Escola d'Enginyeria de Telecomunicació i Aeroespacial de Castelldefels
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MASTER THESIS

TITLE: Performance Comparison of a Platooning Scenorio Using the IEEE 802.11p

MASTER'S DEGREE: Master's degree in Applied Telecommunications and Engineering Management (MASTEAM)

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DATE: September 05, 2018

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Abstract

There has been much technological advancement in the wireless communication in the recent past for the intelligent transportation systems among all Dedicated Short-Range Communication or DSRC or Wireless Access for Vehicular Environment (WAVE) has very important role for the autonomous connected vehicles. It is well known for its support for the time sensitive safety applications.

Along with safety application, the service to provide nonsafety applications is also becoming very popular, these nonsafety applications may include infotainment, electronic toll tax collection and traffic control to name a few.

DSRC protocol consists of WAVE Short Messaging Protocol or WSMP which aims to provide real time safety application and it is also able to support some nonsafety related applications. In our dissertation we aim to evaluate the performance of IEEE 802.11p standard for both safety and nonsafety messages.

Our scenorio for master thseis consists of fleet of vehicles that are moving with constant speed and in the same direction forming the platoon pattern. The distance between every two vehicles is set to be constant and it is kept 200 meters, similarly every vehicle is moving with constant speed of 20 m/sec. To develop the scenorio for Basic Safety Messages, each vehicle is able to generate BSM messages periodically and it fixed payload size of 200 bytes and data rate of 6 Mbits/sec.

For the nonsafety messages we also compare the performance of existing protocols such as optimized link state routing OLSR protocol and Ad-hoc On-demand Routing AODV protocol, the packet size is kept 256 bytes at 8 kbps.

We have used the metrics such as throughput, packet delivery ratio, packet loss ratio and end to end delay for evaluaing the performance of as optimized link state routing OLSR protocol and Ad-hoc On-demand Routing AODV protocols

Our simulation results conducted in Network Simulator NS-3 show that WSMP protocol have adequate level of packet delivery ratio and throughput with moderate level of packet loss at lower intervehicle distances and higher packet loss ratio at greater distances between the vehicles. On the same way, when the simulation results of as optimized link state routing OLSR protocol and Ad-hoc On-demand Routing AODV protocol are compared it is evident that AODV protocol better performs in terms of throughput, packet delivery ratio as well as in terms of packets loss, but AODV protocol being reactive in nature, assumes much higher end to end delay for the packet delivery.

CONTENTS

I CHAPTER 1. INTRODUCTION

I.1 Motivation

Road traffic accidents are supposed to be some of the largest potential threats to the public worldwide, therefore security of people has been major concern for the transport stockholders. During the recent past government authorities and other security officials including different automotive organizations have shown keen interest regarding the improvement in the safety application for intelligent transportation systems that aim to reduce the impact of the roadside accidents and formulating the policies to decrease the injuries and fatalities created in the accidents. One of the major reason for these accidents is the lack of experience of drivers as well as their unawareness for the reaction time to the road hazards are some of the key issues for road side safety. As reported [4] around 25,700 fatalities occurred in 2014 in the EU at the rate of 51 million of total inhabitants. Due to congested roads lot of times and resources are being wasted, all these major issues could be reduced by platoon -based driving manner, in this case all vehicles follow one another, and they maintain small but constant intervehicle distance among each other. It has been observed that instead of driving the vehicles in individual pattern, if platoon-based pattern is adopted by the transportation system, it will lead not only to improve road capacity and fuel efficiency but also results into traffic safety. Furthermore, due to emerging vehicular ad-hoc network (VANET), platoon pattern of communication can improve the performance in terms of safety and fuel consumption efficiency [23]. Due to fast movement of the vehicles the topology is also changing with respect the speed of the vehicles, therefore there is the need of stable routing protocols which can make sure that transmitted messages are correctly received at the destination. Design of such robust protocols for the VANET is an emerging area which aim to tackle the key issues such as vehicle speed and frequent changing topology.

One of the most promising technology for safety communication for inter-vehicles is IEEE 802.11p protocol that has attracted lot attention nowadays, most of the inter-vehicle safety communication applications demand strict real time requirements to broadcast messages to make sure that vehicle drivers have enough time to react when emergencies occur [5]. Among these routing protocols, there are many protocols that have been proposed such as optimized link state routing protocols OLSR and adhoc On-Demand distance vector AODV, these protocols are basically used for Mobility Ad-hoc networks (MANET) but they can still be used for VANET, but they cannot provide good performance in it [29].

Our master thesis consists of WAVE Short Messaging Protocol or WSMP that is used for safety applications in vehicular ad-hoc networks, we have computed the throughput, packet delivery ratio and packet loss ratio for different intervehicle distance and realize that fleet of vehicles that consists of 45 vehicles representing urban environment has highest level of throughput and packet delivery ratio when compared with other platoon of vehicles representing sub-urban and rural environment, at the same time resulting into more loss of packets when the intervehicle distance is approached to 1000 meters.

Similary, we have also performed simulations to compare both proacitve and reactive type of routing protocols which are used for non safety application
Among these protocols, Optimized Link State Routing OLSR which is proactive type of routing protocol in which routes for sending the data packets are defined in advance and Ad-hoc On-demand Routing protocol also known as reactive kind of protocol in which routes are establised as per demand. For the comparative study we have used the performance metrics such as packet delivery ratio, packet loss ratio, throughput and end to end delay.

simulation results show that AODV protocol outperforms in terms of throughput and packet delivery ratio where AODV maintians the level of throughput of 71 kbps for the intervehicle distance upto 700 meters and it is decreased to 66 kbps when the distance of 1000 meters is reached whereas in case of OLSR the throughput is continously in declined state, it gives the value of 60 kbps when the intervehicle distance is 400 meters which in case of AODV is 70 kbps, the level of throughput is further decreased to 50 kbps at the distance of 1000 meters where as AODV still maintians 65 kbps for the same distance,both protocol maintain throughput at moderate level for sub-arban and rural enviroment.

Similarly packet delivery ratio for AODV protocol provides better resutls than its counterpart. For example when the interdistance between the vehicle is 500 meters the PDR results for AODV at level of 97%, which is maintained to 94 % till the distance of 1000 meters is reached,where as OLSR protocol gives results into 90% of PDR value for urban areas when total number of vehicles are 45, at 500 meters and it is rapidly decreased to 56% at the distance of 1000 meters.
In the same way, simulations results also show that more number of packets are lost when Optimised Link State Routing protocol is used, packet loss is reached to 0.9 when intervehicle distance is reached to 1000 meters for urban areas where number of vehicles are 45, where as it is almost at the level of 50% for rural areas, where as there is significant difference when we observe the packet loss ratio for Ad-hoc On-demand Routing protocol which results into 9% of data packet loss for 1000 meters in urban areas where as it is dropped to 7% and 6 % for suburban and rural areas where vehicle density is 30 and 15 respectively.
At the end when we observe the end to end delay for both proactive and reactive type of routing of protocol, we realize the significant difference in it. AODV protocol has much higher end to end delay than its counterpart, it is because it takes more time for the route discovery of the packets, becasue the path to send the data packets are not established in advance but they are created whenever they are requested.
Inspite of good performance of AODV protocol for both throughput and packet delivery it has highest end to end delay.

I.2 Problem statement

The main objective of the thesis is summarised below:
To develop the Vehicle to vehicle scenario by using network simulator NS-3 which consists of following features:
Scenario: 01

- The fleet of vehicles that move with constant speed and in the same direction forming the platoon pattern.
- The intervehicle of all the vehicle is set to be constant throughout their journey.
- Each vehicle generates basic safety messages periodically which has certain periodicity and fixed payload size.
- The vehicle speed is kept constant to 20 m/sec.
- The packet size for basic safety message is kept 200 bytes and data rate is fixed as 6 Mbit/sec.
- Calculate the packet delivery ratio and packet loss ratio for the basic safety messages.
- Calculate the throughput for basic safety messages.
- Calculate the packet loss ratio for the basic safety messages.

Scenario: 02

- The fleet of vehicles that move with constant speed and in the same direction forming the platoon pattern.
- The vehicle range is kept 45 to represent the urban areas, 30 for sub-urban and 15 vehicles representing the rural areas.
- The packet size for non-basic safety message is kept 256 bytes and data rate as 8 kbps.
- The vehicle speed is kept constant to 20 m/sec.
- The intervehicle of all the vehicle is set to be constant throughout their journey.
- Each vehicle generates non-safety messages periodically which has certain periodicity and fixed payload size.
- Calculate the packet delivery ratio, packet loss ratio, throughput and end to end delay by using the Optimised Link State Routing OLSR protocol for different ranges of distance and fixing the simulation run time to 20 seconds and then vary the simulation run time from 10 seconds to 100 seconds and keep the distance constant 200 meters.
- Calculate the packet delivery ratio, packet loss ratio, throughput and end to end delay by using the Ad-hoc On-demand Distance vector AODV routing protocol for different ranges of distance and keeping simulation run time fixed to 20 seconds.
- Calculate the packet delivery ratio, packet loss ratio, throughput and end to end delay by using the Ad-hoc On-demand Distance vector AODV routing protocol by fixing the intervehicle distance to 200 meters and changing the simulation run time for each vehicle from 10 seconds to100 seconds.
- Compare the performance of both proactive and reactive protocols.
- Compute and compare throughput, packet delivery ratio, packet loss ratio and end to end delay by changing the simulation run time for each vehicle from 10 seconds to 100 seconds.

I.3 Thesis Structure

The structure of this Master’s thesis consists of the following 6 chapters:

The current one, Chapter 1, it corresponds to introduction and motivation for the vehicular adhoc networks and the problem statement for the master thesis.

Chapter 2 describes the vehicular ad-hoc networks in detail, types of vehicular communication, properties of the vehicular ad-hoc networks, functional entities of IEEE 802.11p, architecture for Wireless Access for Vehicular Environment (WAVE), Dedicated Short Range Communication (DSRC) and applications of vehicular ad-hoc networks.

Chapter 3 presents the platoon pattern of vehicles, benefits of platooning in vehicles, formation of platoon mechanism and some existing literature over platoon pattern of connected vehicles.

Chapter 04 describes the routing protocols used in vehicular ad-hoc networks, Optimized Link State Routing OLSR protocol and Ad-hoc On-demand AODV routing protocol, existing literature for their comparative study.

Chapter 05 provides the simulation results performed in NS-3 for Basic Safety Messages using Wave Short Message Protocol WSMP and for non-safety messages using Optimized Link State Routing OLSR protocol and Ad-hoc On-demand AODV protocols.

Chapter 6 provides the conclusion for the master thesis.

II CHAPTER 2. VEHICULAR AD-HOC NETWORK ARCHITECTURE

II.1 Chapter Overview

We present brief Overview about the architecture of vehicular ad-hoc network. We present the fundamentals about the vehicular communication and identify some of its key components. We also discuss the general architecture from functional point of view. In the next step we present different standards that are responsible for the vehicular communication.

Starting from the section 2.2 of the chapter we present general overview of various patterns in vehicular communication, section 2.3 describes the different characteristic of VANET, section 2.3 elaborates the functional entities of it, and we end the chapter with standard architecture and protocols.

II.2 Types of Vehicular communication

In intelligent transportation system ITS every vehicle behaves like the transmitter, receiver and it also exhibit the role of router to propagate the information within the network for the other vehicles or nodes. The fundamental responsibility of the vehicular networks is to create the communication environment for the different vehicles present in the network. When vehicle can communicate with other vehicle in direct way, we term it vehicle to vehicle communication or V2V and when one vehicle establishes the communication with other entities present in the network such as Road Side Units or RSU it is known as Vehicle to Infrastructure type communication [4].

If one vehicle wants to establish the communication with other vehicle or with RSU, it must be mounted with a radio interface also known as vehicle On-Board Unit or OBU. To collect the information about the location of the vehicles all vehicles should be installed with Global Positioning System GPS unit.

