles and RSUs moving across the road was considered in two lanes, with the upper lane vehicles moving faster than the lower lane vehicles. At RSU, incoming packets are divided into two categories: emergency and normal. Vehicles produce data packets, which are then classified and prioritized by the RSU assisted SDN-controller.

3.4.1 Priority-based Emergency Dissemination Model

Regional SDN-controller is mounted centrally to support efficient routing for emergency message dissemination by maintaining a global view of entire network. RSUs can synchronize data among them. RSU contains emergency and normal data items that are classified by using optimal indexes. When a request packet from passing vehicle arrived at RSU, it is classified into emergency packet and normal packet through policy-based multifold classifier implemented (PMF) at RSU. PMF make use of packet features associated in request packet. The incoming evolved packet is associated with following fields: (1) source address, (2) service flag and (3) emergency level. Here, the service flag represents the packet type (i.e. if this flag set to 1, the packet is an emergency type and if it is set to 0, the packet is normal. If a packet is classified as an emergency packet and normal packets, RSU assisted SDN-controller performs priority scheduling based on various severity levels of emergency packet as shown in Figure 3.3.

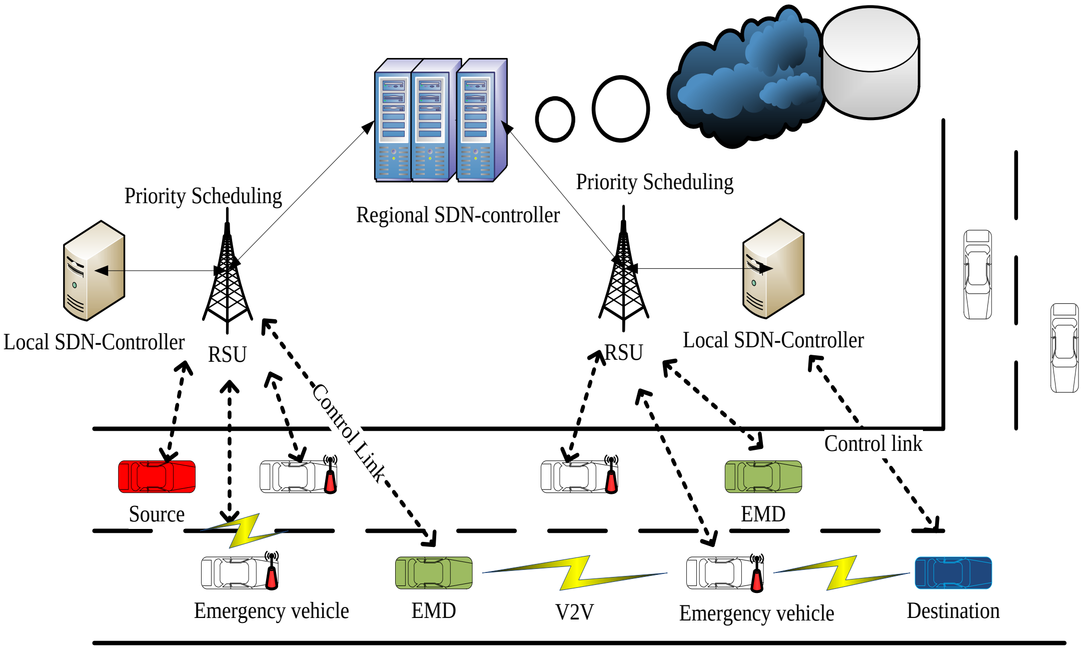


Figure 3.3: SDN-controlled Prioritised Emergency Message Dissemination Model

PMF classifier performs the classification in multiple steps. Both packets are categorized into normal and emergency packets in the first step, emergency packets and normal packets are performed for priority scheduling at RSU assisted SDN-controller in the second step, and the novel weight value is assigned to normal and prioritized emergency packets in the third step to pick the best emergency message disseminator (EMD) based on significant metrics such as velocity (v), number of neighbors (Nnei) , traffic density (TD) , distance (Dr) with RSU assisted SDN-controller. Emergency message dissemination is involved with three processes such as RSU’s range divisions, prioritizing the emergency packets and selecting the best EMD based on priority levels. In the first process, the road according to RSU’s range is divided into possible number of segments. Emergency and normal packets are prioritized according to severity levels in each segment, and each vehicle is assigned a priority value to help choose the best EMD node. The EMD will send emergency messages to a number of different destinations. For non-safety communications such as parking lot information, traffic rates, and weather information, a normal packet may be requested.

3.4.2 Simulation Environment

The device model has been used to frame our proposed novel SDN-based simulation model. The network simulator NS-3.29 is used to test communication between vehicular environment components and the SDN controller. We build a simulation topology about openvswitch (OVS) and wifi modules. OVS is connected to an external controller. The packets are sent from host (0) to wifista (0) and when host (0) receives the packet from wifista (0) as shown in Figure 3.4.

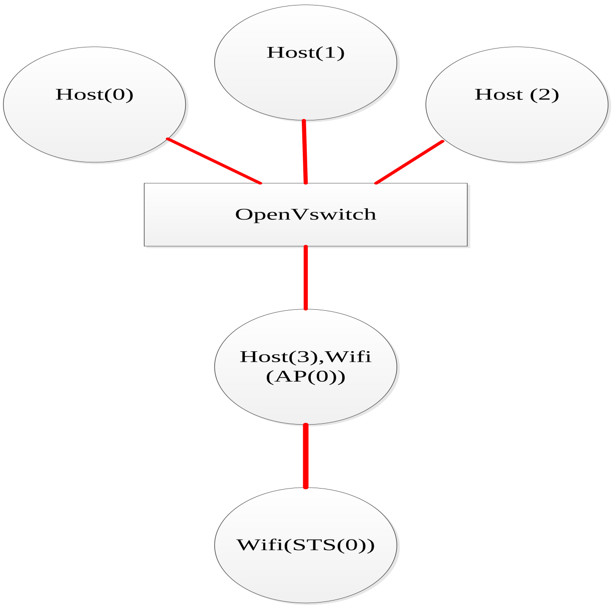


Figure 3.4: Simulation Model using SDN

RSUs have been strategically placed at intersections and are uniformly distributed around the routes. Because of its unique characteristics, such as topology specification, model creation, node configuration, and so on, NS-3 is used. WaveNetDevice, which was created to implement VSDN experiments based on significant metrics of benchmark schemes as illustrated in Table 3.2, aids in the implementation of data exchange in VANET. To help our simulation, the Ubuntu-20.04 operating system has been mounted on the PC.

Table 3.2: Limitations in Benchmark Schemes

Existing Work	**Architecture**	**Limitations**
ED dissemination in VNDNs [24]	SDN and NDN with VANET	Lack of scalability for IoVs and QoS for safety messages and emergency type is not further segregated to enable real-time and efficient data dissemination.
AdPS [42]	Priority Scheduling for EM dissemination with VANET	Lacks collaborative data dissemination among

		heterogeneous networks.
FCFS and EDF [39], [40]	FCFS and EDF with VANET	Starvation among user requests.
RUFS [27]	VANET with CCN	Preference value assigned to each node is equally distributed, that increases delay in data forwarding.

