A Framework to Control RSU Based TCP Traffic Congestion in VANETs

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2022

Dedicated to

my

Mother & Father

DECLARATION

I, **Ajay Kumar**, solemnly declare that this thesis of research on "***A Framework to Control RSU Based TCP Traffic Congestion in VANETs***" is my original work. The study has been conducted under the guidance of **Dr. Raj Shree**, Associate Professor, at Department of Information Technology, Babasaheb Bhimrao Ambedkar University (A Central University), Lucknow (U.P.), India-226025. It is further declared that, to the best of my knowledge and belief, it has not been submitted earlier for the award of any degree. I also declare that the thesis is essentially free from all kinds of plagiarism.

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CERTIFICATE

This is to certify that the thesis titled "***A Framework to Control RSU Based TCP Traffic Congestion in VANETs***" submitted by **Mr. Ajay Kumar** is an original research work and has not been previously submitted in part or full for the award of any other degree or diploma to this or any other University.

The thesis submitted to Babasaheb Bhimrao Ambedkar University, Lucknow satisfies all the requirements as stipulated in the *Doctor of Philosophy (Ph.D.) regulations-1999 as amended in 2008/2010/2013* and it is fit for submission and evaluation for the award of the degree of Doctor of Philosophy of the University.

Date: 16/03/2022

Supervisor

Head of the Department

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Ajay kumar.

Ajay Kumar

ABSTRACT

The perspective of the technological landscape is growing with rapid pace where there is a huge utility in the transport management systems. Because the latest statistical analysis has been reported by the transport research wing of the Ministry of Road Transport and Highways, India that the various incidence occurring in the form of accidents approximately every day such as 449002 accidents, 151113 fatalities, and 451361 injuries etc. Due to which an average of 17 deaths occur in 51 accidents every hour. When the principle elements instantly get identified for such incidences and the outcomes appeared as that inefficient use of technology to control the high-speed vehicle collisions, signal assaults, and out dated conventional techniques etc. Moreover, the comparative analysis made with other countries such as USA, China, Japan, and Europe with respect to road accidents has shown the quite less results. Because such countries have been implemented the efficient technologies which makes their robust transport management systems. In order to overcome such issues that a novel framework has been proposed with the intelligent incorporation of the VANETs techniques. The VANETs are a well-defined family of MANETs which gets characterized by high mobility and frequent changes in the network topologies. Moreover, in which various moving vehicles and other connected RSUs communicate with each using wireless channel for sharing the fruitful information. For sharing the information the VANETs facilitates with the multiple services but most popular connection services are Vehicle-to-Vehicle (V-to-V) and Vehicle-to-Infrastructure (V-to-I) which is commonly known as Road Side Unit (RSUs). The primary objectives of the RSUs are to acquire and update the traffic information in real time using the different protocols for making the traffic control system smoothly. In addition, for making efficient communication between V-to-I there are some

other technologies incorporated such as 2G, 3G, 4G (LTE-cum-VoLTE), and WiMax to ad hoc networks. There are two types of conventional techniques named as connectionless and connection-oriented are employing for the transmitting of data whereas for smooth transmission of the information the connection-oriented technique is most preferable. For enhancing the services of VANETs it very complementary due to its highly dynamic nature especially in urban environments.

The congestion and multipath propagation delay is a quite common issue in every transmission protocols which is completely restrict the amount of data that may be transferred and it also relying on the expected network capacity and the TCP congestion window of the receiver. But the TCP ensures the quite less for frequent link failures, short session durations, packet drop-off without affecting the Quality-of-Service and reliability in VANETs. Therefore, to provide the efficient congestion avoidance system for TCP in VANETs environment is one of the objectives of the proposed methodology. In addition, to find out the precise solution by computing the packet intervals on throughput while transferring and packet delivery ratio for the VANETs infrastructure. The recommendation has been suggested by the researchers for making the effective congestion control system which is also consider for developing the proposed method. The VANETs has the greater adaptability in a transportation management system which is especially get recognized in business sector. The proposed methodology is the fusion of the VANETs, RSUs and TCP techniques to develop the framework for controlling TCP traffic congestion over the course of this research. The performance metrics such as the cumulative sum of packets, end-to-end delay, throughput, packet lost, and TCP traffic congestion window has been used to testify the efficiency of the proposed framework.

ABBREVIATIONS

ACK	ACKnowledgement
ACO	Ant Colony Optimization
ADTCP	AD-hoc Transmission Control Protocol
AODV	Ad hoc On-demand Distance Vector
AOMDV	Ad-hoc On-demand Multipath Distance Vector Routing protocol
ASV	Advanced Safety Vehicle
ATP	Advanced Threat Protection
BAHG	Back-bone-Assisted Hop Greedy Routing
CoAP	Constrained Application Protocol
CSMA	Carrier-Sense Multiple Access
DCF	Distributed Coordination Function
DSRC	Dedicated Short-Range Communications
DSDV	Destination-Sequenced Distance Vector routing
DSR	Dynamic Source Routing
EDCA	Enhanced Distributed Channel Access
ETX	Expected Transmission Count
FANET	Flying Ad doc Network
FCMA	Fuzzy Cost Metric Based Adaptive
GPSR	Greedy Perimeter Stateless Routing
GSM	Global System for Mobile
GUI	Graphical User Interface
IEEE	Institute of Electrical and Electronics Engineers
IETF	European Telecommunications Standards Institute
IHACO	Improved Hybrid Ant Colony Optimization
IoT	Internet of Things
IP	Internet Protocol

IPv6	Internet Protocol version 6
IPv4	Internet Protocol version 4
ITS	Intelligent Transportation System
LTE	Long-Term Evolution
LTS	Long-term support
MANETs	Mobile Ad hoc Network
MAC	Medium Access Control
MDDV	Mobility-Centric Data Dissemination
MPECS	Multipulse Excited Coding
NAM	Network Animator
OFDM	Orthogonal Frequency Division Multiplexing
OSI	Open Systems Interconnection
PAN	Personal Area Network
PDGR	Platelet-Derived Growth Factor
QoS	Quality of Service
RPL	Routing Protocol for Low-Power and Lossy Networks
RREQ	Route Request
RREP	Route Reply
RRER	Route Error
RSUs	Road Side Units
SEVECOM	Secure Vehicular Communication
SUMO	Simultaneous Underfloor Mounting Operation
TCP	Transmission Control Protocol
UDP	User Datagram Protocol
VANET's	Vehicular Ad hoc Networks
VPGR	Vertex-Based Predictive Greedy Routing
VSC-A	Vehicle Safety Communications – Applications
WAVE	Wireless Access in Vehicular Environments
WiFi	Wireless Fidelity

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CHAPTER 1
INTRODUCTION

1.1 CHAPTER OUTLINE

Smart and self driving vehicles were meant to be the future of the transportation industry. A decade ago this future seemed a century away. Today the future seems closer than ever. Smart vehicles with always connected internet have paved the way for new navigation technologies, driver assistance and voice controlled activation function for the dash. The internet has brought technologies to vehicles that seemed out of reach. The edge learning and fog computing models have been brought closer to the vehicle and driver. These models tend to learn drivers preferences and behavior to spontaneously adjust the vehicle environment like air conditioning, navigational preferences, cruise control and driver warning systems. A driver can simply ask the car for adjusting air conditioning, find new routes and dangerous situation with voice command without taking eyes off the road. The modern vehicle industry has a driver assistance system that are so intelligent that then can drive the cars and even wake up the driver that is dozing off while driving. The new era of the automobile industry will have autonomous car systems that can not just drive and adjust the car environment, they will also be intelligently adjusting routes and avoid collision without the driver assistance. The future of the automobile industry is here.

The driving force behind the technological innovations in the automotive industry is the high wireless bandwidth, which is perhaps the single most factor. The wireless network brings together a wide set of features including the internet. The mobile ad-hoc network is perhaps the best viable technology for use with the automobiles. IEEE 802.11p and WAVE are the standardized version of the VANET's. The IEEE 802.11p is the subset of previously existing IEEE 802.11 for wireless network known popularly as WiFi. The wireless ad hoc networks are known for their versatile performance and lower costs. However the wireless ad hoc network suffers from route congestion, unrealistic delays in some situation and rapid performance degradation with higher number of nodes.

Route congestion is perhaps the most vulnerable spot for the wireless ad hoc network. The congestion on the route is the direct outcome of using the wireless channel beyond its capacity. For this reason multipath routing has been proposed in the literature. Multipath routing formulates multiple path from source to destination in order to relieve the most used route. The multipath routing, however fails to perform when the a link connects two isolated parts of the topology.

Route congestion doesn't just lead to packet drops it's also the major cause of delays in packet delivery. The packet queues for a congested route become long and hence the packet drop ratio increases. The increase in packet drop results in re-transmission of the packets and thereby reducing the overall network performance and throughput.

A VANET deploys RSUs to provide services to automobiles. The RSU placement and deployment can significantly enhance the performance of the VANET. Multipath routes of data communication can be made available with the help of RSUs in VANET. The deployment strategies of the RSU can lead to high performance connectivity between the vehicles.

A VANET is a network of wirelessly connected vehicles and RSUs that communicate with one another through a wireless channel and share essential information. As is required for information exchange between vehicles over long distances when they're in proximity, Vehicle to Vehicle and Vehicle to Infrastructure connectivity must be introduced. When these networks become a vital component of the smart system, which should be shielded against failures and threats. The increase in traffic congestion on essential infrastructure should be extended to Wi-Fi enabled systems [1]. Therefore, it is important to introduce the MANETs, VANETs, and TCP Traffic Congestion Window in detail. In addition, motivation for research, problem statement, research objective, methodology, and significance are mentioned in this section.

1.2 MANETS: AN OVERVIEW

A MANET is a combination of wireless mobile phones. Smartphones, Personal Digital Assistants, and wireless devices, are shown in the architecture of MANETs in figure 1.1. The wireless devices called nodes constitute the MANET and provides routing and maintenance mechanism for data communications.

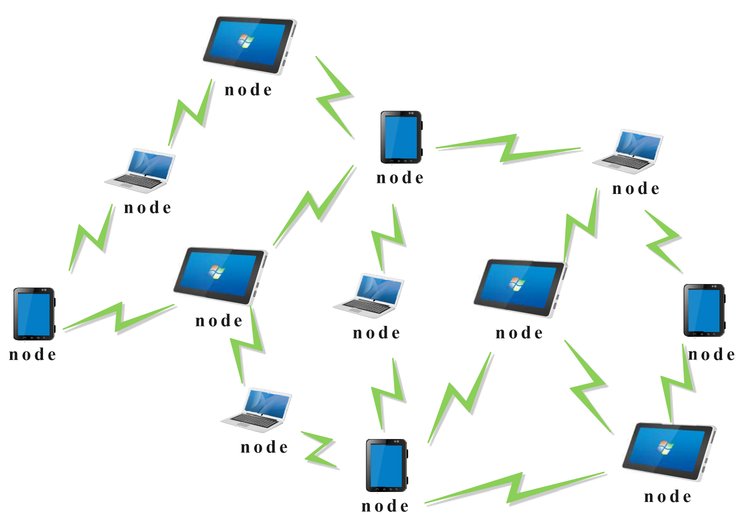


Figure 1.1 Wireless architecture of MANETs.

The MANET network topology varies with time because nodes move around, new nodes get connected, and some nodes leave the networks. In MANETs, there is no need of RSUs for collecting and transmitting the information from one node to another node. For communication the nodes are not just only connected with the other nodes but also performing routing activities within the network. Whenever any node wants to make the interconnection, it uses intermediate nodes to transmit the request. MANETs have a number of benefits over conventional network including the ease with which it can be built up and rip down. Therefore the consistency could not get insured in the network with respect to node connectivity. Based on the time period, the network technology generation classified as follows:

i. **1st Generation networks (the 1970s):** Packet radio networks for military purposes came in the 1970. The first ever ad hoc network architecture was created, and CSMA was the next innovation. The University of "Hawaii" was the first in the world to merge communications and electronic networks in 1971. A bidirectional communications network, named "AlohaNET," was developed[204].

ii. **2nd Generation networks (the 1980s to mid-1990s):** The 2nd Generation in 1980s when survival adoptive networks (SURAN) had been improved upon the radios, scalability of the algorithm[204], and flexibility to electronic attacks. Development during that period include Global mobile information system and near-term digital radio (NTDR) which is observation the time as per need.

iii. **3rd Generation networks (the late 1990s to early 2000s):** As in the industrial ad hoc networks come with laptop computers and other functional networking devices. The concept of a group of mobile nodes was suggested at research conferences, such as Bluetooth and

Ad-hoc sensor networks [2, 3]. In 1996, the STARS project was launched. The IETF released multiple drafts about the MANET routing protocol in 2000, and an IEEE workshop on MANETs and computing was established in 2000.

iv. **4th Generation networks (from the 2000s onwards):** Handheld ad hoc routers are being used to deliver internet access to mobile phones, as well as distributive collaborative networking, remote sensor networks, including disaster response networks [4, 5, and 6].

Table 1.1 Manet applications and its Descriptions/Services

Applications	**Descriptions/Services**
Tactical networks	Exchange of information in the military, Automated battlefields
Sensor networks	BAN, Smart sensor nodes, Embedded transducers in home appliances, Monitoring mammal movements, Weather & geological activity monitoring, chemical/ biological detection, Highly precise farming, etc.
Emergency services	Search & rescue operations, as well as recovery efforts after a disaster, In the event of an earthquake, storm, fire, or other disaster, permanent infrastructure must be replaced. Providing assistance to physicians and nurses at the hospital.
Industrial & residential configuration	Payment through electronic means in e-commerce, Business dynamic databases, vehicular services like Inter-vehicle communication network for road and accident warning, Statistics on the weather, Statistics road conditions, community

	network, trade shows, shopping mall network.
Home/workplace network	Home and Office Wi-Fi networking, PAN, Halls for conferences & seminars.
Academia	Campuses & universities have ad hoc network connectivity, allowing the use of online teaching, conferences, and seminars.
Entertainment	Multiplayer gaming, indoor and outdoor network connectivity, and Wi-Fi enabled artificial toys.
Locate-aware Applications	Follow-up applications, conversation redirecting, smart workstation-telephone service, location-based assistance, and tourism info services
Extensions of accessibility	Increasing cell phone coverage, Interconnecting private networks with the internet.

The cons of the MANETs are a cost-effective alternative for delivering connectivity in places where fixed infrastructure is unavailable, unreliable, or where establishing fixed infrastructure is not a feasible choice due to regional limitations and financial considerations. Because ad hoc networks are generally self-organized as well as self-controlled, they can be created quickly with minimum user involvement. In addition to being able to function as an autonomous network, ad hoc networks can be linked to the internet and other networks to extend connectivity to areas without fixed facilities. MANET implementations, both current and prospective, address a variety of issues. Despite the fact that MANET is proving to be a technology with a vast range of applications. The most important application and their services fields are described in table 1.1. Due to the ad hoc nature, MANETs find themselves more vulnerable to data and access control breaches as compared to infrastructure-based networks.

1.2.1 BASIC FEATURES OF MANETS

The below are some of the most notable characteristics of MANETs:

- **Wireless connections:** Radio nodes inside a wireless networking system interact and communicate with one another. Connections can vary as one or more radio interfaces can be fitted with each node, with differing capacities for transmission/receiving over the various ISM bands.
  - **Mobility:** In MANETs, the devices can switch from one node to another node over time. It can be extremely mobile such as PDA, Mobile in a moving car or largely stationary such as laptops used in the home or office setting.
- **Dynamic Topology:** It occurs because of node mobility and when nodes enter and exit the network.
- **Self-configure:** The nodes are responsible for building, maintaining, and coordinating the topology of the mobile network. Basic factors like IP addressing, connectivity, sensing of movement, and signal amplification must be determined independently by the device.
- **No server for node coordination:** There is no control room. There are only nodes to coordinate with one another.
- **No permanent structure:** Because there is no permanent structure, it is simple to install in terms of configuration. Specific access points in the permanent network can be available under certain circumstances.
- **Cooperation:** Since there are no other enabling systems except cell nodes, all of the nodes operate together to control the network. Consequently, a node acts as both a server and a sponsor of the network by forwarding messages to other nodes.

- **Finite supplies:** Due to the fact that the active nodes are movable with restricted computational capabilities as well as restricted processing and storage capacity.
- **Limited battery capacity:** The mobile nodes have limited power and has to be recharged over time.
- **Heterogeneity:** The nodes in the network can differ significantly in computing resources, battery capacity, and versatility.

1.2.2 MANETS BRANCHES

Ad hoc networks are available in numerous forms, which are described below:

- **Personal Area Network:** A PAN [7] is a limited network of computing facilities commonly used for personal purposes. Bluetooth [8], infrared (IR) [9], and ZigBee wireless technology [10] are examples of wireless systems that utilize PAN networks.
- **PtoP Networks [11]:** Peer to Peer Networks run decentralized various network users, with the computers in the network serving as both servers & clients simultaneously.
- **Networks of sensor devices:** A network which is made up of sensor devices that have different measurement units for capturing physical parameters like humidity, heat, vibration and converting them to digital form**.** These components are commonly utilized in IoT [12] solutions like IoT SHE[13] [14] & IoT E-health [15] etc.
- **Vehicular networks:** Vehicles today include an increasing amount of infrastructure and have a greater requirement to connect with anyone else in the world. Vehicles with sensors on their bumpers and roofs will build platforms dependent on ad hoc networks [15] and link vehicle moving near each other. For emergency vehicles, designs have already been produced (ambulances, fire engines, etc.).

1.3 VANETs

The DSRC was established by the United States and is utilized for V2V communication (contact between vehicles). An additional 75 MHz of bandwidth (which includes the 8.5 to 9.25 GHz range) has been set aside. The DSRC was assigned to the U.S. FCC in February 2015. The DSRC bandwidth has seven frequencies of 10 MHz in the range. Six of the seven channels are used for service purposes; the other one is used for purposes of power. In table 1.2, the DSRC bandwidth allocation of the DSRC is distributed.

Table 1.2 DSRC bandwidth allocation [16]

<table>
<tr><th></th><th>Reserved</th><th colspan="3"></th><th>Control channel</th><th colspan="2"></th><th>High Power Public Safety</th></tr>
<tr><td>Frequency (MHz)</td><td>5850-5855</td><td>5855-5865</td><td>5865-5875</td><td>5875-5885</td><td>5885-5895</td><td>5895-5905</td><td>5905-5915</td><td>5915-5925</td></tr>
<tr><td rowspan="2">Channel Number</td><td rowspan="2">Grand Band</td><td rowspan="2">172</td><td>174</td><td>176</td><td rowspan="2">178</td><td>180</td><td>182</td><td rowspan="2">184</td></tr>
<tr><td colspan="2">175</td><td colspan="2">181</td></tr>
<tr><td>Channel Usage</td><td></td><td>SCH</td><td>SCH</td><td>SCH</td><td>CCH</td><td>SCH</td><td>SCH</td><td>SCH</td></tr>
</table>

On September 25, 2009, an IEEE Fact Sheet was published. The current state of IEEE is 1609.1, 1609.2, 1609.3, & 1609.4 standards. Four criteria were trialed and written, with a draught standard in the works. 1609.0 and 1609.11 had the status of being under progress. P802.11p was listed as an approved as active Draft. Current IEEE standards for communication are listed in table1.3.

Table 1.3 IEEE Standards for communication

	IEEE Standards for communication			
Accessibility	**Vehicles Automatic, Integrated, & Smart**	**Traffic Security**	**ITS**	**Modernisation of public transport services**
IEEE802.3 Defines the PHY and data link layers MAC of wired Ethernet in LAN and WAN Applications.	IEEE P2040 Series A series of standards for connecting and automated vehicles that includes architecture, definition, testing and verification	IEEE1512 Multiple Standards for traffic safety, hazardous materials and public safety incident communication	IEEE Wireless Family IEEE802.11 IEEE802.15 IEEE802.16 IEEE802.20/21/22 IEEE 1609 Family IEEE1609.0 IEEE1609.1 - - - IEEE1609.12 IEEE1616	IEEE 2030 Series A series of standards to provide the best approach for achieving smart grid interoperability. It includes vehicle to grid connectivity. IEEE 1547 Series A series of standards for distributed power to maximize the benefits of

				interconnection IEEE P1562 Standards for array and battery sizing. IEEE 1901 Series Standards relating to broadband connectivity over electric power lines

1.3.1 THE WAVE 1609 FAMILIES

WAVE stands for "Wireless Access in Vehicular Environment". In November 2004, the ASTM set the "DSRC", which is wholly dependent on the 802.11 MAC layer and IEEE 802.11a. The primary issues with IEEE 802.11a at 54 Mbps are that it faces excessive delay and lag. Due to major topological changes and high mobility, fast data and communication are important for complex vehicular applications. The IEEE 802.11p working group also renamed the DSRC to WAVE by the ASTM-2313 Additionally, it operates on both the physical and MAC layers. WAVE is made up of two distinct, portable data terminals, called RSU and an OBU. WAVE uses OFDM to provide multiplexing. Figure 1.2 illustrates WAVE, as well as 802.11p and an OSI model. Following the introduction of new valuable applications, many consortia (e.g., automobile industries, control agencies, highway operators, and tolling businesses) have engaged in large-scale VANET ventures (like Vehicle-to-to-Organization Network Communication). There have been real-world instances of these systems partnerships, which support the benefits of the VANET theories. Vehicle-based projects that have been completed in Japan, United States of America, and Europe.

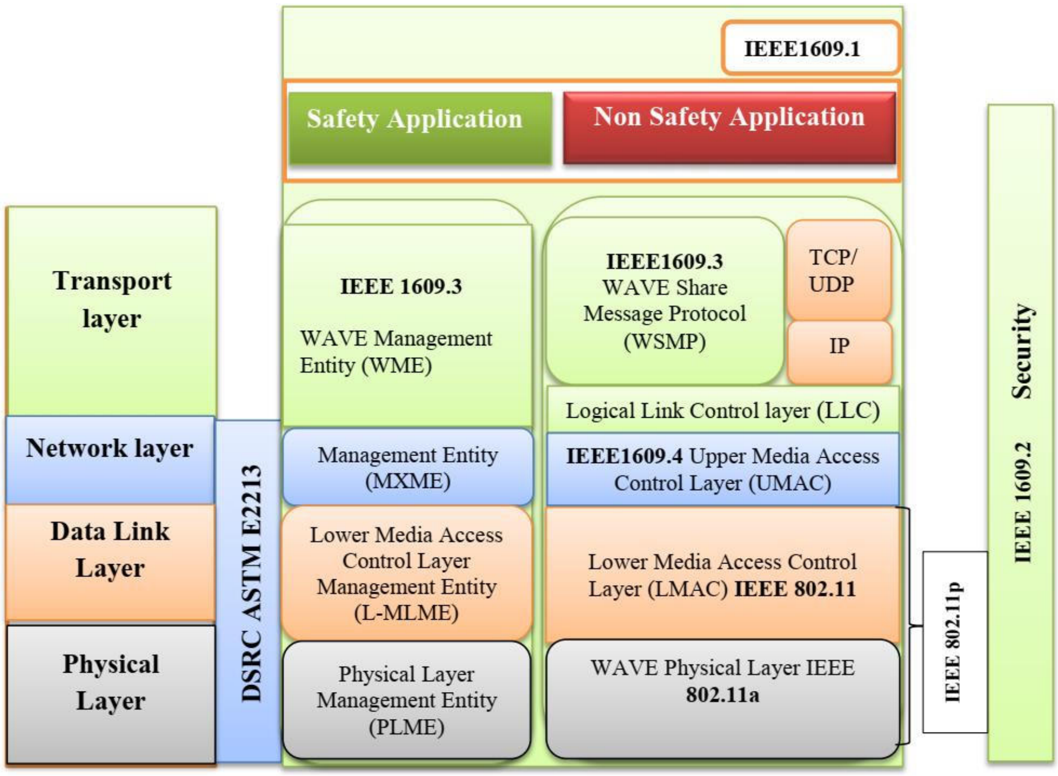


Figure 1.2 WAVE (1609.0) protocol Stack Diagram [17]

The WAVE 1609 family categorized five standards which are as follows:

- **1609.1 Standards:** RSU and OBU application data read/write protocol is defined by the WAVE Resource Manager.
- **1609.2 Standards**: WAVE Secret Services offers 5.9 GHz spectrum to ensure
  a) Authenticity,

b) Confidentiality,

c) Security, and

d) Anonymity.

- **1609.3 Standards:** WAVE Internet Services define network and transport layer applications for secure data transmission.
- **1609.4 Standards:** Its Multichannel Operations provide DSRC frequency band coordination and management, where it manages lower-layer usage of the seven DSRC channels, and IEEE 802.11p is strongly integrated into the system.
- **1609.11 Standards:** The ITS Over-the-Air Data Exchange Protocol will describe the services and secure communication formats that will be used to protect money transfers.

1.3.2 VANETS PROJECTS

United States of America

(1)Vehicular Interactions for the Purpose of Safety: Partnership with VSC [18] aims to improve the overall quality of traffic systems, specifically cooperative forwarding collision alert, curve speed alert, slow-motion assistant, and other related sites. A new platform named VSC-A [19] was started to further the study of VSC, as well as its goals and areas:

- Determine how DSRC technologies and positioning systems will improve performance.
- Establish minimum device specifications as well as associated specification criteria for vehicle risk modules and,
- Set up navigation systems for car emergency situations..

(2)Integration of Vehicle Infrastructure: Main carmakers (like Daimler-Chrysler, General Motors, Ford, and several others), national highway agencies, and technical societies are all served by the VII Consortium [20]. VII's testing area is 50 km^2. This is used to evaluate some model VII applications, including

- Informing passengers of dangerous situations and impending accidents,
- Provides accurate information to service providers about congestion, climate conditions, and other extremely dangerous occurrences, and
- Ensuring operators with reassuring info.

(3) **The PATH:** The PATH [21] means “Partners for Advanced Transit and Highways”. This proposal is being initiated by the California University in collaboration with some government agencies. The PATH proposal is primarily concerned with policies and behavior analysis, highway protection, traffic management research, and technology to develop communication services.

European Union (EU)

(1) **Cooperative Perception and Communication**: CooPerCom is a subset of vehicle technologies. It has preliminary focused on to enhance the efficiency of the framework regarding the perception and communication[22]. Resilience of vehicle inbuilt devices and technologies, that are more trendy, numerous, and complicated. The complexities of maintaining adequate functionality and protection are becoming daunting, as are the estimated sensors and devices. Furthermore, the vehicular world is extremely complex, necessitating a high degree of networking, which necessitates stability and robustness. Further research and development of advanced processing techniques is another objective of the research. This can take advantage of several vehicles presences and inter-vehicle communication capabilities to collect source data, reduce the possibility of an unanticipated failure by validating specific data elements, assessing uncertainty, and making use of redundancy.

(2) **Cars and Service Networks that Operate Together:** CVIS [23] is responsibility of traffic control services and uses a number of vehicle routing systems that are focused on dangerous situations. The trial's key goals are to establish V2V and V2I communications guidelines, improve vehicle position accuracy, and generate more complex and precise mapping using modern location referencing techniques. The trials also look into technologies for mutual traffic and network control in vehicles and roadside facilities, as well as the capacity to track potentially hazardous accidents. It also uses a "floating car info" program to update the service center with each vehicle's operating specification.

(3) **Cooperation Frameworks and Protection Technologies with Privacy-Enabled Capabilities**: PRECIOSA [24] is a voluntary scheme that complies with potential privacy laws and protects relevant position details. The following are the project's goals:

- Identify a framework for cooperative testing system for data and contact storage protection,
- Develop privacy-aware frameworks for incorporating it into cooperative systems that provide acceptable confidence models and ontologies,
- Suggest and verify recommendations co-operative systems with privacy-aware considerations and
- Study unique privacy issues.

(4) **Car Interference Secure E-Safety Applications:** EVITA [25] is recommended to counter protected risks by prohibiting unauthorized abuse of on-board networks, thus preventing penetration into in-vehicular systems and compromised data transfer to the outside. In reality, EVITA is a supplement to SEVECOM [26] and NoW [27], both of which focus on

communication security. The following are EVITA's major contributions:

- The overall protection specifications are identified by specifying the required industrial use cases and compiling significant scenarios of potential risks,
- Suggested Secure Confidence, and
- Assertion of a secure on-board structure.

Japan

(1) Network for Public-Private Partnerships: ITS Safety 2010 [30] is a project that verifies current ITS technology and the effectiveness of ITS systems installed on public roadways. In 2011, two V-to-I cooperative networks were launched as part of ITS-Safety. The role of ITS is given below.:

- Intelligent Transportation Systems (ITS) on highways to provide broad-area traffic intelligence, danger warnings, and road conditions ahead, and
- In ordinary roadways, DSSS makes it easier to identify road markings, crosswalks, and rear-end collisions.
- ETC [31, 32]: The Electronic Toll Collection system is a vehicle-to-infrastructure coordination device that provides driving assistance through bidirectional high-throughput contact with use of ITS spots built alongside Expressways. This method will result in a reduction in traffic volume in particular areas, a reduction in the time it takes to avoid collisions, and a reduction in the degradation of highway systems. Consequently, modest road networks can be used more efficiently and wisely.

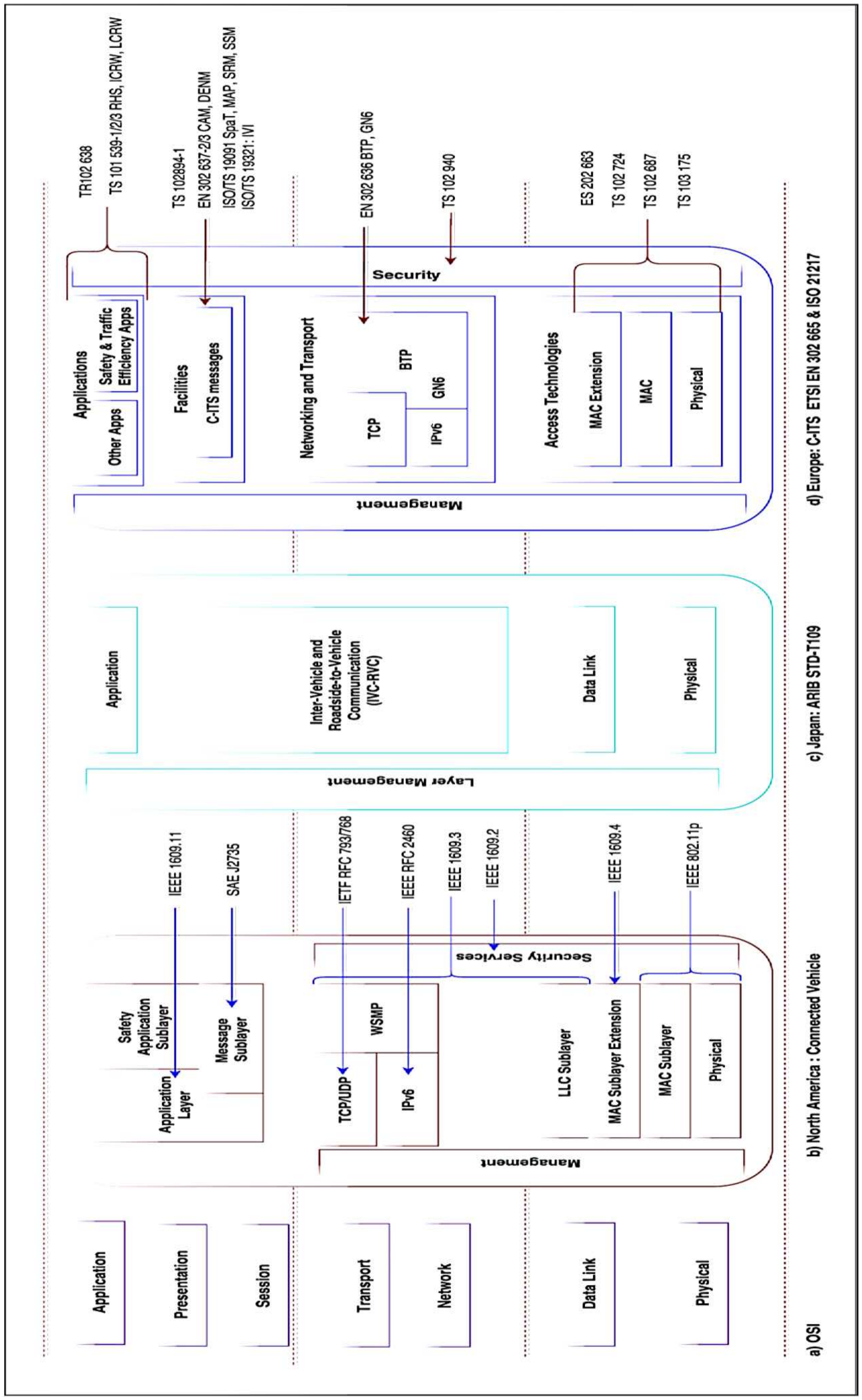


Figure 1.3 The ITS protocol with a) OSI Layers, b) America, c) Japan, and d) Europe.

- **Safe Driving Assistance:** The device provides visual and auditory warnings when an obstacle is detected, a dangerous lane merging point is detected ahead, and an unseen road jam is detected around the corner, among other things.
- **Traffic Avoidance Assistance:** Based on traffic statistics, automobile drivers, can pick the best path while approaching a metropolitan area. They should also use a car navigation system with ETC to determine the required period.
- **Disaster Assistance:** As disasters strike, the system offers disaster assistance statistics, including current effects of disasters. According to the aforementioned definitions, vehicular networking standardization and testing efforts have been researched and encouraged in the US, Japan, & Europe in order to implement related technology in VANETs to enhance traffic protection, mitigate road congestion, and improve traffic quality. Furthermore, these efforts demonstrate that diverse design objectives for modern applications demand distinct QoS assurances, which remain difficult to provide in the said environment.