There are different ways to place the infrastructure which can be either at regular interval it could be integrated within the existing road infrastructure, the RSU distribution is linked with the protocol to be used, for example some protocol demand RSU must be distribute evenly around the road and others may work fine at the intersection of the roads only.

II.2.1 V-V Communication

The V2V is the acronym for vehicle to vehicle communication systems that are configured in such a way that it uses the multi-hop broadcast pattern for transmitting the information to different hops for sending it to intended destination. The intelligent transportation system make use of two different of inter-vehicular messages known as naive and intelligent distribution. The vehicles broadcast the periodic messages at the regular interval in the first, when vehicle the receive the messages, they can react into two different ways, if they receive the broadcast message from the vehicle behind them they ignore it and if they receive the message from the front vehicle they send their own broadcast message to the vehicle following them, which assure the movement of all vehicle is directed towards the diffusion of message [5].

II.2.2 V/I Communication

In this mode of communication, the Road Side Unit RSU is responsible for broadcasting message to all the vehicles present in its coverage area. It can provide enough bandwidth link between RSU and vehicle. RSUs are installed at every KM or less distance for maintaining the high data rates in the congested traffic. For instance, when dealing with speed limits for different traffic conditions, it determines suitable speed limit for traffic conditions. RSU is used to broadcast the message on periodic basis that contains the speed limit, if vehicle exceeds the speed limit it will send the broadcast to indicate the driver for the reducing the speed to appropriate level.

II.2.3 Routing Based Communications

It is the multi-hop unicast pattern of communication, in this form of communication messages is delivered in multi hop manner to the desired destination. If any vehicle receives the request for information, this information is sent in unicast message, which contains the information regarding the vehicle which will forward the request to the source vehicle.

II.3 Properties of VANET

VANET exhibit many properties of Mobile Ad-Hoc Networks (MANET), however there are significant amount of difference between both type of networks. We elaborate some fundamental properties of VANET [4][14] in this part.

II.3.1 Network Topology

It is established fact that vehicle moving with high speed effect the changes in the network topology. Vehicles have freedom to join the network and it can exit from the network after some time which is indication about variation in node density. In addition to that number of vehicle may vary from urban to rural area which is highly challenging for the vehicular network protocols. Other challenges include, the obstacles present on the roads which attenuate the wireless signals in crossing between the roads.

II.3.2 Mobility Model

The path followed by the vehicle and amount of traffic lanes are some of the constrained that affect the mobility of the vehicles, since the path taken by the vehicle can be predicted in advance but other factors such as obstacles, speed and traffic limit can influence the mobility model to great extent. As a matter of fact, vehicle travel with higher speeds, therefore road topology also create the constraints. Due to increased vehicle density, the protocols undergo collision and interference between communication vehicles.

II.3.3 Security and Privacy of data

The biggest challenge for the vehicular networks is to keep the data secure and privacy of vehicle must remain intact. If the network observes malicious attack it can lead to road accidents, which makes network highly unreliable. It is therefore dire need to formulate efficient communication protocols for this purpose.

II.4 Functional Entities of IEEE 802.11p

IEEE 8011p network has been designed and recommended for wireless access network. The composition of its architecture consists of several components providing interaction for wireless networks. The functional entities of IEEE 8011p architecture are given in the Fig 1 [1].

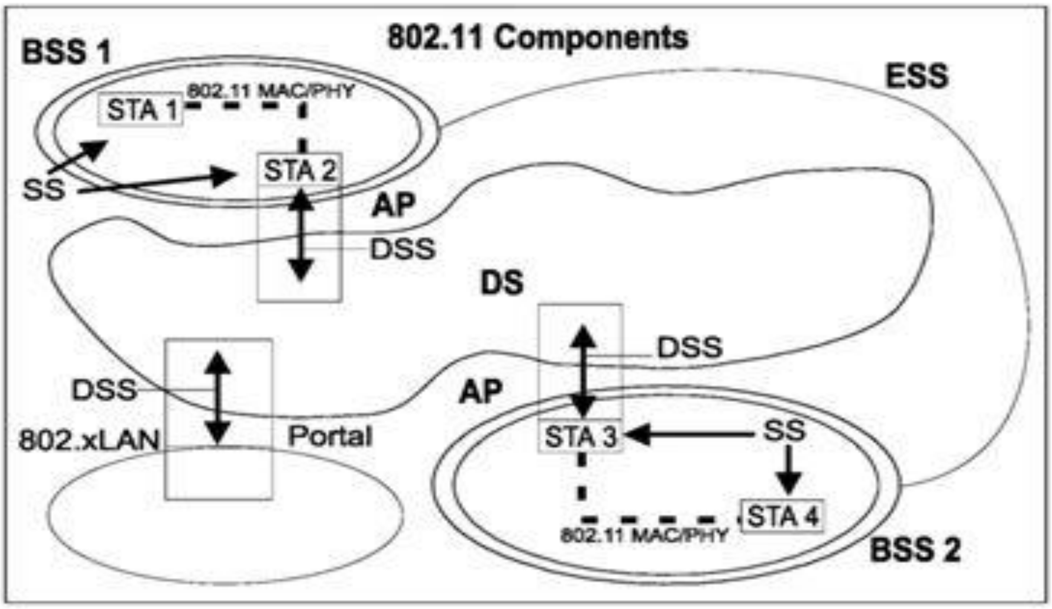


Fig 1. Functional entities of IEEE 80211.p architecture [1]

It is the group of stations that are being controlled by coordination function. It covers the limited geographical area. If any station or vehicle wants to join this group, it must apply for the synchronization procedure. The one independent Basic Service Set or IBSS can form ad-hoc network without infrastructure.

II.4.1 WAVE Basic Service Set

If the vehicles want to establish the communication between each other they create WBSS. At the first stage an RSU or OBU starts transmitting advertisement frames, node that is starting WBSS procedure is termed as provider and the receiver of these frames is called user. OBU or RSU can play the role of provider or user. WBSS has two types, persistent WBSS and non-persistent WBSS.

II.4.2 Access Point

The function of the Access Point is to establish the intrastate network, the RSU unit is being mapped with it, it is same as providing base station function in the cellular network, it establishes the connection distribution system using wireless system.

II.4.3 Distribution System

It is used to interconnect multiple BSSs. It is also responsible to establish the communication for the station to other BSS through access point.

II.4.4 Extended Service Set

It is formed when multiple basic service set are added together which is connected by distributing system. The station can establish communication within single ESS or they can shift to one BSS to another.

II.5 Architecture for Wireless Access for Vehicular Environment (WAVE)

The full use standard for WAVE as shown in the Fig 2, is based on DSRC standard. The communication is carried in a short range dedicated band using the frequencies of other standards which are not being used, hence reducing the interference. To deal the physical and MAC layer IEEE 802.11p has been recommended. IEEE 1609.1 [1] is used to process the type of message being exchanged between vehicles to vehicle or vehicle to infrastructure, it is also used to store some useful data in the vehicles. Its application related to VANET is developed for data or time, whereas security mechanism for the automotive environment is dealt in IEEE 1609.2 [1].

The standard IEEE 1609.3 [2] is meant to state the Wave Short Message Protocol which is designed as an alternate of TCP/IP protocol stack and specially designed for critical applications related to vehicles. It has been divided into high priority data that has relatively smaller time window size, whereas control channel (CCH) and service channel (SCH) are used for transmitting the messages. It gives one single channel CCH specially reserved for transmitting control information as well a safety messages and 6 CCH channels are reserved for transmitting non-safety messages.

WAVE can support both IP and non-IP applications. WSMS consumes minimum capacity of the channel and it can either be sent on CCH or on SCH.

The standard IEEE 1609.4 [2] defines the physical and MAC layer, it proposes the multichannel coordination and it is used for setting priority based traffic.

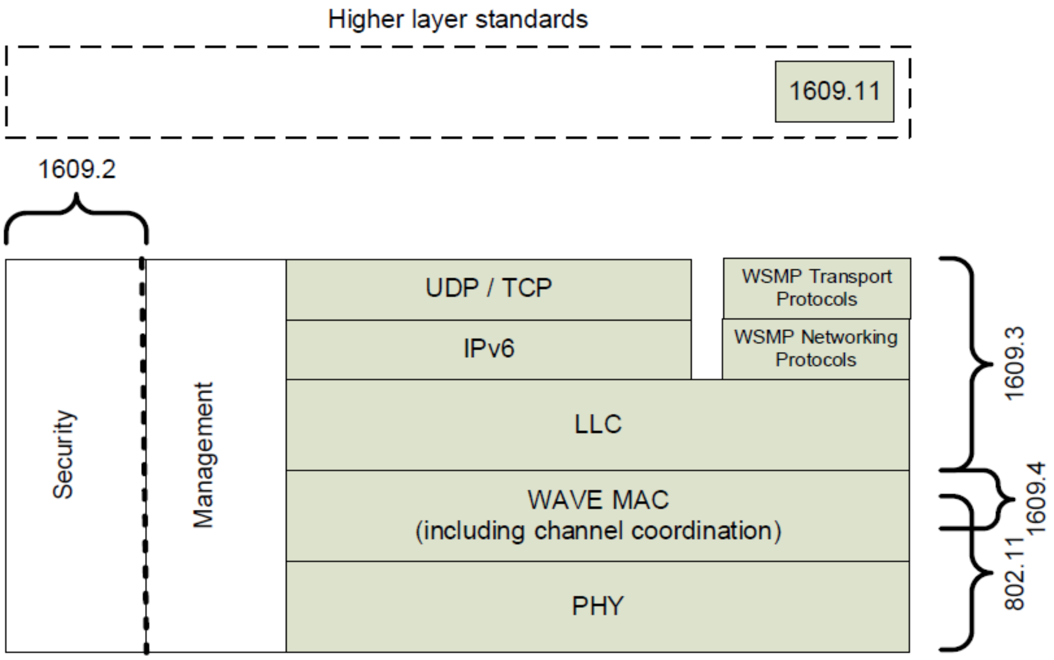


Fig 2. Full use standard for WAVE [35]

It allows all stations for monitoring the CCH for same time interval and they can shift to SCH channel for transmitting the insecure messages. Two different types of protocol stacks have been accommodated by the WAVE which include TCP/UDP and WSMP which is recommended for the wireless access in vehicular environment. Following protocols are being incorporated by the data plan, Logical Link Control, IP version6,User Datagram Protocol and Transmission Control Protocol and Wave short message protocol.

II.5.1 Facilities Layer

IEEE 802.11p supports facilities layer that aims for transmitting special purpose Intelligent Transportation System ITS messages known Cooperative Awareness Messages(CAM) and Decentralized Environmental Notification Messages(DENM), both messages are sent to Facilities Layer before they are sent to the network or transport layer. The functional architecture is given in the Fig 3.The Facilities Layer has been divided into vertical planes known as Common and Domain Facilities. The Common facilities consist of basic generic services for ITS applications some of them are addressing mode and V2X messages and CAM message management. Whereas Domain facilities specify personalized services some functions such as queues are managed depending on priority of V2X messages and verification of the relevant messages. Both plans are further categorized into three layers such as application support facilities, Information support facilities and Communication support facilities [2].