3.4.3 Assumptions and Limitations

In priority-based VSDN, the following assumptions are considered:

i. Broadcasting scope of all RSUs (BR) in the entire network is equivalent.
ii. Broadcasting scope of all vehicles (BV) in the entire network is equivalent.
iii. Each vehicle is able to interact with no less than one RSU by either a direct connection or multi- hops communication through neighboring vehicles.
iv. BV < BR.

3.5 Summary

Each methodology has its advantages and disadvantages and can demonstrate better performance and efficiency under different traffic conditions. The implementation of priority based emergency messages dissemination using SDN-enabled 5G technology can be effective as it can provides scalability, reliability and efficiency. The PMF classifier uses multiple steps to perform classification. All packets are divided into normal and emergency packets in the first step. The packets are performed further priority scheduling at RSU assisted SDN-controller in the second step, and the prioritized emergency and normal packets are sorted based on their weight values in the third step. The best EMD is selected based on highest prioritised weight value.

CHAPTER 4

PRIORITY-BASED EMERGENCY MESSAGE DISSEMINATION SCHEME

4.1 Overview

In this section software-defined system architecture has been presented to support emergency message dissemination among V2V, V2I and VX communications. SDN controlled priority-based emergency messages dissemination (PEMD) scheme is proposed. At RSU, policy-based multifold classifier (PMF) is deployed to classify packets into multiple folds. After that the packets are scheduled at RSU assisted SDN-controller that also provide intelligent decision making system for imprecise inputs. Furthermore, weight of the prioritized packets is calculated to select best emergency message disseminator (EMD). Due to high mobility, dense traffic and limited time of communication between vehicles, it is important and challenging to design a reliable dissemination strategy in VANETs that can minimize the transmission delay to meet the needs of delay-sensitive applications. Therefore, the existing work lacks reliable software-defined mechanism for scheduling and dissemination of emergency messages based on different severity levels. A four class priority emergency packet scheduling method in VSDN is presented to provide real-time data services in vehicular network components based on cooperative decisions of mounted sensors in vehicles to control the emergency situation. It mainly consists of four priority classes, medium, high, very high and extremely high.

4.2 Priority-Based Emergency Message Dissimination Scheme

The system model comprises of four system units: including vehicles, RSUs, SDN controller and cloud servers. The vehicles can communicate via V2V and V2I interfaces from end to end wireless communications. RSUs lies in the coverage area interlinked through wireless or wired connections.

Sample packet for emergency support is illustrated in Table 4.1. In this example, P1, P2, P3 and P4 are emergency packets. This separation process is performed by PEMS scheduler and packets are prioritized according to emergency levels. Then weight value is computed for each packet. P1 has weight value higher than P4; it means P1 has extremely high priority.

Table 4.1: Prioritised Classes of Vehicles in Abnormal Conditions that needs Emergency Support

Packets	**Priority Values**	**Service Flag**	**Dmax**	**Emergency Level**	**Speed Classes**	**Location Status Classes**
P1	1	1	Extremely Low (8ms)	Extremely high	80-100 km/h	CASE A: When vehicle’s sensor detects problem in breaks or accelerator condition indicates any failure or vehicle’s sensor indicates poor tire condition at normal and dense traffic regions.
P2	2	1	Very high (12ms)	Very high	60-80 km/h	CASE B: When vehicle’s sensor detects temperature increase or detects over speed limits at dense traffic regions.
P3	3	1	High (15ms)	High	30-60 km/h	CASE C: When vehicle sensor detects blind spots or indicates poor engine condition.

P4	4	1	Medium (20 ms)	Medium	0-30 km/h	CASE D: When vehicle’s sensor detects non-usage of safety gears like seatbelt and use of mobile phone in normal and dense traffic regions.

A priority based emergency message dissemination (PEMD) scheme is anticipated to present an efficient solution to provide real-time data services in vehicular networks based on cooperative decisions of mounted sensors in vehicles to control the emergency situation. The main modules of proposed scheme are illustrated in Figure 4.1.

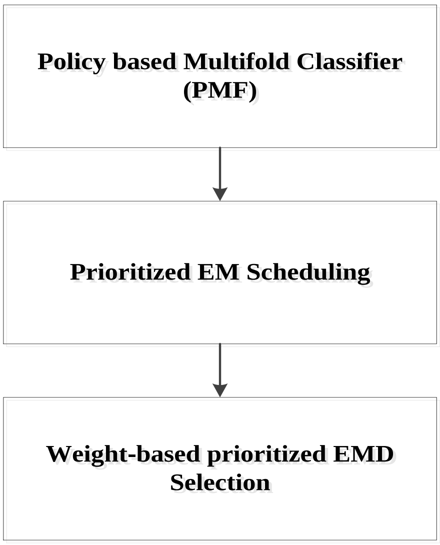


Figure 4.1: Proposed System Components

4.2.1 Packet Classification

Since the destination address is unknown to vehicles, priority-based VSDN interest packets are sent to the nearest RSU first. In previous work, neighbor node information had to be exchanged on a regular basis among vehicles, resulting in high congestion and a decrease in network capacity. To solve this problem, RSU collects interest packets from vehicles and classifies them using the best policy-based multifold classifier (PMF) policies, as shown in Algorithm 4.1. It makes use of packet features found in interest packets. The following fields are included in the interest packet: (1) source address, (2) service flag, and (3) emergency level. The following packet features are taken into account by the PMF classifier in evolved priority packets: name, maximum delay, service flag, and emergency level. The name here refers to the data name, the service flag represents the packet type (i.e., if this flag is set to 1, the packet is an emergency packet; if it is set to 0, the packet is a normal packet), and the emergency level represents the emergency packet's priorities.

Algorithm 4.1: Policy-based Multifold Classification

```
1.  Separate packets based on emergency flag
        1- Emergency packet ($P_E$)
        0- Normal packet ($P_N$)
2.  For all $P_E$
        Get prioritised weight value
        $PV_E = \sum$ Dmax, Emergency Level
        Sort $P_E$ based on $PV_E$
3.  For all $P_N$
        Get prioritised weight value
        $PV_N = \sum$ Destination, Dmax
        Sort $P_N$ based on $PV_N$
```

Here, the values for T, emergency level and priority classes are assisted from regional SDN-controller after the synchronization of data is performed among RSU and SDN-controller.

4.2.2 Packet Scheduling

The priorities are defined based upon different severities of the packet and maximum delay (Dmax) represents the delay time that is set with each emergency level. If a packet has service flag as 0, then the packet is normal packet. If a packet is emergency packet then the packet is sent to the RSU assisted SDN-controller for priority-based emergency message scheduling (PEMS) as shown in Algorithm 4.2.