(2) ASV [28, 29]: Japan's government has given funding to complete an advanced safety vehicle program that includes a list of ongoing infrastructure projects named ASV-1, 2, 3, and 4, vehicle companies (notably Honda, Mitsubishi, Suzuki, and Toyota), and research institutions. The projects are focusing on two types of safety: active and passive. Any similar technologies (such as drowsiness warning, vision enhancement, navigation, automated collision avoidance, and lane departure) are developed and tested to prevent an accident in the case of active protection. Several devices are deployed for impact absorption, passenger security, pedestrian protection, and door lock sense are used in passive safety to shield passengers in the case of an accident. The ITS protocol stack is the USA, Japan and Europe is systematically arranged in figure 1.3[52].

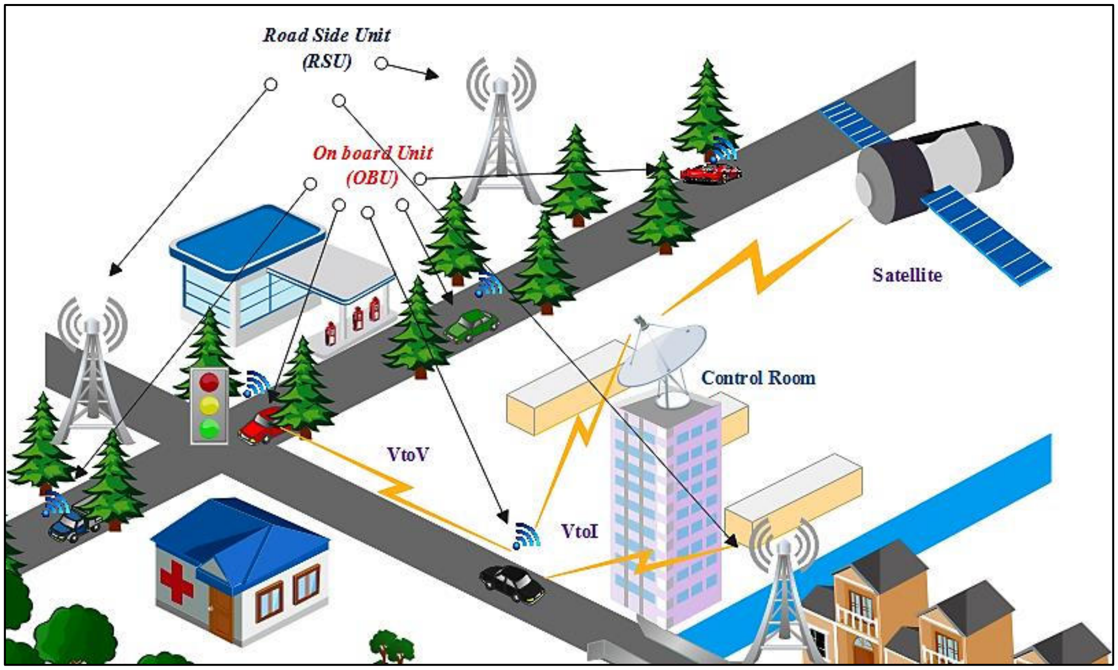


Figure 1.4 VANETs model diagram

1.3.3 VANETS CHARACTERISTICS

The advancements in mobile networking technologies and emerging developments in wireless networks, diverse implementations of VANETs in expressways, metropolitan, and village regions are now possible to serve a wide range of applications of varying QoS criteria[33]. The VANET model diagram shown in Figure 1.4 shows the virtual image of VANETs communication.

Three V-to-V, V-to-I, and hybrids are important parts of VANETs:

i. **Vehicle-to-Vehicle (VtoV) Communication:** Instead of relying on permanent infrastructure, instantaneous vehicular connections are created by using Onboard Units mounted inside vehicles. This eliminates the need for infrastructure. As long as the percentage of

Wi-Fi capable vehicles' system use remains low, the present network infrastructure will provide a unique spectrum for high speed vehicle [34], which is advantageous. However these kind of networks require complex protocols communication [35, 36].

ii. **Vehicle-to-Infrastructure (VtoI) communication:** Vehicles equipped with RSUs can interface with fixed infrastructure. Knowledge and data collection applications are the most popular applications for V2I communication. In the literature, there are two key variables: Or the access points (AP) are deployed only for the purpose of maintaining internet connection to vehicles, or they could use free 802.11 technology. Opportunistic Wi-Fi access points are found along city streets [34]. As opposed to cellular-based technology (e.g. GSM, 3G and 4G etc.), the drawbacks of this connection approach are that vehicles use higher-to-low-rate internet (e.g., 11 Mbps). In addition, GSM is a cellular device which offers the maximum data rate of 9.6 Kbps and is classified as 2G. Audiovisual streaming requires a high data rate, which aided in the progress of 3G. This cellular infrastructure will support a 2 Mbit/s date rate. One downside is the expense for gaining enough coverage via the construction of access points along the highways. Additionally, in the case of free gateways, prior to launching such a business, the owner's approval might be required by federal law.

iii. **Hybrid-communication:** VtoV and VtoI networks are merged to form hybrid communication networks. Vehicles can connect with roadside utilities in a one or many hops. It also allows for long-distance, internet access or communication with Vehicle that are far apart. The advantages of this approach include a high likelihood of compatibility and the potential to reach the optimum bandwidth by cooperating with one another. In terms of cost effectiveness it is not a recommended model.

1.3.4 VANETS FEATURES

Furthermore, VANETs retain a set of notable characteristics, including the following:

i. **Enough power:** As opposed to MANETs, power shortage in VANETs is less serious. Stronger batteries in new communication systems built in cars have more storage and rechargeability, which is helpful for efficient communication and the flexibility to make routing decisions and other computing activities.

Table 1.4 Vehicle Communications use Wireless Access Technologies [37, 38].

Features	DSRC/IEEE 802.11p	Wi-Fi	VLC	LTE	LTE-A	5G Technology
Standard	IEEE 802.11p	IEEE 802.11	IEEE 802.15.7	3GPP Rel-8/9	3GPP Rel-10/11/12	3GPP Rel-15/16
Mobility Support	Up to 60 Km/h	<30 Km/h	<30 Km/h	up to 350km/h	Up to 350km/h	Up to 500km/h
Frequency Bands	5.86-5.92 GHz	2.4 GHz, 5.2 GHz	380-800 THz	700-2690MHz	450 MHz-4.99GHz	700 MHz- 100 GHz
Channel Width	10 MHz	20 MHz	-	1.4, 3.5, 10, 15, 20 MHz	Up to 100 MHz	-
Bit Rate	3-27Mbps	6-54 Mbps	11.67 Kbps, to 96 Mbps	Up to 300 Mbps	Up to 1Gbps	Up to 20 Gbps
Range	Up to 1 Km	100-500 m	<100m	10m to 30 Kms	10m-30 Kms	Ubiquitous
QoS Support	EDCA	EDCA	-	QCI and Bearer selection	QCI and Bearer selection	-
VtoV Support	Yes	Yes	Yes	No	Yes	Yes
VtoI Support	Yes	Yes	Yes	Yes	Yes	Yes
Deployment	RSU	Hotspot, Access Points	Available Road Lights	e Nodes	e Nodes	NSA and SA mode
Market Penetration	Low	High	Low	Potentially High	Potentially High	-
Broadcast/multicast Support	Native Broadcast	Native Broadcast	Broadcast	Through eMBMS	Through eMBMS	-

ii. **Effective capabilities:** Since vehicles have a lot of space, multiple devices with a lot of computing and communication capacity can be mounted. Furthermore, sensing technologies such as sophisticated antenna technology and GPS can be mounted, allowing vehicles to perform powerful functions and have high computing ability.

iii. **Predictable mobility:** Unlike MANETs, where mobile nodes travel at random, vehicle movements in urban VANETs are partly governed by fixed street topologies, traffic lights, and regulations. As a consequence, the upcoming route of a vehicle will be forecasted using highway data, such as a visual map and the vehicle's current location.

iv. **Rapid changes in topology:** Because vehicle nodes in VANETs move at different rates and change paths on a regular basis, network topologies in VANETs are extremely complex, making connections unstable. Table 1. 4 consists of the latest ad hoc network features and is compared with the different technologies.

1.3.5 VANETS APPLICATIONS AND USE CASES

C-ITS will assist in the introduction of a wide variety of VANETs applications. The communication specifications for the various C-ITS technologies and communication protocols that must adhere to help them can be identified by identifying and characterizing these applications. ITS Technical Committee of ETSI has summarized and identified a number of standard reference uses and possible implementations of C-ITS [39] which is based on the usual characteristics of VANETs. The applications can be classified into three categories: road protection applications, traffic quality and maintenance applications, and infotainment applications. Some potential usage cases are also listed for each of the recorded application grades.

i. **Road Safety Applications:** Cooperative recognition or road hazard warning apps are the two types of road safety applications. Cooperative awareness applications use cooperative wireless communications between vehicles to identify potentially hazardous conditions. For e.g. the authors in their research [40] [41] [42] include traffic safety applications such as reducing automobile accidents, deaths, and emergency for fire departments, ambulances, and police. Applications for real-time road accident monitoring have the responsibility of alerting the surrounding environment to dangerous incidents that occur on the road[43]**.** The primary concern of the application which is facilitating with alarming services that it gets notified to the concern person in case of emergency. Moreover, it is also provide the assistance in case of lane shift assistance, stationary vehicle on the road, crash warning etc. Whenever the accident has occurred on road it is quickly broadcast via VtoV/VtoI wireless communications to ensure proper traffic flow. This scheme will prevent major traffic jams and more traffic collisions by directing traffic to another lane (left or right) or, immediately, exiting the lane as soon as possible [44].

ii. **Traffic Efficiency and Management Applications:** Traffic optimization & monitoring software optimize the movement of vehicles by providing smoother paths, flexible traffic signals, and real-time and localised traffic statistics. The majority of the applicants in this category necessitate a high level of information availability, as drivers must make decisions based on the information received. Speed control and cooperative navigation systems account for the bulk of these deployments. In this regard, a standard example of a speed control system [45] [46] that helps the driver manage the vehicle's speed for comfortable driving and to avoid unnecessary braking. Furthermore, this technology warns relevant drivers of regulatory or contextual speed limitations and provides superior speed recommendations when the light turns green. To improve traffic performance, a cooperative navigation system [47] [48] [49] is used to manage vehicle navigation through VtoV and VtoI communications. An approaching vehicle can provide a warning to a vehicle about unforeseen situations, for example, traffic congestion, road conditions, accident incidents, etc. Summery of the above described application of VANET is tabulated in table 1.5.

iii. **Infotainment Applications:** Infotainment applications [50] [51] are non-safety areas of operation that help to increase driver and passenger satisfaction levels and render trips more enjoyable. In terms of contact settings and efficiency specifications, each of the defined applications and use cases has specific requirements [54]. Vehicles are capable of transmitting data at a lower frequency while receiving data with a reduced time interval and retaining a defined bandwidth [43]. For making the robust transportation management system, it is necessary that the adopted technology must be reliable, ensure availability and accessibility, in order to facilitate to the vehicle driver with fruitful information at the right time. Considering the example of a collision warning protocol, it broadcasts messages at a 10Hz frequency and receives messages with a 10ms delay while transmitting messages.

The traffic information protocol, on the other side, will initially accommodate latencies of 500ms and run with a transmitting frequency of 1Hz. These distinctions result from the need to improve the robustness and stability of active protection applications [43]. Figure 1.5 illustrates some of the big infotainment applications, such as Apple's Car Play device [55]. It is a system that lets the driver use almost all the iPhone's features (like playing Gaana apps, finding shopping stores, making calls to anyone, and playing audiobooks) without touching it, allowing the driver to keep a better eye on the devices [44]. Furthermore, there are various advanced apps that can include weather prediction forecasts, the location of the closest open restaurant/hotel, and play online sports, among other items, to drivers and passengers.

Table 1.5 Applications of vehicular ad-hoc networks. [39] [43].

VANET Applications			
Applications class	**Active Road Safety**	**Traffic Efficiency and Management Applications**	**Infotainment Applications**
Applications	✓Driving assistance-cooperative awareness ✓Driving assistance Road - hazard warning	✓Speed management ✓Cooperative navigation	✓ ITS Station life cycle Management ✓ Location Based Services ✓ Communities Services
Use cases	✓ Emergency vehicle warning ✓ Slow vehicle indication ✓ Intersection collision warning ✓ Motorcycle approaching indication ✓ Emergency electronic brake lights ✓ Wrong way driving warning ✓ Stationary vehicle-accident ✓ Stationary vehicle - vehicle problem ✓ Traffic condition warning ✓ Signal violation warning ✓ Road works warning ✓ Collision risk warning	✓ Regulatory/ contextual speed limits notification ✓ Traffic light optimal speed advisory ✓ Traffic information and recommended itinerary ✓ Enhanced routing guidance and navigation ✓ Limited access warning and detour notification ✓ In vehicle signage	✓ Point of interest notification ✓ Automatic access control and parking management ✓ ITS local electronic commerce ✓ Media downloading ✓ Insurance and Finance services ✓ Fleet management ✓ Loading zone management ✓ Vehicle software/ data provisioning and update ✓ Vehicle and RSU data calibration

1.4 AN OVERVIEW OF TCP

To serve non-safety-related purposes, the DSRC contains the universally agreed transport layer protocol, TCP. At present, TCP is extensively used for interaction and is a trustworthy protocol for assuring data flow between nodes. It is said to be reliable since it successfully applies to traffic systems and congested systems. Aside from maintaining connectivity between two nodes, TCP generally interacts equally with other transport layer agents such as UDP while not burdening the network.

TCP sends data in segments, each of which has a Maximum Segment Size. This MSS is defined by common agreement between two communicating devices using a three-way handshaking protocol. Each byte of data transferred has a sequence number. A device receives a segment and stores its sequence number. The receiving device responds with a cumulative ACK for each received segment, guaranteeing receipt of the given sequence number of bytes back to the sender. For a period of time, the source node waits for an acknowledgement of the segment that was sent out; once, the timer flags a fault, which means that something isn't right. The TCP source node has a Re-Transmission Timeout (RTO) timer. When the RTO timer expires, the fragment is assumed to be ignored and to be re-sent again. The congestion window, which limits the data packets in transit, and the slow-start threshold, which is the edge between slow-start and congestion avoidance, are both the sluggish start and the avoidance of traffic congestion, which limit the data bit rate of the TCP source node, respectively. The TCP sender tunes the cwnd based on various network parameters, and it most notably avoids network congestion. When the destination node promotes the receiving window, the receiving window is changed at regular intervals in order to ensure that the arriving segment does not exceed the capacity of the segment. The TCP sender, on the other hand, checks and limits the data transmitting rate by using both the cwnd and the announced rwnd parameters. The transmitting window size (W) is defined as the lowest possible combination of the values of cwnd & rwnd.

$$W = Min(\text{cwnd}, \text{rwnd}) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1.1)$$

Where W = Window Size, cwnd = Consegation Window, and rwnd= Receiver Window,

TCP detects packet losses in one of two ways: when it gets three consecutive duplicate ACKs, which is the faster and more reliable method, or when the RTO expires, which is the slower and less powerful method. The Transport Layer Protocol is a window-based system for managing traffic and errors. It effectively handles data transfer across the network using the sliding window protocol. Two mechanisms regulate the TCP sending rate: Flow Control and Congestion Control [56].

The TCP-Flow Control system regulates the sender's transfer rate so that it does not surpass the receiver's accepted rate. TCP application can't transmit and receive data at the same time in general. If no flow control is in place, these discrepancies can result in bandwidth waste due to a high percentage of packet drops. As a consequence, the flow control mechanism is employed to prevent the TCP sender from pushing data into the recipient's buffers over its capacity. To do this, the receiver uses the rwnd variable, which is essentially the socket size of the receiver buffer available for the communication, to advertise the receiver window cap to the sender when responding with an ACK.

Congestion happens as a source node sends TCP data quicker than the network can accommodate it. The aim of a congestion management system is to regulate data traffic within a network in order to reduce congestion. A TCP sender issues a variable, cwnd, to keep a watch on the pace at which data packets are being sent so that pumped data does not exceed the network's capacity; otherwise, a network meltdown scenario could occur.

1.4.1 TCP'S CONGESTION CONTROL MECHANISMS

RFC-5681 specifies the first step of the TCP congestion management mechanism. When a connection between two nodes is established, the slow-start process begins with a window size of one segment, denoted by the MSS, which is first initiated mostly by the receiver and gradually increases in size. In the slow-start procedure, the sender delivers a small amount of data and waits for the receiver to confirm receipt of it. When an ACK is received, the size of the cwnd is doubled or expanded by one segment. In other words, once the first packet is lost, the cwnd grows exponentially. Slow-start takes a long time to start up, which is inconvenient for a high-speed, congested network and therefore unsuitable for VANET. Furthermore, since tiny data packets must be sent constantly, bandwidth reliability would be severely harmed. When there isn't a lot of traffic on the network, slow start is still not that slow because the cwnd grows exponentially after a good transmission.

During the delayed start procedure, the congestion window expands exponentially. The doubling time of the development will proceed until either packet loss occurs or until the slow-start threshold is reached. When a packet gets misplaced, it is referred to as a "packet drop." The TCP sender interprets this as a network congestion condition and reduces the available load. TCP switches from exponential to additive growth until it reaches slow-start threshold, with cwnd increasing by 1 segment for each Round Trip Time.

It is another crucial step of the TCP congestion management system that decreases the time a TCP sender must wait before re-transmitting a missing fragment. When an RTO has elapsed and a TCP host does not respond to three ACKs, it is thought that the segment was lost. During the quick re-transmit, process, the TCP host retransmits the missing segment without waiting for the RTO to expire.

The rapid recovery process begins shortly after the event of fast retransmission. During quick recovery, the ssthresh is reduced to half of the previous window size, and the cwnd size is reduced to ssthresh+3 segments due to the reception of three duplicate ACKs. In most cases, Fast Re-transmit Algorithms and Fast Recovery Algorithms were combined. Each submitted section has a timer associated with it. The TCP sender maintains track of the RTO in order to detect segment failure. The expiration of the RTO timer indicates that a segment has been lost due to congestion or packet error.

It is one approach that's often employed by TCP. If a packet is dropped at the receiver, the packets in-flight are considered lost due to network congestion, TCP emits 3 ACKs to notify the sender that there is packet loss, whereas in this case, the TCP receiver does not modify the ACK field's sequence number. A packet is presumed lost if the TCP sender receives three consecutive ACKs with the same sequence number. The TCP sender switches to rapid retransmit and recovery mode after receiving three consecutive duplicate ACKs. After receiving all active ACKs, the TCP sender sets the cwnd to ssthresh, exits the quicker recovery process, and restarts the congestion avoidance phase.

1.4.2 TCP IN VANETS

In spite of the fact that DSRC is designed for moment, real-time safety applications, it can also be used to provide delay-tolerant information services by incorporating TCP at the transport layer. The majority of non-safety and comfort applications depend on a direct connection between the RSU and the car. TCP, the most widely used Internet protocol, was not built for and is not suited for the volatile existence of wireless channels [57], but it works better than UDP. Its usage over the MANET/VANET is a prerequisite for providing data for infotainment. TCP/IP is not only the Internet's widely recognized common network protocol stack, influencing a wide range of implementations, but it also allows for smooth connectivity of the Internet anywhere it is possible [58]. Using the V2I network to download material such as music or road maps is thought to be a valuable delay-insensitive feature. The current Internet protocols, such as the File Transfer Protocol, are used to retrieve the contents (FTP). The files are split into several sections and sent over TCP. The sender and receiver create two packets for each section of the file to be transmitted via TCP: one of the TCP data segment and second for TCP ACKs [33]. Over DSRC, the stability of both TCP and UDP in non-safety applications can be calculated. While TCP can be used for any kind of downloading operation, UDP can be used for both bursty and non-bursty applications. TCP performs poorly in 802.11a in terms of throughput, owing to the inclusion of both non-TCP-friendly and non-safety UDP applications. DSRC, on the other hand, improves TCP efficiency significantly because each kind of programme has its own time slot [59].

Wireless radio communications have radically different characteristics than wired networks. TCP provides low throughput in complex wireless networks, according to many investigations into the effect of these properties on TCP efficiency [60]. TCP's conservative flow and congestion management systems are solely to blame for this bad result. TCP interprets propagation errors as a latency condition in cellular networks, and as a result, it reduces the bandwidth consumed [61]. The presence of congestion in wireless networks is not the major cause of packet losses in these networks. The presence of congestion in wireless networks is not the major cause of packet losses in these networks. It can occur as a result of high Bit Error Rate (BER) and regular link interruptions. In a VANET, high node mobility causes regular network disconnection and reconnection cases, which degrades TCP efficiency [62]. In this case, the TCP isn't set up to take into account wireless network features like multi-path signal transmission and limited bandwidth. This means that it can't guarantee high reliability and efficiency when transmitting data over a complicated communication network. TCP's dependability is ensured by the effective application of flow and error management. The TCP flow control system limits the sender's transfer rate such that it does not exceed the receiver's accepted rate. In general, the devices cannot send and receive data at the same rate.If no flow control is in place, these variations could result in bandwidth waste due to a high amount of packet loss. TCP congestion management is a system for dealing with network congestion and preventing a network meltdown. In vehicular settings, TCP's traditional congestion management system fails miserably. This is because future congestion forecasts are based on local data, which can or can not represent the actual state of the network [63]. In the VANET climate, designing successful congestion management systems is also a difficult challenge. To control packet traffic, TCP employs a window and acknowledgment framework. When three duplicate acknowledgments are obtained or a timeout is hit, the transmitting window continues to expand exponentially and then additively. The problem with an extremely complex topological VANET is that the transmitting medium is unreliable, exposing the data to bit errors that can totally destroy it. The cwnd shrinks as the packets are interrupted, lowering throughput [63]. In this case, the disrupted packet must be resent and transmitted at the fastest possible transmission rate. TCP's slow-start, congestion management system, on the other hand, begins with a relatively low transmission rate and gradually increases as each acknowledgment is received. In addition, the slow-start, congestion management system shrinks the sound and doubles the re-transmission timeout value[56]. This slow-start method avoids maximum bandwidth usage for the duration of the session. As a result of this needless congestion management, the efficient use of bandwidth is limited, and efficiency suffers as a result. Furthermore, a sequence of timeouts on the TCP sender side limits total throughput more than packet losses. Serial timeout is triggered by the TCP sender's inability to obtain acknowledgment on a daily basis, and is caused by repeated disconnection. There must be an effective congestion management system to keep infotainment services working well in the VANET environment while still giving critical safety applications a fair amount of bandwidth at the same time.

1.5 MOTIVATION FOR RESEARCH

A VANET suffers from rapidly changing topology. Vehicles in an urban environment tend to form higher vehicle density regions. The wireless network places an upper bound on the achievable throughput in an area. The maximum throughput is inversely related with the number of nodes communicating in an area. Higher node density region, tend to generate more traffic than the wireless bandwidth, this results in delays and packet losses. The key issue that impacts TCP performance in VANET is packet loss, which affects all vehicle nodes and is one of the catastrophic faults that can occur. TCP regards higher packet loss as route congestion. The congestion in connection is dealt by reducing the transmission rate by resetting the congestion window. This results in a reduction in overall transmission rate. A significant reduction in throughput and an increase in ultimate delay are experienced as a consequence of the wireless ad hoc medium being exposed to multiple losses in addition to congestion loss. Consequently, rather than presuming that a loss is caused by congestion, a VANET can be designed to allow for the determination of the reason for the losses, and formulating proper procedures to overcome the loss. This can substantially improve the performance of the VANET. Packet loss caused by congestion in the network, connection issues, and communication errors are the most prevalent forms of packet loss that can occur in a wireless network and they are preventable with the use of proper methodology and technological constructs. The need for finding wireless network performace losses incurred as they occur, planning the network topology in view of fast-moving nodes, estimating new routing path free of congestion and probabilistic analysis of the routes can be used to prevent and significantly reduce the packet losses. Thereby reducing the route congestions and increasing the overall network capacity and TCP performance in VANET's.

1.6 APPLICATIONS

Network applications that need trustworthy edge communication use TCP. TCP performance on Vehicular Ad-hoc Networks has been scientifically proven to be low in research. Data packets are seen by TCP as a symptom of data traffic. However, losses in wireless networks occur due to overcrowding of data packets and channel capacity. As a result of the high number of vehicles, TCP data traffic increases, thereby lowering throughput. Vehicle designs should include applications for safety, driver assistance, highways monitoring and traffic efficiency to RSU based platforms. Once emergent vehicular networks like intra-vehicle, VtoV, and VtoI internet activity are accessible, these applications will become a reality. This is predicted, given that business, telecom and network operators, universities, and governments throughout the globe are investing heavily in the implementation of vehicle networks in order to create a more secure transportation infrastructure. The focus of government, commercial, and scientific efforts were on vehicle networks. The idea of an interconnected vehicle has received a lot of attention recently in digital technologies. Providing vehicles and roads with capabilities to improve traffic, data traffic security, and efficiency is now a popular application. It also improves the quality of the journey for passengers. RSU-based technology provides fast information regarding traffic jams, accidents, dangerous road conditions, potential detours, and weather conditions, as well as the location of amenities (e.g., petrol stations and restaurants) in an emergency.

1.7 PROBLEM STATEMENT

i. A sender overflows a network by sending an excessive number of packets, resulting in congestion on the network. This amount of traffic is too much for the network to handle adequately.
ii. Network congestion is caused by a lack of available connection bandwidth, outdated network equipment, and data transmissions that are excessively large.
iii. Poorly designed and unorganized network infrastructure is the main causes of congestion.

Thereby, given the need and urgency of the work, a problem has been formulated with the title, ***"A Framework to Control RSU Based TCP Traffic Congestion in VANETs",*** to carry out the research.

1.8 OBJECTIVE

The proposed method is aimed to analyze a framework for controlling TCP traffic congestion over the course of this research. To achieve the goal, the following objectives have been decided:

- To review and critically examine the literature on TCP traffic congestion.
- To design an approach for congestion control.
- To test the proposed algorithm for TCP congestion.
- To develop an organised RSU deployment strategy.
- To examine the energy consumed by each node.
- To increase throughput (data packets per second) and the cumulative sum of packets to all nodes in the VANET.
- To reduce delays and packet drops.
- To validate the proposed design.

1.9 METHODOLOGY OF RESEARCH

The proposed framework covers the tasks of implementation, development, and analysis of the framework. The development of an efficient framework, a virtual model, and model validation is a major goal of this research. It is expected to be completed in various stages, including the following:

- Enumerate all characteristics associated with TCP traffic congestion.
- Enumerate/Select characteristics that are comparable or nearly comparable in their approach.
- Investigate the effectiveness of developing a framework by doing research.
- Put that structure into action.
- Run simulations and validate the findings.

1.10 SIGNIFICANCE

The main contribution of this thesis including a methodology with organized RSU to control TCP traffic Congestion. To achieve the goal, the following outcomes:

- Proposed framework may reduce data traffic Congestion.
- The proposed framework has the potential to minimise the costs of VANET design and deployment.
- This may reduce the energy consumed by each node
- The proposed algorithm enhances the throughput (Data Packets per Second) and Cumulative Sum of packets for all nodes in the VANET.
- The proposed framework may reduce delay and packet drop for better communication.

1.11 CONCLUDING REMARKS

The chapter briefly introduces the basic theory of MANETs, VANETs, and their applications. It also introduces TCP and TCP in VANETs. Various applications related to ad hoc networks are discussed. The major problem found in the VANETs is targeted in this chapter, i.e., traffic congestion. Traffic congestion in VANETs causes delays in data packet delivery. It effects the VANETs' communication, which results in road accidents. Consider this to be one of the most significant and serious matters associated with VANETs. Reducing traffic congestion is the main problem statement of this thesis while preserving the fine details of the TCP. All the contributions to this thesis are also discussed.

1.12 OUTLINE OF THE THESIS

This section offers a quick outline of the research framework in this part by giving the key topics of the thesis chapters, as follows:

- **Chapter one**: The chapter briefly introduces the basic theory of MANETs, VANETs, and their applications. It also introduces TCP and TCP in VANETs. Various applications related to ad hoc networks are discussed. The major problem found in the VANETs is targeted in this chapter, i.e., traffic congestion..
- **Chapter two:** In this chapter, an exhaustive review of the literature to determine what has been done in this area to date. Section 2.2 examines current wireless TCP modifications that adapt TCP traffic Congestion in vehicular ad hoc networks. Section 2.3 reviews existing literature on the design and analysis of VANET, as well as future directions. Putting our conclusion in context is discussed in Section 2.4, which outlines the limits of our work and places it in context.
- **Chapter three**: Through the use of RSU, the proposed methodology frames several modules of packet traffic congestion control in this chapter. The proposed RSU Placement Algorithm is a unified approach for conducting effective congestion management in vehicular communication networks that includes generic (reordering) and failure, transmission channels, such as wireless networks, by combining many algorithms. The suggested approach involves routing data packets only via the use of the AODV algorithm and TCP traffic, hence enabling the possibility of widespread implementation in the future. According to the findings of the literature analysis in Chapter 2, the majority of current TCP variations are solely concerned with dealing with the presence of either non-congestive link failure or congestion. Only a few unified

solutions for both challenges are now available, and most of them need information and alterations that are beyond the scope of the transport layer, preventing widespread use in the future.

- **Chapter four**: Analysis of VANET networks is not easy because of the high mobility of vehicular nodes. This chapter discusses the experimental results of two scenarios, i.e., random RSU placement and fixed RSU placement. The details and analyses are in tabular and graphical form. These two scenarios run successfully in the NS-2 simulator. The result comes in the form of residual energy used, the cumulative sum of packets, end-to-end delay, throughput, packets lost, and the TCP traffic congestion window. After analysis of the outcome, validation of the TCP traffic congestion window by considering 30, 40, and 50 nodes with the Z-test is presented.
- **Chapter five**: In this study, the AODV routing protocol is combined with the RSUs placement algorithm that was proposed. Then, the Network Simulator-2 was used to do a detailed analysis. Simulations show that an RSUs placement algorithm is best for getting less traffic, a low E2E delay, high throughput, and no packet loss. Overall, the proposed RSUs placement algorithm is the ideal solution to reduce TCP traffic in any environment.

CHAPTER 2

LITERATURE SURVEY

2.1 CHAPTER OUTLINE

The first thing to do in this section is to look through the literature to see what has been done in this field so far. Section 2.2 examines current wireless TCP modifications that adapt TCP traffic Congestion in vehicular ad hoc networks. Section 2.3 reviews current research on the design and analysis of VANET, as well as future directions. Putting our concluding remarks in context is discussed in Section 2.4, which outlines the limits of our work and places it in context.

2.2 TCP TRAFFIC CONGESTION IN THE VEHICULAR ENVIRONMENT

Congestion management in vehicular network systems is a difficult problem to solve, mostly because of the rapid change in VANET topology and VANET bandwidth, which is used by many vehicles. Indeed, route modifications caused by the dynamic and mobile nature of nodes result in uneven delays and packet losses, which should not be regarded as congestion control errors. Furthermore, the utilization of shared Vanet bandwidth restricts the amount of data that can be sent from a node to a nearby node. As a result, congested channels impact the entire network rather than just the nodes that are overburdened. Several management systems have been proposed in past years, which are designed to function inside VANETs and are described in this research. This section does not purport to provide a comprehensive discussion of all approaches. Congestion control techniques in wireless ad hoc networks include end-to-end, but also hop-by-hop strategies, which are both effective. The purpose of end-to-end protocols is to ensure that data transfers smoothly among senders and recipients. However, internal relay nodes are taken into consideration when designing these protocols, while internal link capacity is taken into consideration when designing hop-by-hop congestion management techniques. Various procedures that fall under these methods are discussed.

2.3 MAJOR RELATED WORK

There is a technical possibility to obtain the high throughput as per given facts TCP has poor throughput in multi-hop networking [64]. TCP is now conservative, and the loss of efficiency is primarily due to congestion control systems. Connection faults, for example, are perceived as latency by TCP, which limits throughput. Both the slow start and congestion avoidance methods are employed [65]. Over time, TCP has acquired a range of new protocol capabilities. In TCP Reno, the concept of simplified retransmit/fast recovery was established, and this concept was later refined in TCP New Reno in accordance with RFC 2582. TCP has benefited from restricted ACKs (RFC 2018). These extensions are already present in the TCP frameworks for different OS's. Such extensions do not address TCP's underlying problems in mobile settings. On the other hand, TCP tends to struggle in the VANET setting, i.e., when a vehicle communicates with a proxy [66].

Depending on the expected scenario, TCP's congestion control techniques will react accordingly. TCP Westwood [67] is one of many methods that intelligently estimate the available bandwidth used to optimise TCP Westwood capacity. Other approaches, such as a TCP DOOR [68], rely on out-of-order packet transmission or rate-driven congestion control based on inter-packet arrival times. ADTCP [69] uses a changed TCP state machine to adapt efficiently in these situations and measures throughput, PER, and packet out-of-order distribution ratio. Like the TCP Vegas [70], another traditional solution is to entirely overhaul the slow start, traffic management, and timeout measurement formulas. TCP's congestion reduction is fully replaced by other algorithms, such as ATP [71]. The congestion control scheme lacks mechanisms for dealing with both short-term and long-term service outages. The main alternative is to use feedback from intermediate networks if the network can sense various situations. Explicit Congestion Confirmation (ECN, RFC 3168) is a standard tool for intermediate nodes to identify and alert interacting end systems about pending congestion. On the other hand, TCP extensions such as ECN do not fix the general TCP issues in VANETs since they often use exponential backup timers to determine retransmission timeouts. Since it can result in a TCP link reset or a prolonged recovery time after reconnecting to the internet, this mechanism is ineffective at addressing long-term Internet disconnections.