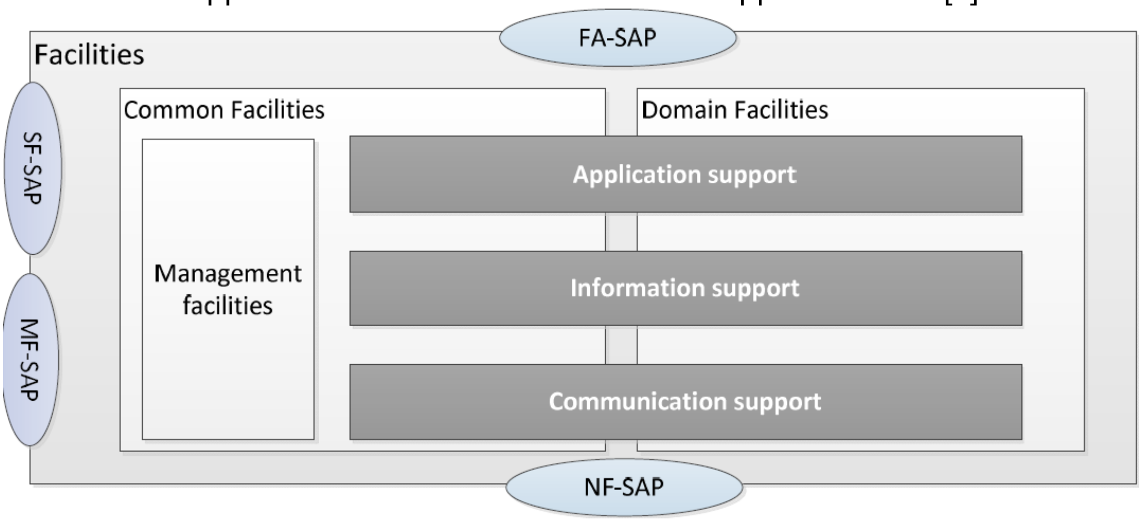


Fig 3. Facilities Layer functional architecture [2]

II.5.2 MAC Layer

The purpose of MAC-layer is to give access to reliable channel in fair manner. For instance, the safety messages must be propagated with lowest possible latency with lowest possible packet loss ratio. All this requires that channel must be share effectively and efficiently which is hard and challenging job due fast movement of vehicle and topology is also being changed rapidly.

II.5.3 Quality of Service Mechanism in MAC Layer

The QoS is used transmitting the given traffic in adequate conditions which assures the better throughput, average transmission delay, jitter and reduced packet loss rate. Network resources are optimised for critical applications. The MAC layer supports two different function, one is called Point Coordination Function or PCF for providing the centralized mechanism which is used in networks with infrastructure. The Coordination Point maintains the pool for active stations and identifies appropriate node for the transmission. The other function is known as Hybrid Coordination Function which integrates QoS with frame types, it depends on access method of EDCA.

II.6 Physical Layer and Dedicated Short Range Communication (DSRC)

American Society for testing and materials (ASTM) has defined the Dedicated Short-Range Communication DSRC[4] standard for vehicular communication, whereas WAVE has been defined by IEEE. IEEE 802.11a is the enhancement for physical layer of WAVE. The data rate supported by it ranges from 3 to 27 Mbps for bandwidth of 10MHz channel and it supports the distance range of 1000 meters. Orthogonal Frequency Division Multiplexing (OFDM) has been used as modulation scheme. Physical layer has been divided into seven different communication channels each of 10MHz which is between 5.850 and 5.920 GHz range[2]. The high priority messages such as critical information is being sent on control channel. Six other channels as shown in the figure below are reserved for the data services. The protocol allows both unicast as well as multicast. The channel arrangment for WAVE standard has been shown in the Fig 4.

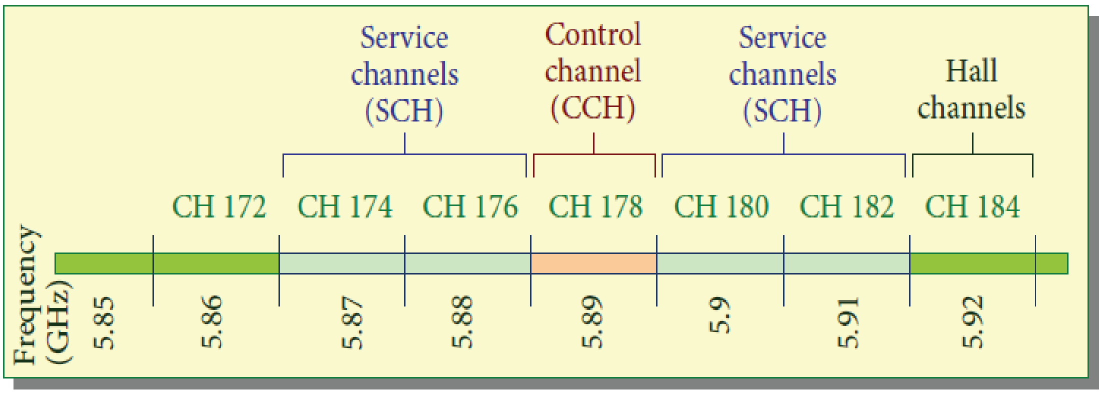


Fig 4 WAVE standard channel arrangent [11]

To accomplish the safety requirements and for avoiding the collisions the period for CCH and SCH should not exceed more than 100 ms. The European standard as proposed has the following characteristics:

1. 5.875 GHz to 5.905 GHz designed for security related applications
2. 5.855 GHz to 5.875 GHz: designed for non-safety related applications
3. 5.470 GHz to 5.725 GHz:

Operational band used for Dedicated Short Range Communication is 5.9 GHz that is specifically used for the safety purpose applications, where as in America it has been reserved 75 MHz band by the FCC within band of 5.850-5.925 GHz on the other hand ETSI has reserved the bandwidth of 30 MHz falling 5.875-5.905GHz band. The vehicle speed supported by the DSRC is up to 200 km/h and transmission range is supported for 1000 meters.

The spectrum in the DSRC standard has categorised for time intervals of 50 ms, the broadcast messages are transmitted using SCH that is assigned high priority and they are non-safety related messages they have been assigned low priority, the high priority messages such as safety related are sent on control channel CCH. In case if control channel is found to be active, the vehicles must stop their communication for this period. Dedicated short range communication also is known as IEEE 802.11p WAVE.

II.7 VANET Applications

There are wide range of applications provided by vehicular networks some of them are lane changing service, electronic emergency brake light etc. There is extensive study that has discussed the and classified the vehicular applications [17]. There are three different types of applications which are known as traffic management, safety and comfort.

II.7.1 Safety Applications

Since due to emergence of these safety applications which aim to reduce the number of accidents because these applications provide the awareness, hazard warning and assistance. Safety application are related with Active Road Safety class which provides the awareness to the drivers on road and they can issue hazard warning which can reduce road accident fatalities.

II.7.2 Cooperative Awareness or CA

In this application the derivers of the vehicles are provided information such as surrounding environment of the vehicle. Other applications may also include Emergency vehicle indication, indication when Motorbike is approaching. All these applications vehicles broadcast the messages to its neighbours to make them aware about the surrounding conditions.

II.7.3 Cooperative Deriver Assistance Applications or CDA

These applications provide the information regarding the inter-vehicle distance so that in case of applying emergency brakes the collision of vehicles may be avoided, it can also assist the deriver when he wants to change the lane on the highway.

II.7.4 Road Hazard/Collision Warning Application

It gives information for imminent collisions observed due to worst road conditions. The crash detection system makes use of radars, cameras and sensors for detecting the accidents, therefore warning is issued to the derivers which can give them to make some necessary arrangement such as moving the passenger seat etc. There are many other applications in this category we discuss some of them below:

Cooperative Collision Warning: the vehicle keeps monitoring the kinematics status coming from other vehicles for the indicating the potential threat to collisions.

II.7.4.1Electronic Emergency Brake Light:

Vehicle broadcast warning notification to inform derivers about hazard situation with least losable delay.

II.7.4.2Road Hazard Condition Notification:

When critical situation is observed for example it fog, fluid or wind is detected such warning notification is issued in the affected area.

II.7.4.3 Road Feature Notification:

When road curve is detected such notification is issued to other neighbour vehicles present in the coverage area.

II.7.5 Chapter Summary:

In this chapter we have discussed the classification of vehicular communication, which has two types, vehicle to vehicle communication and vehicle to infrastrucrue, we extended the chapter by presenting some important properties of the vehicular ad-hoc networks highlighting the effects of topology, mobility model and security and privacy aspects of VANET. We presented the architure for Wirelss Access for Vehicular Enviroment (WAVE) and Dedicated Short Range Communnication (DSRC) standrads and lastly some important application of vehicular ad-hoc networks.

III CHAPTER 3. Platooning in Ad-Hoc Communication Network

III.1 Platoon pattern of vehicle

The pattern of vehicle could be considered for extending the present capacity of the road network. One of the fundamental objective of this pattern is to organize the vehicles in tightly controlled teams, is termed as platooning pattern of vehicles, therefore main road will accommodate additional vehicles once vehicles drive in platoons compared to the manual conditions. There are vast number of implementation of vehicle platooning some of the explained in our thesis.

III.1.1 Adaptive cruise control

ACC is presently out there in several of the upmarket vehicles and its availability is assured for other vehicles close to the near future. Car makers have placed it within the market as future generation system. It can be thought adaptive and no-adoptive cruise control systems perform in same pattern if the vehicles are not following each other. Pre-set speed is conditions are maintained by this systems. In case when vehicle preceding to other vehicle has been detected, the systems adjusts the vehicle speed so as to take care of set time gap for neighbor vehicle. It is performed without direct involvement of the driver. All vehicle having adaptive cruise control systems are well equipped with a radar front. When preceding vehicle is detected by the radar it measures it speed and distance, which supports the ACC for reacting to the changes due to speed and distance and vehicle maintains the safe distance from the next vehicle [20].

The platoon pattern in vehicles can be generated if vehicle is mounted with ACC and follows the other vehicle in its neighbor. The Fig 5 depicts the adaptive cruise control system for the three vehicles connected in platoon manner.

Fig 5. platoon pattern of vehicles using adaptive cruise control system

The vehicles installed with ACC can operate autonomously, it is not necessary for the preceding vehicle to have ACC installed but to penetrate into the higher market increased number of vehicles can be adjusted in platooning.

III.1.2 Cooperative Adaptive Cruise Control system:

When radar in front is adopted to adaptive cruise control it can only discover the vehicles present in the line of sight of that vehicle which means that it can't measure distance and speed of vehicles which present in position just ahead to the preceding vehicle and vehicle behind them or in same is true if vehicle is present in the next lane of the road. This scenario is more clearly explained in the Fig 6.

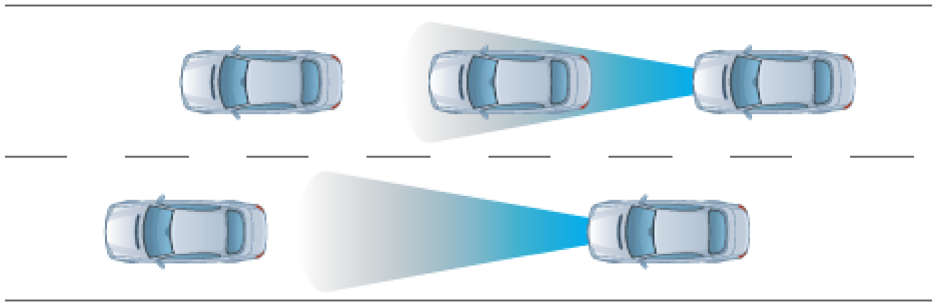


Fig 6. Adaptive cruise control view of front radar

When any of the above discussed condition is hold the information reaches to platoon vehicles with increased delay. For example in case if first vehicle applies the brakes, it can be detected by the second vehicle and react to it with some delay but the third vehicle is not able to detect the changes due to speed of the first vehicle therefore reacting only after detecting the behavior of second vehicle. To eliminate this shortcoming the notion of cooperative adaptive cruise control CACC has been presented which adds the ACC wireless communication and some control logic as well as GPS system as shown in the Fig 7.

Fig 7. Platooning of vehicles by using Cooperative Adaptive Cruise Control

Wireless communication enables the vehicles for extending its view beyond light of sight of radar. In addition of CACC third vehicle as shown in the figure above issues the notification through wireless communication about the pattern of vehicle leading to it, and third vehicle may easily reacting to speed change of the first vehicle present [20].