Algorithm 4.2: Emergency Queue Prioritisation

```
Input: Priority value (Pr), Emergency Flag (EF) & Emergency level ( EL)
Output: Emergency priority Queue Selection
Select extremely high priority packets
If EF= 1 & EL=very high & (pr=1) then
   Store request to Queue_EH;
   Select very high priority packets
Else if EF= 1 &EL= Very high & (pr=2) then
   Store requests to Queue_VH;
   Select high priority packets
Else if EF=1 & EL=Medium & (pr=3)  then
   Store packets to Queue_M;
   Select Medium priority packets
Else if EF=1 & EL=Low & (pr=4) then
   Store packets to Queue_L;
Else
      Remove the request from priority queue;
End
```

The RSU assisted SDN-controller analyzes the emergency packet and assigns an emergency level based on four priority classes and sets the maximum delay (Dmax) to reach the destination. If the emergency priority class is “1”, then the packet conveys extremely high emergency information based on the mounted sensor signals. Therefore, the packet’s emergency level (EL) is set to “extremely high” and Dmax is set to EH. The extremely high priority packets are stored extremely high priority queues (Queue_EH). If the emergency priority class is “2”, the EL is set to “very high” and Dmax is set as VH. The very high priority packets are stored in high priority queues (Queue_VH). If the emergency priority class is “3”, the EL is set to "high" and Dmax is set as H. The high priority packets are stored in high priority queues (Queue_H). If the emergency priority class is "4", the EL is set to "Medium" and Dmax is set as M. The medium priority packets are stored in medium priority queues (Queue_M) as shown in Algorithm 4.2. The PMF classifier uses multiple steps to perform classification. All packets are divided into normal and emergency packets in the first step. The packets are performed further priority scheduling at RSU assisted SDN-controller in the second step, and the prioritized emergency and normal packets are sorted based on their weight values in the third step. When RSU receives a request, it follows the optimal policies mounted at RSU assisted SDN-controller.

4.2.2 Emergency Message Dissemination

According to the assumptions of the system model, the road is initially located in the RSUs' broadcast scope, which is divided into multiple parts. The RSU is in charge of calculating the number of road segments and selecting the most appropriate EMD for each prioritized emergency packet as shown in Algorithm 4.3. Number of segments (G) is determined as $G = \frac{BV}{BR}$ Eq. (1). The road under RSU broadcast reach is divided into G equal segments for EM dissemination after the number of segments is determined.

Algorithm 4.3: Modified TWG scheme

```
1. RSU collects interest packets from vehicles
2. Classify packets into PE and PN
3. For ∀P ∈ PE
      Compute G
      Divide $B_R \rightarrow$ G segments
      In each Segments
      Construct graph with vehicles
4.       For each V ∈ Graph
            Compute PWV
            $PWV = (\sum Nnei) - (\sum V,D,TD)$
            Sort vehicles accordance with PWV
            Select V with highest PWV as EMD
5.          Broadcast $P_E$ through EMD
```

```
        End For
      End For
      End
12. End For
13. End
```

RSU segregates data packets into two categories: emergency packets (P_E) and normal packets (P_N). After that the emergency packets are performed further priority scheduling. Vehicles are uniquely identified with V_id and vehicular nodes transmit the sporadic beacon messages to nearby RSUs. The following fields are included in the vehicle beacon message: (V_id, V_st, P_loc, Dest, V_i, V_dr) where V_id uniquely identifies vehicles. V_st is status of vehicle. P_loc is the current position of vehicle. Dest is the intended destination of the vehicle. V_dr denotes the vehicle's mobility path as illustrated in Table 4.2.

Table 4.2: Set of Notations

V_id	Identity of vehicle in range of RSU
V_st	Status of vehicle
P_loc	Current position of vehicle
Dest	Destination location of the vehicle
V_i	Velocity of vehicle
V_dr	Direction of mobility of vehicle

It is important to understand the network topology in order to improve the system's intelligence. To obtain the details of all nearby vehicles, a beacon message is sent to all neighbor nodes. This data is then sent to the SDN-controller, which uses it to create a graph of linked nodes, which is used to make emergency communications decisions including choosing a path to route the data packet through the entire vehicular network. RSU assisted SDN-controller also analyzes the arrived packet and assigns a priority value and stores it in a respective priority queue. The packet which have shortest deadline will be given highest priority. All packets are maintained in priority queues. Packets which have highest priorities will be processed first.

4.2.3 Weight-based prioritized EMD selection

The best EMD election is implied with modified TWG scheme in which a weight value is calculated for each vehicle in the segment. On the basis of weight value, the best disseminator vehicle is selected for emergency message dissemination and the trust worthy disseminator is selected on the basis of weight value. The weight value is calculated on the basis of number of neighbors ($\mathrm{N_{Nei}}$) , velocity (v), density of traffic (TD), distance (D) with RSU assisted SDN-controller. The PEMS cycle time determines the service interval for which RSU processes data packets and denoted by T maximum and delay (Dmax) of prioritized emergency and normal packets which is determined by T= $\frac{2BR}{Vmax}$ where BR is coverage range of RSU in the network and Vmax is the maximum allowed velocity associated with each vehicle. Weight value for each node is calculated by PWV= $(\sum \mathrm{N_{Nei}})$ - $(\sum \mathrm{V, D, TD})$ Eq. (2) where the prioritized weight value is calculated by considering following metrics. $\mathrm{N_{Nei_i}} = \frac{\mathrm{N_{Nei}}}{\mathrm{N}}$ Eq. (3), $\mathrm{NV_i} = \frac{\mathrm{BV_i}}{\mathrm{V_{max}}}$ Eq. (4), $\mathrm{D_i} = \frac{\mathrm{D_i}}{\mathrm{B_R}}$, $\mathrm{T_D} = \frac{\mathrm{TD}}{\text{Total number of vehicles}}$ Eq. (5). Each significant metric calculated value is considered as prioritized weight value [24].

The overall phase of PEMS scheme-based EM dissemination is depicted in Algorithm 4.1. The PEMS scheme's implications allow priority-based efficient dissemination EMs by selecting the best EMD, thereby reducing service delay across the network. The requests in Case A, B, C and D are serviced by PEMS scheduler, which is mounted at RSU assisted by SDN-controller. For each packet arrived at RSU, it is classified into emergency packet and normal packet. After that the classified packets are performed priority scheduling at RSU assisted SDN-controller based on different emergency cases/level. The maximum delay (Dmax) has been computed for each packet in terms of PEMS cycle time.

Each packet is stored in a respective queue depending on the flag, priority value and Dmax (as per PEMS algorithm 4.2). The packets presented in priority queues Q_EH, Q_VH, Q_H and Q_M are serviced at RSU assisted SDN-controller in PEMS cycle time as shown in Algorithm 4.2. The PEMS cycle time, denoted by T, specifies the operation interval for which the RSU assisted SDN-controller processes data packets. The scheduling time cycle is determined by the vehicle range in the network and the overall maximum speed of the vehicles. $T=\frac{2BR}{Vmax}$ where B_R is range of RSU in the network and Vmax is the maximum speed associated with each vehicle. To retrieve the emergency priority queues, the scheduling cycle time is divided into four time spans t_{eh} , $t_{vh,}$ $t_{m,}$ and t_l ; where, 't_{eh}' is the time span to retrieve exceptionally high emergency priority queue, 't_{vh}' is the time span to retrieve very high emergency priority queue, 't_m' is the time span to retrieve medium emergency priority queue and 't_l' is the time span to retrieve low emergency priority queue. The time span to retrieve respective priority queue is computed by $T= t_{eh}+t_{vh,}+t_{m,}+ t_l$; where $t_{eh} > t_{vh,}>t_{m,}> t_l$. The time spans t_{eh} , $t_{vh,}$ $t_{m,}$ and t_l retrieve the Q_EH, Q_VH, Q_M and Q_L respectively.