C. Lochert et al. [72] addresses the link timeframe for both nodes by sharing mobility information, such as vehicle momentum and driving path, with a link expiration period variable is utilized in the evaluation of the link depending on the information collected, and it is also used to mark a link as expired or not. To prevent message failure, an outdated connection is omitted from the route table. According to C. Lochert et al. [73], routing protocols are based on four aspects, one of which is node movement. The data packet size increases by 4 bytes for vehicle mobility and speed data, which is continuously transmitted in HELLO packets and delivered by each node to neighbouring nodes. The receiver uses the source's speed information to calculate the speed differential of two nearby nodes, Which is then used to update the receiving side route information table. A lower speed differential means that the two vehicles are more likely to be close to each other, resulting in a longer connection lifespan. S. Wankhade et al. [74], suggested a routing protocol depending on encounter information and a clustering scheme for nodes to resolve high-speed node mobility and its effect on the communication channel reliability and availability. A vehicle routing protocol always maintains records of the movement of surrounding nodes and its present position as a future forwarding node by employing an encounter-aware method. Furthermore, the clustering approach is utilized to reduce long-distance information exchange among cluster nodes while restricting short-distance information exchange between vehicles within a cluster, which lowers the mean communication overhead for vehicles. C. Perkins and E. Royer [75] proposed the SAFE-MAC scheme to ensure vehicle-to-infrastructure exchange of information is the same when using the same wireless channel. The SAFE-MAC uses mobility metrics, including node location, travel direction, mobility, and speed to measure how long a vehicle will last in a service area with the roadside. The measured residence time is often used to monitor each vehicle's packet transmission probability. Since high-speed vehicles have a short residence period, they are equipped with a limited contention window height, giving them more chances to communicate with low-speed vehicles. Low-speed cars, on the contrary, have a longer residence time, so they are built with a broad contention window size. J. Zhao and G. Cao [76] proposed an MPECS in which each vehicle node makes use of a mobility model, i.e., Gauss-Markov, to anticipate the specifics about its mobility and probable moves in order to avoid collisions. It is used by a vehicle node to assess how long it will be able to operate in a cluster area (vehicle lifespan), as well as how much it will be compensated to operate as a cluster head (CH) node within the area. Vehicle Lifetime Value is a suggested metric for determining a vehicle's acceptability as in the cluster head (CH). Both vehicle lifetime and vehicle expense are weighted in the VLV metric. The head of the cluster is the vehicle having the greatest VLV between the other member nodes. The MPECS aims to improve the stability by utilizing a bigger number of cluster heads (CH) and also the mean lifespan of a cluster head in VANETs by deploying a larger number of CH.

Due to the importance of communication delays in VANET implementations, especially in safety-related services [77,78], the majority of current research has primarily concentrated on reducing communication delays. The Furthest Distance technique [79] is a technique for locating relay nodes in the network that are away from the source node, and it is used in many applications. The aim of the study is to reduce data packet delays. This was achieved by reducing the total number of hops required to deliver a message from its source to its final destination. The technique most commonly used in VANET message propagation schemes is FD-based relay node selection [80,81]. Due to its positive results in terms of message receipt efficiency, recent developments have centered on connection consistency-based message propagation schemes [70,74,78]. The level of connectivity between the sender and its neighbouring nodes is assessed, and the approximate connection qualities are used to select the next-hop relay nodes. Concerning connection performance analysis, a well-known technique is the estimated transmission count [72], which determines the number of transmissions necessary to send a packet over a communication network. The ETX tries to increase the throughput (bits per second) of delivering messages by selecting connections with the fewest planned transmissions. Another method was suggested in [82], in which the obtained signal intensity over a node backward connection was used to estimate the contact quality on its forward link. J. Lee et al. [79] proposes a bidirectional stable communication system that includes forward relation utility measurement for multi-hop connectivity in

VANETs. Via an implicit recognition loop among neighbouring nodes, The suggested approach considers active packet reception on forwarding connections. Many hybrid packet forwarding techniques for VANETs are recommended [83]. Lochert et al. [73] proposed a hybrid scheme based on geography and topology was suggested, which calculates a composite weight value by considering node mobility, connection lifespan, neighbouring node density, and distance. By exchanging simultaneous RREQ & RREP messages, it is only used to find the optimal route to the destination.

For EDCA, the researchers [86, 87] proposed a Markov-chain framework. Internal collisions are not taken into consideration, since their models are confined to the case when each unit has a single operating AC. As a consequence, it's difficult to extend the notion to the general scenario of all ACs being located one at a station, which affects the model. Han et al. Investigated the impact of the post-collision cycle in depth in [88], by adding propagation probabilities unique to various contention zones triggered by the disparity in AIFS values. However, while the connection is busy, this approach ignores a back off mechanism to stop it. Qiong Wu et al. [85] expanded the work of [88] by considering the back of the counter freezing. Furthermore, the model covered all of IEEE 802.11p EDCA's essential QoS features, as described in [84]. The area of IEEE 802.11p EDCA simulation and optimization has received support from this methodology. The researchers proposed an IMCA and Coordination System for the IEEE 802.11P standard [89]. The findings support the AMAC proposal's applicability for protection and safety reasons over the old rule. The effectiveness of multichannel (IEEE 802.11p) VANETs was investigated by Song et al. [90]. Many elements of the standard, such as multichannel switching, were taken into consideration in the model. However, in both references, 1D & 2D Markov chain models were developed [89,90], resulting in increased difficulty. Furthermore, only two ACs were taken into account, and the influence of data transmission problems on system performance was not investigated. H. Peng et al. [91] focused on how multi-platinum communications affected the DCF mechanism's functionality. The authors proposed an observational approach for testing the performance of transmitting data packets of IEEE 802.11p/WAVE vehicle networks in [93,94,95]. The effect of using a mechanism of packet separation on DCF under an error-prone network was also researched by Yazid et al. [92].

Ji B et al. [96] suggested a new MAC standard to address issues on the WAN created by the essential bandwidth infrastructure of IEEE802.11ac. The suggested protocol is designed to decrease congestion while maintaining the quality of performance of concurrent IEEE802.11ac networks. By introducing back-off counter freezing into the Markov chain, Barowski et al. [97] aimed to broaden the Bianchi model and were successful in demonstrating enhanced accuracy. This model lacked sufficient detail.

Engelstad PE et al. [98] used the Z-transform method to conduct a queue dynamics study in order to measure waiting times in entry queues. And on the other hand, the model that has been disclosed is focused on 3D Markov chains. Xu K et al. [102], did a multidimensional experimental analysis of the Markov chain on EDCF was proposed by Xu et al., in which the number of observations is influenced by the frequency of active inputs in the channel. It's really undeniable that seeking a solution to this problem is becoming extremely complex. Furthermore, certain aspects of the method were left unaddressed, including the data transfer limit and individual collisions, including back off buffer freezing. The back off buffer freezing feature was implemented in the Ergen et al. approach [103].

Table 2.1 Research article with different parameters used

Reference	Performance Metrics	Protocols in Comparison	Transmission Range (m)	Operation Scenarios	Simulation Tool	Topology Size (m^2)	Speed (Km/h)
[162]	Packet delivery rate, link breakage rate	GPSR, GPUR, GPCR	125	Urban city with traffic signals	Ns-2	700*1000	0-80
[163]	Overhead Packet delivery, E2E Delay	AODV-ETX, MTL	150-250	Gaussian, Rayleigh Uniform	Ns-2	-	40-100
[164]	Packet delivery rate, E2E Delay	GPSR, GyTAR	250	City map	Matlab	7000*7000	-
[165]	Latency, packet loss, jitter	NEMO, fast NEMO	WiMAX =1000 And WLAN= 300	Highway with four lanes	Ns-2	1000*1000	5-100
[166]	Packet delivery ratio, link Failures	AODV, PBR	-	Highway with three lanes	OMNet ++	5000*5000	40,60 and 80
[167]	Packet delivery ratio, routing overhead	AODV, AMODV and GPSR	-	Urban traffic scenario with streets	NS-2 Vanet Mobi-Sim	500*500	25, 50, 75 and 100

The authors, assume that the collision risk is equivalent to the channel busy probability, and that the collision risk governs the back off buffer freezing, which is unjustified and also too restrictive. In this paper, researchers present a model for the IEEE802.11p EDCA mechanism that captures specific quality of service functionality as described by the standard [84]. Furthermore, the AIFS waiting process, back off buffer freezing, virtual collisions with ACs on the same network, existing collisions with other channels, post-collision period, and data transfer limit are all taken into consideration. Table 2.1 describes different research, with performance analysis.

When the vehicle nodes are running at high speeds, Xu et al. [110] used the delay as an estimation parameter for routing reliability, selecting the vehicle node with the least delay as the next hop vehicle node, essentially reducing the overall delay. The algorithm has been checked only in the rear-end alarm method on a highway, and the simulation findings show that it can reduce the number of emergency warning messages and transmission latency.

Rasheed et al. [111, 112] investigated the impact of node contact radius and travelling path on routing updates and developed a routing updating model using the duration and latency as assessment parameters. The authors compared their algorithm to other standard algorithms in a variety of traffic scenarios, and results have shown that the algorithm significantly increases the overall and delay times.

Slavik et al. [113] provide a distribution-adaptive-distance channel consistency algorithm for data transmission with multiple hops that depends on path length, which includes the Packet Delivery Ratio and other parameters. It was found that the algorithm's performance is influenced by density.

Packet delivery ratio & delay were used as route efficiency calculation metrics by Xue et al. [114], and a differential Markov model was used to set up a node location model that is based on the transport infrastructure setup, node velocity, and position. Following that, the authors suggested a routing model for high-speed VANETs. Simulations revealed that this algorithm outperformed DSR and other algorithms.

Mohammed Nasr et al. [115] investigated V2V in the absence of facilities, constructing the priority of various vehicles depending on the on-board contact system and the vehicle's location and velocity, and selecting the highest-priority vehicles as cluster heads.

Miguel Rios [116] proposed an algorithm for locating the best relay nodes in an area based on the potential for low-density VANETs made up of buses and bus stops, and simulations show that this algorithm improved routing efficiency by 159 percent and reduced E2E latency by 36 percent when compared to passive routing algorithms.

Mohammed Nasr et al. [115] determined the shortest route to be the fastest in the cluster and across clusters, and they saved the second-best route to save time when the best route splits down.

Sahoo et al. [117] Cluster heads predicated the vehicle's location and trust value, and then implemented an ACO-based routing algorithm for VANETs. This algorithm performed well in terms of overhead. When applied to VANET routing, clustering and intelligent algorithms will significantly increase routing performance. However, the latency and PDR for current experiments should be increased. Through searching the global and local optima, the swarm optimization algorithm finds the best solution. The PSO's advantages, such as high precision, fast convergence, and ease of implementation, propel it to the forefront and demonstrate its supremacy in solving practical problems [118]. Consequently, the PSO is used in this paper to increase routing efficiency by optimizing routes inside and across clusters.

Several researchers have looked at the problem of traffic congestion in an attempt to come up with solutions. Y. Mohan et al. [125] proposes a traffic congestion detection scheme. This is a hybrid framework that incorporates V2V and V2I connectivity. The machine analyses and processes the accumulated data to detect traffic jams and, as a result, informs the vehicles of future route changes. The Cassandra algorithm was used to create the method. The OMnet++ and SUMO simulators are used to assess and verify it.

C. Panos et al. [119] proposed a strategy for reducing traffic congestion in metropolitan areas. A distinction is made between congested and unencumbered metropolitan centres. The vehicles will differentiate between the zones based on their routes, with the option of shifting direction to the unencumbered zone.

Daniel et al. [120] developed a paradigm to make effective use of vehicular data in real time. This model is built on an algorithm for analyzing vehicle density in a specific lane. Douglas Montgomery [121] proposes a framework for selecting protected trajectories for autonomous vehicles. Big Data mining to handle knowledge from real-life accidents allows for the selection of said trajectories. Human interaction is limited to driving choices and begins at the start of the route. A multi-level knowledge fusion method for detecting congestion in VANET is suggested [122].

It employs the Dempster-Shafer proof logic as well as the classification-based knowledge fusion fuzzy (D-SEMA). The D-SEMA process provides FCMA with the qualities it should have to identify traffic congestion incidents. The most significant advantage is that it conserves bandwidth during treatment. To summarize, a large percentage of strategies and techniques for identifying congestion are based on interactions between different network components (vehicles and RSUs). Furthermore, position data are not adequately used.

Y. Mohan et al. [125] used the NS-2 for DSDV, AODV, & DSR routing protocols' output analysis in a clustered VANET system, evaluating performance parameters like packet distribution ratio, E2E latency, and throughput. The findings showed that the DSR protocol is more applicable to small cluster sizes. Still, as cluster sizes get larger, the AODV protocol exhibits dramatic performance improvements. Although the DSDV evaluation findings are unsuitable as opposed to the other two routing algorithms, it appears more efficient. There was no network traffic used in this simulation. Similarly, Namita Chandel and V. Gupta, [126] investigated the efficiency of the routing protocols AODV and DSDV. The NS-2 uses various parameters such as latency, E2E delay, packet transmission ratio, and jitter for multiple numbers of vehicles. In aspects of the PDR, the author concludes that AODV is good to DSR & DSDV in consideration of performance, but DSR has a lower E2E latency. The DSR is comprised of cumulative throughput for a variety of vehicles. Finally, they advise doing simulation and analysis with a large number of vehicle nodes in their research. Others made additional attempts in [127]. They used Vanet Mobisim and NS-2 to measure the efficiency of the DSR and DSDV protocols in VANET latency & throughput. Compared to DSDV, the DSR was found to be superior for latency. Compared to DSDV, DSR throughput increases with vehicle nodes. There has been no comparative work done with AODV protocols to demonstrate that they perform better in VANET.

With the various numbers of connected nodes, N. M. M. and P. C. Vashist [128] calculated their VANET scheme's reliability in terms of bandwidth utilization, throughput, and E2E delay using OPNET. Here, AODV and DSR are evaluated. According to the results, in each of these scenarios, AODV has a considerably higher throughput than DSR, and DSR has a considerably higher overall E2E latency than AODV. The DSR seems to have a slightly lower total network capacity than the AODV. A further effort was introduced in [129] to influence the ADV, DSR, and GOD protocols' efficiency using the NCTUns-6.0.As per the results, ADV are effectively designed for highway situations, while GOD is more suited for town situations in a free space node. In their articles, the authors of [130] & [131] compiled a list of different routing protocols that can be adapted to the unique attributes of the VANET environment. AODV & DSR are stronger reactive protocols, while DSDV is a strong, proactive routing protocol. M. K. and A. K. Virk [132] did a study on DSR, AODV, & DSDV in VANET. They posed an excellent observation, i.e. no specific routing protocol for VANET could be considered the cheapest and most effective option. The routing protocol should be selected based on the particular routing task requirements. A. G. and A. Shaheen [123] tested & analyzed AODV & DSR in terms of PDR, throughput, as well as a delay with two distinct calculations using the OPNET simulation environment (dense and sparse traffic). According to their findings, in contrast to DSR's performance, AODV outperforms DSR in a crowded traffic setting [124], for example, used a population mobility model on Qualnet 6.1 to assess AODV and DSR VANET performance. These research results are closely related to those [123] and [126]. The authors utilized NS-2, a quite recent and oriented analysis [16], to evaluate four network algorithms in a VANET: DSDV, AOMDV, DSR, and AODV. As a consequence of recent studies, determining an acceptable routing scheme for the VANET approach is important. But there's no such concept as an infallible protocol that can be used permanently. The number, as well as the speed of vehicles in the area, decides the utility of such a routing algorithm. The basic principle of the VANET approach is to identify different protocols after obtaining the mobility & network traffic models. The number and speed of vehicles across the area decide the utility of such a routing algorithm. The underlying concept of the VANET approach is to describe different protocols after collecting mobility & network traffic prototypes. Besides that, instead of using real-world scenarios, some researchers focus on running simulations in VANET. The VANET simulator, which can visualize both the network & traffic as just one path, is important for testing and analyzing architectures. Because of its versatility and affordability, MOVE with SUMO is the best choice for such VANET simulator testing equipment.

Work on [134] indicated a significant model in which to research multi-layer video transmission with reliable QoS guarantees focused on an effective channel capacity and a high chance for delay-bound violation. Fortunately, only these distinct queues are assessed using the multi-layer video delivery process, which disregards the video traffic's statistical properties. L. Deer and P. Jianping [135] proposed an extended 2D Markov chain for IEEE 802 multi-hop wireless connections with throughput measurement and error-prone path recognition, non-persistent flow, post-back off-stage, and a minimal retransmit limit.

Heterogeneous WSN were clarified by the author with the aid of an adaptive MAC protocol in which Quality of Service support was considered to be needed [136]. The QoS aware MAC protocol was designed to provide efficient optimization of traffic on wireless communication networks to ensure high-channel use.

The VANET protocol uses the position of the node, called GPSR [133]. The source aims to determine the route that results in the forwarding of the data by destination. However, it often finds a vehicle close to the source's transmission region. There are no vertical obstacles to the usage of GPS in tall buildings, but GPSR fits well in these conditions. Due to the GPS problems, it was almost impossible to be effective in the city. In the Greedy Perimeter Coordinator Routing Protocol [134], the data is routed using the GPSR device and a virtual node. The data has already been passed on to the junction, and if no three-way split exists, the engineers will devise a solution. This method increases the packet count and lowers the latency by using GPSR. Gearbit Routing

[135] allocates a weight factor to each route segment that contains two or more roads that are not directly linked. The packages are moved to local roads with significant weights. This weight factor takes the location of the product, as well as other surrounding products, into consideration. The MDDV [140] specifies the path in view of automobiles. The selection of the next forwarding node is made based on the idea of opportunity. Traffic frequency fluctuates over time, making this approach ineffective.

In Junction Based Routing Protocol (JBR), a source vehicle computes each vehicle's angle within its transmitting field concerning the destination vehicle's path [141]. The vehicle with the shortest curve between two bends typically sees the farthest amount of data transfer, which facilitates the bonding process and avoids thumb problems-first/statement-then-solution, commonly seen in GPCR sentences and has been seen in GPSR. The challenge is that the signal doesn't always propagate in the city's middle. It is also susceptible to long transmission delays due to repeated retransmission of data packets. Geographic Source Routing (GSR) [142] requires geographic attributes, including intersections and automobiles. It creates a map to determine the vehicle's location. It transmits information to the nearest point on the link. However, in the course of flying, it fails to find the shortest path. The A-STAR uses the city bus path as a data reference point to gain higher bandwidth. Using the GPSR, the pause is extended in this method. Ad hoc and geographic route ideas are part of carry-forward (CAR). In the communication protocols, any node is a guard node. With this instruction, the AODV [143] protocol is able to locate the final destination.

To select the right path, the iCAR framework [144] uses communication links and delay information. It seeks to avoid highways with high traffic congestion in order to minimize delays. It uses the carry-forward method to evaluate the lifetime of link contact. This approach assists in the choosing of the vehicle that will carry the data to its expected location. Dependent on the link specifics of vehicles on the road, BAHG [145] is a dynamic, reactive protocol that selects the path that requires the least possible hop count and moves through the least possible number of nodes. Backbone (also known as Virtual vehicle) cars are used at each intersection. This helps to collect information for each connected road segment, but it avoids the gap among vehicles inside each vehicle's distribution zone. Link loss is expected as a consequence of this problem.

Huang and Z. Wu [149] discussed an information offloading approach and the VANET framework (MEC). This design aims to show how the vehicles can remove data from a V2V path with k hops at which a transfer server swap node must occur. All the different scenarios are focused on the position of the RSU. In their article, they explained how and why the k-hop V2V offloading route is used in the circumstances. To optimise the performance, they also applied the configuration of the time span for RSU signal coverage of to offload.

The intelligent transportation infrastructure supports inter-vehicular connectivity, and infrastructure units are mounted along the side of a road to aid vehicle connectivity. GPS & on-board units are used to obtain the position and direction details needed to route from source to destination [150,154]. High speed causes VANET features such as low PDR, short transfer duration, complex structure, and frequent link discontinuity. The MAC layer can be modified to understand the PHY layer's behavior. Because the PHY layer receives multiple packets, the MAC layer can be modified accordingly. The MAC layer works as a pre-defined layer, whereas the physical layer operates as a set layer. Multiple implementations require a higher level of operation and experience, which involves a high-speed communications system and enhancing the performance of routing protocols with various parameters. The stack's output parameter values are modified during the execution period for dynamic optimization, minimization complexity, and precision [151,155].

Fixed nodes that hold data packets use a wireless channel with a short data transmission distance. In the SADV solution for vehicular navigation, GPS selects the shortest route with the lowest latency. For fault tolerance and efficient vehicle routing, fixed nodes plan hello messages utilizing a packet transmission trajectory dependent on data assembled from an electronic street map, including current position [152].

SIRP [153] increases network reliability by maintaining a packet distribution ratio, low E2E latency, and efficient link failure management. This heuristic has the advantage of lowering message network congestion and improving network connectivity. The constructive solution should be used for RSU to vehicular communications, as the reactive route is also used for V2V contact in reliable RSU dependent routing.

The VANET-LTE is based on a cluster heuristic, which results in increased media performance and Multiservice network compatibility [156].

An RSU [150] describes sensitive and harmful nodes and how trust values are scaled around 0 and 1. According to re-routing, which focuses on traffic design and graph analysis, it is acceptable to compromise on a slight increase in travel time to avoid traffic congestion. Re-rouTE functions on the concept of describing and identifying a network based on location data utilizing a dynamical model. A route to the endpoint is also suggested, based on an updated graph [149]. The proposed SAFE MAC calculates the residence period by localizing the vehicle at its speed and direction. High or low-speed vehicles, including transmission probability, are handled similarly by the V2I in Secure MAC [159]. The IHACO technique, which utilizes pheromone measures to monitor traffic conditions, was used to relieve traffic congestion. The IHACO improves interconnection, total distance, and congestion by enhancing nodes [160].

V. V. Shorin [161], did a detailed study of position-based architectures for FANET with its main characteristics is given. FANETs are like VANETs that extend into three dimensions. The advanced routing protocol for vehicular networks [153] will connect with the area to learn transmission parameters by taking into account various metrics, including channel capacity and route duration. This protocol's root seems to be in the rate estimate algorithm as well as the path selection algorithm. The rate estimation algorithm employs a Q-Learning framework to estimate the receipt ratio by using "Hello" messages as a measure of relation accuracy. The path finding algorithm often uses Q-Learning including fuzzy logic algorithms, to decide the best direction in terms of E2E delay and also to test the direct relation.

A-STAR is based on the amount of traffic a path can handle and the number of buses its access is given by. The source node calculates the best route to a destination node by applying the Dijkstra algorithm on a data set that is calculated from the road transmission properties. VPGR [147] which is based on a vertex forwarding technique that uses either V2V or V2I contact, VPGR casts a sequence of coordinates from the intermediate host to a static structure inside the specific location, which uses the PDGR forwarding technique to forward packets among these coordinates. VPGR chooses the shortest direction based on a measure known as Remaining Time (RT). This method aims to find a position with a substantial remaining vehicle time. This feature would not provide any extra information to the routing mechanism.

The Border node-oriented most forward within radius (B-MFR) [148] routing protocol distinguishes three types of nodes based on the proximity of adjacent nodes relative to the transmission range: "interior nodes," "border nodes," and nodes on the transmission range's border. The key aim of this protocol is to lower the number of hops. The HLAR is a mixHLAR's primary design principle is to choose a reactive route as a fallback for position details. The Hop Limit-Adjusted Greedy Forwarding (HLAR) implements ETX with the original AODV algorithm.

2.4 CONCLUDING REMARKS

A study of routing protocols and congestion management in VANETs was provided in this chapter. Significant research is being conducted on this issue both in academic institutions and industry to make them work with real-world commercial applications. In the VANET context, the outcome of the literature review revealed the benefits and drawbacks of existing routing protocols, including proactive, reactive, and hybrid protocols. However, since they are well suited for VANET applications, the primary emphasis of this research effort is on congestion management techniques. A comprehensive investigation of existing approaches, and their solutions, is discussed in this chapter. RSU Based TCP Traffic Congestion, has been provided to handle the issue of packet congestion in VANETs.

CHAPTER 3

PROPOSED METHODOLOGY

3.1 CHAPTER OUTLINE

This chapter frames several modules of packet traffic congestion control using RSU. The proposed RSU Placement Algorithm is a unified approach for conducting effective congestion management in vehicular communication networks that includes generic (reordering) and failure, transmission channels, such as wireless networks, by combining many algorithms. The suggested approach involves routing data packets only via the use of the AODV algorithm and TCP traffic, hence enabling the possibility of widespread implementation in the future. According to the findings of the literature analysis in Chapter 2, the majority of current TCP variations are solely concerned with dealing with the presence of either non-congestive link failure or congestion. Only a few unified solutions for both challenges are now available, and most of them need information and alterations that are beyond the scope of the transport layer, preventing widespread use in the future.

3.2 CONGESTION DETECTION COMPONENTS

The technique for detecting congestion is segregated into three distinct components.

3.2.1 Road Side Unit (RSU)

The Road Side Unit is shown in figure 3.1. It is planted by road side as the name suggests. The locations with higher node density and mobility are considered the strategic locations for RSU placements. Wi-Fi technologies are frequently used by RSUs to provide connectivity to nearby OBUs. The RSU is often deployed by a wide range of additional network equipment that can be used for communication inside the wireless infrastructure based network. It can transfer data to different OBUs, thereby extending the range of the underlying ad hoc network. Information is transferred to other RSUs so that it can be passed to various other OBUs.

The RSUs are used in the following two primary applications:

i. In implementation of safety systems such as alerts. For example a low bridge alert, accident warning, or a working zone communication channel can be established via the use of vehicular infrastructure communication.
ii. Allow Onband Units (OBUs) equipment to connect directly to the Internet.

Figure 3.1 Road Side Unit (RSU).

3.2.2 Onboard Unit (OBU)

An OBU abbreviation is an Onboard Unit, which is signal equipment that is usually found inside a car. The main function of the OBU is the exchange of data and control information between RSU's and nearby OBU's. Towards this intent the OBU has a processor and memory to perform data processing and management. An IEEE 802.11p short-range VANET network for all other OBUs, and a specialized network interface for all other OBUs. IEEE 802.11a, IEEE 802.11b, IEEE 802.11g, and IEEE 802.11n should be added to the list of network protocols for non-safety applications. When the RSU and other OBUs use the GSM frequency, they can talk to each other wirelessly. The OBU's are responsible for one or more of the following tasks: Wireless radio networking, Ad hoc networking, Geographic routing, Congestion control, Fast message delivery, Data security and IP connectivity.

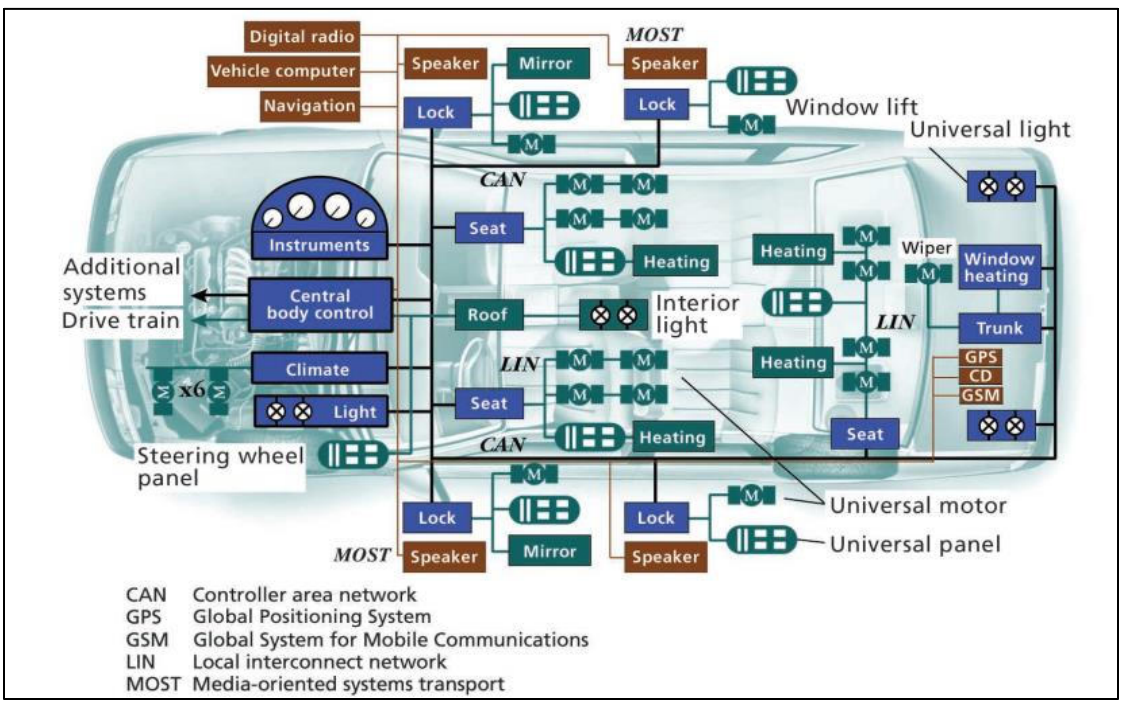


Figure 3.2 Onboard Unit Parts [168]

3.2.3 Control Room (CR)

Control rooms as the name states are used for controlling and monitoring the VANET as well as the vehicles and road conditions. It plays an important role in the VANET as most of the critical management function are assigned to the control rooms. For this intent and purpose, the control room often has a huge video wall and is operable and is supervised continuously. The control room is seen in Figure 3.3.

Figure 3.3 Control Room for traffic congestion and road surveillance. [Taken from intelligenttransport.com website]

3.3 TECHNIQUES FOR CONGESTION CONTROL

3.3.1 $TCP_{NewReno}$ TECHNIQUE

A $TCP_{NewReno}$ is a modified TCP technique. Based on TCP_{Reno} technique. It effectively enhances the TCP_{Reno} by detecting multiple simultaneous packet loss & therefore does not exit the quick recovery mode until the packets in the wireless channel are acknowledged [169]. As with TCP_{Reno}, a fast recovery process is continuous. When an acknowledgment is found, there are two possibilities. An ACK including all messages speeds up restoration, or the message is lost after an unsuccessful ACK. It attempts to resend the duplicate ACK and returns it [170]. $TCP_{NewReno}$ provides many advantages.

TCP $_{Newreno}$ is capable of identifying several instances of network congestion. The congestion control solution optimises network capacity.$TCP_{NewReno}$ gets a restricted retransmission, in addition to its modified route selection & late start.

3.3.2 TCP$_{Vegas}$ TECHNIQUE

The TCP_{Vegas} approach included a better retransmission procedure to replace the lost data. It uses circular route delay computations to calculate the delay duration of each packet [170]. The message packet is resent if the previous ACK packet delay time has expired. Timeouts enables for faster detection of lost packets and restoration from repeated fails without having to restart the process if the reattempt time does not stop until the packet loss is identified. As a consequence, the problem of multiple packet loss is no longer an issue.

3.4 WORKING OF AD-HOC ON-DEMAND DISTANCE VECTOR

When used in conjunction with the Bellman-Ford distant vector protocol, the AODV protocol is capable of operating on a mobile network. AODV is a reactive and on-demand distance vector algorithm, which implies that it only looks for a path whenever a node needs to send data packets to a specific destination, instead of all the time. As part of their ongoing maintenance, proactive routing algorithms, such as OSPF, will distribute their routing tables on a regular basis to keep track of destinations and pathways. As a result, this kind of algorithm is capable of responding quickly to network changes. This method, however, has a large overhead and is only suitable for tiny topological networks. Instead of transmitting request packets in real time, reactive algorithms only communicate request packets when they are required. As a result, network costs are reduced, but latency is increased when compared to proactive algorithms. Furthermore, AODV ensures that there are no loops in the network by counting sequence numbers, which are used to assess the freshness of the path. In the next section, the researcher explains the AODV process in detail, as well as some other major processes that are necessary to understand AODV better.

3.4.1 TERMS AND CONCEPTS

Following are the key terms and concepts defined in this section.

i. An active node is a node that is in use. When a node has a routing table item with a valid status, it is referred to as being active. The only node that is responsible for transferring data packets is said to be the active node.

ii. Ad hoc network messages are sent across the network through AODV, and each node announces it presence to the neighbouring nodes.

iii. A destination is an IP address that data should be sent to when it is sent as a destination.

iv. RFC 3561 [171] defines the term "forwarding node," which is described as a node that is ready to accept data packets meant for the next node by re-sending them to a next hop that is far more reachable towards the endpoint.

v. In networking, the term "forward route" refers to a channel that needs to be built in order to start packet data transmission.

vi. Route A is no longer valid. The route information record for a route seems to have an incorrect state. An incorrect path cannot be used to send data. However, legitimate paths can be used for a limited time. This can be used for path maintenance and RREQ messages.

vii. A node that typically initiates the forwarding of an AODV routing protocol packet is called an originating node. Additional network nodes have the ability to resend these data packets.

viii. According to RFC 3561, a reverse node is described as "a route configured to send a return (RREP) message back to the sender from an alternate node that has a route to the end point.".

ix. Increasing the sequence number performed by sending a request message to the source node with each subsequent request message. It is used as a means of distinguishing the authenticity of the information contained in the node.

3.4.2 DATA PACKET TYPES

When it comes to AODV packets there seem to be four essential kinds of packets required. Which are as follows RREQ, RREP, Address with Sequence Number and RRER.