III.1.3 Automated highway system:

As discussed in above two system the driver has to play some role to operate the vehicle because he has the steering control of the vehicle, the alternative to it is known as automated highway system which is fully automated. As per [20] this system is designed for such system where cars with full automation or other vehicles are being guided to reach to destination and optimizing flow of traffic which can also lead to enhanced traffic safety.

III.2 Advantages of platooning in vehicles:

Platoon pattern of connected vehicles offer several advantages. Some of them are enhanced road capacity improvement in the traffic safety and increased deriving comfort. We present some important advantages for the vehicle platooning in detail.

III.2.1 Road safety

The fundamental benefit offered by the vehicle platooning is increased capacity of the road network. It can be achieved when vehicles operate closely which not possible with manual deriving due to increased risk of accidents among the vehicles. The findings conducted by VnaderWerf, et al, concentrated about the impact of capacity due to enhanced penetration of adaptive cooperative adaptive cruise control systems with respect to manual way of driving [20]. The simulations performed at microscopic level covering distance of 16 KM and one lane highway and on-off ramps of every 16 Km. when manual composition of driving used1.4 seconds time gap and vehicles with full CACC properties with 0.5 time gap, which resulted into nominal capacity of 2100, 2150 and 4250 vehicles present in lane per hourly basis. When more realistic scenario was created by mixing the vehicle, it resulted improved highway capacity due to ACC and CACC, but ACC had created less impact however capacity was increased to 7% as compared to manual driving. It is achieved because smooth traffic flow instead of operating vehicles with some gaps. The time gap of 1.4 seconds is found as modest in comparison to the average time gap of 1.1 seconds with manual control. It showed that CACC can increase the capacity in particular with increased market penetration. This phenomenon explained requirement of CACC system of having preceding vehicle must transmit information to the following vehicles. In case preceding vehicles is not installed the system acts like ACC.

III.2.2 Decrease in environmental impacts

The emission of greenhouse gassed has also been by transportation system which releases approximately 30% of total CO_2. One of the solution to reduce the environmental pollution is to platoon pattern of connected vehicles. When vehicles operate close to one another they reduce the air resistance resulting reduced fuel consumption. It carried in wind tunnel tests and some filed experiments [21], which showed that correlation between the platoon vehicles which saved fuel consumption to the positon of the vehicle in platoon and operational distance. When vehicles operate in front and back, they save approximately 10% of fuel having their inter vehicle distance 3 to 6 meters.

III.2.3 Enhanced safety:

Human errors are one of the major causes of the road accidents. Some of the reasons could be driver is distracted or has fatigue are basis of human error.

Platoon pattern of connected vehicle can reduce them resulting improved traffic safety. Technology used by platoon connected vehicles are able to detect the critical situations well in advance thereby reducing fatalities due to road accidents.

III.2.4 Lateral Control

He function performed by lateral control is to steer the vehicle that is the responsibility of the human drive share the responsibility in ACC and CACC. Lateral control is set to be automated for driverless vehicles. One of the fundamental responsibility of the lateral control is keeping vehicles at center of the road.

III.2.5 Lane Tracking

Due to this function Vehicle are kept at the center of the lane, which requires much accuracy. It can be obtained if lateral position of the vehicle is known. It can be calculated by permanent magnet tracking, or it can be achieved by means of computer vision and differential global position system DGPS which is the enhanced version of GPS.

III.2.6 Lane changing

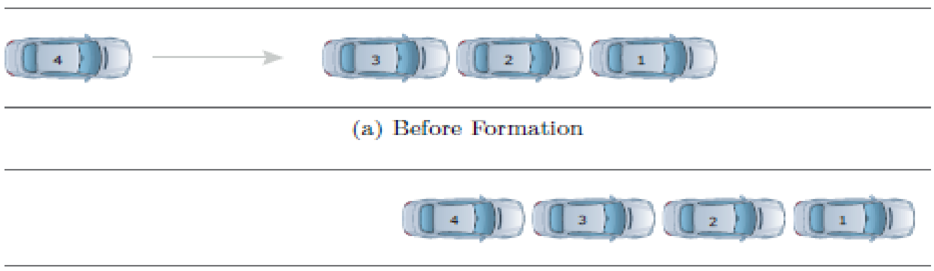
This functionality is used for steering the transport from its current lane to the next lane. It is one of the challenging function performed by the lateral control due to involvement of the vehicle dynamics, the changing of radar front target as well as coordination between other vehicles. This task is performed with the help of magnet tracking system which is used to guide vehicle to the neighbor lane, it is same as railroad switch used in trains. Only those lanes are changed where guiding magnets are installed.

III.2.7 Maneuver Coordination

The purpose of maneuvering coordination is to form and split the platoons as well as they are used to merge the traffic streams and coordination of lane change.

III.3 Formation of platoons.

It is the mechanism used for two or more than two platoons are merged into single platoon. This situation is explained in the Fig 8, where one of the vehicle is accelerated for joining he platoon.



(a) Before Formation

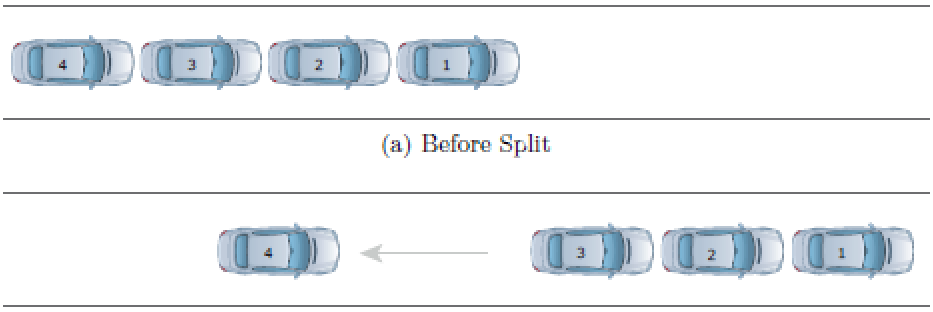
(b) After Formation

Fig 8. formation of platoons

The figure 8 explain the situation where vehicle coming behind joins the platoon which not the only way to be part of the platoon but it can also join in the middle or it can also join in front of the platoon.

III.3.1 Splitting of the Platooning:

It is the situation where any vehicle intends to leave the platoon. This condition is explained in the Fig 9 where vehicle 4 is leaving the platoon.



(a) Before Split

(b) After Split

Fig 9. platoon split situation

III.4 Literature review for platoon pattern of connected vehicles.

In [9] performed the analysis to use over connected vehicle technology (CVT) according to dramatically enlarge the potential over town roads primarily based on the easy concept that postulate CVT perform enable organizing cars between platoons, the capability regarding a section do stay multiplied by means of a component of two after three.
Their work explained how platooning pattern of connected vehicles can enhance an intersection's potential by means of increasing its saturation go with the flow rate, moreover queuing network model has been studied by them to show so much the increasing the flow rate for saturation by a component do assist an make bigger among claim in the identical proportion, including no alternate into the signal control, eventually the ascertain it predictions through simulation exercise. They have also presented the practical challenges for implementing the platoon pattern of connected vehicles. When the vehicles presented in the platoons are passing the intersection with selected head way timing of one second the flow rate saturation was found to be 3,6000 vps, which is almost double that is seen in current intersection conditions. There are many such experiments have been carried out which have found that such type of head way can observed through CACC which has not been standardized in current vehicles yet, but it has the ability of increasing ACC for vehicle to vehicle communications. The could requirement of extra logic necessary for the platoon of connected vehicles. The platoon must either be start when the first driver starts moving or it should move after green signal of the traffic controller. The platoon could be broken either due red signal issued by the controller or CACC mode was disengaged. There are multiple questions left unanswered like the intersection can provide the target speed? Is there any need to recommend the maximum or minimum size of the platoon? Do the vehicle should still be connected in platoon pattern after they cross the intersection point.

In [20] it is proposed that management protocol for the platooning for the CACC used in vehicles using wireless communication by using VANET technology. The protocol included some basic manoeuvres for platooning and some micro level commands for accomplishing the manoeuvres. Many platoon operations for example entrance of vehicle including the platoon leader and exiting from platoon can be obtained with the help of these manoeuvres. They used the Finite State Machine (FSM) to conduct these operations which can be applied to the collaborative type of driving as well as to the intelligent highway system, their simulation work was carried out with platform named VENTOS, which is developed in SUMO and OMNET++. The effectiveness of their approach has been shown by means of simulations performed by calibrating different platoon settings.

In [12] presented the advantages of data received using vehicle to vehicle or vehicle to infrastructure communication for evaluating the performance of autonomous platooning concept. The explained making use of CTHP type controller receiving the data from multiple predecessor connected vehicles and observed that platoon as robust and decreased time headway which increased the platooning capacity and found that by using V2X type communication for feedback information obtained from predecessor connected vehicles has benefits if proper spacing policy has been employed. Further, the sure on the time headway might not be tight and there is also a chance of reducing it furthermore. Hence, an attainable future analysis direction is to search out such bound.

In [31] have explained some of the more efficient technologies for the automated platoon and discussed the potential challenges in relation to wireless networking. There are still many issues open and be investigated with great care before they are implemented in actual system. They have suggested the solutions or it.

In [17] have explored the tradeoff between efficient and secure VANET. They have recommended many techniques such as joined signature, overlapped groups as well as dynamic group formation. They evaluated performance of concatenated signature which is type of combined signature. Their results showed that secure aggregation is one of the most promising technique to enhancing the efficiency of the channel and decreased delay for the messages delivery in VANETs. They concluded that data correctness can be achieved by aggregation for higher level of security.

In [16] presented the survey about some of the latest vehicular applications that include sensor-based vehicles to entertainment. They have studied the architecture based different wireless protocols that include DSRC, WiMAX and 3 G and presented novel characteristics of vehicular communication. They classified point to point applications of VANET describe the role of vehicle for managing the information being source of it or being its consumer. For data source method described the technological applications for vehicular sensing whereas for consumer scenario they summarized application based on contention distribution for example advertisements or media files and for video streaming purpose they examined the emergency point to point application.

In [17] In this paper new protocol for delivering reliable and fast safety messages with the help of control channel of DSRC is introduced and examined. Many core techniques are joined as integrated schemes for increasing the performance and broadcast safety message reliability which is based on cross layer priority setting of the message, dynamic receiver based and packets repetition, relay and AD timer which is based on distance for multi hop broadcasting. They formed protocol that permits the control channel for delivering three categories of safety type messages with the desired QoS and is straightforward to implement. Additionally, analytic models, and simulation models are formed and analysed and investigated the performance of the protocol to know how reliable it is. They have considered for the hidden node problem as well as fading environment of the channel, arrival rate of the messages and backoff counting process for performance and reliability. They presented the analytical results from deigned model were related closely to computer simulations. Their recommended setting for the priority message has been shown effective for improving the reliability as per application requirement and when it is compared with other traditional schemes for VANET safety related it is more robust for distributed vehicular environment.

In [21] showed the results taken from field measurements for vehicle to vehicle communications which is based IEEE802.11p. measurement were carried out during the vehicle movement without presence of obstacles present between source and destination based on non-line of sight environment and urban and highway condition were considered. They used the performance metrics like packet error rate and packet loss. Results compared with platoon application requirements which shows platoon applications are not supported by it.

In [11] proposed a technique to achieve communication for vehicular networks with cooperative strategy using fixed density of vehicles making use of VI and V2V communications, both mobility and vehicles cooperation have increased throughput. Detail analysis for the maximum throughput was showed and equation of closed form for maximum throughput is calculated in three different ways, their assumption is based on the relation between the data rates of V2I and V2V communication and vehicle speed.
mathematical and results based on simulation confirm about the proposed strategy for vehicle cooperation can enhance desired throughput in low traffic density. Results showed that analysis is extended able to other realistic models for example time-changing channel model with fading and path loss as well as log normal shadowing model.