4.3 Summary

The SDN conviction is to use an intelligent SDN-controller to handle the entire network. SDN improves network proficiency by maintaining a global view of the network and maintaining network specifics such as vehicle information, content information, and current vehicle location. Integration of VANET with SDN make traffic network proficient by providing the precise, complete and more accurate network status information.

CHAPTER 5

RESULTS AND ANALYSIS

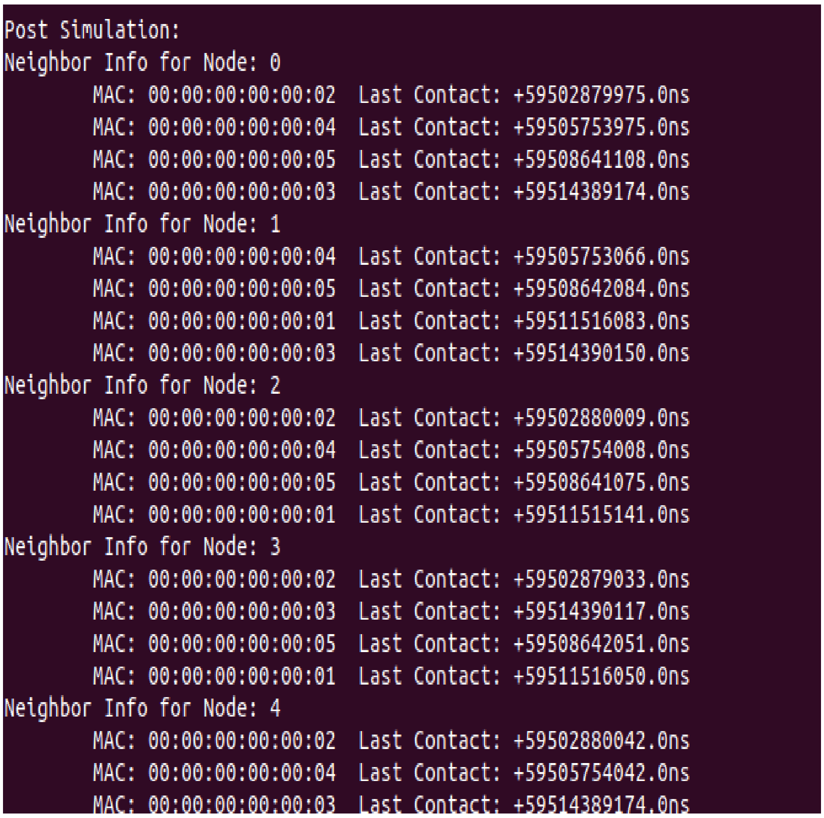
5.1 Overview

In this section, we implement the proposed algorithm for the given SDN-controlled VANET simulation model in terms of performance metrics on emergency cases. The comparative analyses have been presented in following section.

5.2 Results and Analysis

Wireless technology is used to exchange messages in VANETs. V2V (Vehicle to Vehicle) and V2I (Vehicle to Internet) are the two main modes of wireless communication in VANETs (Vehicle to internet). 802.11-based DSRC (Dedicated short-range communication) or WAVE is used for communication between vehicles and RSUs (Wireless Access in Vehicular environment). The standard is sometimes called 802.11p because that’s the standard where it was first specified. However 802.11p was merged with main 802.11 standards under OCB mode (Outside context of BSS). Basically, devices can communication with one another directly, and channel access is managed in a contention-based CSMA (Carrier sense multiple access) fashion.

In our simulation scenario, we utilizes a WaveNetDevice to exchange messages directly based on priorities with the help of SDN-controller that manages the whole network centrally as well as physically installed with the RSUs in order to gain scalability. Every node is maintaining a list of neighboring nodes and mobility is installed in nodes with different position and velocity as shown in Figure 5.1. Nodes are moving in same direction, one lane is going faster than the other. The packets are broadcasted every 100ms. NS-3 implements this in WAVE module, which uses WaveNetDevice as a base device for prioritized communication between packets as shown in Figure 5.2.



```
Post Simulation:
Neighbor Info for Node: 0
        MAC: 00:00:00:00:00:02  Last Contact: +59502879975.0ns
        MAC: 00:00:00:00:00:04  Last Contact: +59505753975.0ns
        MAC: 00:00:00:00:00:05  Last Contact: +59508641108.0ns
        MAC: 00:00:00:00:00:03  Last Contact: +59514389174.0ns
Neighbor Info for Node: 1
        MAC: 00:00:00:00:00:04  Last Contact: +59505753066.0ns
        MAC: 00:00:00:00:00:05  Last Contact: +59508642084.0ns
        MAC: 00:00:00:00:00:01  Last Contact: +59511516083.0ns
        MAC: 00:00:00:00:00:03  Last Contact: +59514390150.0ns
Neighbor Info for Node: 2
        MAC: 00:00:00:00:00:02  Last Contact: +59502880009.0ns
        MAC: 00:00:00:00:00:04  Last Contact: +59505754008.0ns
        MAC: 00:00:00:00:00:05  Last Contact: +59508641075.0ns
        MAC: 00:00:00:00:00:01  Last Contact: +59511515141.0ns
Neighbor Info for Node: 3
        MAC: 00:00:00:00:00:02  Last Contact: +59502879033.0ns
        MAC: 00:00:00:00:00:03  Last Contact: +59514390117.0ns
        MAC: 00:00:00:00:00:05  Last Contact: +59508642051.0ns
        MAC: 00:00:00:00:00:01  Last Contact: +59511516050.0ns
Neighbor Info for Node: 4
        MAC: 00:00:00:00:00:02  Last Contact: +59502880042.0ns
        MAC: 00:00:00:00:00:04  Last Contact: +59505754042.0ns
        MAC: 00:00:00:00:00:03  Last Contact: +59514389174.0ns
```