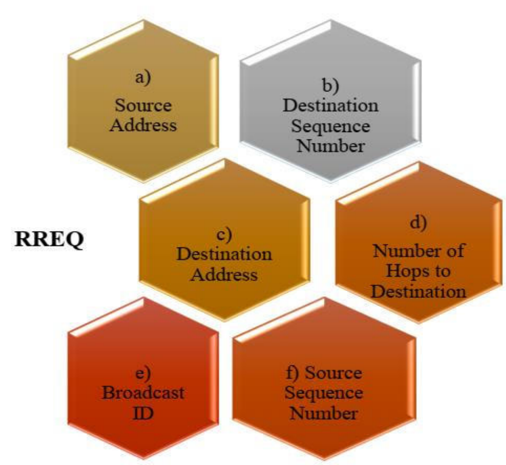


Figure 3.4 Information inside Route Request (RREQ).

Route Request (RREQ): The packet forwarding process is started by the creation and dissemination of a RREQ packet by a source node. The following information is included inside a RREQ which is shown in figure 3.4.

Route Reply: Whenever a network node responds to a request, it sends out an RREP packet, This packet caries details shown in figure 3.5:

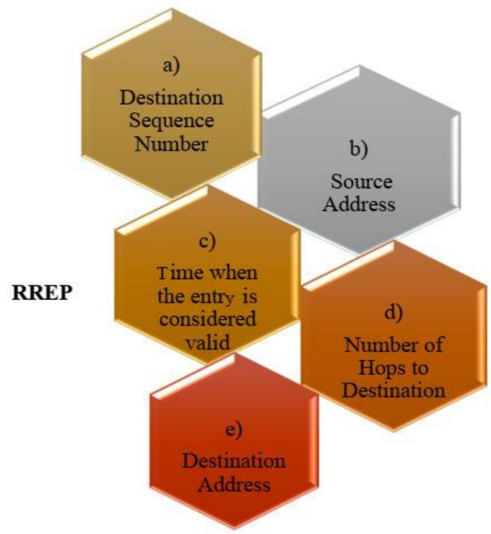


Figure 3.5 Information inside Route Reply (RREP)

Hello: However, each HELLO packet is sent by a node in order to determine who its neighbours are. It only contains the address and the sequence number.

Route error: Route error is noted as "RRER." In the case of broken routes, the node will check the link status of the hops. When a broken connection is found, an RERR message is sent to all nodes informing them about the route status. This technique will be detailed in further depth in the section titled "Route Finding Method." Unreachable destination addresses, unreachable destination sequences, and unreachable dest count numbers.

3.4.3 ROUTE MAINTENANCE

When a connection on an active route splits, the node upstream of the break invalidates all routes that depend on the broken link. A RERR [171] alert would be broadcast to all the node's neighbours. The unreachable IP addresses of destinations are stored in each RERR post. Each node monitors its routing table after obtaining an RRER to see if there are any routes to these unreachable destinations. If this is the case, it will be invalidated, and a new path fault (RERR) will be transmitted. The originating node will receive an RRER message at the last of this step, which will invalidate the unreachable route (s) and trigger a new RREQ message if necessary.

3.4.4 MESSAGE FORMATS

Message Format of Route Request

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|     Type      |J|R|G|D|U|   Reserved          |   Hop Count   |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                            RREQ ID                            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                    Destination IP Address                     |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                  Destination Sequence Number                  |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                    Originator IP Address                      |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                  Originator Sequence Number                   |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 3.6 Message format of RREQ

Figure 3.6 shows the format of the route request message. It has the following terms, which are elaborated in table 3.1.

Table 3.1 Explanation of the message format of Route Request (RREQ)

Type	1
J	Join_flag
R	Repair_flag
G	Gratuitous_RREP_flag (Specifies whether a free RREP be a one-to-one packet transmission to the destination Node.)
D	Destination_only_flag; specifies that this RREQ can only be responded to by the receiver.
U	Unknown_sequence_number; specifies that the number of the target sequence is unknown
Reserved	Sent_as_0; Utilized.
Hop Count	Number of Hop from the Start IP Address to the node of the request.
RREQ ID	ID is a sequence number utilizes a certain RREQ.
Destination IP Address	The destination's IP address for which a route is requested..
Destination Sequence Number	For each path and toward the destination node, the most recent sequence number collected from the source in the past.
Originator IP Address	The IP address (Node) from which the Route Request was sent.
Originator Sequence Number	The present sequence number should be utilized for the routing table, referring to the path request's source.

Message Format of Route Reply:

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|     Type      |R|A|    Reserved     |Prefix Sz|   Hop Count   |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                     Destination IP address                    |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                  Destination Sequence Number                  |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                    Originator IP address                      |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                           Lifetime                            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 3.7 Message format of RREP

Above, figure 3.7 shows the format of the route reply message. It has the following terms, which are elaborated in table 3.2.

Table 3.2 Explanation of the message format of Route Reply (RREP)

Type	2
R	Repair_flag
A	Acknowledgment_required
Reserved	Sent_as_0; Utilized.
Prefix Size	5 bit Prefix Length indicates that the selected next hop can be utilized for any nodes to the identical routing prefix (as described by the Prefix Size) as the desired destination, if it is nonzero.
Hop Count	Number of Hop from the Start IP Address to the node destination IP Address.
Destination IP Address	The destination's IP address for which a route is requested
Destination Sequence Number	It is linked to the path.
Originator IP Address	The IP address of the node which originated the RREP for which the route is supplied.
Lifetime	The time (milliseconds) that RREP-receiving nodes accept the path to be legitimate.

Message Format of Route Error

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|     Type      |N|          Reserved           |   DestCount   |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|            Unreachable Destination IP Address (1)             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|         Unreachable Destination Sequence Number (1)           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-|
|  Additional Unreachable Destination IP Addresses (if needed)  |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|Additional Unreachable Destination Sequence Numbers (if needed)|
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 3.8 Message format of RERR

Above, figure 3.8 shows the format of the route error message. It has the following terms, which are elaborated in table 3.3.

Table 3.3 Explanation of the message format of Route Error (RRER)

Type	3
N	No_delete_flag; Whenever a node does a local link repair, while upstream nodes really shouldn't discard the route, this flag is set.
Reserved	Sent_as_0; Utilized.
Dest Count	The message's total number of inaccessible destinations.; MUST be at least 1.
Unreachable Destination IP Address	The destination's IP address that has been inaccessible due to a connection failure.
Unreachable Destination Sequence Number	The sequence number for the destination indicated in the previous Unreachable Destination IP Address section in the route table record.

It is necessary to send the RERR message [171] if a connection failure causes one or more destinations to become inaccessible from any of the node's. Information on how to keep the relevant data for this decision, as well as specifics on how to generate a list of potential destinations, is provided.