In [15] This paper focuses for reducing the losses in BSM messages due collisions in IEEE WAVE standard. They have recommended protocol called NCR and is analytically evaluated. For fast transmission of packets Short Tree Routing techniques is proposed for messages carrying more critical information with minimum possible of losses and increased reachability.

In [19] analytical model has been proposed to evaluate 802.11 adhoc network based on broadcast not assuming the saturation condition that does not hold for related application in vehicle to vehicle communications, they have added M/G/1 queue which is discrete model for safety messages which occur occasionally. Using recursive algorithm and probability generation function solution is achieved. They have many performance indices for said broadcast service like PDR, throughput and packet delay. Proposed analytical model has close results to the simulations, delay requirements are achieved for DSRC for typical environment using direct broadcast network which does not guarantee reliability due to message collisions, throughput is improved by increased packet arrival rates but PDR and loss ratio are degraded, they have also shown reliability of broadcast messages is achieved by using higher back off window size and reducing the size of the message.

In [23] this paper has presented the detail study regarding vehicle cyber physical systems based on platoon pattern of connected vehicles, they have architecture and standards and platooning analysis using mobility model and control techniques of platooning and pointed basic problems using VCPSs platoon concept. These issues are cluster management for platoon, achieving cooperation in platoon driving. They have presented efficient simulator to verify the system.

IV Chapter 4. Routing Protocols used for VANET

Due to increased level of mobility of vehicle present in the vehicular ad-hoc network system, designing of efficient routing protocols for computing and maintaining the routing paths more efficiently has been a great challenge for the research. There are many protocol have been designed that were initially developed for mobile ad-hoc networks can also be used to evaluate the performance of VANET system. We present some protocols used for VANET, these protocols have been classified into different categories. topology based, position based, and some are infrastructure based and cluster based [27].

IV.1 Ad-hoc Routing Protocols based on Topology

The protocols based on routing topology were recommended for Mobile Ad-hoc Networks in the past but are also being used for Vehicular Ad-hoc Networks with some adjustments. There are two different types of protocols which fall in this category, proactive routing protocols which use the technique for maintaining their routing table that contains the information about topology and this information is exchanged on periodic basis, other type is known reactive type protocols reactive type of routing protocol which works distributed fashion where it is not necessary for the source node to store the information about the entire path and intermediate nodes in order to transmit the data packets from source to destination.

In our work we have used two different protocols one from each category, named as Optimized Link State Routing Protocol OLSR and Ad Hoc On-demand Distance Vector or AODV, we illustrate their working principle and compare their performance in this section.

IV.2 Optimized Link State Routing Protocol OLSR

OLSR routing protocol is proactive routing protocol which means that its routing table is always maintained with available routes. One of the fundamental objective of this protocol is reduce the number of retransmission duplicates. This protocol is forwards the packets on hop by hop basis [24]. This mechanism is achieved by exchanging the periodic topological information with the help of Multi-Point Relay or MPR. Some of the additional features of the OLSR include the sensing of neighbour, HELLO and control messages (TC). The multipoint relay offers some of the benefits when used in topology which include decrease in number of control messages in the network which decreases the control overhead information. The working of multipoint relay has been illustrated in the figure 10. It is shown that it uses control messages on periodic basis for advertising the information about the status of the links to the other nodes present in the network [33].

As shown in the Fig 10, HELLO message has been broadcasted periodically by each of the nodes present in the network for sensing the link as well as for detecting its neighbour and to select the multipoint relay. The process in which any two nodes present in the network consider each other being their neighbour is called the neighbour detection process. It is obtained by establishing the symmetric links. The information contained in the HELLO message is address of the node and other node present in its neighbourhood. Each node is able get information from HELLO message up to two hops. The Multi-Point Relay selection process utilizes the information of hop by hop to calculate the MPR. It is achieved when there is notices any change in the first and second neighbour of the topology. When MPR gets the update information, every node calculates the node again sends updated information to tis destinations. The topological information is being broadcasted by a TC messages but is only forwarded by the MPR to other nodes..

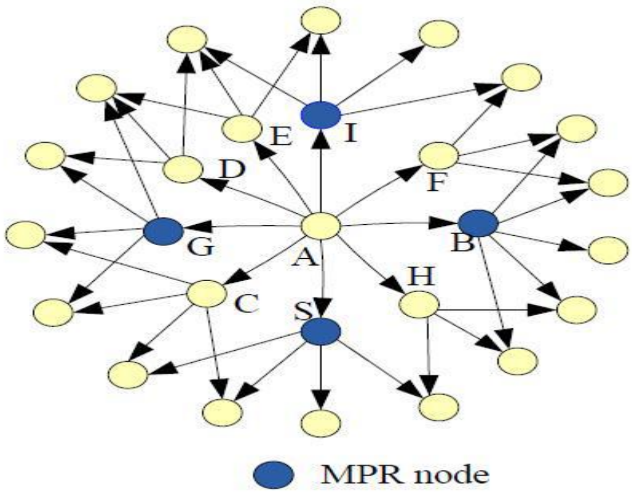


Fig 10. Multi-Point Relay used in OLSR [34]

The illustration of OLSR routing protocol is given in the Fig 11, where the entire process of sending the packets from the source node to the destination has been shown. In the first instance, route from source to destination is checked by the algorithm in the available routing table. If no information about the route is present, the source node prepares the broadcast message to the all alliable routes. As per proactive nature of OLSR protocol, the route must exist in the routing table well in advance which is establish by sending HELLO message for informing the destination node that source is ready for sending the packet. Once the source node receives the route reply message it starts transmitting the data packet. In case of failure of any node occurs, a TC message is transmitted to update the possible topological changes occurring in the MPR node.

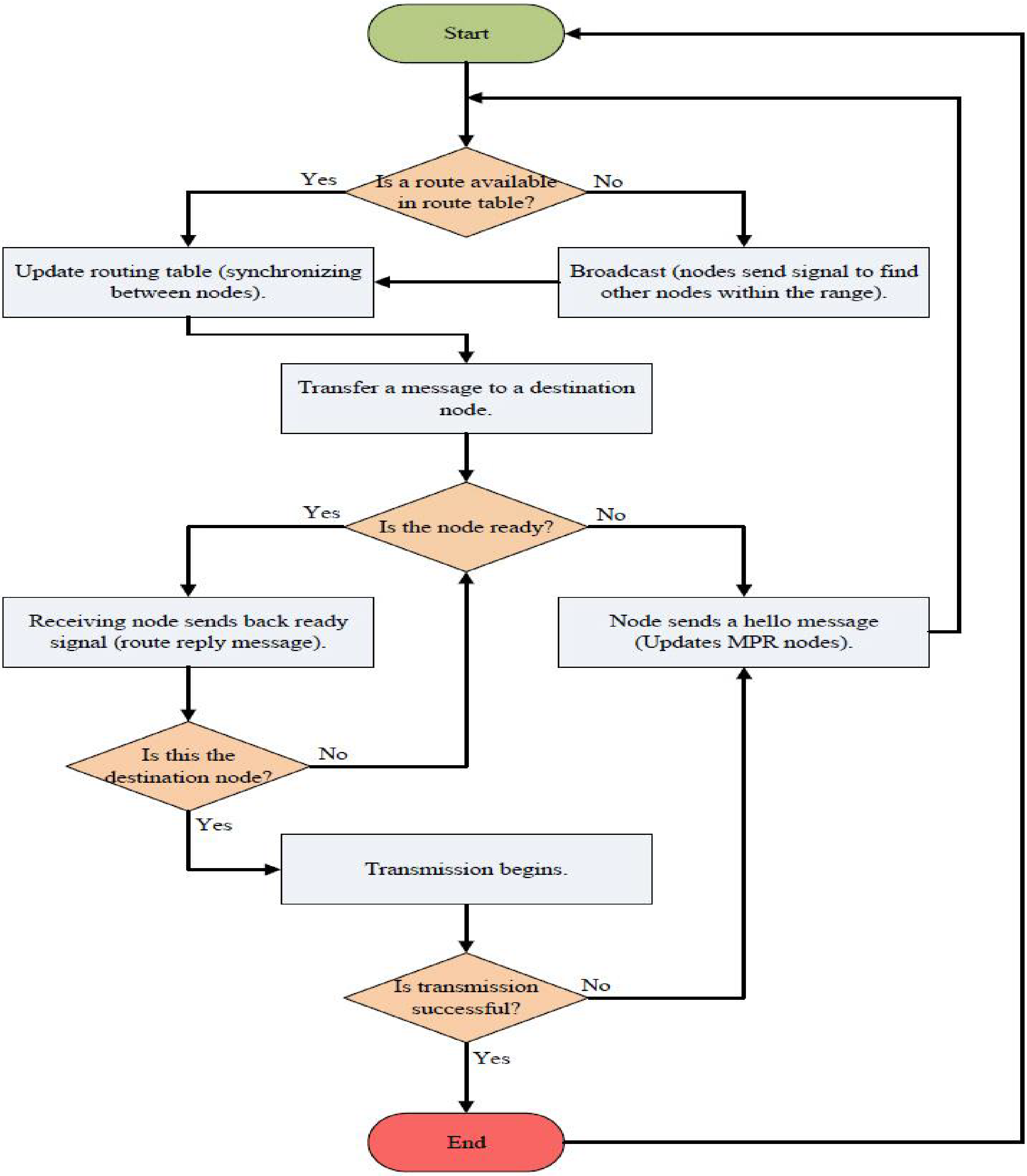


Fig 11. Routing Algorithm of OLSR Protocol

IV.3 Ad Hoc On-demand Distance Vector or AODV

It is the reactive type of routing protocol which works distributed fashion where it is not necessary for the source node to store the information about the entire path and intermediate nodes to transmit the data packets from source to destination [28]. AODV protocol stores the information in the routing table at every node, and information of one or two most recent routes are stored. the periodic beaconing messages are used by this protocol, and routing is performed in hop by hop style, periodic beacon messages are used to determine the identity of its neighbouring nodes where as it used also uses the sequence numbering to make sure for loop free routing, it is able to minimize the size of the routing table as well as the process of broadcast once the routes are determined.
There are two different approaches available for discovering the route process, they are explained below.

IV.3.1 Route Discovery Mechanism

When any node must transmit the data packets it starts the process of route discovery in first instance. It sends the route request message (RREQ) through the network. The RREQ message consists of source and destination node address, source and destination sequence number, number of hops and broadcast ID. When source adress and its broadcast ID are combined it forms the message called for requesting the route. During the route discovery process two pointers are set between source and destination at intermediate nodes. Set of pointers are forwarded for requesting the routes and to send the packets from source to destination, on other hand back pointers transmit away a message replying in opposite direction.

IV.3.2 Route Maintenance Mechanism

This is achieved by the help of HELLO messages. It consists of HELLO, route error message RERR and route timeout message. For avoiding the forward and reverse pointers being discarded HELLO message is periodically used. when there is no activity found for certain period which results into route being deleted from the routing table route timeout message is used for this indication. In case of link failure from any node, a route error message or RERR is started which broadcast the error packet.

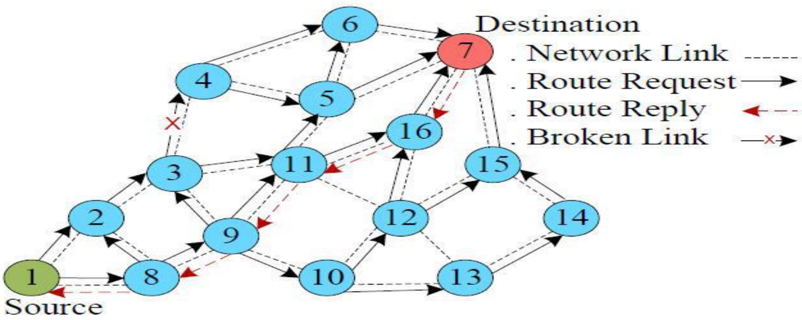


Fig 12. Routing Mechanism of Ad Hoc On-demand Distance Vector Routing protocol

This process is explained in the Fig 12, it is showed that link between the node number 3 and 4 is broken, in this case the node sends message directly for recovering its route. When the link is failed repairing for the route is carried by means of local as well as global route repairing. The local route means that very next node attempts to recover the route, when the route is not achieved by the neighbour node it sends this information to the source node for starting global route repairing process. One of the disadvantages of this reactive type of protocol is lot of time consumed during route construction process which increases the end to end delay for the messages delivery, this is also illustrated in our simulations.