Figure 5.1: Nodes maintaining neighbor information in NS-3.29

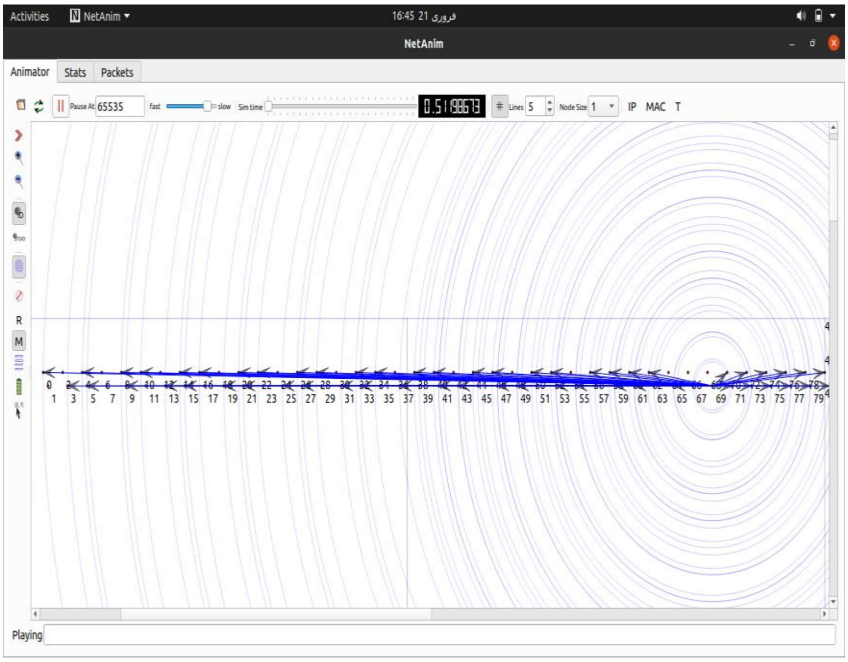
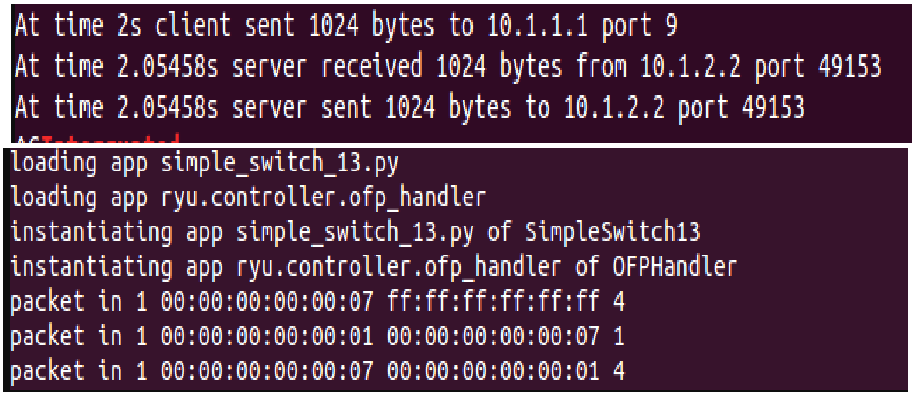


Figure 5.2: Prioritized communication between different nodes

In the present simulation model, a vehicle can generate data packet that is received at RSU, which lies in the range of vehicle. RSU assisted SDN-controller performs further packet scheduling based on priorities as depicted in Figure 5.3. To evaluate the execution of the proposed algorithm, simulation has been carried out at a traffic scenario.


```
At time 2s client sent 1024 bytes to 10.1.1.1 port 9
At time 2.05458s server received 1024 bytes from 10.1.2.2 port 49153
At time 2.05458s server sent 1024 bytes to 10.1.2.2 port 49153
```

```
loading app simple_switch_13.py
loading app ryu.controller.ofp_handler
instantiating app simple_switch_13.py of SimpleSwitch13
instantiating app ryu.controller.ofp_handler of OFPHandler
packet in 1 00:00:00:00:00:07 ff:ff:ff:ff:ff:ff 4
packet in 1 00:00:00:00:00:01 00:00:00:00:00:07 1
packet in 1 00:00:00:00:00:07 00:00:00:00:00:01 4
```

Figure 5.3: Log Information and Controller Information

The execution of the proposed algorithm has been weighed up with earlier existing data service scheduling algorithms (a) FCFS, (b) EDF and (c) AdPS and (d) TWG. The statistical data for dissimilar network parameters which includes number of data packets received at RSU assisted SDN-controller, service time for scheduling each data packet, the number of data packets which fails to catch the deadline etc. has been gathered and examined.

The service ratio (the number of data packets supported at the RSU assisted SDN-controller divided by the total number of packets inserted into the RSU assisted SDN-controller), the deadline miss ratio (the number of packets that miss their maximum delay divided by the total number of packets), and the service delay ratio (the number of packets that miss their maximum delay divided by the total number of packets) are used to calculate the results (It is defined as delay occurred while assisting a packet at RSU during a scheduling cycle).

5.3 Comparison with Benchmark Schemes

The proposed SDN controlled PEMD is compared with existing work such as SDN controlled VNDN, RUFS and priority based schemes like FCFS, EDF and AdPS respectively. The proposed algorithm has been implemented and the results have been evaluated for a given simulation topology. The comparison with benchmark schemes have been presented as follows:

5.3.1 Effect of number of vehicles on service ratio

The number of packets served on an SDN controller is known as the operation ratio, which is divided by the number of packets sent to the SDN controller. As the traffic route grows, the number of data packets is increasing exponentially and the operation load on the SDN controller is increased. As the service load increases, there is also a reduction in the service ratio in the number of data packets to handle during a scheduling cycle.

The proposed algorithm surpasses previous algorithms as it priorities requests depending on their level of urgency and gives driver assistance pre-crash care. Thirty of the 100 emergency packages priority, twenty of them very high priority, ten high priority and the remaining 40 listed as the medium emergency category, is considered highly high priorities. The service relationship of the proposed algorithm ranges from 61 to 90%, more efficient than the previous algorithms. When considering 20 engines, the service ratio for FCFS, EDF and AdPS is between 18%, 33% and 70%. As Figure 5.4 shows, we have a factor of 80 in this proposed PEMD scheme.

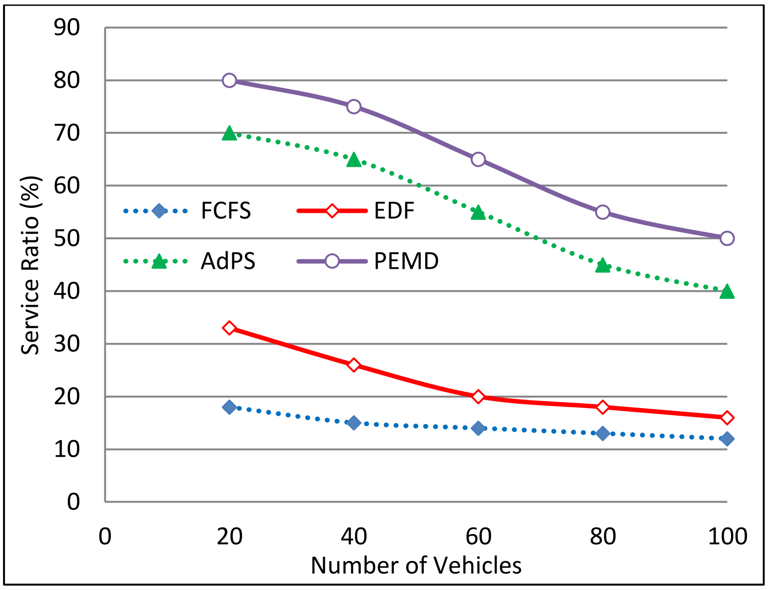


Figure 5.4: Effect of number of vehicles on service ratio

5.3.2 Effect of number of vehicles on deadline miss ratio

The maximum delay for packets separated by total numbers of packets is called the missing deadline ratio. As the number of vehicles producing data packets is increasing, so is the number of data packets that have to be managed within a given time frame, which results in a higher time frame lost ratio. There is a much higher delay than prior studies in the proposed algorithm. The suggested algorithm has a much smaller time-limit error ratio relative to FCFS and EDF algorithms. Figure 5.5 shows that the miss ratio of the proposed algorithm is considerably smaller than the FCFS, EDF, and AdPS for the period of 15% to 40%, respectively. The FCFS, EDF, and AdPS time limit for 20 vehicles is 84%, 66% and 25% respectively when 100 vehicles are considered.