Route Reply Acknowledgment (RREP-ACK) Message Format

```
 0                   1
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|     Type      |   Reserved    |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 3.9 Route Reply Acknowledgment

Above, figure 3.9 shows the format of the Route Reply Acknowledgment. It has the following terms, which are elaborated in table 3.4.

Table 3.4 Explanation of the message format of RREP-ACK

Type	4
Reserved	Sent as 0; ignored on reception.

It is necessary to send the Route Reply Acknowledgement (RREP-ACK) packet in reply to a Packet header with the 'A' bit set, which is indicated by the A bit. Unidirectional linkages have the potential to prevent a Route Discovery cycle from being completed, hence this is normally done when this is at risk of occurring.

3.4.5 Packet Size of AODV Messages

There are four messages used to carry out the AODV protocol's operations: RREQ, RREP, HELLO messages, and RERR. The HELLO message, which is a special instance of the RREP message with TTL = 1, can be used to provide local connection information. RREQ, RREP, and RERR messages are summarized in table 3.5.

Table 3.5 Packet Size of Route request, Route reply and Route error message

Route request (RREQ)	Route reply (RREP)	Route error (RERR)
Type (8 bits)	Type (8 bits)	Type (8 bits)
J. R. G. D. U. Flags (5 bits)	R. A. Flags (2 bits)	N flag (1 bit)
Reserved (11 bits)	Reserved (9 bits)	Reserved (15 bits)
Hope count (8 bits)	Prefix size (5 bits)	Destination count (8 bits)
Request ID (32 bits)	Hope count (8 bits)	Unreachable destination IP (32 bits)
Destination IP (32 bits)	Destination IP (32 bits)	Unreachable destination sequence (32 bits)
Destination sequence (32 bits)	Destination sequence (32 bits)	Additional unreachable IP (if needed)
Qriginator IP (32 bits)	Qriginator IP (32 bits)	Additional unreachable destination sequence numbers (if needed)
RREQ size= 24 bytes	RREP size=20 bytes	RERR =12 bytes (if DST counts=1)

3.5 FRAMING OF DIFFERENT MODULES

A VANET application relies on a set of distinct modules. A number of important parts of the framework are as described below:

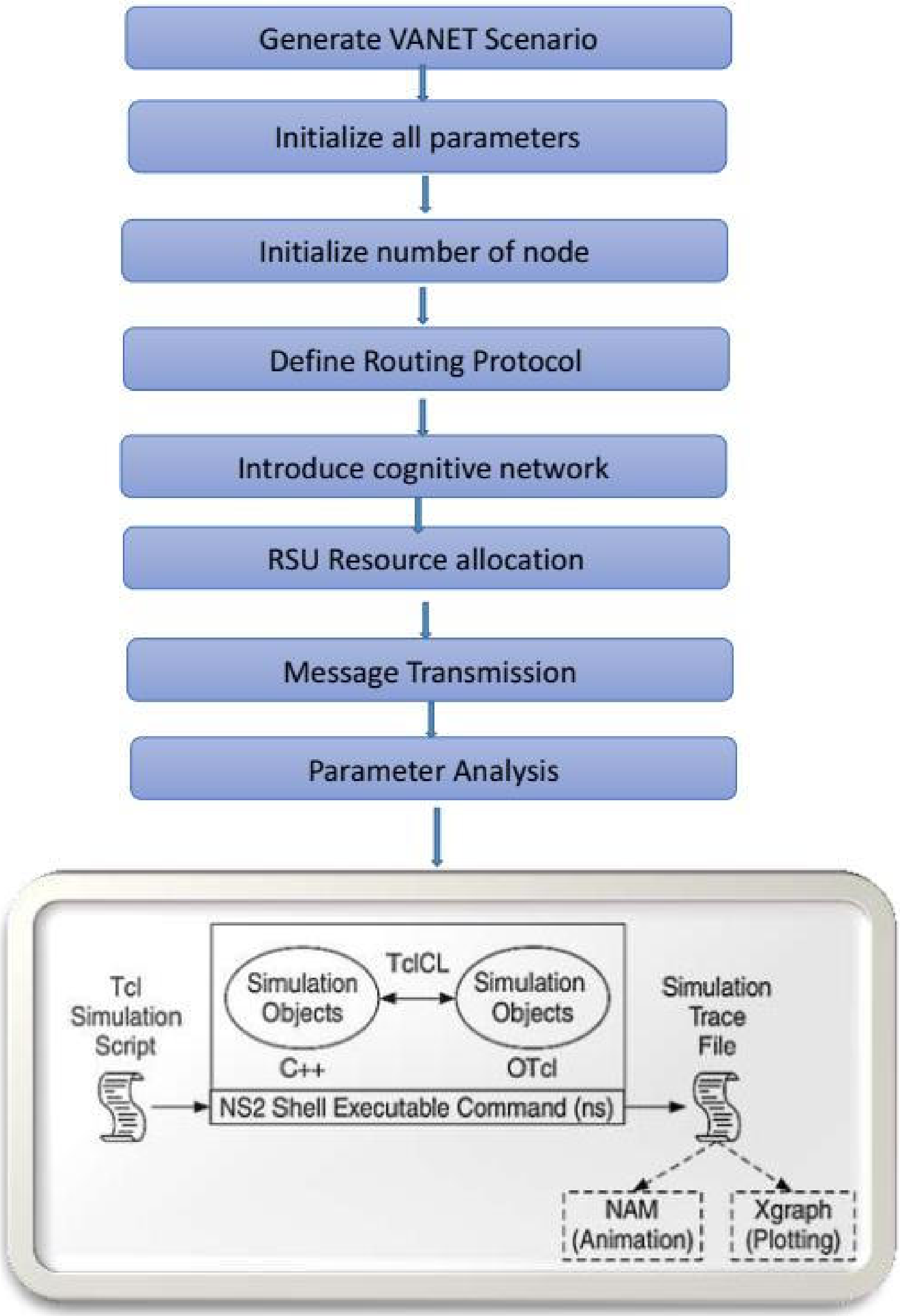


Figure 3.10 Flow chart of Parameter Analysis with Network Simulator.

i. **Input Parameter:** In this section the useful parameter is area, energy, and number of vehicles.

ii. **Topology Module:** A topology is a method of arranging RSU in a specified order. The components of a network topology are organized in a systematic sequence to provide smooth data flow in a VANET. Devices, workstations, and other vehicular nodes are examples of parts in this scenario.

Some are used by commercial and industrial institutions, while others are utilized by schools and households. For the computation of the related parameter, the researcher uses a type of topology, which is the Fixed RSU_i and Random RSU_i topology.

iii. **Data Traffic Model:** Data Traffic Module TCP Congestion

iv. **Mobility Model**: It is possible to have many freeways as well as roads throughout the Freeway Mobility Model. These highways, which are referred to as freeways in the freeway model, are either single-lane or multilane, and they are bidirectional. Each node is constrained to a single lane and one direction, and it travels according to a set of guidelines. Cars are travelling at high speeds, and in most cases, each lane is designated with a pre-defined maximum velocity restriction. Fast cars drive on a pre-defined course or roadways, similar to the freeway model, but with specific mobility limits, such as acceleration and deceleration, as compared to the freeway model. The vehicle's top speed might be as high as 150 kilometers per hour. Fast car models are based on the same concept as slow cars, but in this case, the vehicles drive at a slower speed and so cause less topological change.

v. **RF Model:** RF Module physical layer IEEE 802.11p, WAVE

vi. **Output Parameter:** Residual Energy, Throughput, E2E Delay and Congestion Control window.

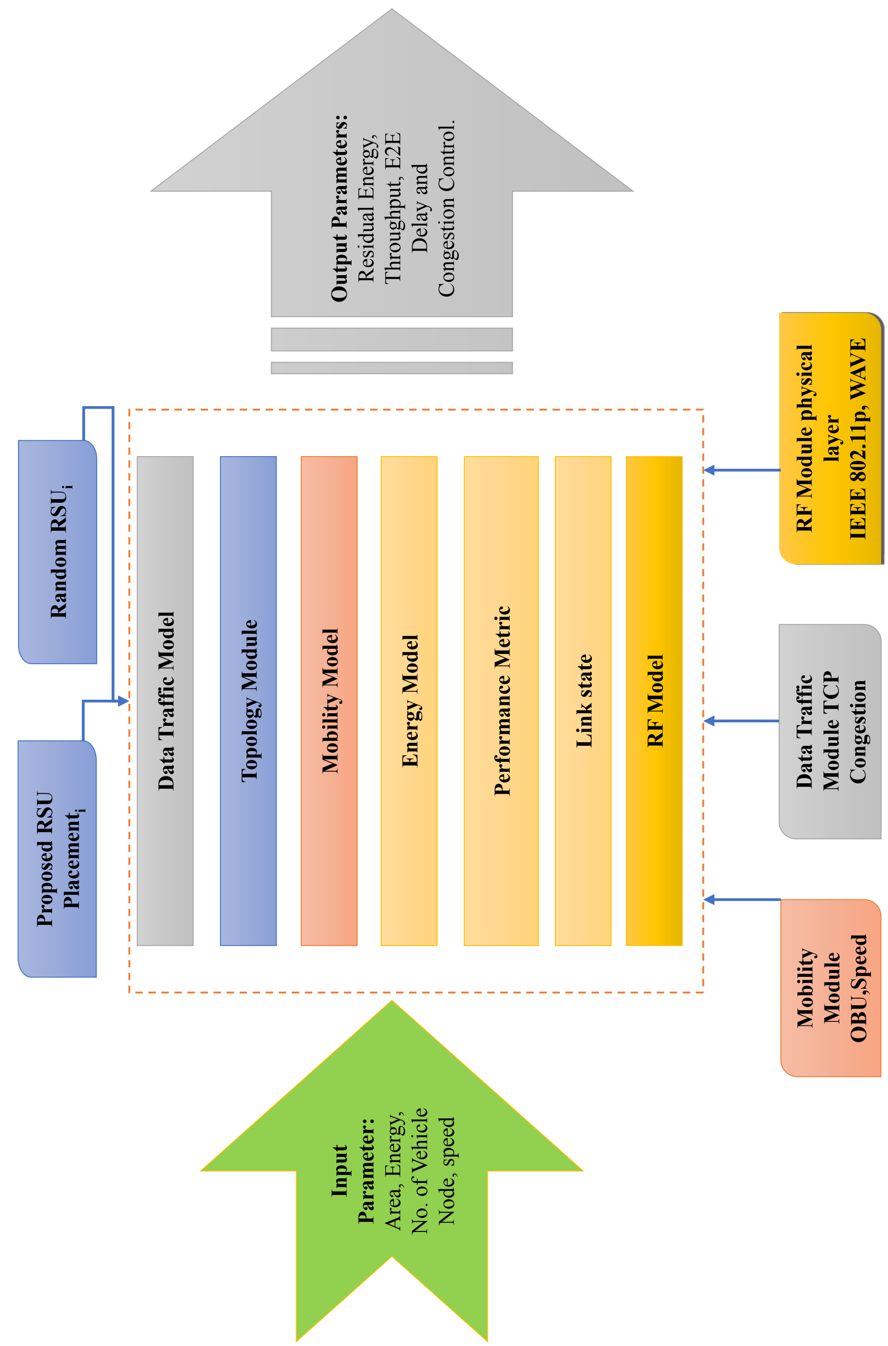


Figure 3.11 Framing of different modules for RSU base TCP Congestion Control parameter analysis.

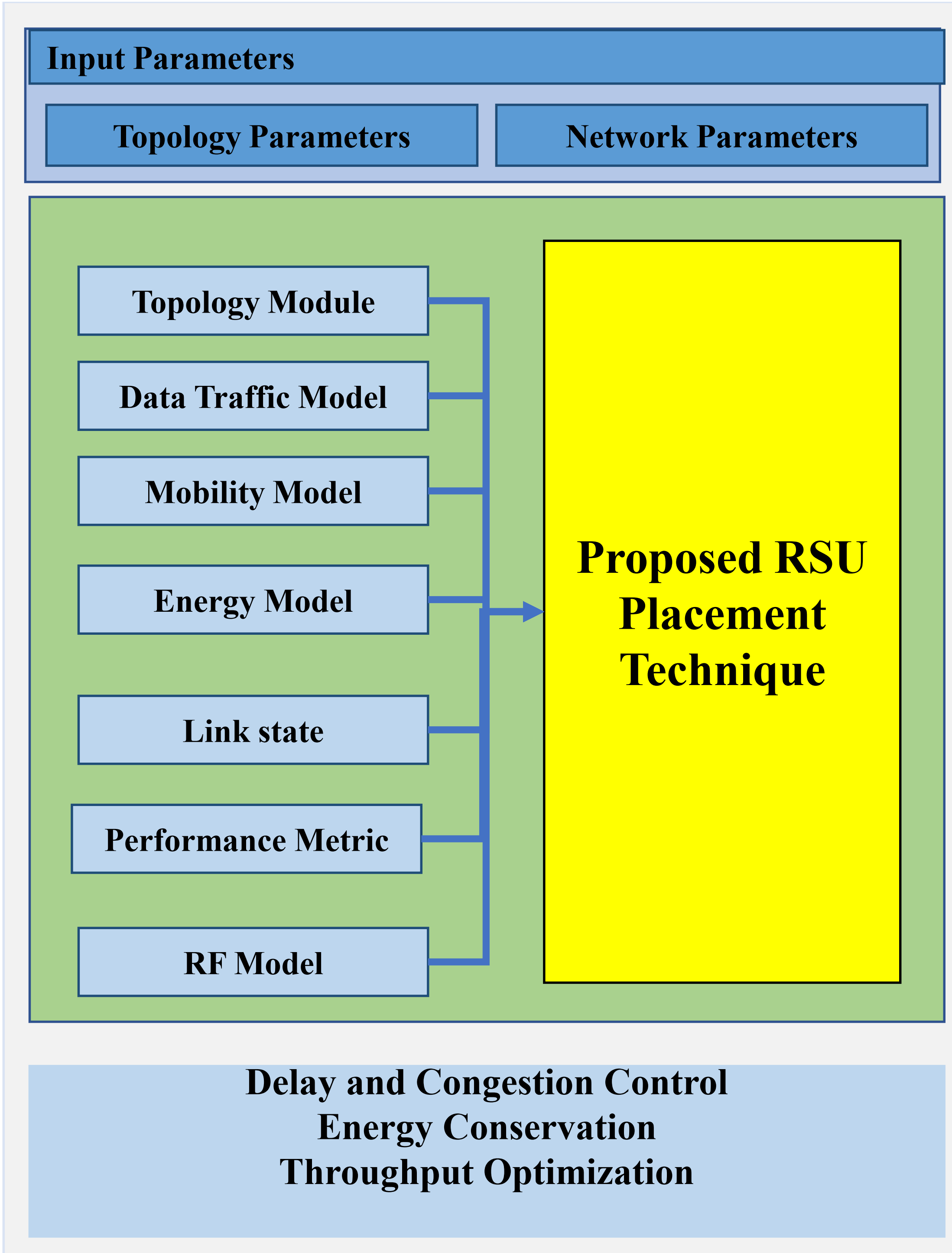


Figure 3.12 The Framework for TCP Congestion Control with RSU Placement Technique

The Pythagoras formula is used to determine the closest node. If the locations of node A and node B are known, the distance (d) between them can be determined using the formula [3.1].

$$d = 2Rsin^{-1}\sqrt{sin^2\left(\frac{i_{y_A}-i_{y_B}}{2}\right) + cos\, y_A\, cos\, y_B\, sin^2\left(\frac{i_{x_A}-i_{x_B}}{2}\right)} \quad \ldots\ldots\ldots(3.1)$$

If the latitudes of nodes A & B are y_A and y_B, respectively, the direction between them is calculated as $\theta = y_A - y_B$

Additionally, the AODV routing table has a column for each neighbouring node's direction information, which will be used to select nodes that carry data with no delay. Priority will be given to nodes with the smallest inclination. If the inclination is smaller, it is assumed that all the nodes are moving in the same direction.

The framework design takes topological, network metric and energy consumption parameters into account for assessment of the topology for delay and congestion control. The proposed algorithm performs efficient placement of the RSU's together with the vehicle density and movement patterns. Figure 3.12 shows the proposed framework. The real time parameters from topology, data traffic intensity, mobility and velocity of the automobile, wireless link quality are the accounted and discrete values are used to construct a effective RSUs placement model. The model considers the high mobility environment of the vehicles and formulates the RSUs placement for efficient handling and control of the TCP. With the help of the RSUs placement algorithm the TCP congestion can, not just be controlled but also enhanced for lower packet drops and network latency. The algorithm effectively increases the data rate of the topology towards the maximum achievable rates.

The proposed framework also enhances the network lifetime by using lowering the energy requirements of the topological deployment. The net throughput of the system is further increased by formulation of multipath routes with co-operative RSU and automobile data communications. The multipath routes for packet data transfer alleviates the inherent high latency of the wireless network in high density node topologies with frequent route adjustments.

3.6 RSUs PLACEMENT ALGORITHM

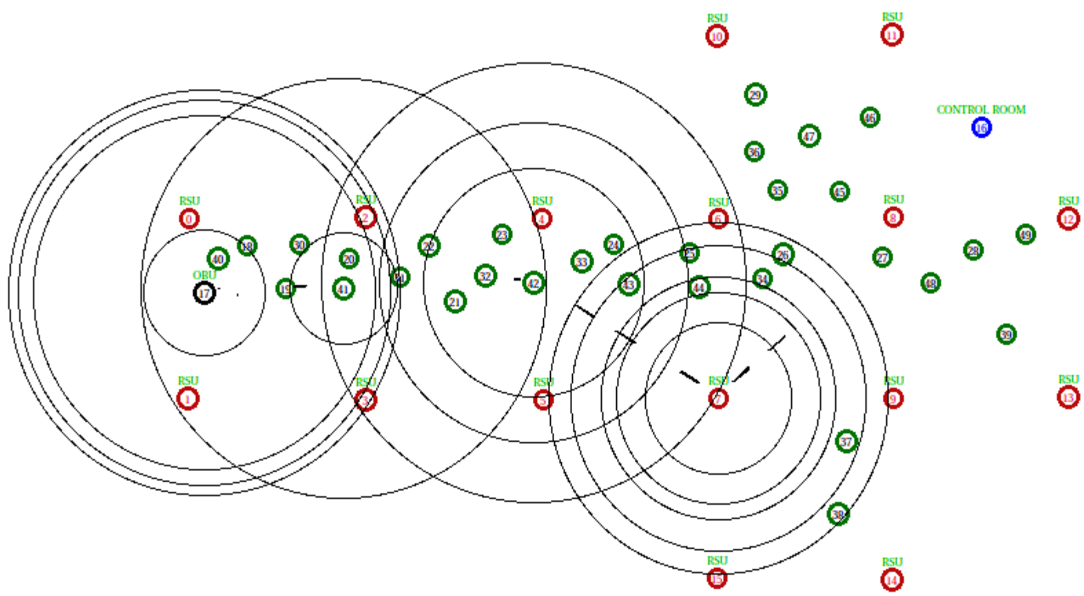


Figure 3.13 Data Packet transmitting between RSU, OBU and CR Unit in Network Simulator.

Algorithm 1: RSUs placement algorithm[53]

Let, RSU_i Range is r_i =300m Area is Pi*$r_i^2$and RSU_{i+1}Range is r_{i+1} 300m Area is Pi r_{i+1}^2than total distance is 600m from RSU_i to RSU_{i+1} the connection have no link to connect. On the base of distance d the four positions are possible:

RSU_i and RSU_{i+1} is placed greater than $d_{(i,i+1)=}600$m

RSU_i and RSU_{i+1} is placed equal to $d_{(i,i+1)}=600$m

RSU_i and RSU_{i+1} is placed less than $d_{(i,i+1)}=600$m

RSU_i, RSU_{i+1} and RSU_{i+2} is placed close to one another in the same direction

Algorithm 1: Algorithm for placement of RSU_i

Input: *RSU Range ($r_{i\ ,}$) Area (a_i) And Distence ($d_{i,i+1}$)*

Output: *RSU Position (P)*

1. *Set RSU $r_{(i,i+1\dots n)}=300m$*
2. *Set Area $a_{(i,i+1\dots n)} = pi*r_i^2$*
3. *Set Distance $d_{(i,i+1\dots n)}=r_i+r_{i+1},\ r_{i+1}+r_{i+2}\dots\dots\ r_n+r_{n+1}<600m$*
4. *Set Direction of $RSU_{(i,\ i+1,\dots\dots n)=}$ North, South, East and West;*
5. *The direction of $RSU_{(i,\ i+1,\dots\dots n)=}$ North*
6. *Initial P_i is fixed Find, locate P_{i+1}*
7. *For P_{i+1}, $d_{(i,i+1\dots\dots n)}=r_i+r_{i+1},\ r_{i+1}+r_{i+2}\dots\dots\ r_n+r_{n+1}>600;$*
8. *Case 1*
9. *When $d_{(i,i+1\dots..n)}>600m;$*
10. *No link between RSU_i and $RSU_{i+1}=$*
11. *P (RSU_{i+1})=? (unknown)*

12. *Case 2*

13. *When $d_{(i,i+1\dots..n)}=600m;$*

14. *link between RSU_i and RSU_{i+1}= less*

15. *P(RSU_{i+1})=? (unknown)*

16. Case 3

17. When $d_{(i,i+1\ldots..n)}<600m$;

18. link between RSU_i *and* $RSU_{i+1}=1$

19. P (RSU_{i+1})*=set (known)*

20.Case 4

21. When $d_{(i,i+1)}<600m$, $d_{(i+1,i+2)}<600m$ *but* $d_{(i,i+2)}<600$;

22. link between RSU_i *and* $RSU_{i+2}=1$

23. Eliminate RSU_{i+1}

24. P (RSU_{i+2})*=set(known)*

25. Direction of $RSU_{(i,\ i+1,\ldots\ldots n)=}$ *South;*

26. ……

27. Direction of $RSU_{(i,\ i+1,\ldots\ldots n)=}$ *East;*

28. ……

29. Direction of $RSU_{(i,\ i+1,\ldots\ldots n)=}$ *West;*

30. ……

31. End for

Matrix based RSU_i placement: As RSU_i is an important section of the VANET Communication which help to regulate the HPM to Destination**.**

Table 3.6 Matrix of RSUi Mapping (where ∞ = no link and 1 = link to their neighbor RSUi.)

RSU	R_0	R_1	R_2	R_3	R_4	R_5	R_6	R_7	R_8	R_9	R_{10}	R_{11}	R_{12}	R_{13}	R_{14}	R_{15}
R_0	∞	∞	1	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞
R_1	1	∞	∞	1	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞
R_2	1	∞	∞	1	1	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞
R_3	∞	1	1	∞	∞	1	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞
R_4	∞	∞	1	∞	∞	1	1	∞	∞	∞	∞	∞	∞	∞	∞	∞
R_5	∞	∞	∞	1	1	∞	∞	1	∞	∞	∞	∞	∞	∞	∞	∞
R_6	∞	∞	∞	∞	1	∞	∞	1	1	∞	1	∞	∞	∞	∞	∞
R_7	∞	∞	∞	∞	∞	1	1	∞	∞	1	1	∞	∞	∞	∞	1
R_8	∞	∞	∞	∞	∞	∞	1	∞	∞	1	∞	1	1	∞	∞	∞
R_9	∞	∞	∞	∞	∞	∞	∞	1	1	∞	∞	∞	∞	1	1	∞
R_{10}	∞	∞	∞	∞	∞	∞	1	∞	∞	∞	∞	1	∞	∞	∞	∞
R_{11}	∞	∞	∞	∞	∞	∞	∞	∞	1	∞	1	∞	∞	∞	∞	∞
R_{12}	∞	∞	∞	∞	∞	∞	∞	∞	1	∞	∞	∞	∞	1	∞	∞
R_{13}	∞	∞	∞	∞	∞	∞	∞	∞	∞	1	∞	∞	1	∞	∞	∞
R_{14}	∞	∞	∞	∞	∞	∞	∞	∞	∞	1	∞	∞	∞	∞	∞	1
R_{15}	∞	∞	∞	∞	∞	∞	∞	1	∞	∞	∞	∞	∞	∞	1	∞

Algorithm 2: Efficient Data Flow Algorithm[53]

Input: Position of RSU_{ij}, Position of Vehicles OBU_{ij}, Energy (E_{ij}), Traffic of data

Output: Energy (E_{ij}), Total Energy (TE), Packet received (P), Throughput (T).

1. *Set position of* $RSU_{ij}<300m$
2. *Set position of* $0<OBU_{ij}<=300m$

3. Set energy (E_{ij}) = 50 joule

4. Set Packet=1500

5. Set $TCP_{0,}$, TCP_{Vegas}

6. Set $Sink_{0,}$, $Sink_{Vegas}$

7. Number of queues at each node as HPM, LPM

8. #Node compares priority

9. #Packet in queue

10. If Priority=HPM

11. Put HPM FF

12. Else put LPM

13. End if

3.7 CONCLUDING REMARKS

This chapter, discusses a unique RSUs placement algorithm that is designed to reduce packet delivery delays and packet losses from source to destination while maintaining high performance. It is possible for the control room to monitor the TCP traffic using this approach. RSU is a unified solution for the complicated communication between VtoV and VtoI that helps to alleviate TCP congestion on congested networks. In particular, the researcher concludes from this chapter that the RSUs placement algorithm and the AODV algorithm are the most appropriate algorithms for the analysis of TCP traffic on a crowded channel, respectively. The following are some probable outcomes of this effort, which are detailed below:

1. Develop a module for RSU-based TCP Congestion Control.

2. Implement and examine the operation of TCP traffic on experimental testbeds.

CHAPTER 4

IMPLEMENTATION AND VALIDATION

4.1 CHAPTER OUTLINE

The previous chapter presented a framework and position based RSU algorithm that presents the solution for TCP Traffic Congestion in VANETs. In order to attain the aims of the congestion requirements defined in this framework. To show the efficiency and correctness of the proposed framework, there is a requirement of implementing the defined RSU and TCP agent in an effective manner with six different parameters. Here, the parameters have been taken to verify the correctness of the protocol, these are residual energy, the cumulative sum of packets, throughput, end-to-end delay, lost packets and Congestion window. It also shows that the proposed mechanism can be useful in fixed RSU based TCP traffic congestion scenarios.

4.2 HARDWARE AND SOFTWARE USED

The analysis was carried out with the assistance of the Network Simulator-2 software. In network research, Network Simulator-2 is a virtualization technology that was developed expressly for that purpose. TCP, network routing, and multicast routing protocols are all supported extensively in this program for both wireless and wired networks, and this software can simulate all of these protocols. Platform requirements for NS2 on a window frame system include the following, which are recommended:

- Intel (R) Core (TM) i5

- CPU Clock cycles @ 2.50 GHz
- 8 GB memory
- 500 GB free disk space
- 32/64- bit Operating System
- Ubuntu (Linux family)
- OS Version 18.04 LTS Bionic Beaver

4.2.1 BRIEF ABOUT NS-2 SIMULATOR

A Network Simulator-2 (NS-2) [172], [173] is a software tool which simulate the input/output, behavior, and acts of a network in a variety of scenarios when no real network is present. Users will usually customize the simulator to suit their requirements in order to accomplish their objectives. Several network simulators exist that support prominent protocols like TCP and AODV, as well as network nodes like wireless sensor networks and Wi-Max. Network simulation is a methodology for modeling the activity of a network by calculating the connection between different network entities such as wire/wireless routers, network switches, and data connections, or by obtaining and replaying incidents from a production network in the area of computer networks.

Changing network parameters helps one to monitor and evaluate the actions of a network and different programmes under varying conditions. To see how a network acts in a high-congestion environment, Mobile nodes' arrival times are shortened or their velocity is increased as a result of this. The simulation effects can be contrasted to the results from statistical simulations during the validation process. When opposed to building up a whole training area comprising of networked machines, switches, routers, and information connections, there are a number of explanations to use network simulators. Two of the most important factors are that simulators are both inexpensive and fast. The simulators should enable researchers to provide a controlled and repeatable setup to analyze the simulations, which requires a lot of time and money. In theory, network simulators help researchers introduce nodes & connect nodes together to construct a system model. Network Simulator 2 is one of these simulators (NS2) [173]. It is an object-oriented discrete event simulator developed at UC Berkeley.

The command and setup interface of NS2 is an Object Tcl (OTcl) interpreter written in C++. C++ is quick for running programs, but it is sluggish for changing configurations, which is why this technology stack was created. On the other hand, Otcl should be easily modified when operating imperceptibly. This is known as split-language programming, and it enables complex scenarios to be quickly run and modified. NS2 necessitates a comprehensive understanding of both languages, as well as parallel compilation, operating, and debugging [175].

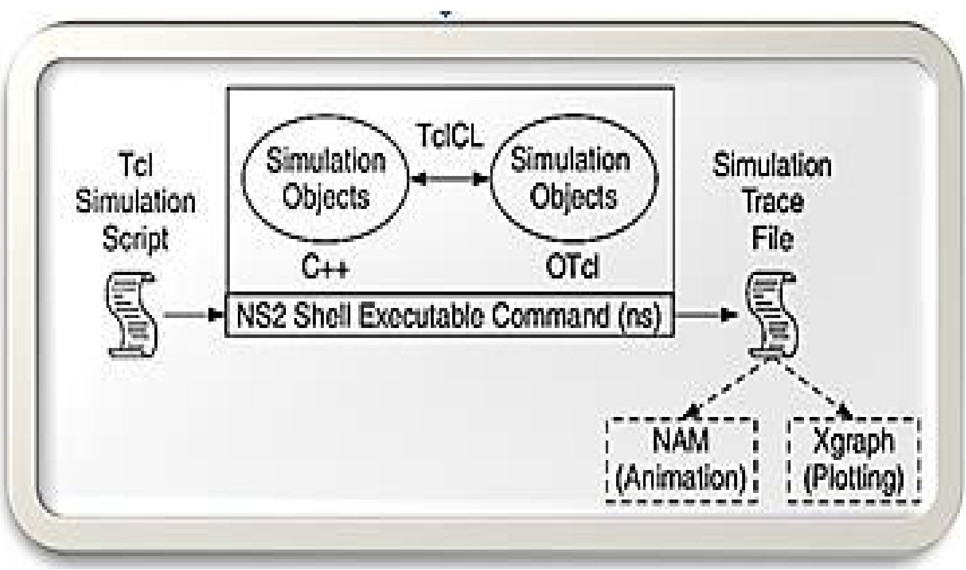


Figure 4.1 NS2 architecture [175]

Numerous network related C++ libraries are available in NS2. Tcl script is used to code a new model. To create a new protocol base model, researchers need to construct a new set of C++ libraries. As seen in Figure 4.1, NS2 generates a text-based production that a network animator can view graphically and interactively (NAM). Figure 4.2 depicts the NAM in side NS2 architecture.

NAM is a popular visualization method for animating network simulation traces, allowing users to see packet requests, acknowledgement, replies, and drops in real time.

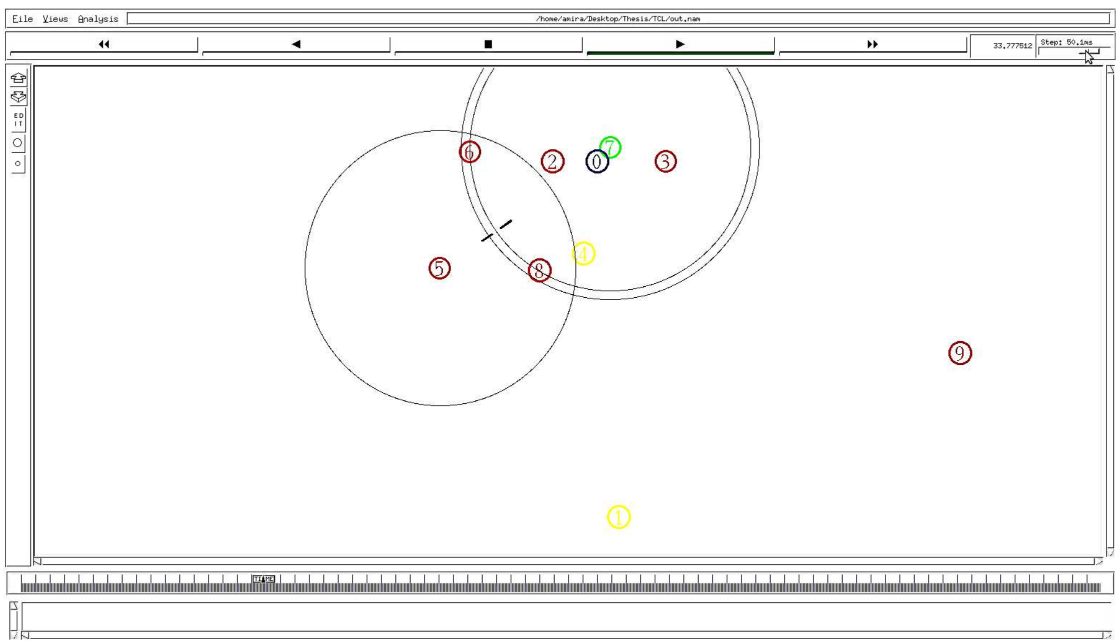


Figure 4.2 Nodes, Packets and coverage in Network Animator window

4.2.2 NS-2 AWK SCRIPT

The researcher used AWK [176], to analyses and generate reports, to extract the necessary data from the NS2 trace file (.tr). The following number of commands is used to execute the AWK script in Linux: "awk –f filename. awk filename. tr"

4.2.3 MOBILITY MODELS FOR NS-2

Dynamics simulations show how the mobile nodes move, such as how they move and how quickly, or slowly, they move. People who have a lot of flexibility can choose from a lot of different ways to move, like the random walk model and also the Gaussian Markov model.