The flow chart as shown in the Fig 13 has explanation of this process adapted for sending the packets from source to destination node, it also explains the process adopted in case of observing the error. As explained in the algorithm, the connection is established when route is existing for the destination and node starts transmission data packets, but when destination path is not available broadcast message will activate the global route repair process from source node.

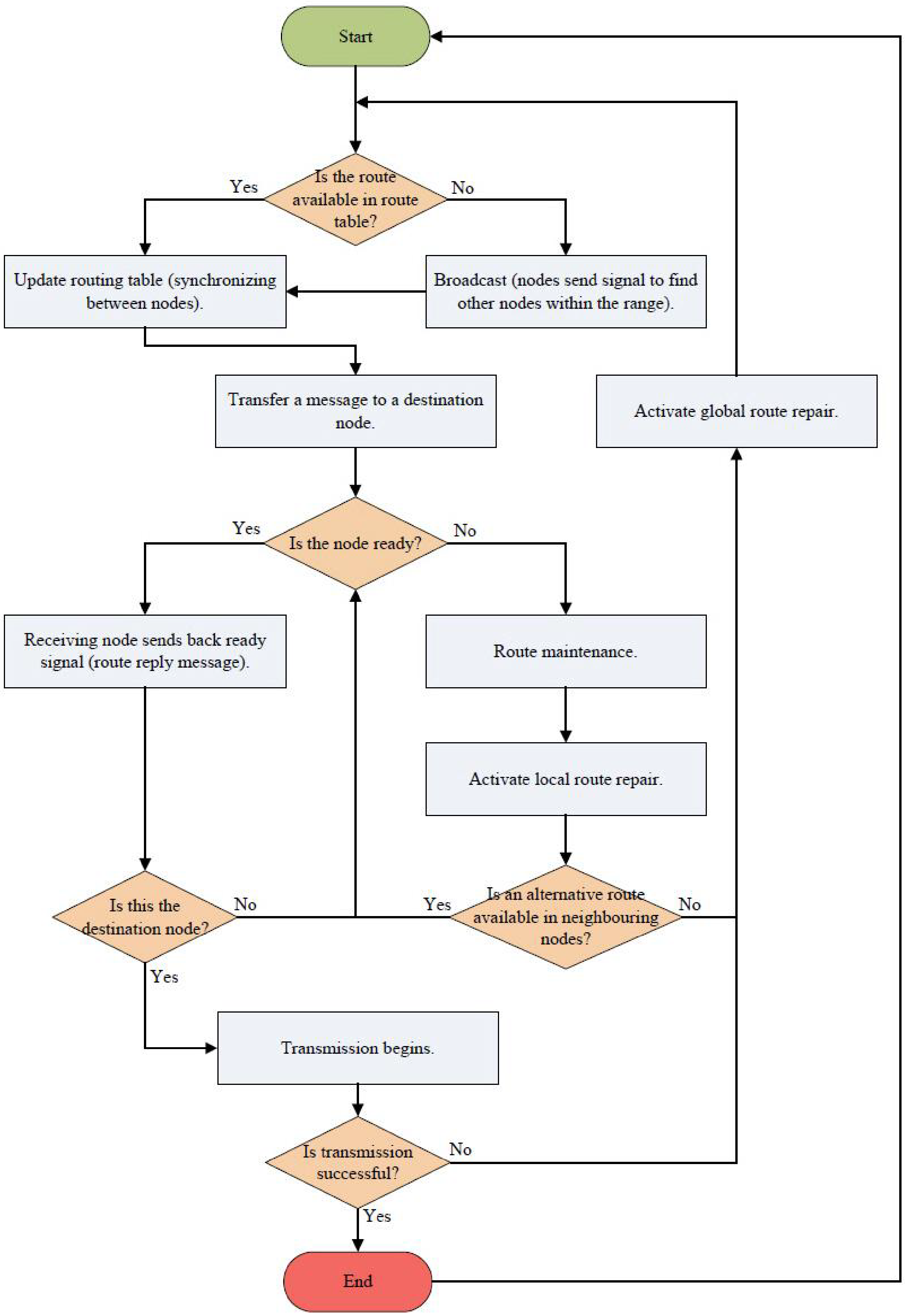


Fig 13. Routing Algorithm of Ad Hoc On-demand Distance Vector Routing Protocol

IV.4 Literature review for performance evaluation of routing protocols

In [24] authors have evaluated the performance of three protocols which are mainly topology based and considered as proactive and reactive protocols. These protocols include AODV, DSDV and DSR. They have evaluated the protocols by increasing the node size. They used the performance metrics including throughput, PDR and delay and concluded that reactive protocols can achieve better performance as compared with proactive protocols. Moreover, topology-based protocols are less likely to perform as compared with position-based protocols.

In [25] authors have presented the performance of AODV, OLSR, DSDV and DSR protocols. They have used the PDR, throughput as their performance metrics. They have used different values for the pause time for their analysis. Their result show that Optimized Link State Routing has better throughput among all other protocols when used for different vehicle densities. All the protocol used in study showed the consistence performance with respect to throughput even if at different values of pause time and varying number of nodes. Whereas Destination Sequenced Distance Vector undergoes highest change due varying pause time also PDR as well as throughput has lot of variation as compared to other protocols.

In [26] it has been presented the comprehensive comparison for OLSR, AODV and DSDV routing protocols used in VANET for the safety related environment. The simulation results have shown that DSDV protocol has been used for MANET for great extent, but it can be used for safety related applications and on the other hand other protocols like OLSR and DSDV and not achieved the expected performance.

In [27] paper three different routing protocols have been evaluated using VanetMobiSim as simulator, the protocol included AODV, DSR and DSDV. Different driving environment have been used by making clusters as well as different road characteristics have been used such as road lane and traffic lights. The study evaluated for different transmission ranges, number of vehicles and different speeds. AODV has obtained much better network node sharing. The DSR protocol showed better performance at specific values only.

In [28] paper two different routing protocols known as OLSR and AODV we evaluated for vehicular ad-hoc networks. They have used the vehicular mobility model to characterize the vehicles. The clustering and intersection effects have also been considered. It is also shown that starting and maximum velocity does not affect the performance of the routing protocols when used in urban environments. In fact, when intersection applied with spatial environment, the vehicles present in the neighbors observe negligible decay in speed which is independent of network velocity. Increased vehicle density result into some consequence has been testing to evaluate the performance of the routing protocols. They have done evolution of protocols against vehicle density and data rate. It is realized that OLSR has outperformed as compare with AODV protocol for VANET environment. The overhead calculated for the OLSR resulted into smaller values when compared with AODV, same is true for end-to-end delay and the lengths of the routes. For the packet delivery ratio OLSR has better result to a certain threshold which has the limit of 10%,

In [29] paper it has been presented that tuning parameter used in OLSR protocol through some automated too for optimization. They have coupled the NS-2 simulator with optimization algorithm (GA). Optimized results are validated with comparison to standard tuning, they have QoS scenario for VANET. The results obtained by tuned-OLSR have better than OLSR, which increased the throughput, packet delivery as well as decrease in delay. It has been achieved by using simulate annealing algorithm as well as particle swarm algorithm.

In [30] authors have evaluated the performance of four different protocols OLSR, AODV and DSR, DSDV with different performance metrics. Their analysis shows that DSR protocol have shown best results in terms of packet delivery ratio, throughput as well as achieved the lowest end to end delay among all protocols. The performance was examined by using varied size of nodes, varied speed and different size of the network. When mobility condition is increased the performance of DSR protocol gives results for packet delivery ratio same is true for the network size below 600x600sqm. When the size of the network is further increased the OLSR protocol gives better performance in terms throughput and packet delivery ratio under increased mobility environment.

V Chapter 5. Simulation & Results

In our project we have used four different classes of NS-3 simulator to complete our scenario. RoutingStats is used to store packet information for the routing or IP based messages and it contains the information like (Transmit Packets, Received Packets, Transmit Bytes, Received Bytes, PDR) whereas WaveBsmStats class is used to store packets information like (Transmit Packets, Received Packets, Transmit Bytes, Received Bytes, PDR) for the basic safety messages.
We have used the routingHelper class to control our scenarios (like routing protocols, packet size, data rate, loss model, number of nodes, distance, speed and mobility) and vanet class has been used as main class to control over all program in which all configuration of project is performed. It is used to set the simulation time, to conduct the average of the simulation and for generating the graphs.
There are two different scenario that we have implemented in our work. First scenario consists of fleet of vehicles moving with constant speed 20 m/s with constant simulation time 20 seconds. All vehicles are moving in platooning fashion as depicted by the NS-3 diagram in the figure. As we see all the vehicle are located in the one row observing the platoon pattern.

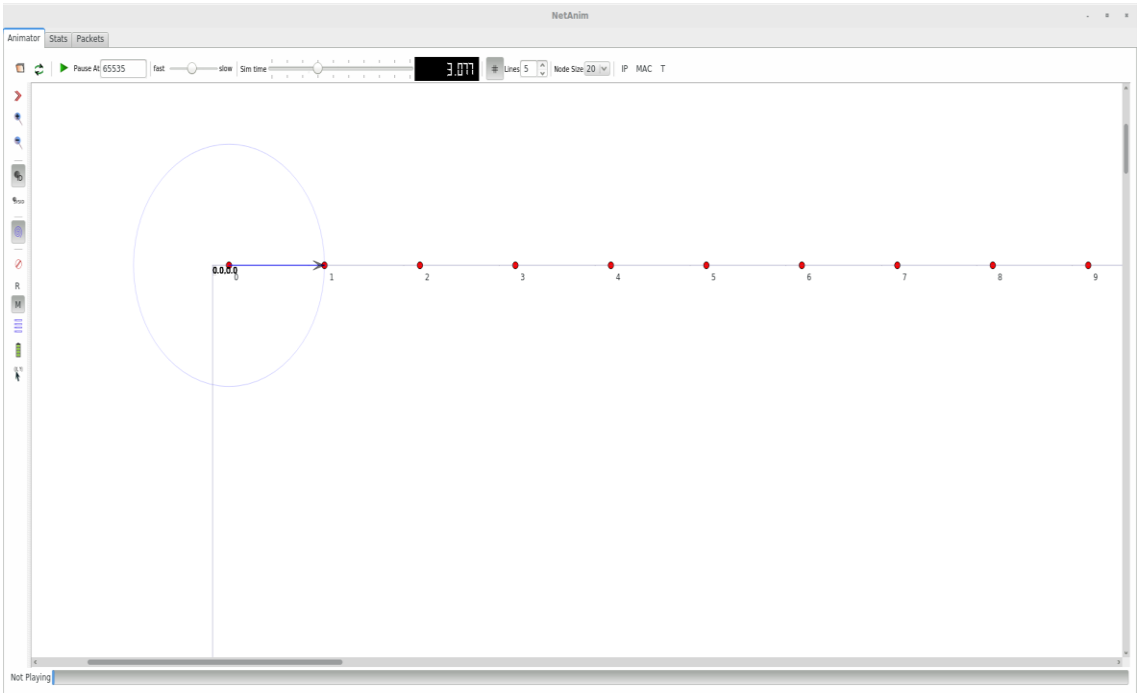


Fig 14. Platoon Pattern of connected vehicles in NS-3

The vehicles generate two different types of traffic. In first instance, they generate periodic messages and each vehicle is able to generate 10 basic safety messages per second, the inter-vehicle distance between the vehicles is kept 20 meter throughout their journey. For non-basic safety messages, we have used two different protocols Optimised Link State Routing OLSR and Ad-hoc On-demand Routing AODV to generate the routing traffic, each vehicle generates one to two messages per second. For BSM messages the packet size is kept 200 bytes with data rate of 6 Mbits/s, and similarly for non-basic safety messages the

packet size is kept 256 bytes and data rate is 8 Kbits/s. we have used fries loss propagation model along with nakagami fading for the channel.
We have used three different categories of nodes that consists of 15,30 and 45nodes. We have run simulation for 100 times to calculate the average values for all the metrics we have selected.