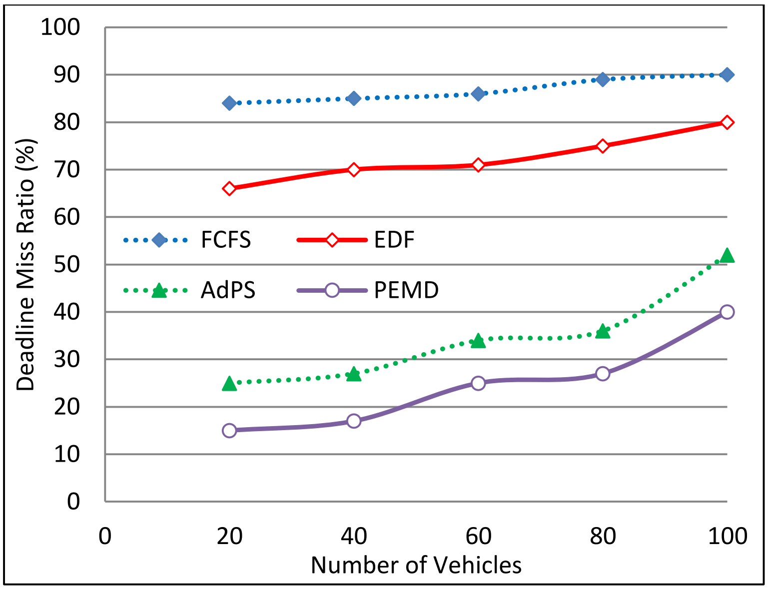


Figure 5.5: Effect of number of vehicles on deadline miss ratio

5.3.3 Effect of service delay

The data-packet deadline is directly proportional to the speed of the vehicles. When the number of vehicles expands, so does the time it takes for services to arrive. The service delay is proportional to the time it takes for data packets in queue to arrive. The service delay is 4–9 milliseconds, which is very low as compared to other algorithms. When 20 vehicles are included, the service delay for FCFS, EDF, and AdPS is 11.5 msec, 6.5 msec, and 6 msec, respectively. The proposed PEMD dominates by reducing up to 4.5msec as shown in Figure 5.6.

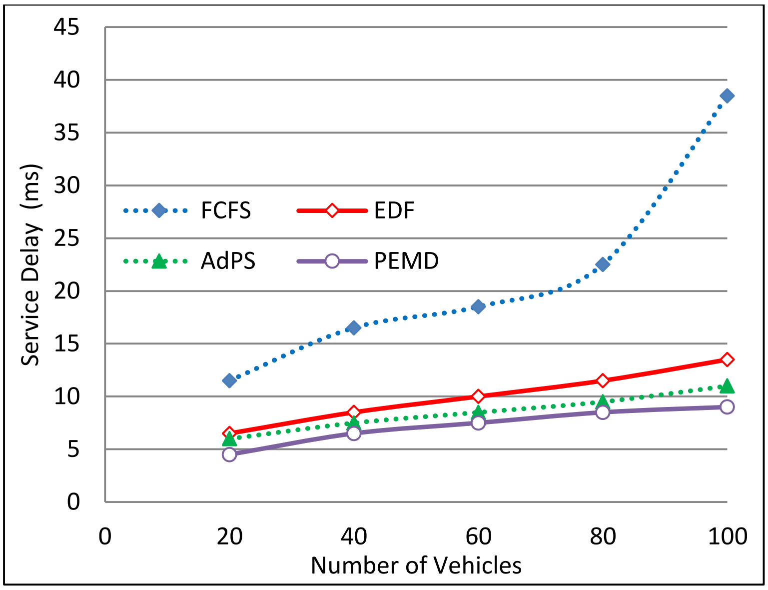


Figure 5.6: Effect of number of vehicles on service delay

5.3.4 Effect of speed of vehicles on service ratio

Since vehicles travel faster, the connection time between the RSU and the SDN-controller is much shorter, reducing the service ratio. At different speeds, the service ratio ranges between 45 and 75 percent, which is significantly higher than other current algorithms as illustrated in Figure 5.7. It happens because data packets created by high-speed vehicles are prioritized in the proposed algorithm.

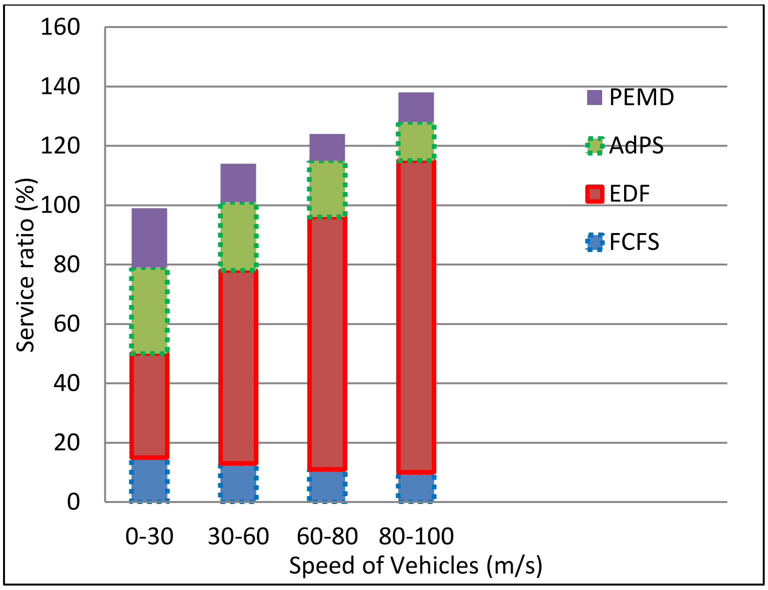


Figure 5.7: Effect of speed of vehicle on service ratio

5.3.5 Effect of service ratio on network size and vehicle speed

The ratio of total number of serviced data packets to total number of submitted data packets is known as the service ratio. Regardless of network size, SDN-controlled PEMD maintains a constant service ratio. Despite the limited number of vehicles, our proposed SDN-controlled PEMD achieves a service ratio of 0.98 percent, while other schemes achieve service ratios of 0.6 percent and 0.4 percent respectively. If the speed of vehicle increases, the disseminating control of vehicular node gets limited. Achieving maximum service ratio with elevated speed of vehicle indicates that our proposed SDN-controlled PEMD perform better as compared to RUFS and SDN-controlled VNDN which shows drop off in service ratio with respect to vehicle speed as illustrated in Figure 5.8 and Figure 5.9.