4.2.4 MOBILITY GENERATOR FOR NS-2

BonnMotion was used to produce spontaneous movement. "BonnMotion is a Java programme that generates and analyses mobility situations. It is most widely used to investigate the features of VANETs. For that, as well as the simulation applications, including ns-2, GloSim/ONE, COOXM, and MIXI XL, these scenarios can be saved in GloNet (a competitor) [177].

4.2.5 OMNET++

OMNeT++ [178] is a simulation toolkit and framework written in C++ that is specifically developed for the development of network simulators. [179] [180] [181] Non-commercial simulations, such as those used in academic institutions and for training, can be carried out using OMNeT++ at no charge. It is an upgraded edition of OMNeT++ that has been built specifically for corporate applications. In contrast to IP and HTTP, which are both network protocols, OMNeT++ is a simulation framework that lacks models for these protocols. The principal computer network simulation models are included inside a number of external frameworks. A popular model for network protocols and technologies such as IPv6, BGP, and others is provided by the INET model, which is the most widely used of the models available today. For the purpose of modelling node movement, INET additionally includes a variety of mobility models. The INET models are distributed under the LGPL or GPL licenses. NED is the topology description language used by OMNeT++ (NEtwork Description).

4.2.6 TOSSIM SIMULATOR

In the beginning stages of implementing a Tiny OS communications system, TOSSIM [182] can be used as a real-time simulation software. TOSSIM involves modification of the parts of the program with their own modelled versions. TOSSIM is a discrete event tool which is used to keep the modelling of different events in order. The period is measured in ticks, which are changed to fit the user's needs. TOSSIM Software supports C++ and Python as high-level scripting languages. Python is used to control and error-check written scripts that can be added to the programming language so that the analysis of any program runs smoothly. Whenever a Tiny OS installation is completed on a mote, it is connected to the device through USB to debug the written program. After debugging, the building of the program takes place in the form of an image file.

To run on TOSSIM software, TinyOS software must be made with a subprogram. When the instruction starts to be typed, the compiler starts working. The command sim enables programmers to do the computational phases. TOSSIM accepts micaz wireless technologies, which must be taken into consideration while implementing the system. The simulator is solely text-based if no graphics connector is utilized. By adding debugging commands to the primary source code provided to the administrator, it is possible to examine a program by writing out a series of basic Python commands. The Nesc software developers create the simulated filename as sim.o, which the programming language now uses to run the code. On the other hand, the topo.txt file includes the network's topology. An alternative to using a sensor device is to keep track of simulated sensor readings, which are periodically assessed in place of the actual sensor devices.

4.2.7 COOJA

Contiki OS is an open-source IoT operating system [183]. Adam Dunkels created it at the Swedish ICS. It is written in C. Contiki is a very portable OS that has been deployed on multiple systems with various CPUs. Most systems employ the Texas Technologies MSP-430 as well as Atmel ATmega microcontrollers [184]. Contiki handles concurrency through event-driven programming. All processes share one stack, conserving memory. It is the Contiki's key benefit. This model uses protothreads. When protothreads block, they employ local continuations to preserve the state. The protothreads resumes at the next command [185]. Contiki supports IPv6 and IPv4 stacks, as well as 6lowpan, RPL, & CoAP. It utilizes Rime Stack [186]. It is a sensor network communication stack with fewer layers than standard stacks. Simple layers with modest headers (only a few bytes). This protocol's major goal is to facilitate the development of sensor networks. Some systems Contiki is employed in include electrical power meters and industrial monitoring. Contiki 3.0 (26.08.2015) [188] is the newest version.

A Contiki network simulator cage which is a Java program with a Swing-based GUI [187]. Cooja also supports radio simulation and interaction with other tools to enhance the application. It can mimic big and small Contiki networks (simulated sensor modules). In order to simulate bigger networks, motes can be emulated at a lower degree of detail than hardware, or at the machine level. It contains two emulators: Avrora & MSPSim. Cooja uses Avrora to emulate Atmel AVR devices and MSPSim to emulate TI MSP430 devices. The MSP430 is used on most platforms. That is why MSPSim is extensively used WSN simulation program. Cooja can replicate TelosB/SkyMote, Zolertia Z1, Wismote, ESB, and MicaZ. It is a great tool for developing and debugging Contiki OS apps. For example, it can simulate power consumption of nodes and display radio broadcasts and receptions.

4.2.8 SIMULATOR COMPARISON

Table 4.1 Comparison NS-2, OMNet++, Tossim and Cooja Simulator

Simulator		**Ns2**	**OMNet++**	**TOSSIM**	**COOJA**
Level of Details		Generic	Generic	Code level	All levels
Timing		Discrete event	Discrete event	Discrete event	Discrete event
Siftware Licence		GNU GPL	Academic Public Licence	BSD	BSD
Popularity		780000	11900	9810	3010
Simulator platform		FreeBSD, Linux,SunOS, Solaris, Windows(Cygwin)	Linux, Unix, Windows (Cygwin)	Linux, Windows (Cygwin)	Linux
WSN platforms		n/a	n/a	MicaZ	Tmote Sky, ESB/2
GUI Support		Monitoring of simulation flow	Monitoring of simulation flow, c++ development, topology definition, result analysis and visualization	none	yes
Available models and protocols	Wireless channel	Free space, two-ray ground reflection, shadowing	Lognormal shadowing, experimentally measured path loss map, packet reception rate map, temporal variation, unit disk	Lognormal shadowing	Multi-path ray-tracing with support for ellenuating obstacles, unit disk
	PHY	Lucent WaveLan DSSS (approximated)	CC1100, CC2420 (approximated)	CC2420	?
	MAC	802.11(several implementations), preamble based TDMA(still at a preliminary stage)	TMAC, SMAC, Tumable MAC (can approximate BMAC, LPL, etc)	Standard TinyOS 2.0 CC2420 stack	X-MAC,LPP, NULLMAC
	network	DSDV, DSR,TORA,AODV	Simple Tree, Multi-path Rings	?	?
	transport	UDP,TCP	none	?	?
	sensing	Random process with mannasim add-on	Generic moving time-varying physical process	?	?
Energy consumption model		yes	yes	With Power TOSSIM z add-on	yes

4.2.9 WHY SHOULD CHOOSE NS2?

Finally, the NS2 is chosen as the simulator for this research, since it is an open-source application with readily editable code that researcher can utilize. A comprehensive collection of libraries covering a broad number of aspects is available, including alternative routing techniques, layers, and mobile computing. NS-2 is found in multiple different versions. For this research, the researcher selects the most recent versions of NS-2, i.e., NS-2. 35. [175].

4.3 DESIGN OF EXPERIMENT

The data set contains the process measurements that have been defined in order to explain the simulation scenario that has been developed.

Table 4.2 Parameters and its values setup

Parameters and Values Setup	
Parameters	**Values**
Mac or 802.11 SET Data Rate	11 Mb
Mac or 802.11 SET Basic Rate	1 Mb
SET Value (channel)	Wireless_Channel
SET Value (propagation)	Two_Ray_Ground
SET Value (net_if)	Wireless_Phy
SET Value (MAC)	802_11
SET Value (if_q)	Queue/Drop_Tail/Pri_Queue
SET Value (ll)	LL
SET Value (Ant)	Antenna/Omni_Antenna
SET Value (if_qlen)	50
SET Value (nn)	30,40, and 50
SET Value (rp)	AODV
SET Value (x)	2289x
SET Value (y)	100y
SET Value (STOP)	10.0 sec
SET Avg. (Speed)	60 km/h

Furthermore, several performance metrics were investigated in a VANET network using the NS2 simulation in order to monitor and compare the effectiveness of the AODV algorithms. To be more specific, the total of all packets is calculated as follows: Summaries are a form of graph that displays the accumulation of data over time, often known as "running totals." They are used to illustrate the accumulation of data as it rises over time. This will assist in plotting the cumulative sum of all data packets over a period of time.

i. **Throughput:** In a VANET, the throughput of a system is described as an average rate of data exchange via a wireless network connection, and its unit is bits per second and packets per second, respectively.
ii. **Packet loss:** Packet loss happens when a data packet does not arrive at its intended destination. Real-time applications rely on the efficiency of transmission, and this value is critical to that efficiency.

There are two scenarios implemented using the NS-2 Simulator. The first scenario is implemented for Random position of mobile nodes and the Second scenario is for fixed base position of RSU nodes. Each scenario has three 30, 40, and 50 the number of nodes.

In accordance with characteristics such as the NIC spectrum, packet size, and utilized bandwidth, the network interface of the node decreases energy consumption. The energy model [189, 190] can be used to calculate the level of energy used. According to factors like transmission and reception, idle and sleep, transition power, and transaction time, the node uses the energy that is made available to it (initial energy). Table 4.2 shows the results of this investigation, as well as the parameters of the energy model that was used and the particular value. Figure 4.3 shows the details of this investigation and the parameters of the energy model that was used.

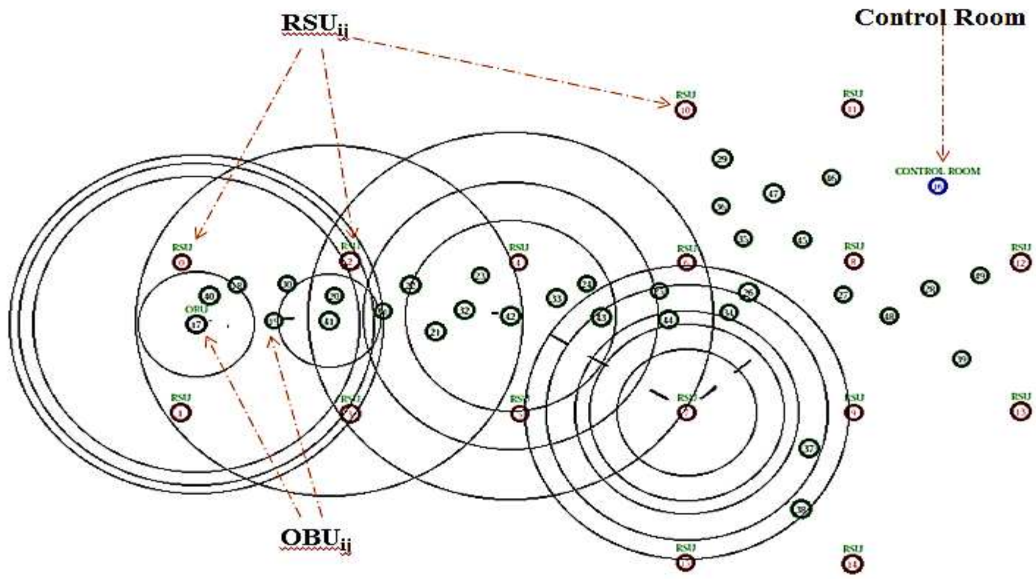


Figure 4.3 Scenario having OBU, RSU and Control Room shown

4.4 ANALYSIS OF RANDOM AND PROPOSED RSU PLACEMENT ALGORITHM

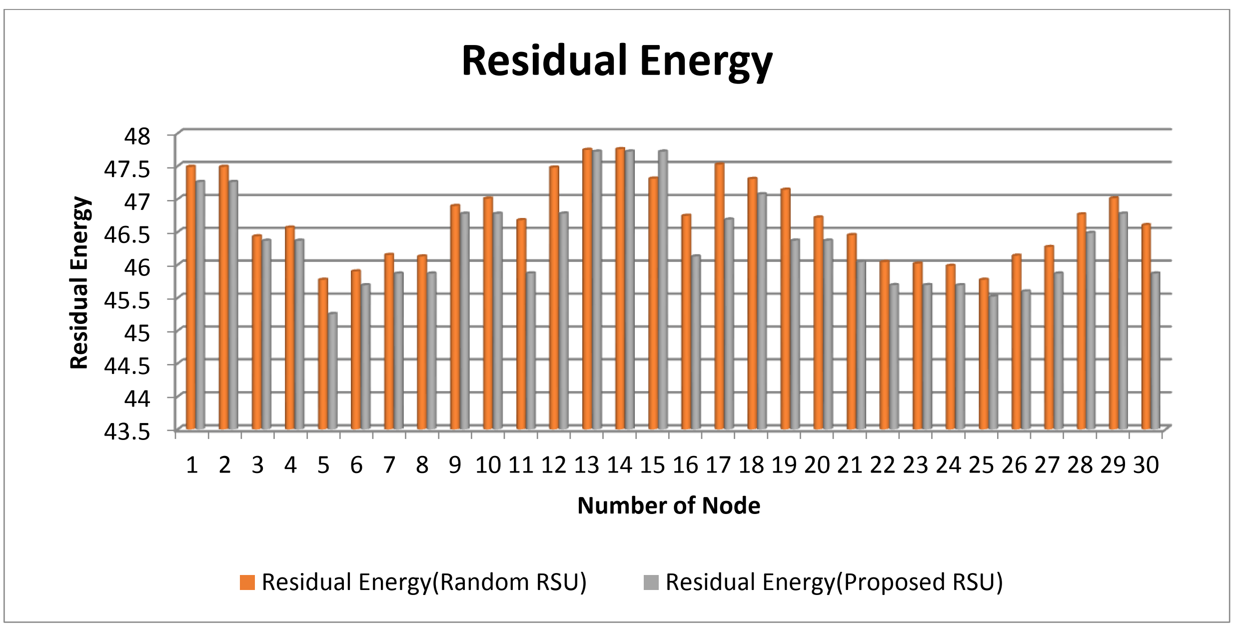


Figure 4.4 Residual Energy (Random RSU) and Residual Energy (Proposed RSU)

Table 4.3 Energy model's initial value

Energy_Model "Energy-Model"	
Initial_Energy	50.0 J
Tx_Power	0.9 W
Rx_Power	0.7 W
Idele_Power	0.6 W
Sleep_Power	0.1W
Transition_Power	0.02W
Transition_Time	0.0005s
Agent_Trace	ON
Router_Trace	ON
Mac_Trace	ON
Movement_Trace	ON

All the results are obtained straight from the network simulator once all the parameters and algorithms have been defined. In Figure 4.4, the result of the energy used by the individual node is compared with two different scenarios.

Table 4.4 Residual Energy (Random RSU) and Residual Energy (Proposed RSU) comparison

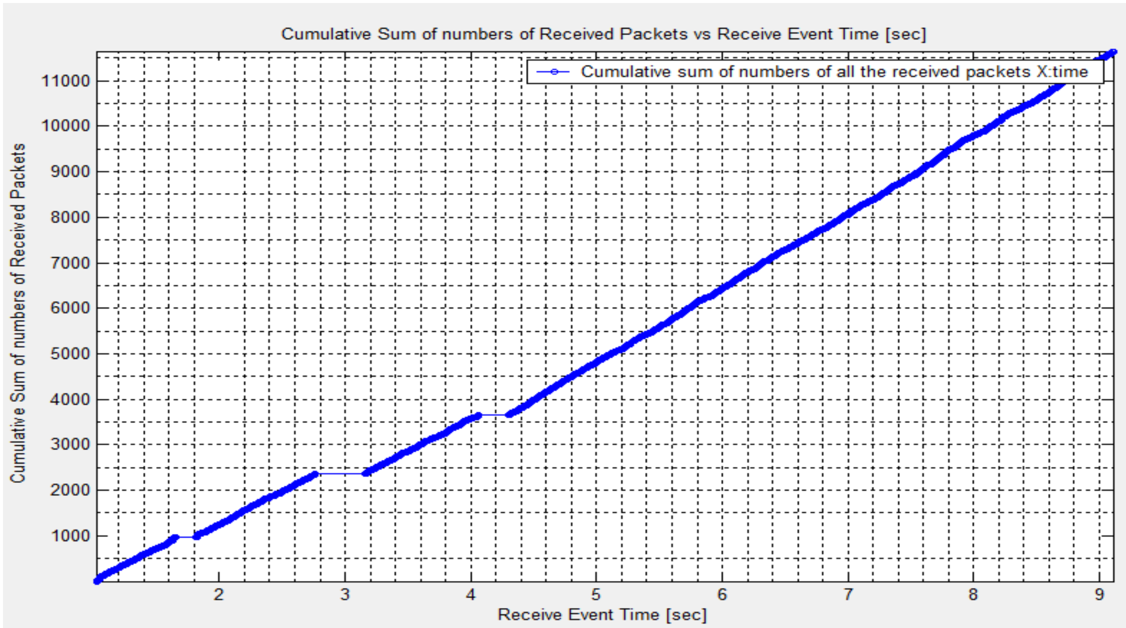
Node	Residual Energy (Random RSU)	Residual Energy (Proposed RSU)
0	47.488433	47.259727
1	47.488433	47.259727
2	46.433368	46.367291
3	46.565637	46.367875
4	45.772394	45.250165
5	45.898831	45.690425
6	46.14804	45.866085
7	46.124918	45.866681
8	46.892303	46.774653
9	47.008386	46.775247

10	46.677514	45.868816
11	47.477534	46.777369
12	47.74513	47.718582
13	47.755754	47.718582
14	47.310607	47.718583
15	46.743864	46.12475
16	47.523516	46.686592
17	47.305453	47.0744
18	47.1416	46.369642
19	46.716855	46.369055
20	46.45227	46.041275
21	46.040045	45.691326
22	46.017096	45.691911
23	45.982791	45.69016
24	45.772928	45.517914
25	46.136443	45.596426
26	46.27225	45.866693
27	46.764993	46.485698
28	47.013029	46.77584
29	46.603633	45.867298
	Total RE= 1401.274048	Total RE = 1391.128788

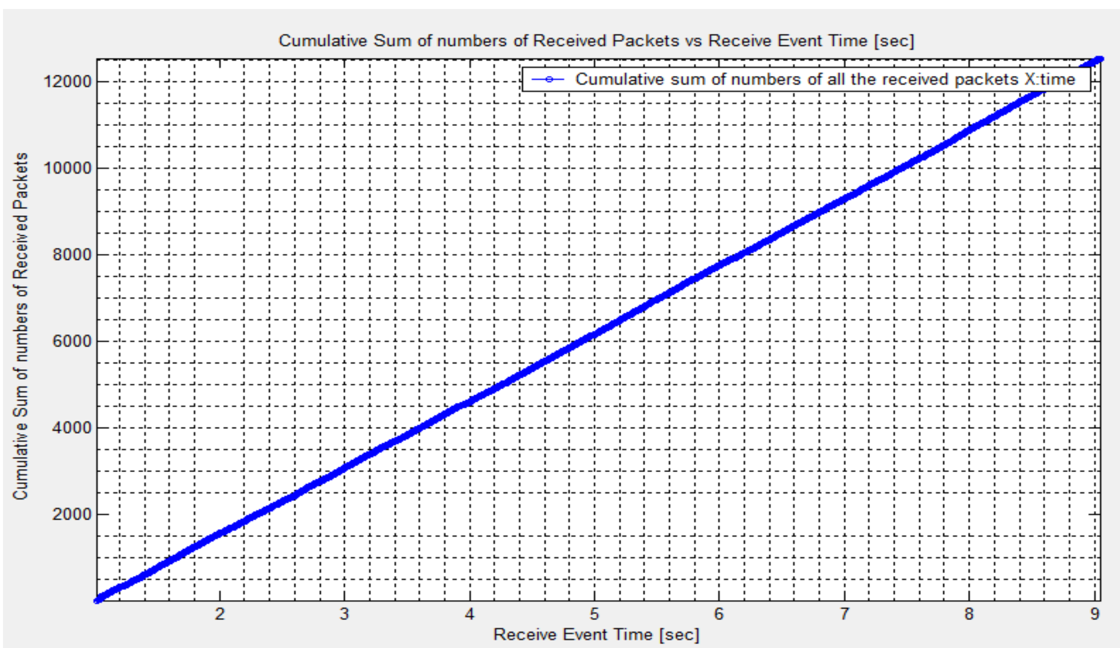
4.4.1 VANET SIMULATION FOR 30 NODES (OBU WITH RSU AND CR)

A cumulative sum graph, also known as a running total graph, depicts the rise in the quantity of data over time as a continuous line of data is drawn over the graph (progression). This will assist in plotting the cumulative contribution of a particular metric over a certain period of time.

The cumulative sum of packets (a) Random RSU and (b) Proposed RSU placement



(a)



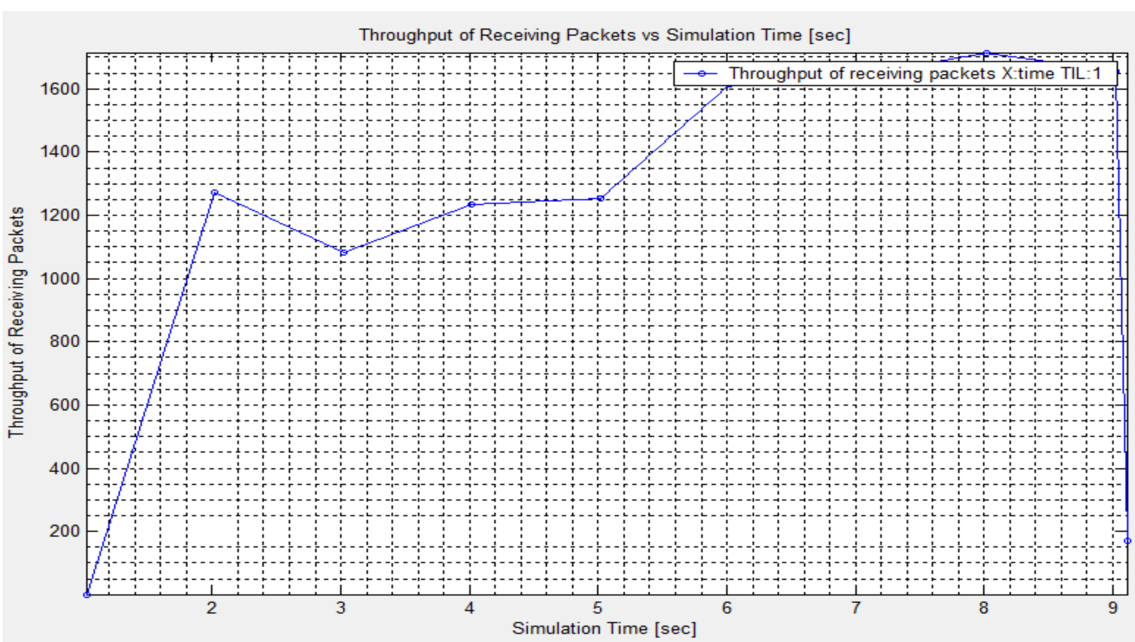
(b)

Figure 4.5 (a) Random RSU and (b) Proposed RSU placement shows the cumulative sum of packets

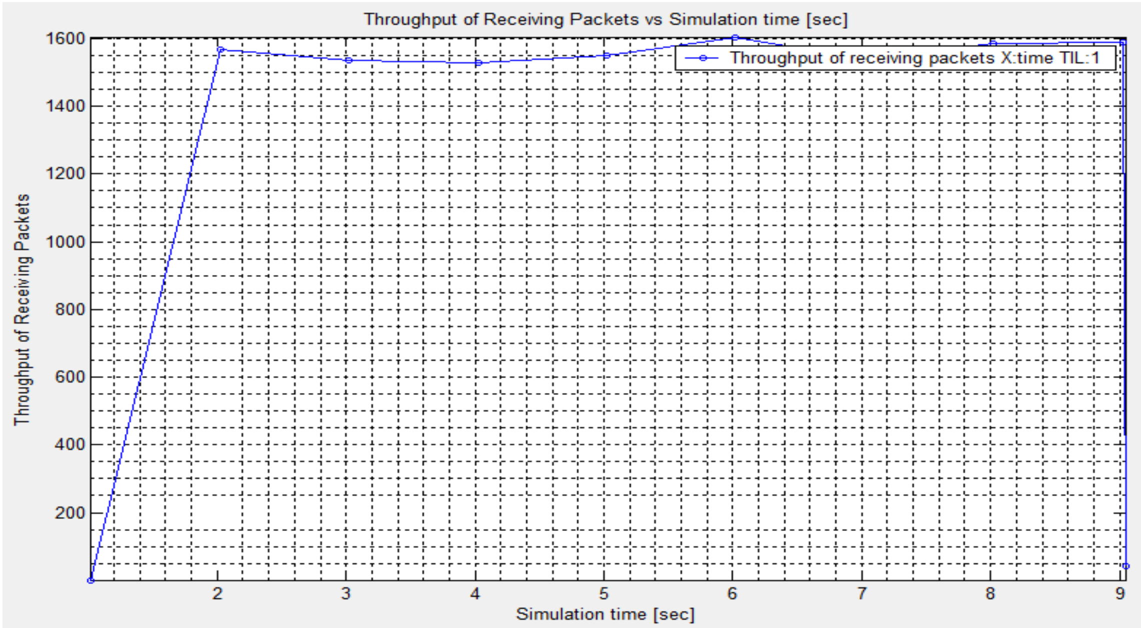
Throughput is the measure of packet delivery per unit time. The throughput is the ratio of packets successfully transferred from host to receiver in a given time interval. The time interval is usually taken in seconds. The numerator in this ration can be packets, bits, byte, kbps, mbps etc. The throughput is the actual data rate that can be achieved for a network medium given the bandwidth of that medium. The wireless network uses shared media for data communications, furthermore multiple channels can be used for uplink and downlink for data communications.

However the achievable throughput in a given topology heavily relies on the number of nodes communicating simultaneously. As all the nodes in a vicinity will be on the same shared wireless network, they will effectively bring down the per node throughput. Furthur due to congestion, latency will be increased therby decreasing the net achievable throughput.

Throughput of receiving packets on (a) Random RSU and (b) Proposed RSU placement



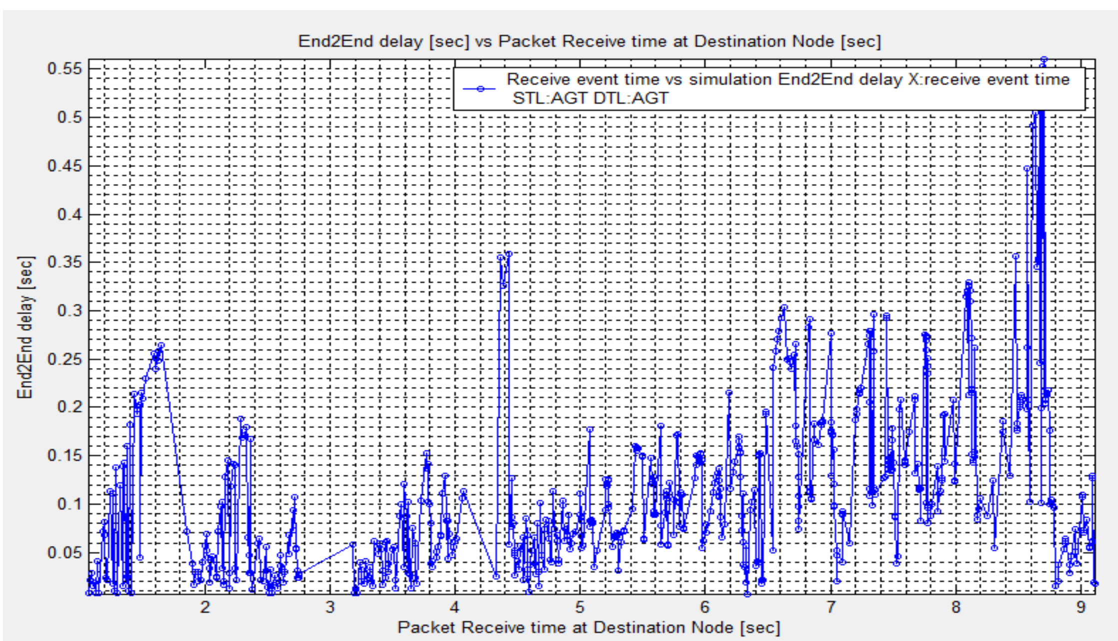
(a)



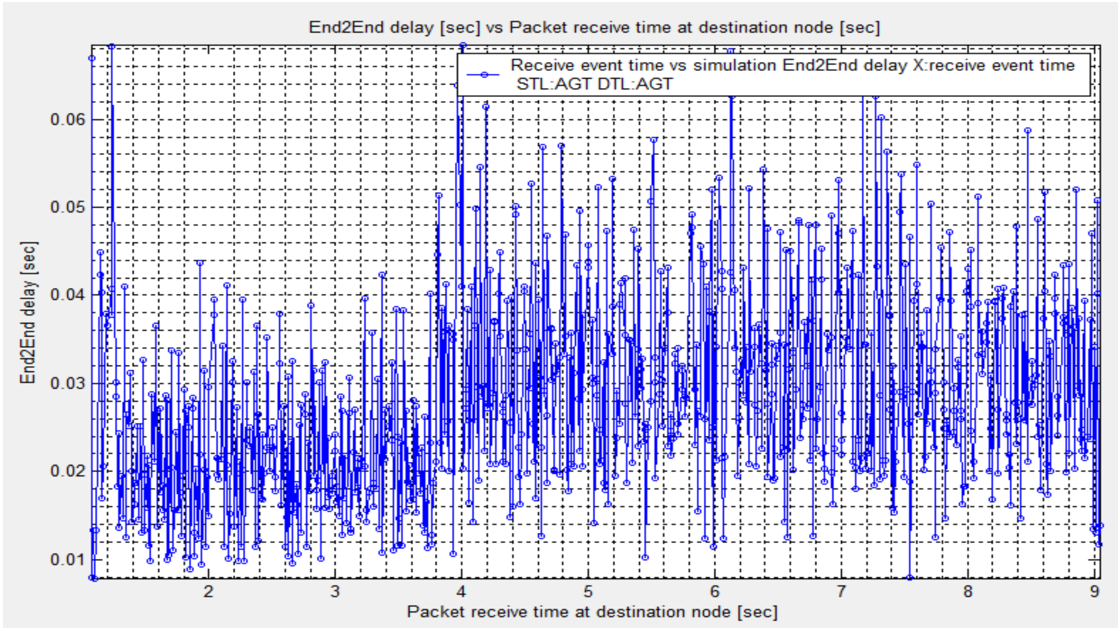
(b)

Figure 4.6 (a) Random RSU and (b) Proposed RSU placement shows the throughput of receiving packets

End to end delay in (a) Random RSU and (b) Proposed RSU



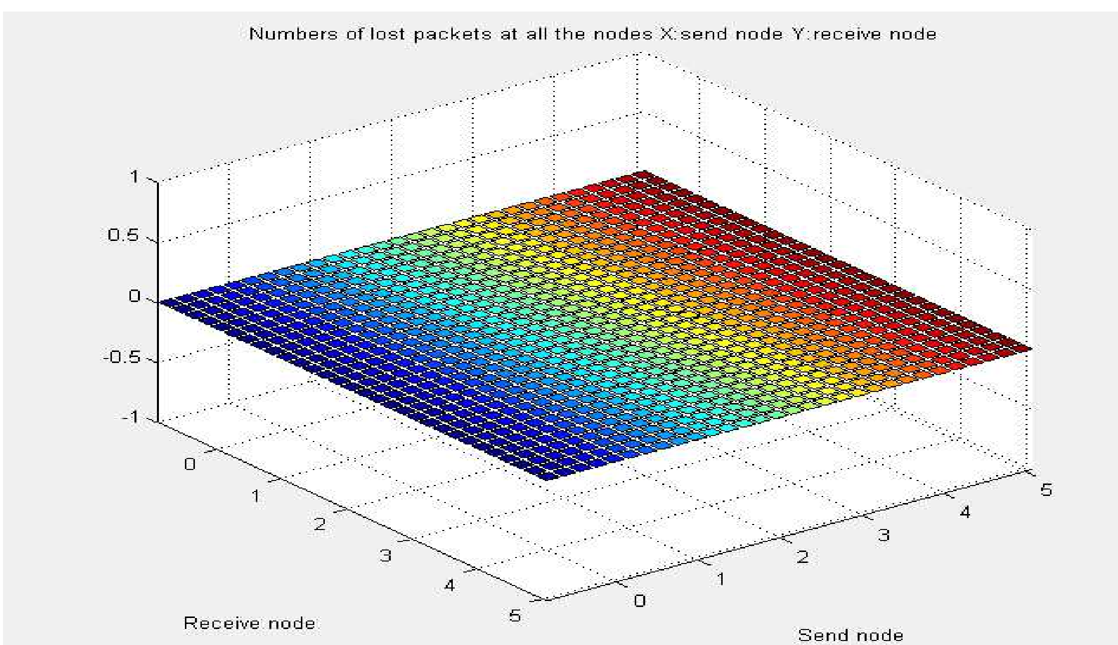
(a)



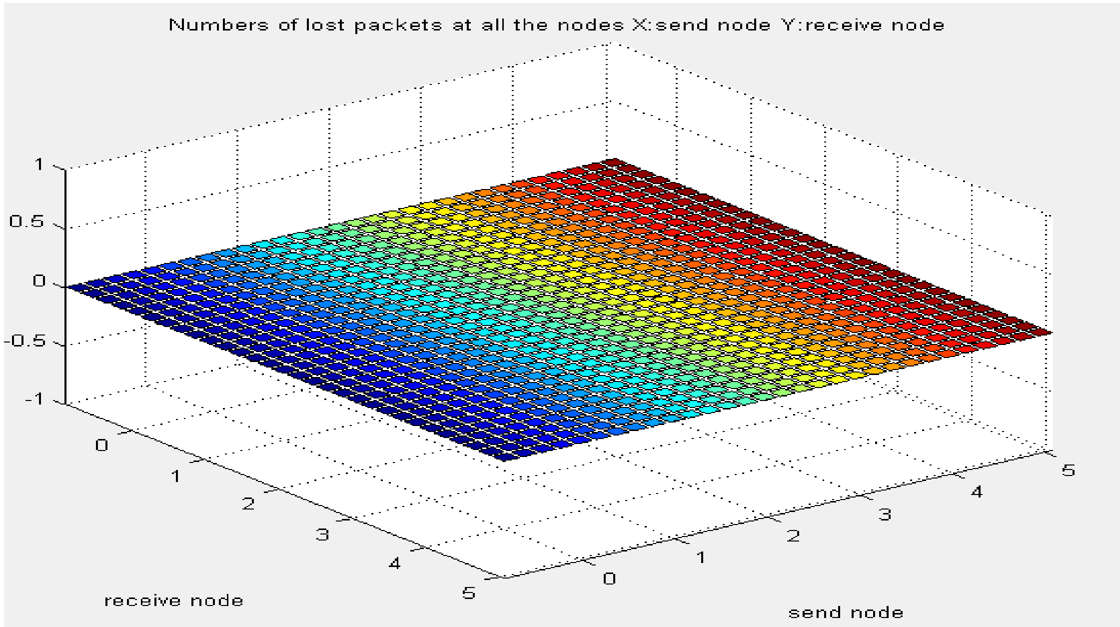
(b)

Figure 4.7 (a) Random RSU and (b) Proposed RSU placement shows end to end delay

No. of lost packets at all nodes (a) Random RSU and (b) Proposed RSU placement shows.



(a)



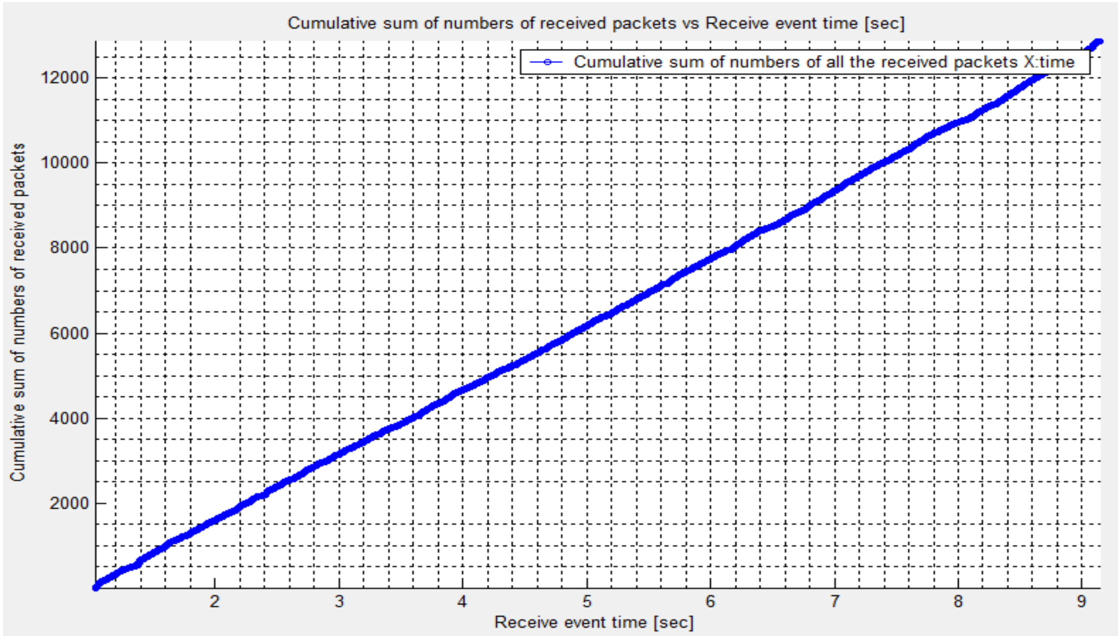
(b)

Figure 4.8 (a) Random RSU and (b) Proposed RSU placement shows no. of lost packets at all nodes

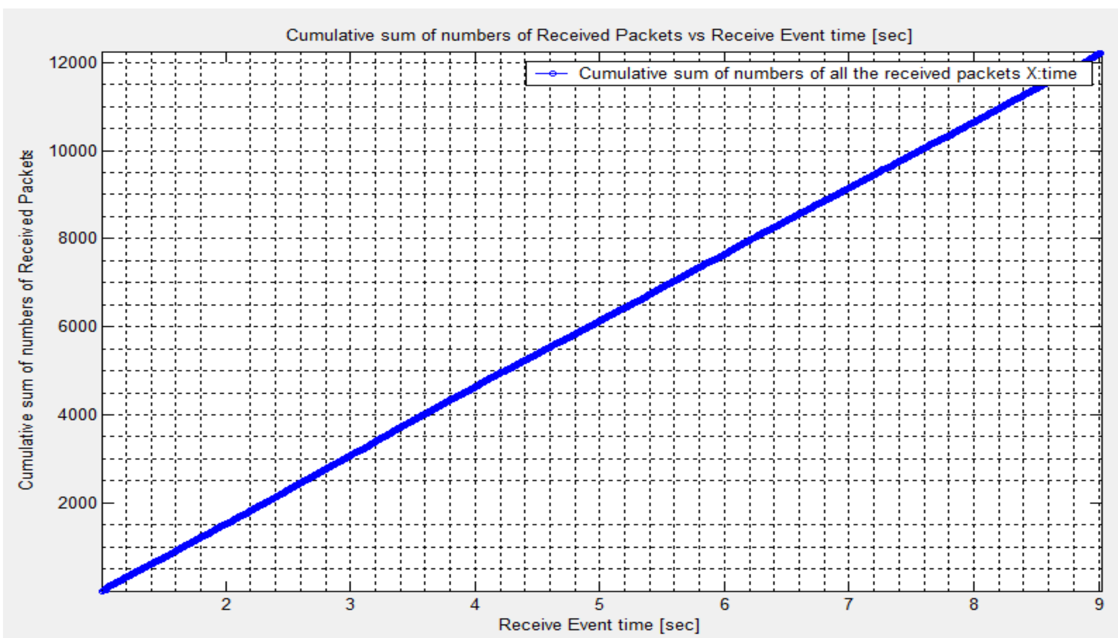
Package loss happens when one or more data packets moving via a network fail to reach their intended destination because of a network failure. In an ad hoc network, packet loss can be caused by a variety of factors, including data transmission errors, which are prevalent, and node movement [9].

4.4.2 VANET SIMULATION FOR 40 NODES (OBU WITH RSU AND CR)

The cumulative sum of packets (a) Random RSU and (b) Proposed RSU placement



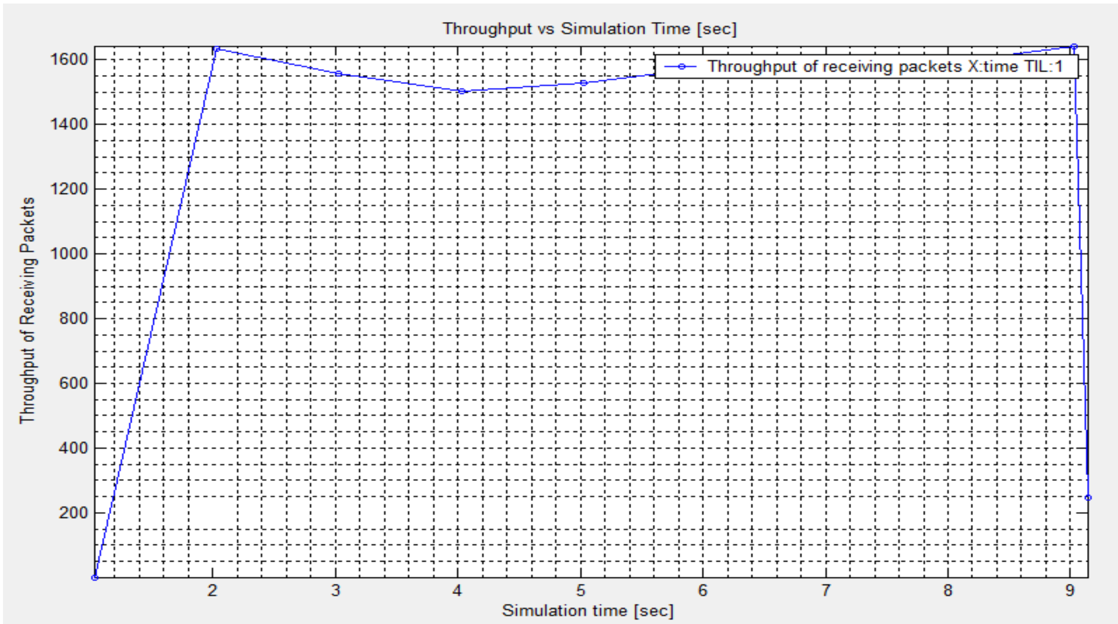
(a)



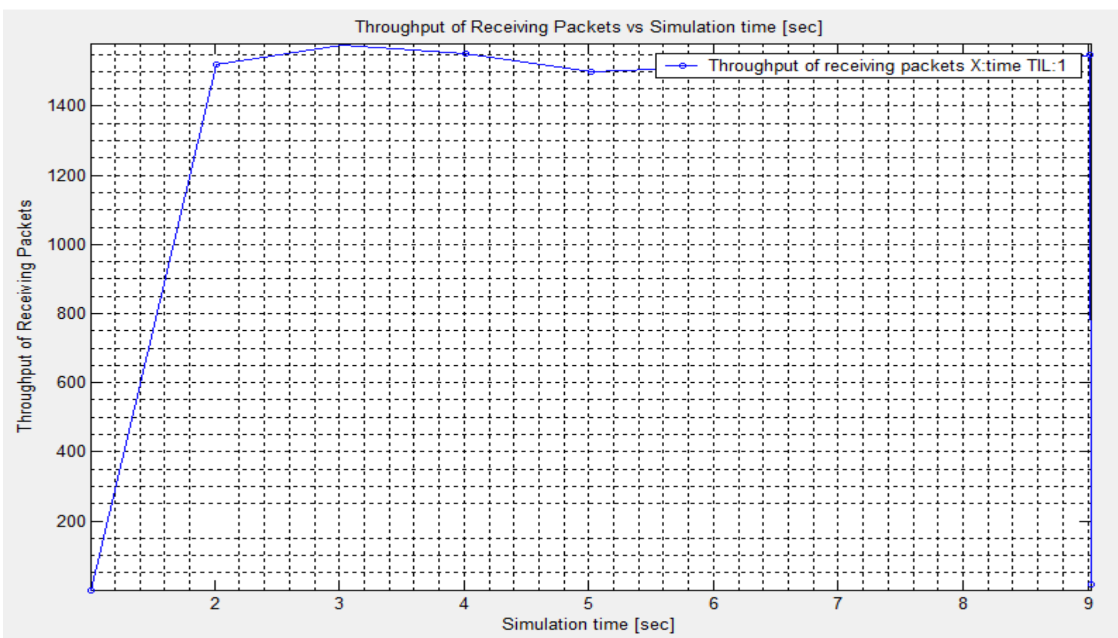
(b)

Figure 4.9 (a) Random RSU and (b) Proposed RSU placement shows the cumulative sum of packets

Throughput of receiving packets on (a) Random RSU and (b) Proposed RSU placement



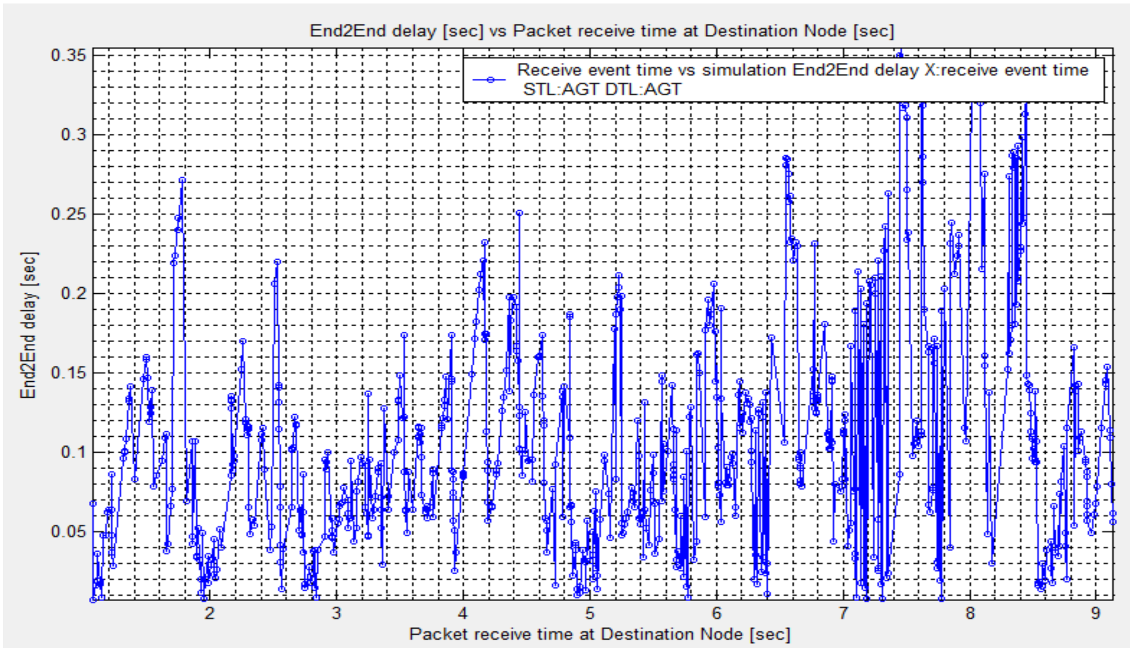
(a)



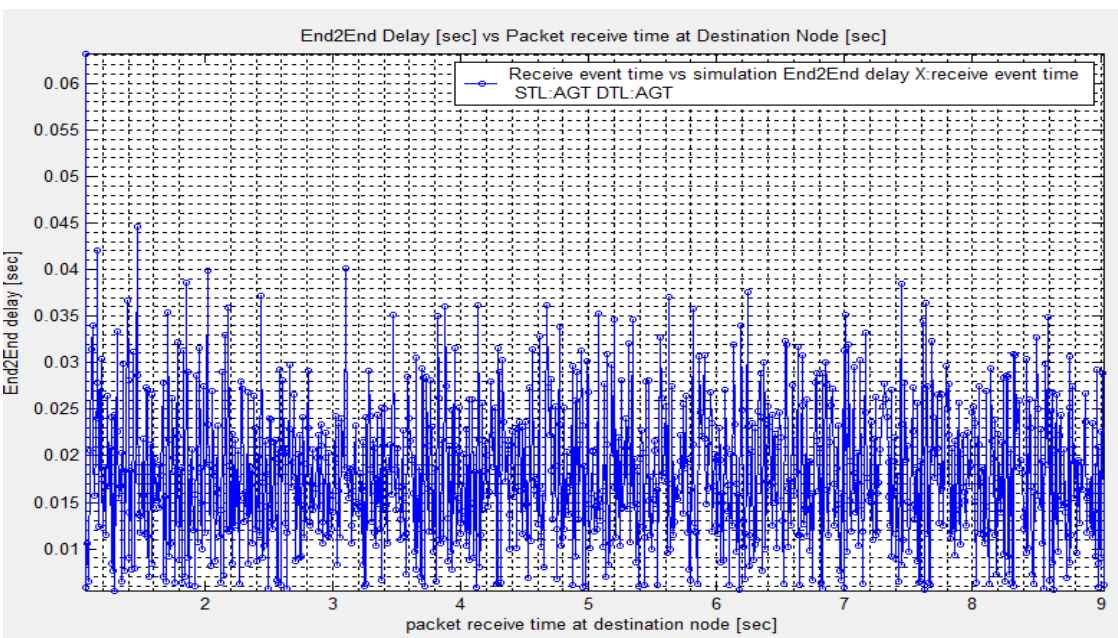
(b)

Figure 4.10 (a) Random RSU and (b) Proposed RSU placement shows Throughput of receiving packets

End to end delay in (a) Random RSU and (b) Proposed RSU placement



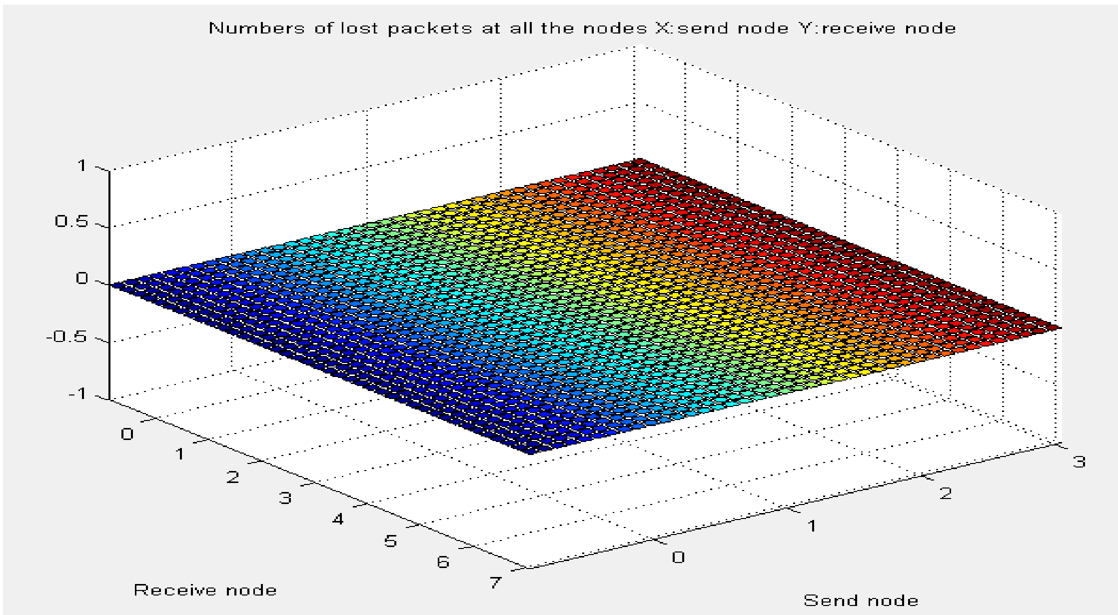
(a)



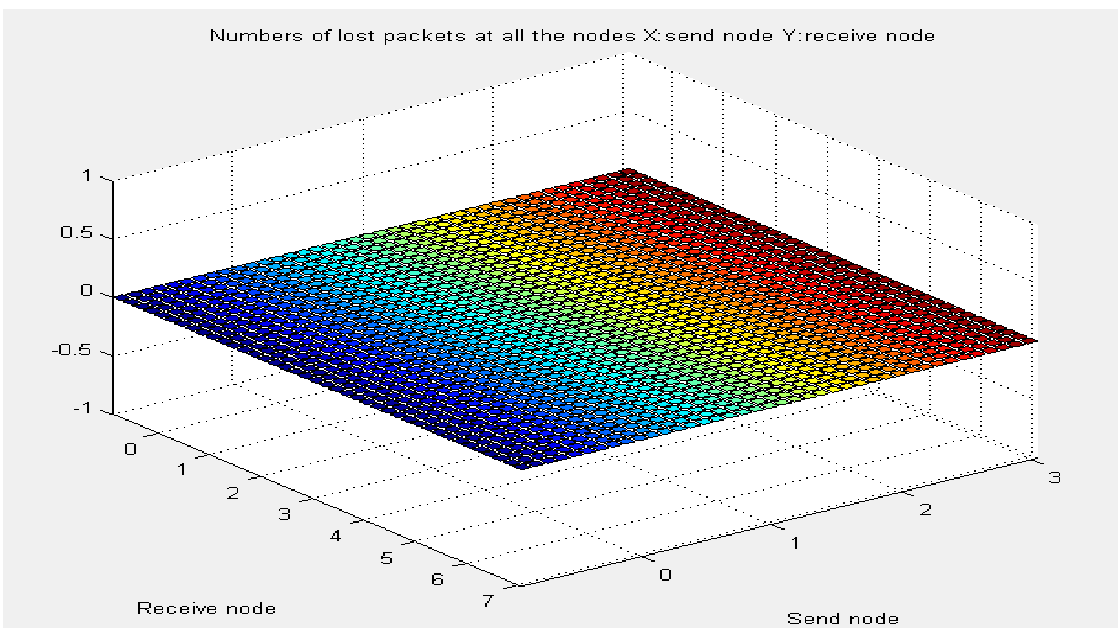
(b)

Figure 4.11 (a) Random RSU and (b) Proposed RSU placement shows end to end delay

No. of lost packets at all nodes in (a) Random RSU and (b) Proposed RSU placement shows



(a)

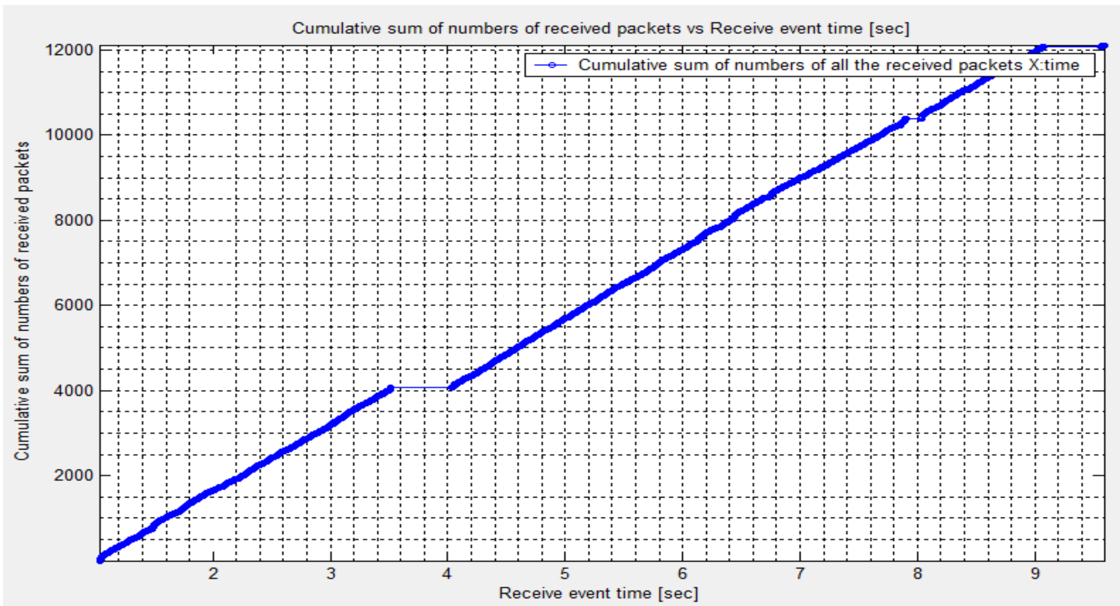


(b)

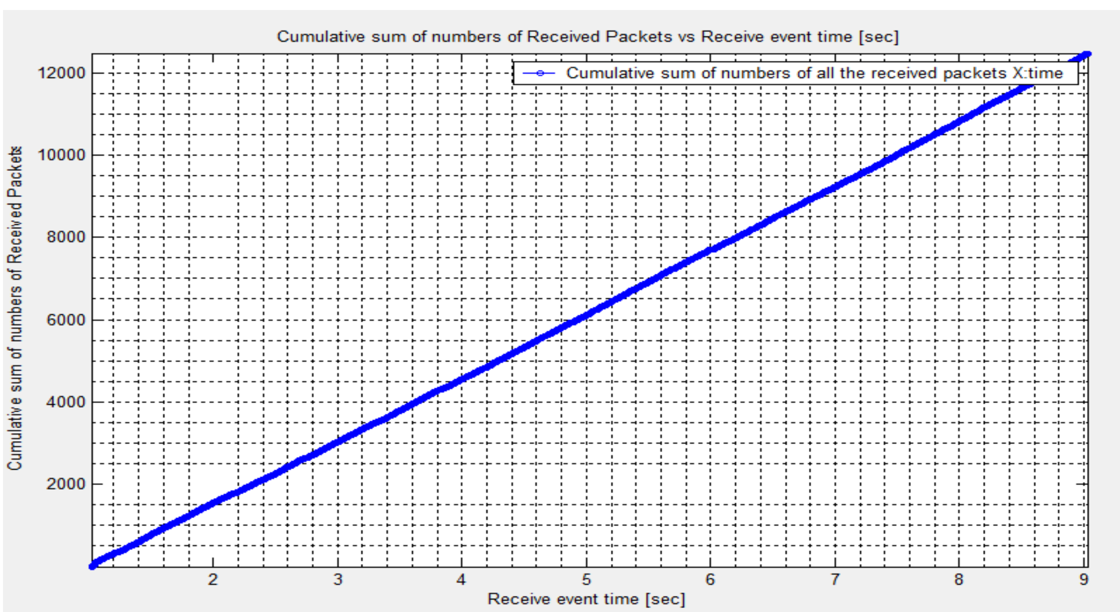
Figure 4.12 (a) Random RSU and (b) Proposed RSU placement shows no. of lost packets at all nodes

4.4.3 VANET SIMULATION FOR 50 OBU (NODE) WITH THE RSU

The cumulative sum of packets (a) Random RSU and (b) Proposed RSU placement



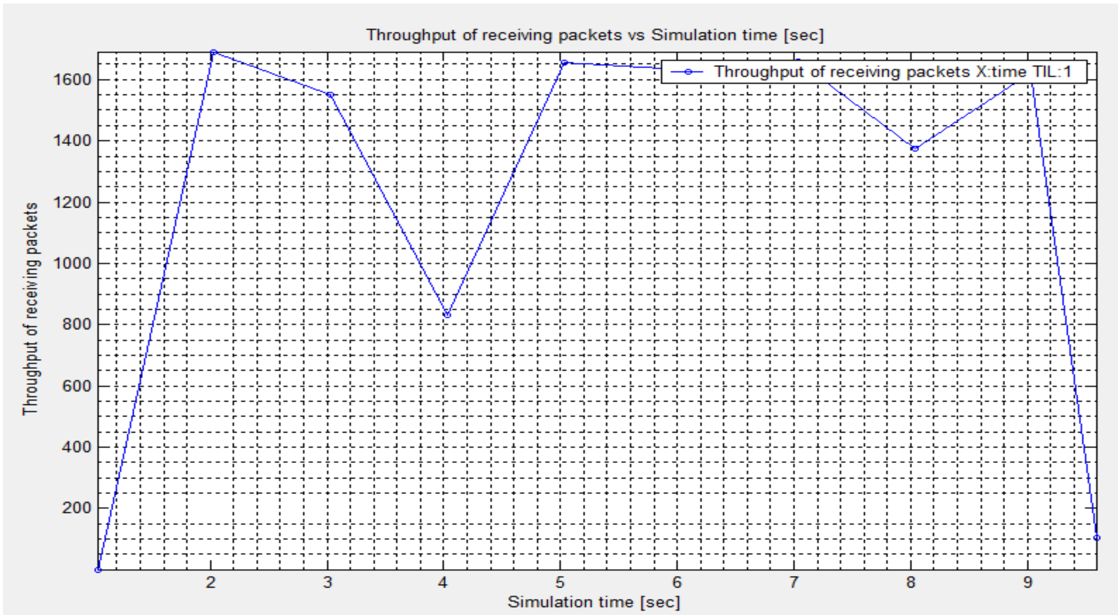
(a)



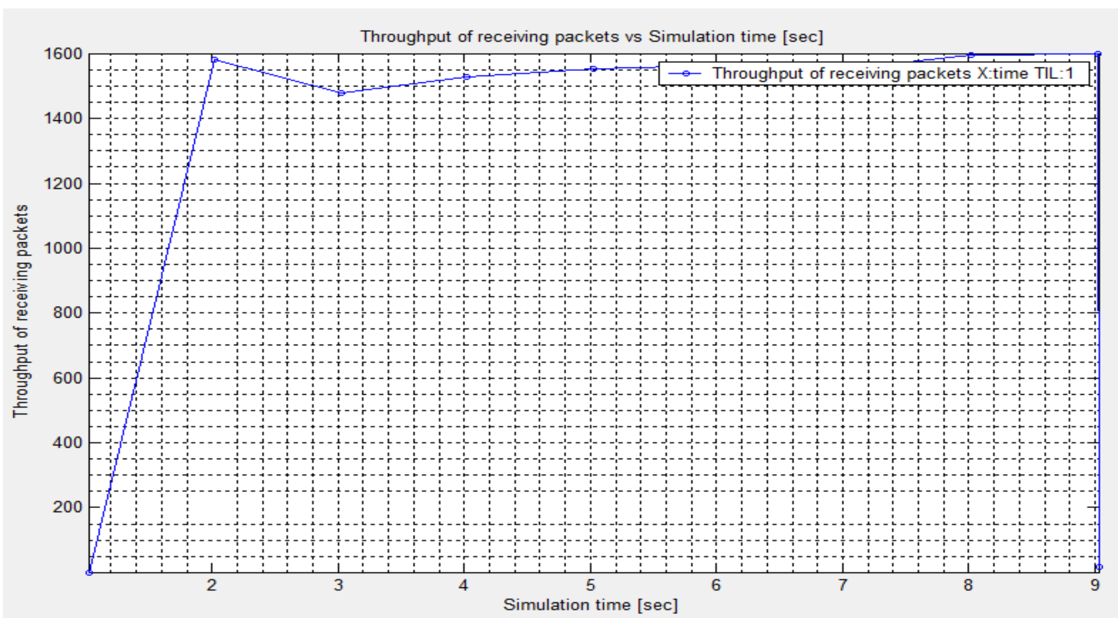
(b)

Figure 4.13 (a) Random RSU and (b) Proposed RSU placement shows the cumulative sum of packets

Throughput of receiving packets on (a) Random RSU and (b) Proposed RSU placement



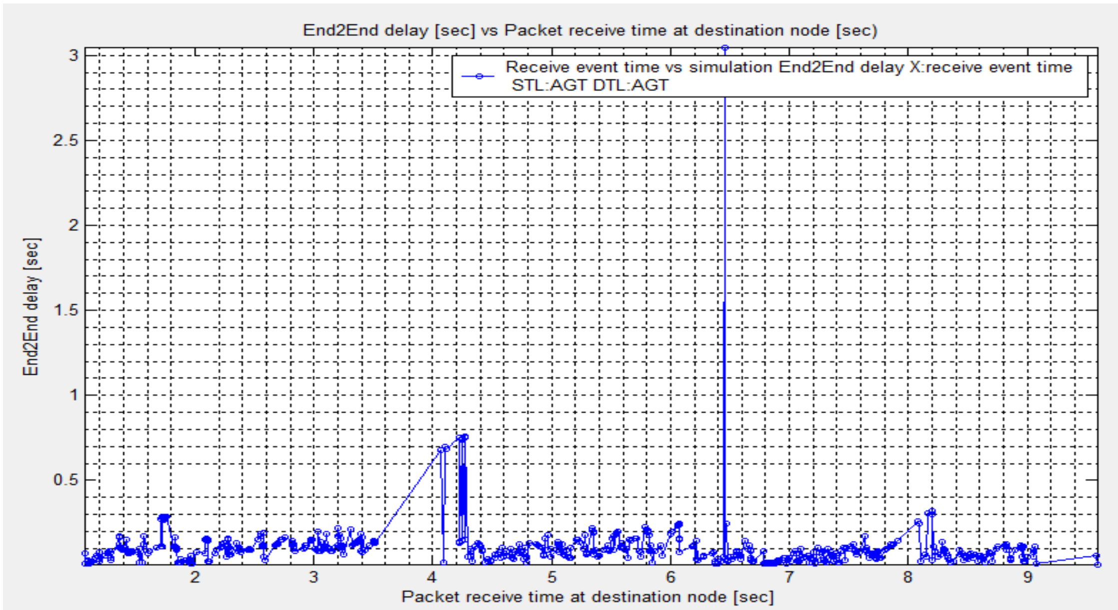
(a)



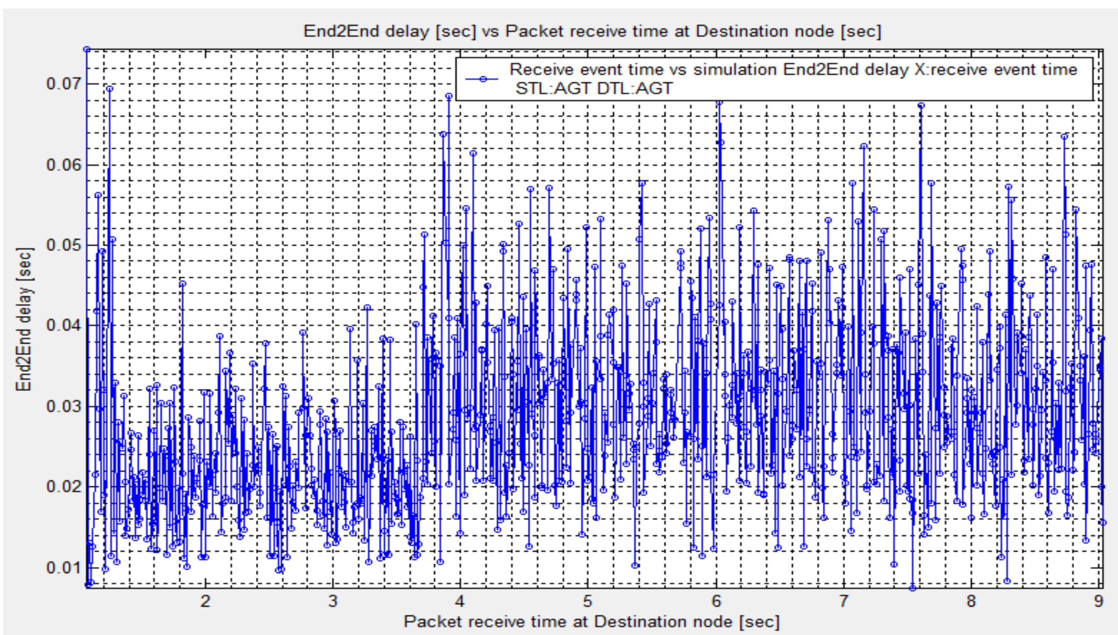
(b)

Figure 4.14 (a) Random RSU and (b) Proposed RSU placement shows Throughput of receiving packets

End to end delay in (a) Random RSU and (b) Proposed RSU placement



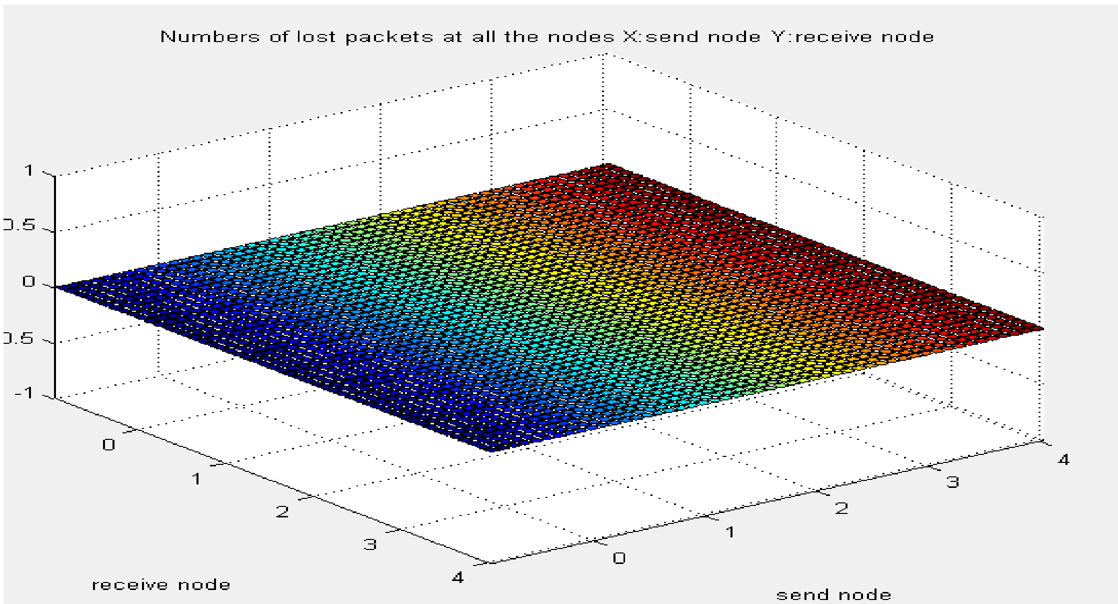
(a)



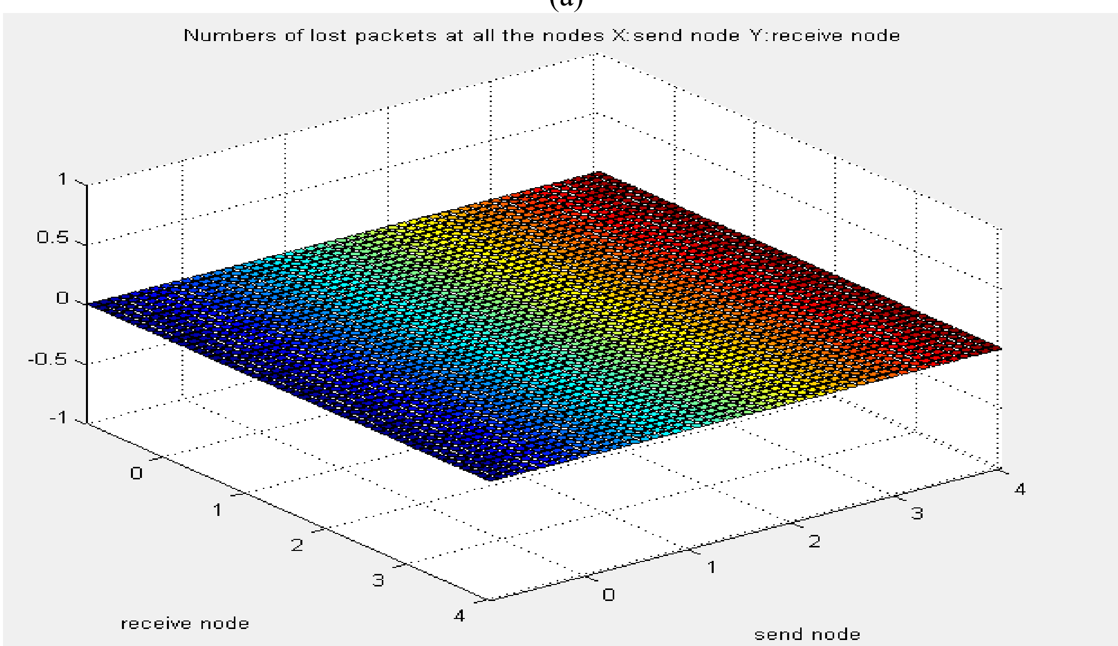
(b)

Figure 4.15 (a) Random RSU and (b) Proposed RSU placement shows end to end delay

No. of lost packets at all nodes in (a) Random RSU and (b) Proposed RSU placement shows



(a)



(b)

Figure 4.16 (a) Random RSU and (b) Proposed RSU placement shows no. of lost packets at all nodes

4.5 TCP TRAFFIC CONGESTION ANALYSIS