Table 1 Parameters used for simulations

Parameter	Value
Platform	Linux Ubuntu 16
Simulator	NS-3 V 3.19
Animator	Netsim
Routing Protocols	OLSR & AODV
Packet Size	200 bytes and 256 bytes
Data Rate	6 Mbits/sec & 8 Kbits/sec
Transmission power	20 dB
Propagation loss model	Friis propagation model
Fading model	Nakagami fading
Number of mobile vehicles	15, 30 & 45
Vehicle Speed	20 m/s
Traffic Type	CBR
Simulation Run Time	20 seconds

V.1.1 Propagation Models used in NS-3

In order to simulate the mobile radio system, propagation model is one of the key element that is used to determine the characteristics of the channel. The aim of using propagation path loss models is for predicting the different characteristics of the wirelss channel such as signal strenth, multipath effects and interference if it exists. NS-3 release 3.19 has four differrent propagation loss models included in its library. These propagation models includes, two-ray ground, ITU-R 12, log distance and Friis propagation model. In our simulations, we have used Friis propagation loss model which is briefly described here.

V.1.2 Friis Propagation Loss Model

The friis model is described by the following equation

$$P_r = P_t G_t G_r \left(\frac{\lambda}{4\pi R}\right)^2 \qquad \textbf{1}$$

The two antennas, where $\boldsymbol{P_r}$ is the received pwer, $\boldsymbol{P_t}$ is the transmitted power, $\boldsymbol{G_t}$ is the gain of the transmitting antenna and $\boldsymbol{G_r}$ is the gain for receiving antenna, $\boldsymbol{\lambda}$ is the wavelength and R is the distance between the antennas. The factor contained in the parentheses is known as free space path loss. The equation can be written in the units of decibels as

$$P_t = P_t + G_t + G_r + 20\, log_{10}(\lambda/4\pi R) \qquad \textbf{2}$$

V.1.3 Multipath fading model for simulations

In our simulations we have selected, Nakagami fading propagation loss model, this option of using fading model is given in library by default. The Nakagami fading takes into account the various changes in the signal which occur due to multipath fading, it consists of different equations for short and long distance transmissions.

V.2 Scenario 1 Basic Safety Messages BSM

We have used three different metrics to calculate the performance of the basic safety messages. We have used throughput, packet delivery ratio as metrics, we also analyse the packet loss ratio by calculating the number of loss packets during the transmission.

1. Throughput:

we have calculated the throughput for our scenario as following

$$Throughput = \frac{\frac{totalBytesRecieved * 8}{1000}}{totalSimTime} \quad (3)$$

2. Packet delivery ratio:

According to ns3 library we are calculation Packet Delivery Ratio by applying this formula due to node movement, it is possible to receive a packet that is not slightly "within range" that was transmitted at the time when the nodes were slightly "out of range" thus, prevent overflow of PDR > 100%. If distance is increasing delivery ratio is decreased because some nodes didn't receive packets. We have not used pause time to stop vehicles in that condition delivery ratio is increased for little time.

$$PDR = \frac{received\ packtes\ (in\ range)}{transmitted\ packets\ (in\ range)} \quad (4)$$

3. Packet loss ratio

First, we calculate loss packets by using this formula:

$$LossPackets = TxPackets - RxPackets \quad (5)$$

Then we calculate loss ratio:

$$LossRatio = \frac{LossPackets}{TxPackets} \quad (6)$$

Or

$$LossRatio = \frac{LossPackets}{RxPackets + LossPackets} \quad (7)$$

Performance evaluation for Basic Safety Messages:

V.2.1 Packet delivery ratio PDR over different ranges of disances and for multiple nodes:

In the Fig 15, we have calculated the packet delivery ratio for the range of 1200 meters and we have selected three different categories of nodes, for example we have taken 15, 30 and 45 nodes or vehicles. Each node is generating 10 packets per seconds and packet delivery ratio is calculated as cumulative packet delivery ratio for all 15 nodes. We can see that for the lowest distance the PDR is observed to be highest value. It is because when the nodes are initially in rest position, as the vehicles start moving, and the distance between the vehicles starts increasing. We can notice significant decrease in the PDR after 200 meters and for 45 nodes as they approach to the distance of 1000 meters their PDR gets zero that proves the range of the wave protocol is 1000 meters. The stars on the line show the different values for the average simulations.

Hence from the above graph we conclude that, as the number of nodes is increased there is more collision between the packets is observed and packet delivery ratio is decreased significantly when the inter distance between the vehicles is approaching to 1000 meters.

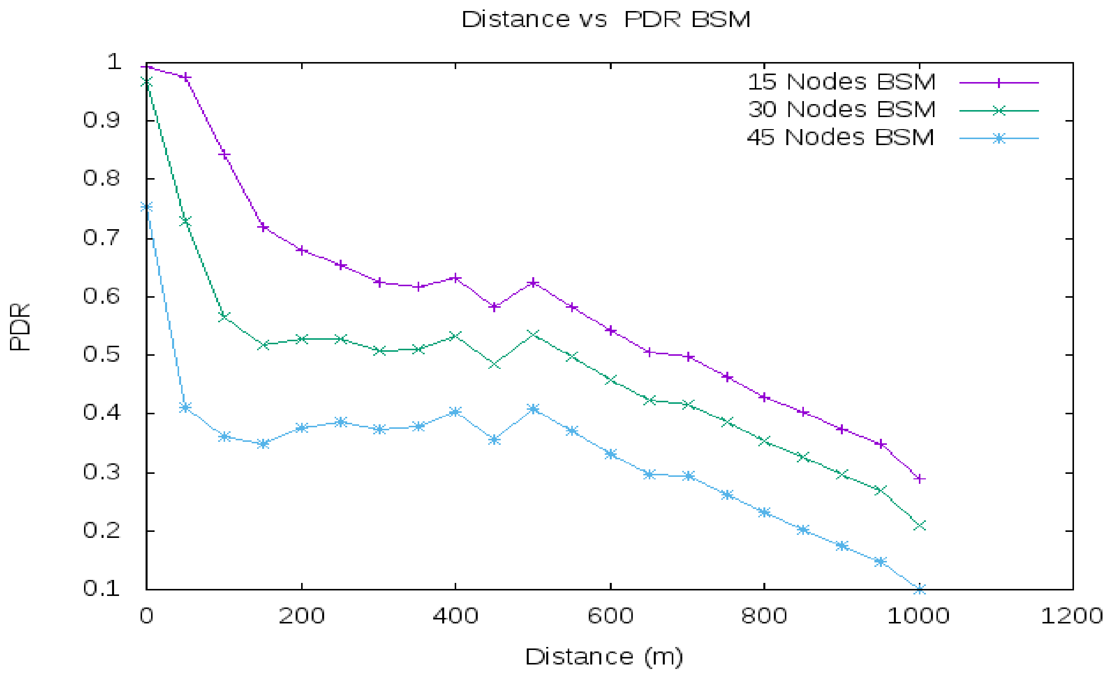


Fig 15. Packet delivery ratio for Basic Safety messages for different nodes

V.2.2 Throughput caculation over different ranges of distances for multiple nodes:

In the Fig 16, we calculated, the throughout for 15, 30 and 45 nodes. As we can see that for more number of nodes like 45 we have highest value for the throughput, it is due to more number of packets are generated with compared to 15 and 30 nodes, hence more number of received packets. The throughput is calculated for the total received packets for the given transmission range.

We can see the sharp decrease in the throughput after 250 meters and throughput for the received packets almost gets closer zero after 1000 meters.

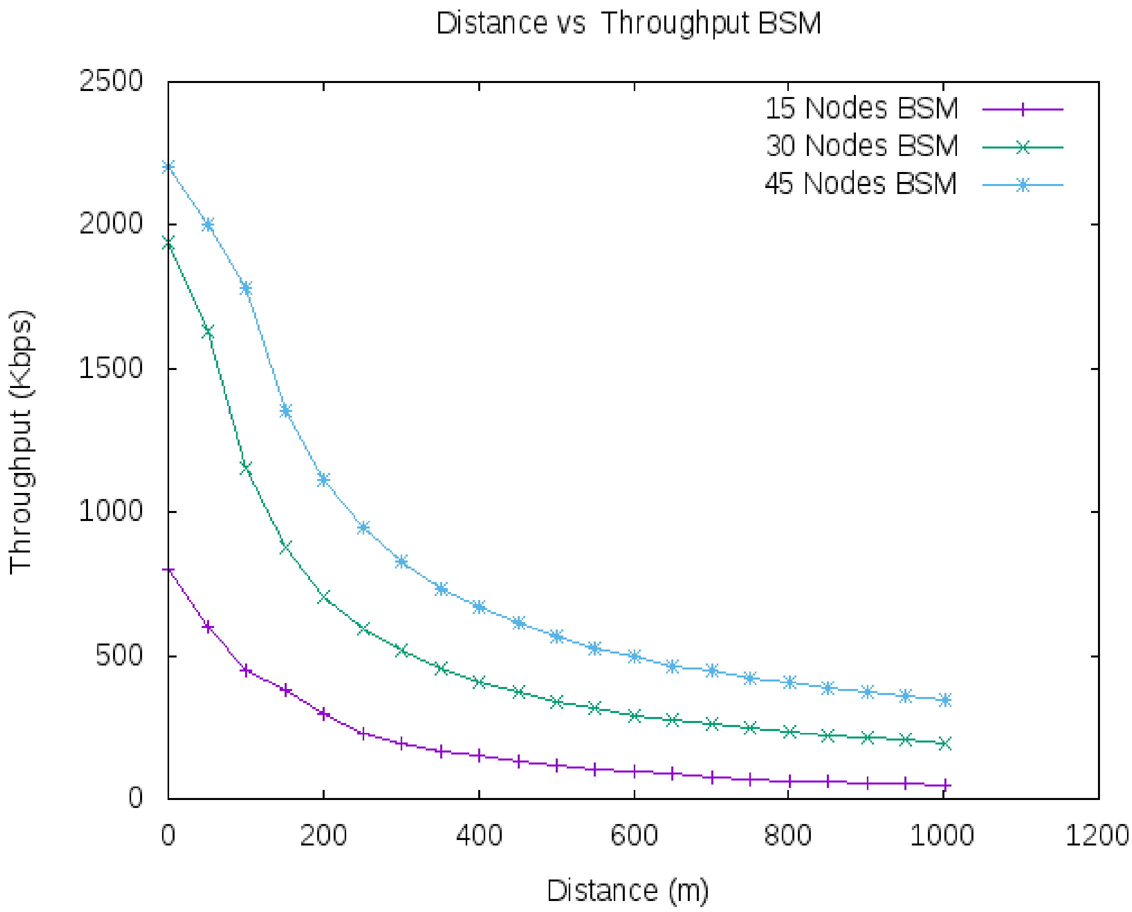


Fig 16. Throughput for Basic safety messages for different node

V.2.3 Packet Loss Ratio calculation for BSM messages over different ranges of distance for multiple number of nodes:

In the Fig 17,We have calculated the packet loss ratio for the different nodes of 15, 30 and 45 for the total distance of 1000 meters. The packet loss ratio is calculated by cacluting the number of data packets that are successfully received , subtracting the amount of total lost recieved data packets at the destination. We can observe that number loss packets are almost negligible when vehicles are very close to each other it is due to the fact all the transmitted data packets have been recieved at the receiver end, and as the inter vehicle distance increase the number of loss packets increase also we can see 45 nodes have highest packet loss ratio to be 0.85 at the distance of 900 meters. For the 45 nodes we observe that when intervehicle distance betwen the nodes is reached beyoned 1000 meteres, there is significant increment in the packet loss which is almost 90% for the set distance. We also note that after 650 meters increase of distance there significant and sharp increase of packet loss ratio for 15, 30 and 45 nodes. As packet loss ratio is increasing the packet delivery is also decreasing.