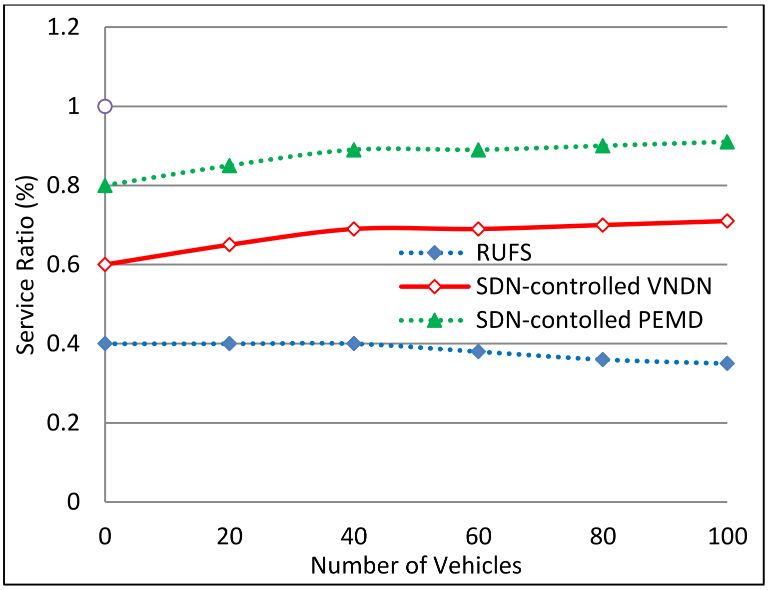


Figure 5.8: Effect on service ratio for number of vehicles

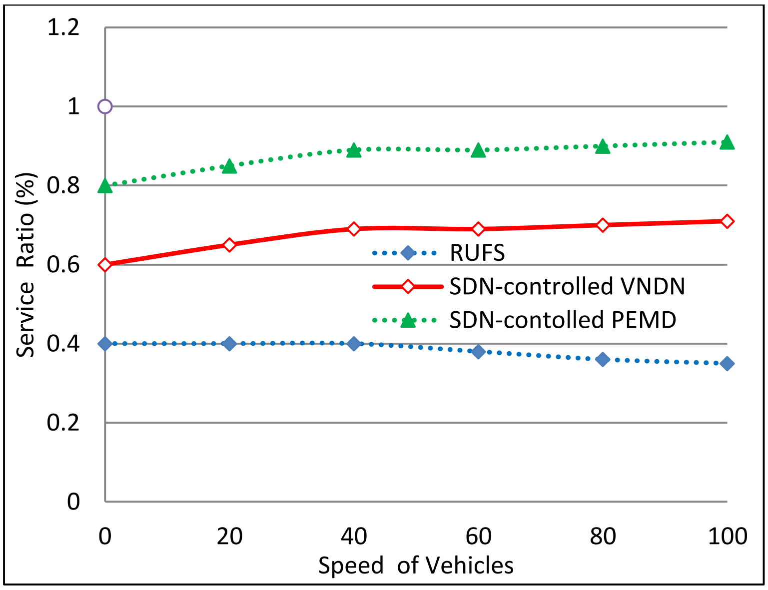


Figure 5.9: Effect on service ratio on speed of vehicles

5.3.6 Effect of service delay on network size and vehicle speed

The time taken by a data packet to retrieve content is referred to as service delay. The interest broadcast storm is primarily to blame for the service delay, as it narrows forwarding nodes and causes packet loss. The above graph depicts a comparative review of service delay. With respect to network size and vehicle speed, our proposed scheme outperforms in terms of service delay. Since the emergency message dissemination in SDN-controlled PEMD is done by priority queues and selection of EMD based on significant metric, this occurs. It reduces the time it takes for data packets to be transmitted. When the number of nodes and vehicle speed are varied, our proposed SDN-controlled VNDN service delay below 0.2 ms with variable density of nodes and speed of vehicle as illustrated in Figure 5.10 and Figure 5.11.

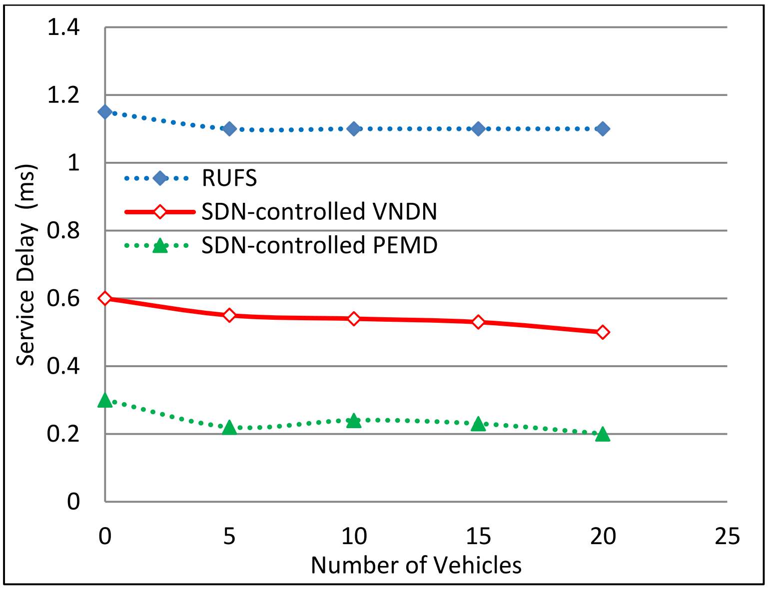


Figure 5.10: Effect on service delay for number of vehicles

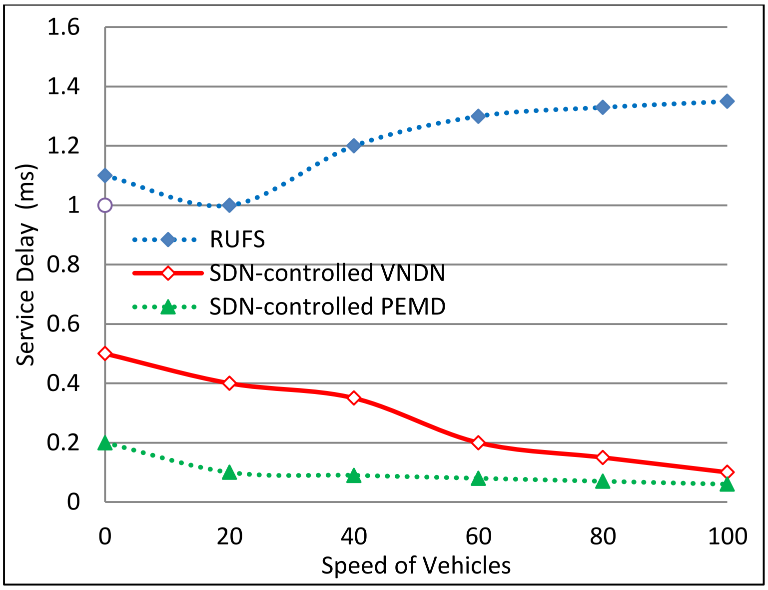


Figure 5.11: Effect on service delay for speed of vehicles

5.3.7 Effect of gain of scalability

Scalability gain is defined as the number of vehicles that are serviced via V2V communication in the network. It shows the network's capacity to accommodate more vehicles based on the specified measurements. A comparative study of scalability gain with respect to vehicle speed is presented. When the vehicle speed is 20 m/s, 180 vehicles participate in communication in SDN-controlled PEMD, while 180 vehicles participate in communication whereas SDN-controlled VNDN controls 90 vehicles as elucidated in Figure 5.12. Due to the involvement of efficient PEMD, SDN-controlled PEMD performs better. As a result, the proposed SDN-controlled PEMD accommodates a large number of vehicles, increasing network performance.