i. **For 30 OBU (Node) with RSU:** This is an observation based analysis for data packet TCP traffic congestion. As it is clearly shown that congestion window is high in random placement of RSU as compared with the Fixed RSU scenario.

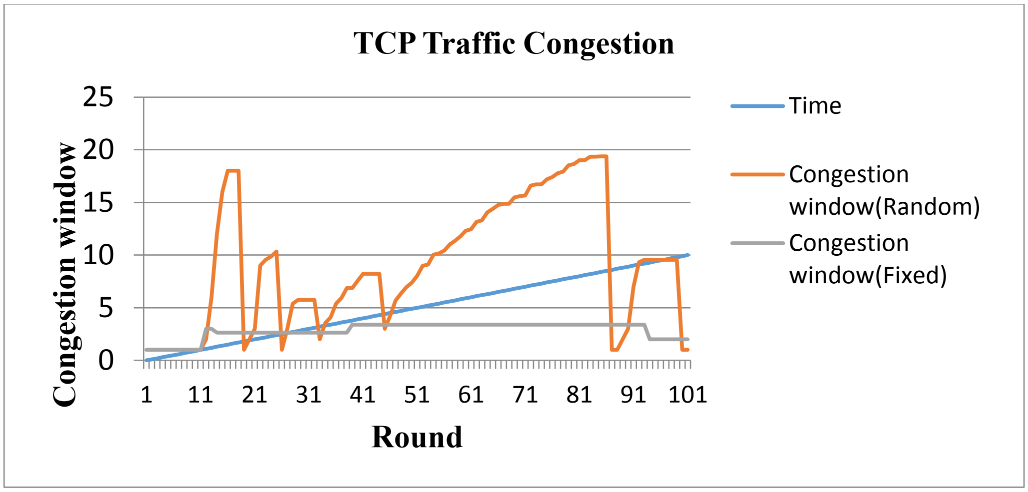


Figure 1.17 Shows TCP Traffic Congestion (30 Nodes)

ii. **For 40 OBU (Node) with RSU:** As it is clearly shown that congestion window is high in random placement of RSU as compared with the Fixed RSU scenario.

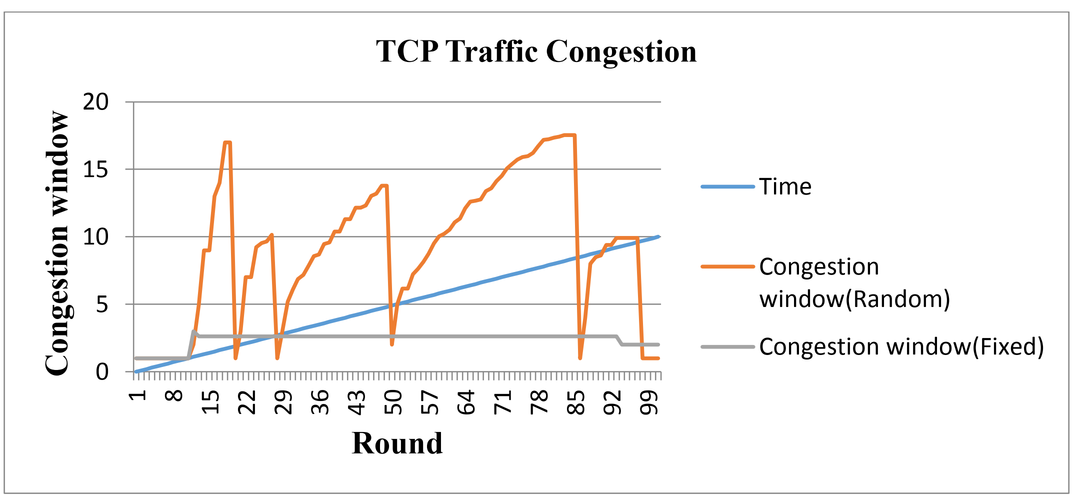


Figure 4.18 Shows TCP Traffic Congestion (40 Nodes)

For 50 OBU (Node) with RSU: As it is clearly shown that congestion window is high in random placement of RSU as compared with the Fixed RSU scenario.

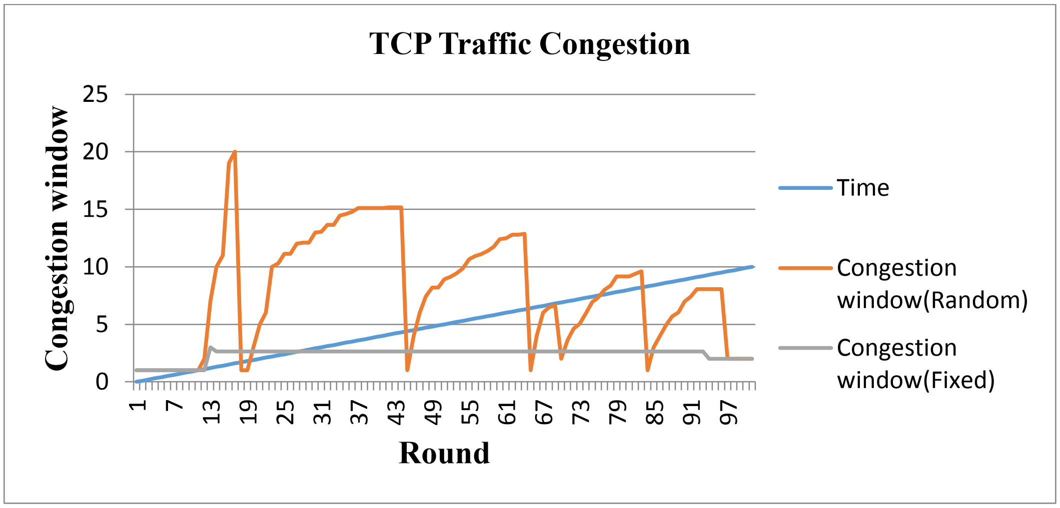


Figure 4.19 Shows TCP Traffic Congestion (50 Nodes)

4.6 VALIDATION

Validation test are applied to infer a significant statistical conclusion and characteristics of the sampled data. When comparing two sets of sample, a hypothesis test can be used to determine the difference between the sample data. A hypothesis test can state with some significance that the sample data do have a significant difference and that the difference is not just a random chance due to sampling. A z-test can be used to validate the hypothesis that the two samples are different or not. The proposed method is validated using the z-test, with the sample from the compared approach. Assuming that the central-limit theorem holds, the z-test hypothesis can be stated as follows:

H_0: The proposed approach does not have any gain over the random RSU placement technique.

H_a: The proposed approach does have significant gains over the random RSU placement technique.

The significance level for this hypothesis test is taken to be 5% i.e. the resulting test results will have 95% confidence interval on the difference between the means. The proposed approach is then validated against random RSU placement method for multiple node sizes.

30 Nodes: The statistical description of the comparison is given in the table 4.5 and the z-test performance is given in table 4.6.

Table 4.5 Comparative statistical analysis of random and fixed nodes

Variable	**Observations**	**Minimum**	**Maximum**	**Mean**	**Std. deviation**
Congestion window (Random)	101	1.000	19.380	9.048	5.993
Congestion window (Fixed)	101	1.000	3.387	2.821	0.778

Table 4.6 Hypothetical results of random and fixed nodes

Difference	**6.228**
z (Observed value)	**10.357**
|z| (Critical value)	1.960
p-value (Two-tailed)	<0.0001
alpha	0.050

As p-value < alpha (~0.0001 < 0.05), the null hypothesis stands rejected and alternate hypothesis is accepted that there is a significant difference in the mean between the compared approaches. The z value

(10.35) is greater than the |z| hence the proposed approach performance better than the comparative approach. Figure 4.20 gives the graphical representation of the results. The corresponding box plot and scattergrams for the sample distribution around the mean is given by figure 4.21 and figure 4.22.

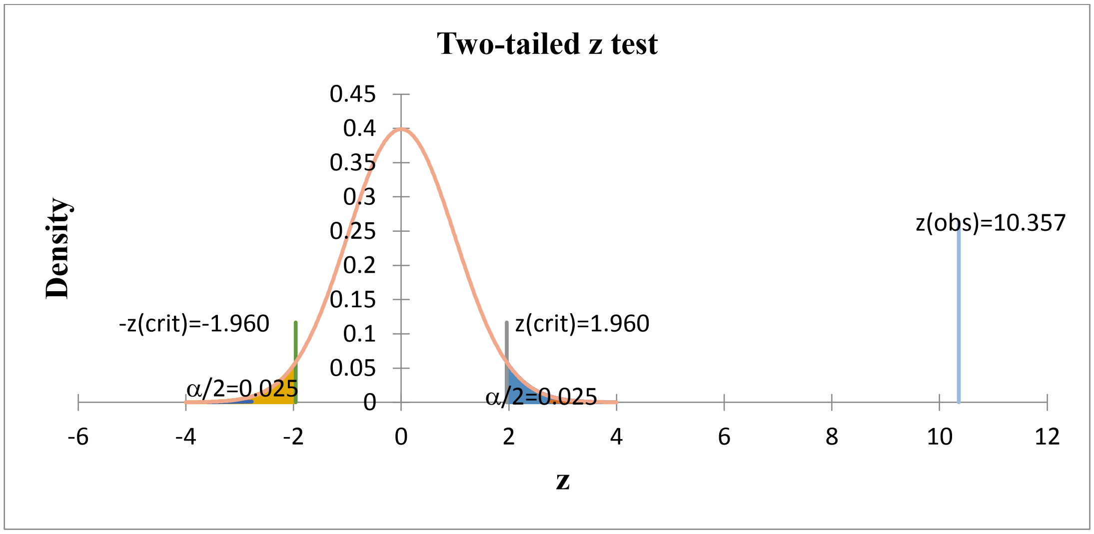


Figure 4.20 z-test for 30 nodes

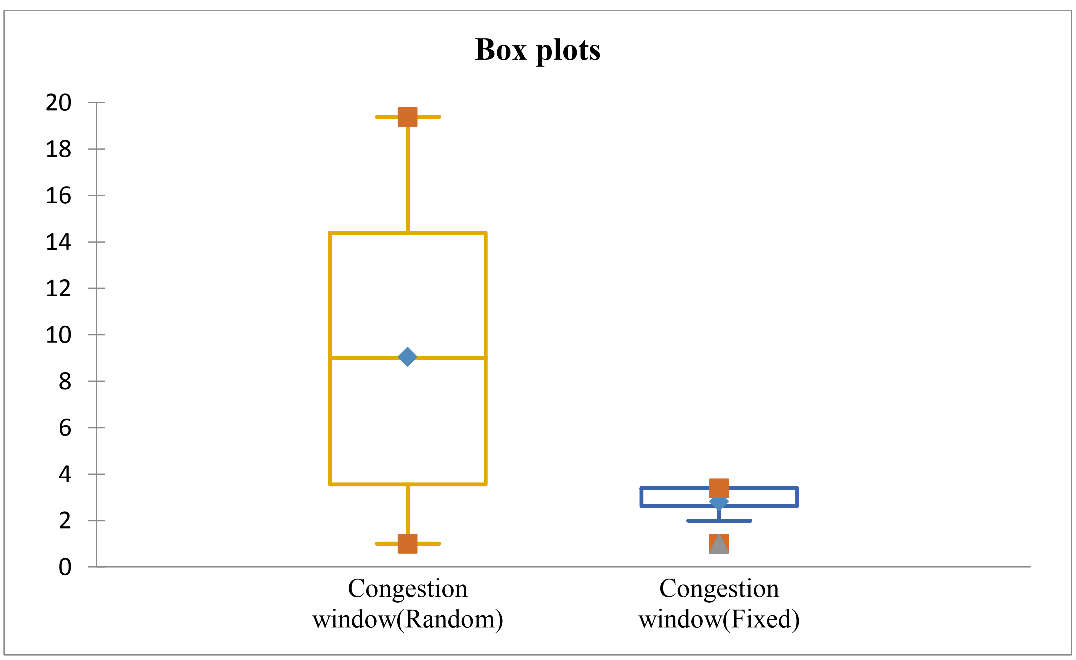


Figure 4.21 Box plot for the sample distribution for 30 nodes

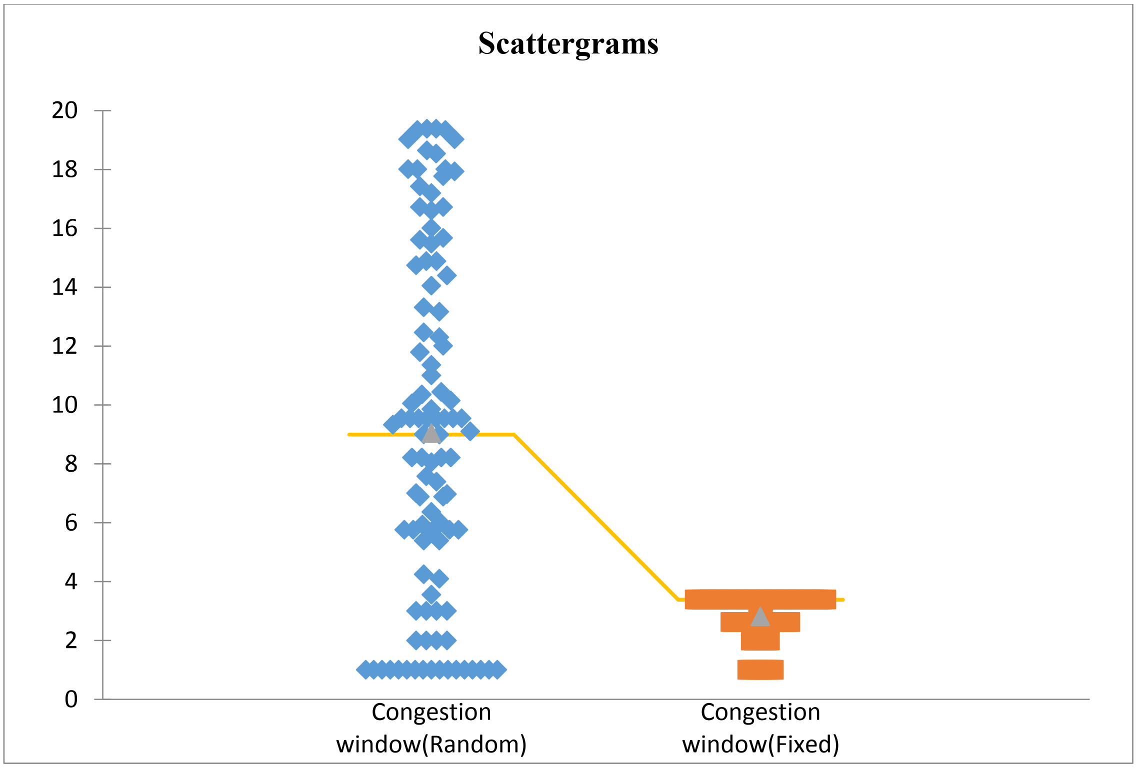


Figure 4.22 Scattergrams for the sample distribution for 30 nodes

40 nodes: The statistical description of the comparison is given in the table 4.7 and the z-test performance is given in table 4.8.

Table 4.7 Comparative statistical analysis of random and fixed nodes

Variable	Observations	Minimum	Maximum	Mean	Std. deviation
Congestion window (Random)	101	1.000	17.524	9.065	5.224
Congestion window (Fixed)	101	1.000	3.000	2.402	0.522

Table 4.8 Hypothetical results of random and fixed nodes

Difference	**6.662**
z (Observed value)	**12.754**
|z| (Critical value)	1.960
p-value (Two-tailed)	<0.0001
alpha	0.050

As p-value < alpha (~0.0001 < 0.05), the null hypothesis is rejected and alternate hypothesis is accepted. There exists a significant difference in mean between the compared approaches. The z value (12.754) is greater than the |z| hence the proposed approach performance better than the comparative approach. Figure 4.23 gives the graphical representation of the results. The corresponding box plot and scattergram for the sample distribution around the mean is given by figure 4.24 and figure 4.25.

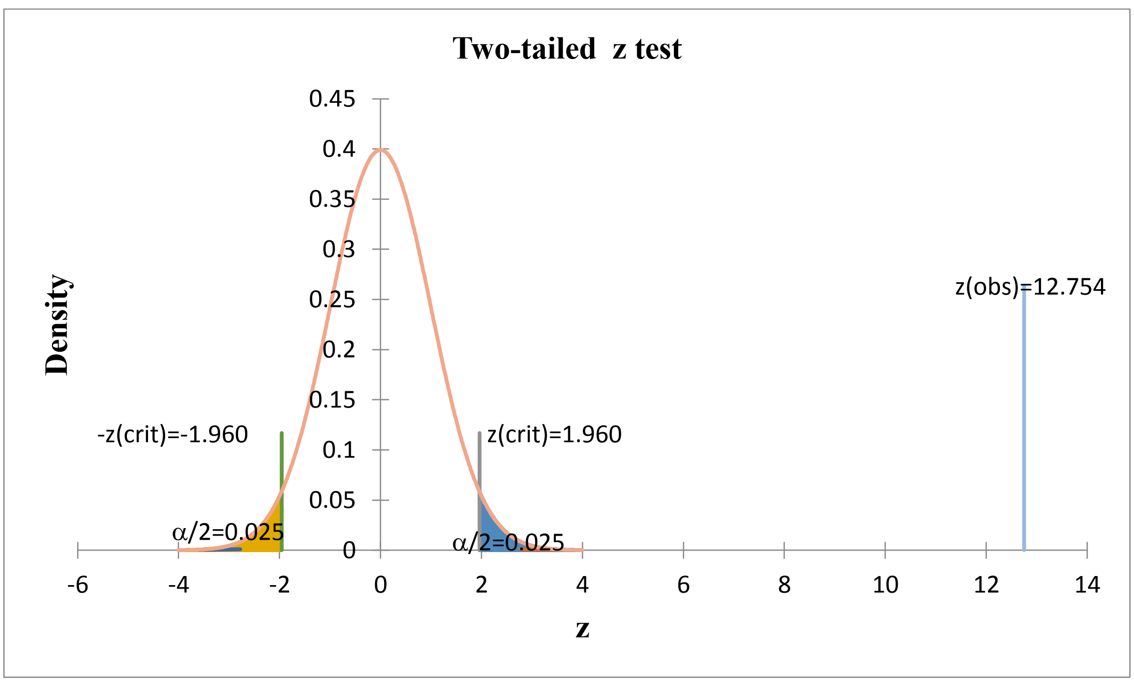


Figure 4.23 z-test for 40 nodes

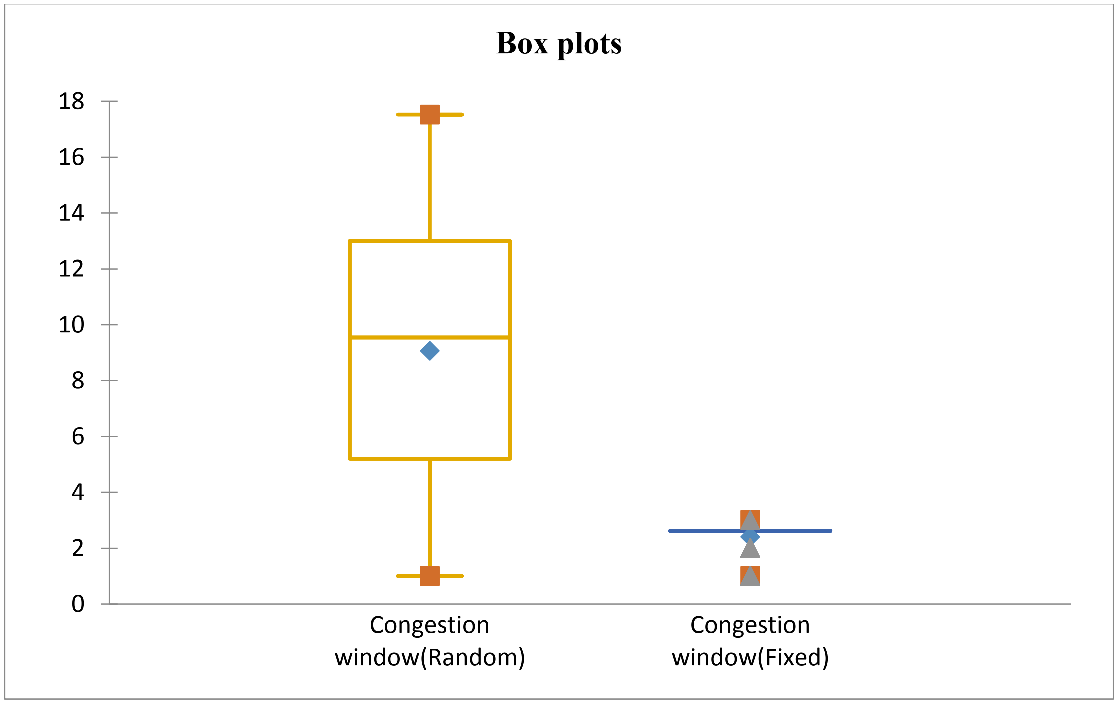


Figure 4.24 Box plot for the sample distribution for 40 nodes

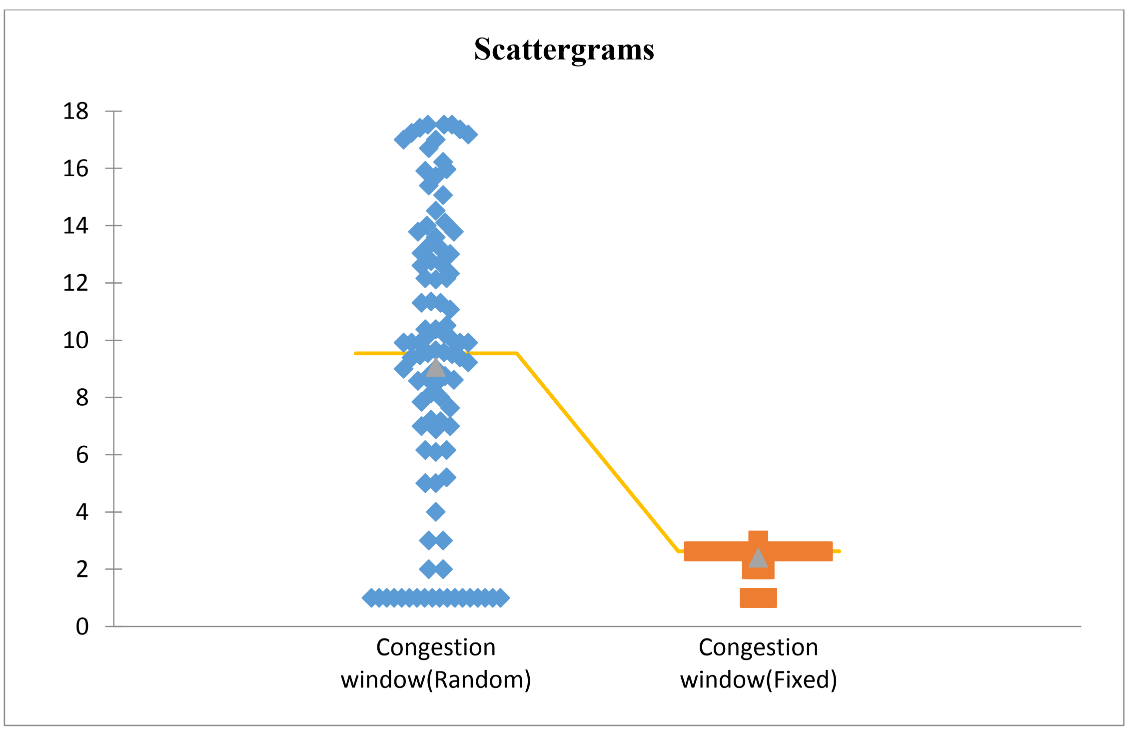


Figure 4.25 Scattergrams for the sample distribution for 40 nodes

50 Nodes: The statistical description of the comparison is given in the table 4.9 and the z-test performance is given in table 4.10.

Table 4.9 Comparative statistical analysis of random and fixed nodes

Variable	Observations	Minimum	Maximum	Mean	Std. deviation
Congestion window(Random)	101	1.000	20.000	7.882	4.908
Congestion window (Fixed)	101	1.000	3.000	2.386	0.540

Table 4.10 Hypothetical results of random and fixed nodes

Difference	**5.495**
z (Observed value)	**11.185**
|z| (Critical value)	1.960
p-value (Two-tailed)	<0.0001
alpha	0.050

As p-value < alpha (~0.0001 < 0.05), the null hypothesis is rejected and alternate hypothesis is accepted. There exists a significant difference in mean between the compared approaches. The z value (11.18) is greater than the |z| hence the proposed approach performance better than the comparative approach. Figure 4.26 gives the graphical representation of the results. The corresponding box plot and scattergrams for the sample distribution around the mean is given by figure 4.27 and figure 4.28.

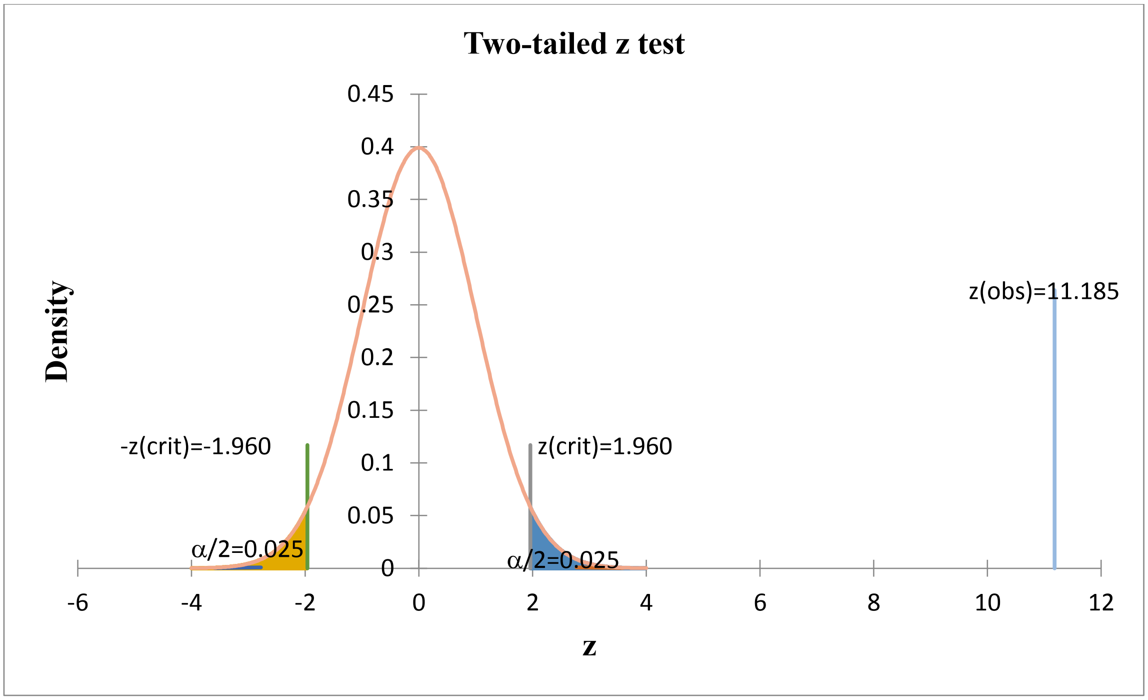


Figure 4.26 z-test for 50 nodes

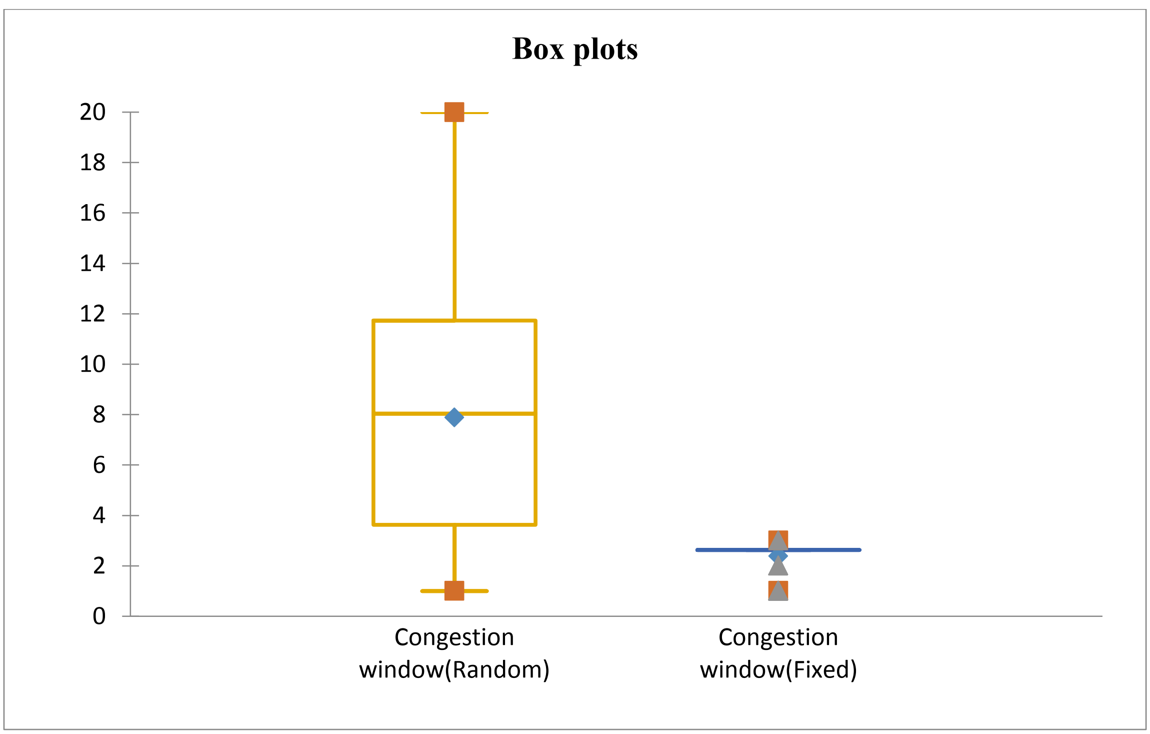


Figure 4.27 Box plot for the sample distribution for 50 nodes

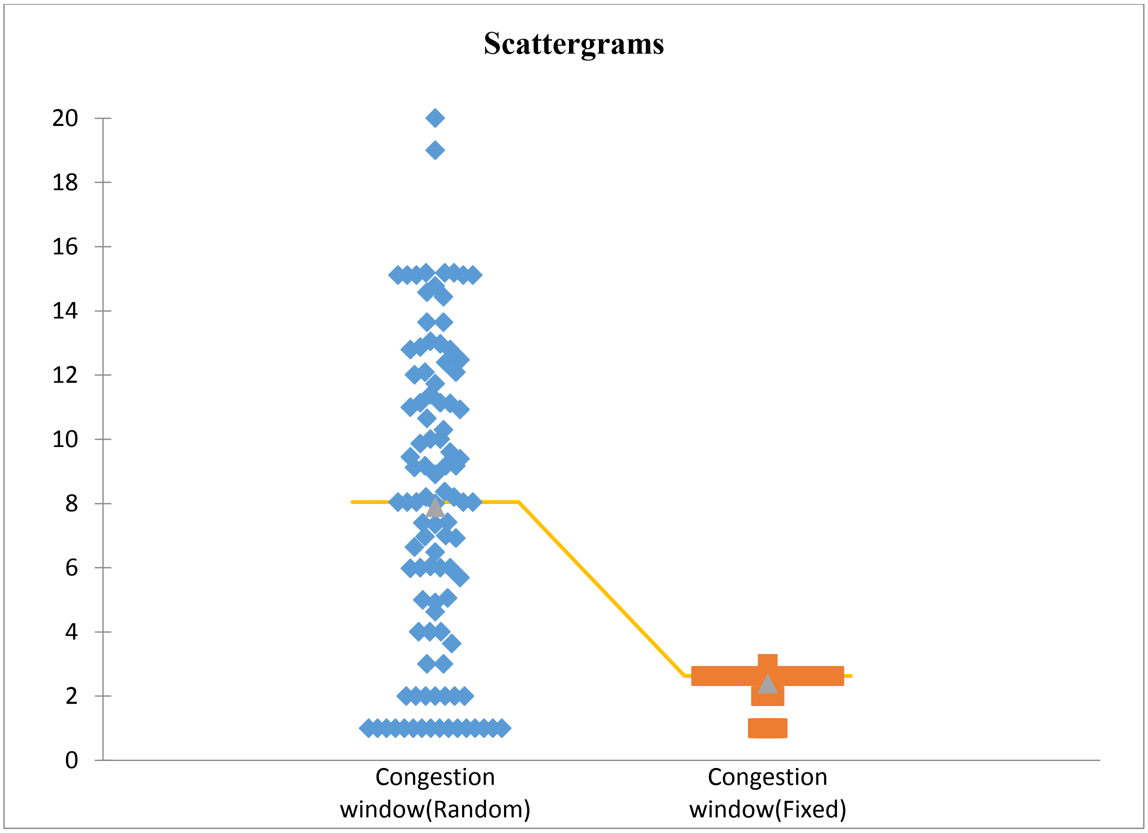


Figure 4.28 Scattergrams for the sample distribution for 50 nodes

4.7 COMPARISON OF VARIOUS RESEARCH WITH PROPOSED TCP TRAFFIC ANALYSIS

In this research, TCP traffic congestion is implemented to examine data flow (packets) from source to destination. This approach uses a number of parameters like energy that can be accumulated, the cumulative sum of packets, end-to-end packet delay, throughput, and congestion window to differentiate available TCP traffic-based solutions. The fixed RSU-based algorithm successfully manages the data packet, which is clearly shown in the previous section.

As per section 4.4, the framework is divided into three different sections: The first sections help to place the node (RSU) as per the algorithm which is described in Chapter 3. The second section picks best-route protocols like AODV. AODV uses request-response cycles to find routes. It does so by sending a RREQ notification to all other neighbours. Nodes that receive a RREQ message, but do not have a route to the specified destination broadcast it. It also saves a reverse-route to the requesting node for future answers to this RREQ. This step is repeated until the RREQ reaches a legitimate route node. This node answers with a RREP message. The RREP is unicast across the intermediary nodes' reverse-routes to the original requesting node. So, at the conclusion of the request-response cycle, a bidirectional route is formed. Unconnected nodes invalidate their routes by sending a RERR to any other nodes that may have received their RREP. The third and final category is to set up the traffic agent from the source to the destination to analyze the data from the control room.

Dependent parameters may now be added to TCP traffic in the suggested solution. To differentiate RSU-based placement algorithms from other available approaches, researchers drew on existing research. The parameters used to differentiate RSU-based placement algorithms from available approaches are energy, sum of packets, E2E delay, throughput, the number of dropped packets, and TCP. The proposed solution is based on the AODV routing protocol. This solution used the NS-2 simulator for implementing various scenarios and analysing these scenarios. After implementation, it was observed that the placement of RSU helped to lower the traffic packet congestion. The overall summary of all the available solutions with described parameters is given in Table 4.11.

Table 4.11 Comparison of Various research with proposed TCP traffic analysis

(✔ = evaluated, **x** =not evaluated and * denoted as not mentation.)

Comparison	Implemented on	Routing Protocol	Energy	Cumulative sum of Packets	E2E delay	Throughput	No. of lost packets	TCP	Network
Proposed Algorithm	NS-2	AODV	✔	✔	✔	✔	✔	✔	VANETs
Torsten Braun et al.[191]	Omnet++ Simulator	*	✔	X	✔	✔	✔	✔	Sensor Networks
Andrew Chen et al. [192]	SWANS and JiST	GPSR	✔	x	x	✔	x	✔	VANETs
Vibha Tiwari et al. [193]	NS-2	*	x	x	x	✔	✔	x	Heterogeneous network
Airong Huang et al. [194]	NS-2	AODV	x	x	✔	✔	x	x	VANETs
Jun-Li Kuo et al. [195]	OMNET++	GSR	x	✔	x	✔	x	✔	VANETs
Evjola Spaho et al. [196]	SUMO+ NS3	OLSR, AODV	x	x	x	✔	x	✔	VANETs
Bijan Paul et al. [197]	NS-2	AODV, DSR, DSDV	x	✔	✔	x	✔	✔	VANET
Joseph et al. [198]	NS-2	*	x	x	✔	✔	✔	✔	VANETs
Parul Tyagi et al. [199]	NCTUns	*	x	x	x	✔	x	x	VANETs
Seiichiro Ishikawa et al. **[200]**	ONE	*	x	✔	✔	x	x	✔	Vehicular DTN
Alpa Barad et al. [201]	NS-2	AODV	x	x	x	✔	✔	✔	VANETs
Yesin Sahraoui et al. [202]	NS-2	**AODV**	x	✔	✔	✔	x	✔	VANETs
Ranjit Sadakale et al. [203]	NS-2	AODV	x	x	✔	✔	x	✔	VANETs

4.8 CONCLUDING REMARKS

Analysis of VANET networks is not easy because of the high mobility of vehicular nodes. This chapter discusses the experimental results of two scenarios, i.e., random RSU based and fixed RSU based. The details and analyses are in tabular and graphical form. These two scenarios run successfully in the NS-2 simulator. The result comes in the form of residual energy used, the cumulative sum of packets, end-to-end delay, throughput, packets lost, and the TCP traffic congestion window. After analysis of the outcome, researcher validated the TCP traffic congestion window by considering 30, 40, and 50 nodes with Z-testing. After complete analysis, the researcher found that the fixed RSU-based algorithm shows better visual results as compared to the random-based.

CHAPTER 5

CONCLUSION AND FUTURE WORK

5.1 CHAPTER OUTLINE

In response to emerging technological developments such as the IoT, LTE/4G networks, as well as dynamic self-configuration, all of which depend significantly on rapid ad hoc networks, because of the quick network connection, all the devices operate without delay and without interruption in any setting. Access control, fault tolerance, & resilience are all key aspects of any networking and routing protocol, regardless of their implementation. It is critical to guarantee that the current routing methods are resistant to "smart technologies." The process of investigating alternative traffic management methods and finding ways to offset their effects is a never-ending one. The results of this study will pave the way for quicker internet applications and will act as a roadmap for future academics who are working on identifying and minimizing further risks. As a result, an ideal approach to eradicating such defects and vulnerabilities in the future will be paved for everyone. A discussion on future work will follow a summary of the most important results that have emerged as a result of the implementation of the RSU base TCP traffic mechanism described in the next section.

5.2 MAJOR FINDINGS

Using the Network simulator-2 simulation platform, this thesis shows how to control TCP traffic congestion in VANETs, and how to set up the necessary routing protocol. This will make VANETs faster and less prone to packet delay. Twelve tests were done to see how well TCP traffic worked. There are 2 different types of situations that are used in this study: This means that the first RSU (node) placement is random, and the second is a fixed RSU (node) placement.

5.3 RANDOM PLACEMENT OF RSU NODES

This is the first scenario toward the implementation of packet traffic analysis. In this section, three different RSU node placements (30, 40, and 50 nodes) were used to examine the experimental outcome.

In this section, RSU and CR are randomly distributed to define areas of 2289m (X dimension of the topography) and 100m (Y dimension of the topography), whereas OBU (movable node, i.e., vehicular node) is determined according to the Freeway Mobility Model. They are either single-lane or multilane highways, and they are bidirectional in the freeway paradigm. These highways are referred to as freeways. Each node is restricted to a single lane and a single direction of movement, and it follows a set of rules as it moves across the network. In most situations, each lane is marked with a pre-defined maximum velocity limit, which allows cars to go at high speeds while maintaining safety. Similar to the freeway model, fast vehicles travel on a pre-defined path or highway.

However, as opposed to the freeway model, fast cars are subject to certain mobility restrictions, such as acceleration and deceleration limitations. As much as 150 miles per hour might be reached by the vehicle's peak speed. Although fast vehicle models are built on the same premise as slow car models, they move at a slower pace and hence create less topological change than slow car models. The researcher calculated the cumulative sum, end-to-end delay, throughput, and TCP traffic congestion window.

5.4 FIXED PLACEMENT OF RSU NODES

This is the second scenario toward the implementation of packet traffic analysis. In this section, three different RSU node placements (30, 40, and 50 nodes) were used to examine the experimental outcome.

In this section, RSU is fixed with the proposed algorithm which is described in chapter 3rd, and CR is randomly distributed to define areas of 2289m (X dimension of the topography) and 100m (Y dimension of the topography), whereas OBU (movable node, i.e., vehicular node) is determined according to the Freeway Mobility Model. This all scenario is written in TCL language and simulate in NS-2. Implementation of this scenario directly to the ground will cost a lot in monetary value and manpower. So, we choose NS-2 to check the efficiency of the proposed algorithm. We have calculated the cumulative sum, end-to-end delay, throughput, and TCP traffic congestion window.

Table 5.1 Comparison between Scenario 1 (Random) and Scenario 2 (Fixed) for 30 nodes

30 nodes	Cumulative Sum		End-to-End Delay		Throughput		TCP traffic Congestion Window	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
Scenario 1 (Random)	0	11500	0	0.55	0	1400	1	19
Scenario 2 (Fixed)	0	12500	0	0.07	0	1600	1	7

According to table 5.1, scenario 2, which is fixed RSU placement, is more efficient than scenario 1, which is random RSU. On the other hand, TCP traffic congestion is three times higher in Scenario 1 as compared to Scenario 2.

Table 5.2 Comparison between Scenario 1 (Random) and Scenario 2 (Fixed) for 40 nodes

40 nodes	Cumulative Sum		End-to-End Delay		Throughput		TCP traffic Congestion Window	
	Min.	**Max.**	**Min.**	**Max.**	**Min.**	**Max.**	**Min.**	**Max.**
Scenario 1 (Random)	0	12500	0	0.35	0	1550	1	17
Scenario 2 (Fixed)	0	12250	0	0.045	0	1600	1	5

According to table 5.2, scenario 2, which is fixed RSU placement, is more efficient than scenario 1, which is random RSU placement. On the other hand, TCP traffic congestion is four times higher in Scenario 1 as compared to Scenario 2.

Table 5.3 Comparison between Scenario 1 (Random) and Scenario 2 (Fixed) for 50 nodes

50 nodes	Cumulative Sum		End-to-End Delay		Throughput		TCP traffic Congestion Window	
	Min.	***Max.***	***Min.***	***Max.***	***Min.***	***Max.***	***Min.***	***Max.***
Scenario 1 (Random)	0	12000	0	3	0	1450	1	20

Scenario 2 (Fixed)	0	12500	0	0.07	0	1600	1	6

According to table 5.3, scenario 2, which is fixed RSU placement, is more efficient than scenario 1, which is random RSU placement. On the other hand, TCP traffic congestion is four times higher in Scenario 1 as compared to Scenario 2.

5.5 OTHER FINDINGS

The packet lost and residual energy is computed for both random and fixed RSU placement scenarios, as discussed below:

Table 5.4 Comparison of Packets Lost and Total Residual Energy.

	Packet lost	**Total Residual energy (Joule)**
Scenario 1 (Random)	0	1401.27
Scenario 2 (Fixed)	0	1391.12

In scenarios 1 and 2, packet loss is zero, which is tabulated in table 5.4. This means all the data packets sent from source to destination are delivered successfully, i.e., no packets are lost during transmission. Setting all the initial values of energy in the energy model, Scenario 2 (fixed) consumes less energy compared to Scenario 2 (random). These two findings contribute to the strength of the main research finding.

5.6 THE SCOPE AND LIMITATIONS OF RESEARCH

While discussing the scope of this study, taking a look at a set of recommendations that could be valuable to the researchers. We need to know how these recommendations would help the people who will be benificiaries of the research, so that informed decisions can be made. Looking at how VANETs can be enhanced or upgraded in the future to allow for a range of innovative applications is an excellent technique to understand these proposals. Network applications that need trustworthy edge communication use TCP. TCP performance on Vehicular Ad-hoc Networks has been scientifically proven to be low in research. Data packets are seen by TCP as a symptom of data traffic. However, losses in wireless networks occur due to overcrowding of data packets and channel capacity. As a result of the high number of vehicles, TCP data traffic increases, thereby lowering throughput. Vehicle designs should include applications for safety, driver assistance, highways monitoring and traffic efficiency to RSU based platforms. Once emergent vehicular networks like intra-vehicle, VtoV, and VtoI internet activity are accessible, these applications will become a reality. This is predicted, given that business, telecom and network operators, universities, and governments throughout the globe are investing heavily in the implementation of vehicle networks in order to create a more secure transportation infrastructure. The focus of government, commercial, and scientific efforts were on vehicle networks. The idea of an interconnected vehicle has received a lot of attention recently in digital technologies. Providing vehicles and roads with capabilities to improve traffic, data traffic security, and efficiency is now a popular application. It also improves the quality of the journey for passengers. RSU-based technology provides fast information regarding traffic jams, accidents, dangerous road conditions, potential detours, and weather conditions, as well as the location of amenities (e.g., petrol stations and restaurants) in an emergency. VANET's inherit the wireless connectivity problems of the wireless ad hoc network. The routing protocol will tend to generate higher number of control packets just to keep up with the fast changing network topology of the VANET's. Number of vehicles in an area has direct proportionality with the achievable throughput rate. A sufficiently high number of vehicles in an area will tend to bring down the overall network performance. The proposed method is resilient to rapid changes in topology however the maximum limit of user that can communicate simultaneously is still dependent on the wireless medium.

5.7 FUTURE WORKS

The proposed method can be furthered by pursuing a number of other research directions in the future. The proposed method highlight four separate areas that need more investigation, as well as places where previous research might be combined into ours.

i. Validation and evaluation of the proposed algorithm in more complex scenarios, The proposed algorithm can cascade complicated traffic modelling and driving behaviours (mobility models) into the simulation framework. This will bring the algorithm closer to real-world applications by incorporating lane changing and multiple entry and exit points.
ii. It is necessary to take into account external occurrences such as traffic signals while planning traffic in the inner city.
iii. Protocols for VANETs that are both efficient and effective, including hybrid protocols that employ both V2V and V2I electronic information exchange; and this research aims to determine the impact that message losses and other network physical parameters such as vehicle involvement, transmission power, and other

transmission characteristics have on the efficiency of congestion detection.

iv. Effective routing can be achieved by the use of congestion information, which includes the use of congestion characteristics such as size, age, and number of vehicles, as well as statistical data to estimate future traffic.

5.8 CONCLUDING REMARKS

The chapter has addressed the burning issue of data traffic congestion in vehicular ad hoc networks. For this purpose, a RSUs placement framework is proposed. The aim of the proposed algorithm is to provide smooth data communication between VtoV and VtoI communication. To test the appropriateness of the proposed algorithm, its implementation has been performed by the researcher. The proposed RSUs placement algorithm is integrated with the Network Simulator. It has been observed that the proposed RSUs placement approach is three times better than the random RSUs placement.

In this study, the AODV routing protocol is combined with the RSUs placement algorithm that was proposed. Then, the Network Simulator-2 was used to do a detailed analysis. Simulations show that an RSUs placement algorithm is best for getting less traffic, a low E2E delay, high throughput, and no packet loss. Overall, the RSU placement algorithm is the ideal solution to reduce TCP traffic in any environment.

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APPENDIX-A

PLAGIARISM REPORT

Curiginal

Document Information

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Sources included in the report

W	URL: http://technodocbox.com/Computer_Networking/128461671-Previous-hop-routing-exploiting-opportunism-in-vanets.html Fetched: 2021-08-26T10:37:38.1500000	2
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W	URL: https://rd.springer.com/content/pdf/10.1007/s13369-016-2377-y.pdf Fetched: 2022-01-24T14:47:24.3900000	4
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APPENDIX-B

LIST OF PUBLICATIONS:

1. **Ajay Kumar, Raj Shree,** Ashwani Kant Shukla, Ravi Prakash Pandey, Vivek Shukla, V. (2021). Impact of ad-hoc on-demand distance vector on TCP traffic simulation using network simulator. Materials Today: Proceedings, ISSN: 2214-7853. https://doi.org/10.1016/j.matpr.2021.04.578.
2. **Ajay Kumar, Raj Shree,** Ashwani Kant Shukla, Ravi Prakash Pandey, Vivek Shukla "Analysis Of TCP Congestion On Random And Structured RSU Distribution For VANET" Turkish Journal of Computer and Mathematics Education Vol.12 No.7 (2021), 210-220 **e-ISSN:** 1309-4653.
3. **Ajay Kumar, Dr. Raj Shree**, "A Novel architecture to secure and robust the Network of Vehicle Communication", published in 4th Lucknow Science Congress, LUSCON-2017.
4. **Ajay Kumar, Dr. Raj Shree**, "Study of Security in VANET Based on Routing Protocol", published in National Seminar on Emerging Trends & Advancement in Cyber Security, Integral University, Lucknow, 4th Apr 2016.
5. **Ajay Kumar, Dr. Raj Shree, "** Study of Wireless Technology and The Use of Vehicular Ad Hoc Sensors Network for Intelligent Control" awarded as **best poster presentation** in National Conference on Science for Society an Interdisciplinary Approach, 3rd Lucknow Science Congress, LUSCON-2015, 31st October to 2nd November, 2015.

APPENDIX-C

PAPER 1

Authors: Ajay Kumar, Raj Shree, Ashwani Kant Shukla , Ravi Prakash Pandey , Vivek Shukla.

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APPENDIX-D

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Impact of Ad-hoc on-demand distance vector on TCP traffic simulation using network simulator

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A B S T R A C T

VANET (Vehicular Ad-hoc NETwork) is a wireless network technology that uses vehicles as mobile nodes to exchange data without the need for a Central Access (CA) point, which is used for safety problems. In this, the vehicles (node) transmit data about traffic and road conditions. Because of the latest advances in information technologies, it is now important to take the first step toward using software to evaluate this network prior to deployment. By implementing the network in a real-world environment, we can use simulation software to perform a detailed review of it. There are various network simulators, each with its own collection of features that set it apart from the others. We should concentrate on finding the right alternative that yields the best outcomes. NS2 is the most commonly used simulator tools; in this paper, we used NS2 to build the VANET, which allowed communication between nodes using AODV routing protocols. By changing the number of vehicles when applying TCP traffic, we use routing protocols (AODV) for various standard metrics, such as Cumulative Sum of Packet, throughput, jitter, and packet loss. The simulation was carried out using the NS2 simulation tool. Different mobility models would be considered in order to make the network situation more realistic. In this paper, we used Five forms of mobility patterns using 10, 20, 30, 40, and 50 vehicle nodes. On NS2, we drafted a TCL script to verify the affectations of the routing protocols used in the VANET. After successfully run, we conclude that the Cumulative Sum of Packet gets less forwarded to the destination, throughput is high in case of sent Packet, Jitter gets stable at last, and the most important is that there is no loss of any packet from Source to Destination.

Selection and peer-review under responsibility of the scientific committee of the 1st International Conference on Computations in Materials and Applied Engineering – 2021.

1. Introduction

In the twenty-first century, traffic congestion is a big problem. People and policy makers are continually met with a rise in the number of automobiles on the route. This problem is far more pressing in developing countries like India and China, where there is no balance between road infrastructure development and traffic growth. Focusing exclusively on the development and improvement of transportation infrastructure is not the most successful solution to this issue. As a result, there is a need for policymakers and countries to find ways to minimize, optimize, and control the significant costs of traffic congestion, as well as for safe, fast, and convenient transportation [1].

There are many approaches to this issue, and one of the most revolutionary is the intelligent transportation system (ITS). ITS is a novel solution to traffic control and prevention. ITS is an umbrella term for a range of novel technology aimed at evaluating, tracking, and assessing traffic, as well as combining different technologies to accomplish the following goals: traffic quality, cost savings, energy efficiency, environmental protection, and time reduction [18,19]. The term "intelligent transportation system" refers to a number of systems, including portable systems [20], stand alone systems mounted on vehicles, systems that allow vehicle-to-vehicle and vehicle-to-infrastructure communication, and cooperative systems [2].

In Literature, there are many types of ad hoc networks, one of which is known as a VANET. VANET (Vehicular Ad-hoc NETwork) is a subset of the Mobile Ad-Hoc NETwork (MANET). Low bandwidth, self-organization, and mutual radio transmission are all features shared by MANET and VANET. The primary function of the

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APPENDIX-E

PAPER 2

Authors: **Ajay Kumar, Raj Shree,** Ashwani Kant Shukla , Ravi Prakash Pandey , Vivek Shukla

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APPENDIX-F

Turkish Journal of Computer and Mathematics Education *Vol.12 No.7 (2021), 210-220*
Research Article

Analysis Of TCP Congestion On Random And Structured RSU Distribution For VANET

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Abstract: One of the significant issues is that can limit the capacity of VANET would be network congestion. The first phase is congestion management, congestion analysis is the focus of the article. We suggest cumulative parameters that can take into account the total structure of the system, including TCP traffic energy used by each node, throughput, the delay, cumulative distribution time and congestion window. The cumulative parameter can reliably, quickly, and instantaneously detect channel congestion by the Control room and eliminating the flaws of using the different variables to reduce the channel congestion. Besides that, the article suggests a necessary, but robust infrastructure-based approach by using the TCP_{Vegas} technique that can normalize these variables through the same aspect, resulting in the normalization of the cumulative value. This article helps to manage the communication traffic in VANET so that the High Priority Message reaches the destination with minimal time. This approach also helps to reduce accidents by getting information on time.

Keywords: On Board Unit, Road Side Unit, Transmission Control Protocol, VANET.

1. INTRODUCTION

According to the WHO Global report about road safety in 2018, released in December 2018, the rate of new road fatalities has risen to 1.35 million road traffic accidents becoming the leading cause of death for public age from 5 to 29; how was motorcyclist, cyclists, and pedestrians, especially in developed countries bears an unfair share of the blame. Due to this, researchers were working on congestion management strategies for standard wired, and wireless networking is extensive [2]. While detecting a swift in acknowledgments obtained from neighboring nodes, TCP manages congestion [3] through end-to-end monitoring by changing the data rate on an intermediate node. Scholars in MANETs (Mobile Ad-hoc Networks) concentrate on forwarding and additional features in multi-hop [4] platforms. Even then, because of particular difficulties and conditions of VANET, such current methods and usually not appropriate for VANET contact. For example, since safety signals are transmitted to all nearby vehicles, expecting an acknowledgment (ACKs) across all collecting vehicles is impractical, while ACK signals absorb bandwidth and worsen congestion. The conditions for single-hop self-monitoring message transmitting in VANETs are entirely different from those for multi-hop contact in MANETs. Due to high node agility and channel fading restrictions, congestion management in VANET becomes much more difficult.

Vehicles (On Board Unit) and Road Side Unit (RSU) in VANET will support VtoI and VtoV communication with IEEE 802.11p based on Short Range Wireless Communication (SRWC) [5] system. People may benefit from a wide range of application services provided by VANETs, including security, comfort & safety services [6]. Advertisements, reports, entertainment news, and other information can be found in comfort service. In this service system [7], the messages spread across the network through broadcast, geocast, and webcast, accumulating in some neighbor node and causing congestion at a specific node or connections. Furthermore, since all services in VANETs are small, the propagation of these comforts, service messages would deplete those resources, preventing protection application messages from reaching an endpoint on time. This creates significant security damage to VANET applications. As a result, congestion management throughout the VANET is now an issue that must be addressed immediately.

2. RELATED WORK

Connectivity Aware Routing was introduced by Naumov et al. [8], who ensures low latency through pre-determining its propagation route. Which, including AODV, establishes the best metric utilizing “Hello” packets from the sender to the recipient and back. Through paper [9], Moreno et al. suggested a rapidly changing transmission capacity adaptation scheme that guarantees all vehicles provide equivalent bandwidths. It involves sending and receiving control messages that included network density and neighbor add-up information. Ayaida et al. introduced an interesting concept in [10], integrating routing protocol with location-based routing to eliminate the signaling overhead in a mixed and hierarchical network. In these schemes, the last update of the receiver’s location is used to send