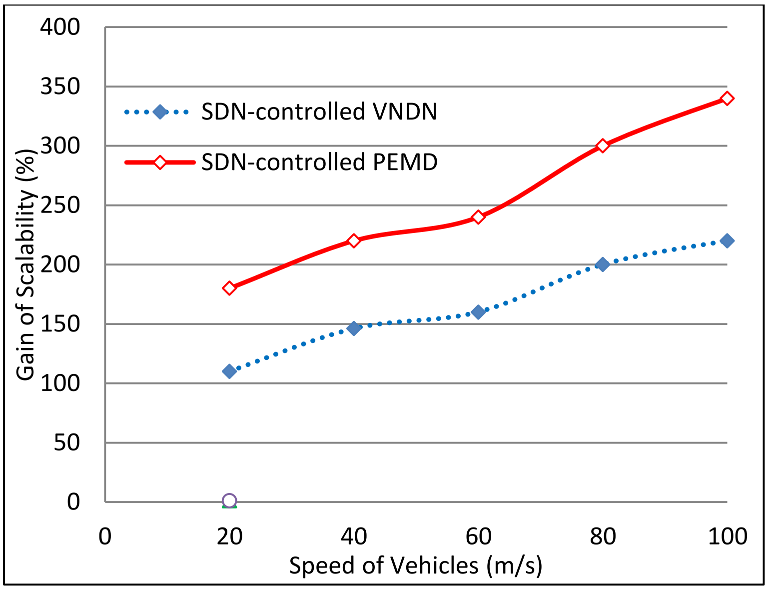


Figure 5.12: Gain of scalability for different speed of vehicles

5.3.8 Comparison on packet loss

The total amount of data packet loss in the network is measured by this quality metric. As the time between packet transmissions exceeds, packet loss occurs. Both planned and current work was contrasted in terms of packet loss. As a comparison, our suggested scheme (PEMD) is outweighed by just 3 percent of the network's data packets as shown in Figure 5.13. The analysis shows how the proposed SDN-controlled PEMD handles a range of network sizes. Based on the contrast the overall results are collected using SDN-controlled PEMS method. SDN controller assistance provides a global network vision, enhances the service ratio, decreases service delays and enhances network scalability.

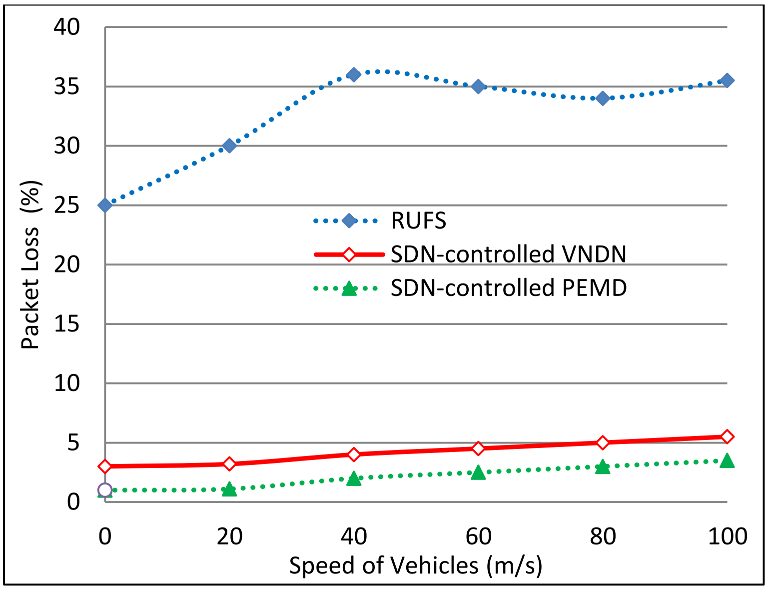


Figure 5.13: Packet loss for different speed of vehicles

From the comparative analysis, it is evident that proposed SDN-controlled PEMD is capable to deal variable network size. From the overall findings are obtained with the assistance of a centralized SDN-controller and PEMS scheduling. Assistance of SDN-controller offers the global view of network, the improve service ratio, service delay, packet loss and gain of scalability.

5.4 Summary

A priority-based emergency message scheduling scheme (PEMS) has been proposed to provide efficient and real-time emergency data dissemination. The main objective of the proposed algorithm is to minimize service latency among the prioritized emergency messages. NS3 simulation model is utilized for proposed system architecture and implemented for performance evaluation. NS-3 is used to deal with peculiar traits of network such as topology definition, model development, node configuration, and so on. After the comparative analysis, it is concluded that the proposed SDN-enabled PEMD is capable to deal with variable network length and network parameters, which results in increased scalability of the network.

CHAPTER 6

CONCLUSION AND FUTURE WORK

6.1 Overview

The performance of the proposed method (PEMD) is analyzed by NS-3 simulations with respect to metrics such as service delay, service ratio, deadline miss ratio, packet transmission and scalability. Compared with the state-of-the art methods include FCFS, EDF, ADPS and SDN-controlled VNDN, the novel PEMD scheme improves average PDR and scalability of the network respectively.

6.2 Conclusion

In this research study, a SDN enabled priority-based emergency message dissemination (PEMD) architecture has been proposed to offer scalable and real-time emergency data dissemination. To facilitate emergency message dissemination, the emergency packets are segregated into four priority classes for driver assistance that provide pre-crash care. After defining priorities according to different emergency levels, the emergency packet are disseminated through best forwarder that is selected by RSU with the assistance of SDN-controller.

On the whole, the proposed priority-based VSDN assists IoV in terms of scalability, as regional and local mounted SDN controllers makes it possible to offer an intelligent EM scheduling method for vehicular networks. The proposed algorithm reduces delay among dissemination of prioritized emergency packets which is achieved by modified TWG scheme and SDN-controller. NS3.29 simulation model is utilized for proposed framework and implemented for effective results. The implementation of priority based emergency messages dissemination using SDN proved to be effective as 3% of data packets are lost in the network and the service delay is 11.5 ms, 6.5ms and 6ms for FCFS, EDF and AdPS respectively when 20 vehicles are considered. Our propose PEMD scheme dominates by minimizing it to 4.5ms. When the vehicle speed is 20m/s, in SDN-controlled PEMD, 180 vehicles take part in communication, which increase the scalability of the traffic network.

6.3 Future Work

In the future, an ideal SDN-enabled priority based emergency message dissemination implementation is planned to be devised for diverse packet sizes in realistic heterogeneous and dense data traffic to further improve the cooperative data service scheduling. It is also intended to improve performance of SDN-enabled priority-based emergency data transmission in terms of Quality of Service (QoS) metrics within cost constraints. In addition, dense traffic leads to more serious emergency situations by creating road safety risks, more effective solutions are required which can improve the dissemination of emergency messages in VSDNs.

A scalable and more proficient EM dissemination model is needed to meet the constraints of data dissemination in various scenarios. The SDN-based PEMD architecture controls data communication overhead. However, the system creates vulnerabilities as there are chances of multiple points of failure. Hence, secure model for emergency message dissemination is needed to be deployed in diverse domains.

6.4 Summary

To efficiently disseminate the EM is a main concern in VSDN. The intense features of VSDN for EMs are analyzed in profundity, to tackle challenges that come across in disseminating the emergency messages across diverse domains. The proposed SDN-based emergency dissemination (PEMD) scheme supports scalable emergency message dissemination with better service ratio reduced service delay and packet loss in realistic traffic environment. The overall findings are attained with the assistance of a SDN-controller which managed PEMS packets and the entire network centrally. The SDN-controller help to provide the global view of the, which upgrades service ratio, service delay, deadline miss ratio, packet transmission and gain of scalability.

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