When we consider the 30 vehicles, we observe the approxinatley 15% of the total recieved packets are lost, when the interdistance between the vehicles approaches to the 200 meters, the number of packet lost is increased to the 60% and it is further increased by 5% when the distance between the vehicles is reached to the 100 meters.

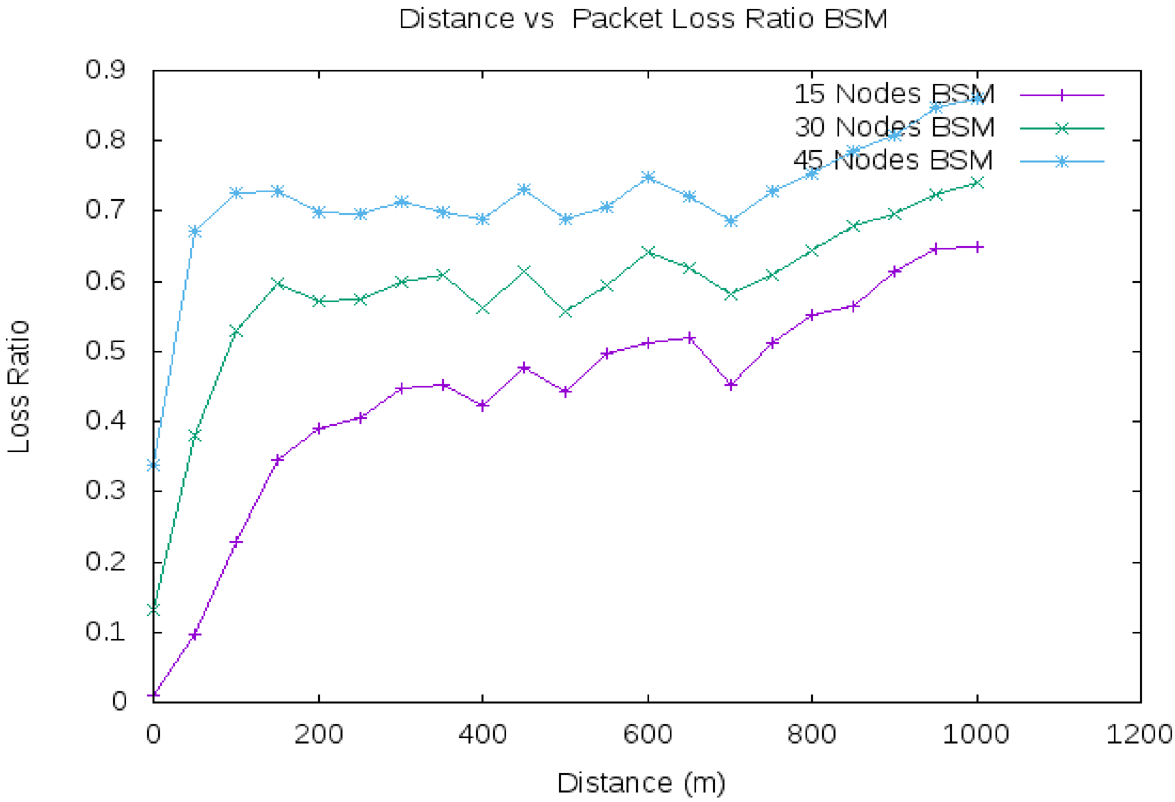


Fig 17. Packet Loss Ratio for BSM messages for different nodes

In case when we reduce the number of vehicles ot 15, the packet loss ratio is also reduced for the said amount of nodes, it is due to the fact, more number vehicles can result into incresaed number of the packets, the packet loss ratio rises to 40% when the distance is observed to be 300 meters and increased to 45% when the intervehicle distance is 700 meters but packets are more frequently lost when distance range is gone beyoend 1000 meters.

V.2.4 Packet delivery ratio for Basi Safety Messages for differnt experiment simulation time:

In the Fig 18, we have calculated the packet delivery ratio for the different experimental simulation time. We have kept the inter vehicle distance constant to the value 200 meter for all vehicle. We have conducted experiment for different vehicles 15, 30 and 45 vehicles. We have run the simulation for the 10 seconds and increased the simulation time to 100 seconds. We can observe that packet delivery ratio has no any significant affect for the experimental simulation time as we observed that PDR was decreasing with increase of distance. For the 15 nodes the PDR is calculated as 0.59 and it almost constant for the entire simulation time except it very slight variation at the 100-simulation time. Similarly, for the 30 nodes we observe the PDR to be 0.49 and it ends at 0.5 value with very little increase and for the 45 nodes the packet delivery ratio is observed to be 0.47 that also tends to remain same for entire experimental simulation duration. It is due to the fact that inter vehicle distance is remained same between all nodes therefore the number of loss packets remains the same.

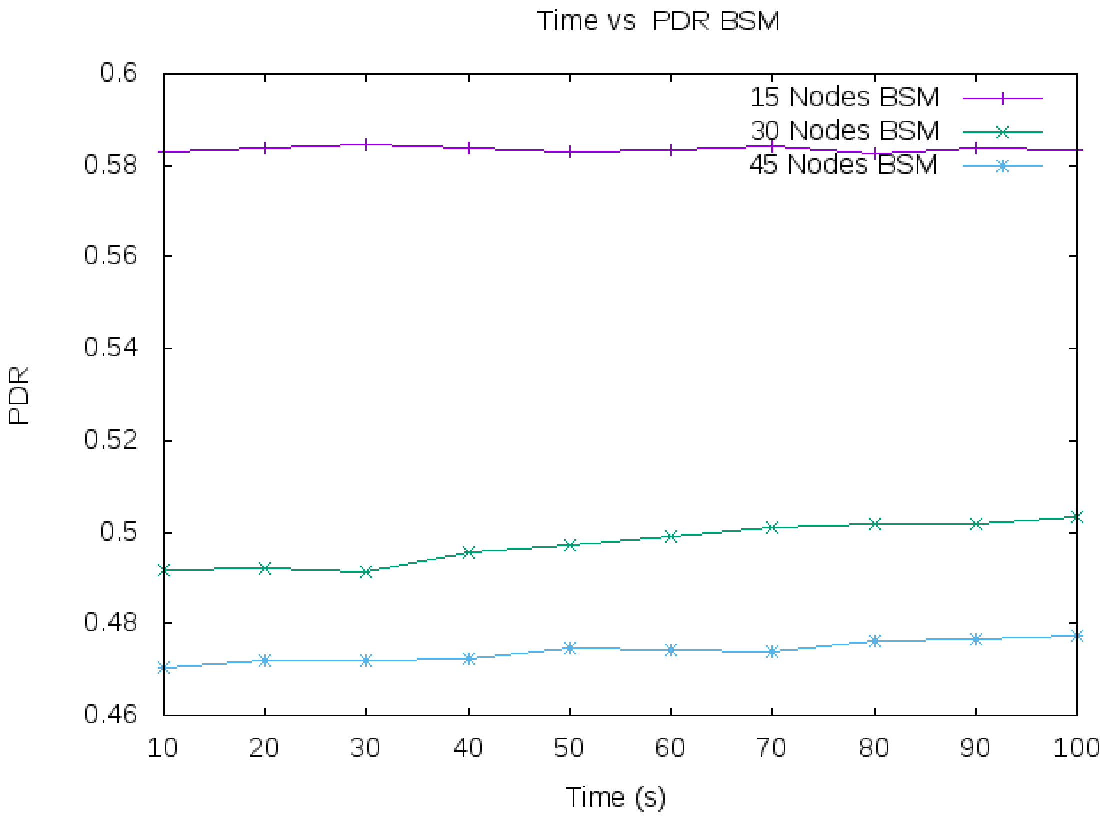


Fig 18. Packet Delivery Ratio for BSM message for different time

V.2.5 Throughput calculation for Basic Safety Messages for different experimental simulatio time with multiple nodes:

The Fig 19 shows the throughput calculated for the different simulation duration. For the first instance the experimental simulation time duration is set to be 10 seconds, all the vehicles selected for this scenario i.e. 15, 30 and 45 broadcast their basic safety messages, each vehicle is able to broadcast 10 basic safety messages per second, the intervehicle distance between vehicle is kept constant to 200 meters and then transmission duration is increased to 20 seconds and all vehicles are allocated the 20 second duration for the transmission, and subsequently the experimental simulation time is increased to 100 seconds. We observe that throughput obtained for the 15 vehicles is almost constant for the entire duration of transmission, hence we can say but we observe slight variation of throughput when the vehicle range increased to 30 and 45 respectively. For the 30 vehicles when transmission time is 10 seconds the throughput obtained is 600 kbps and when it is increased to 20 seconds the throughput is slightly changed to 650 kbps and remains the same when the time duration is approached to 100 seconds. Similarly, for 45 vehicles the throughput obtained is 900 kbps and it is raised to 950 kbps when transmission duration is increased 20 seconds but then it remains constant for the 100 seconds. We can conclude from this simulation result that experimental simulation time does not affect the performance of throughpuhput, because, in case if the vehicle are far way from each other, they can not communicate with each other,irrespective of duration of their tranmission.

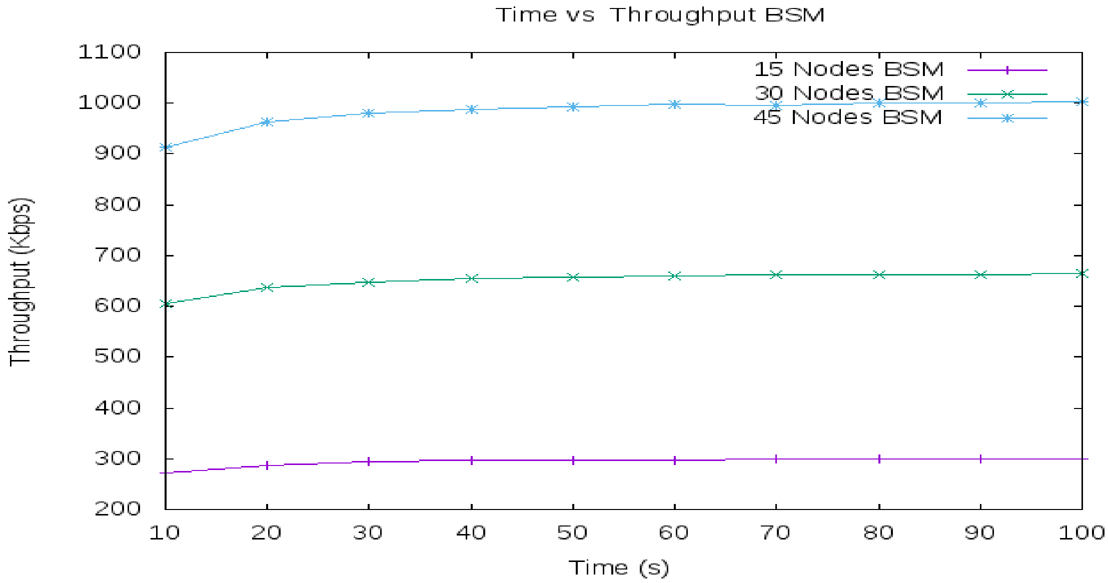


Fig 19. Throughput for BSM messages for different experimental simulation time

V.2.6 Packet Loss ratio for different experimental simulation time

In the Fig 20, we have calculated the number of lost packets by calculating the packet loss ratio, we calculate the packet loss ratio as the number of packets received to the number of transmitted packets.

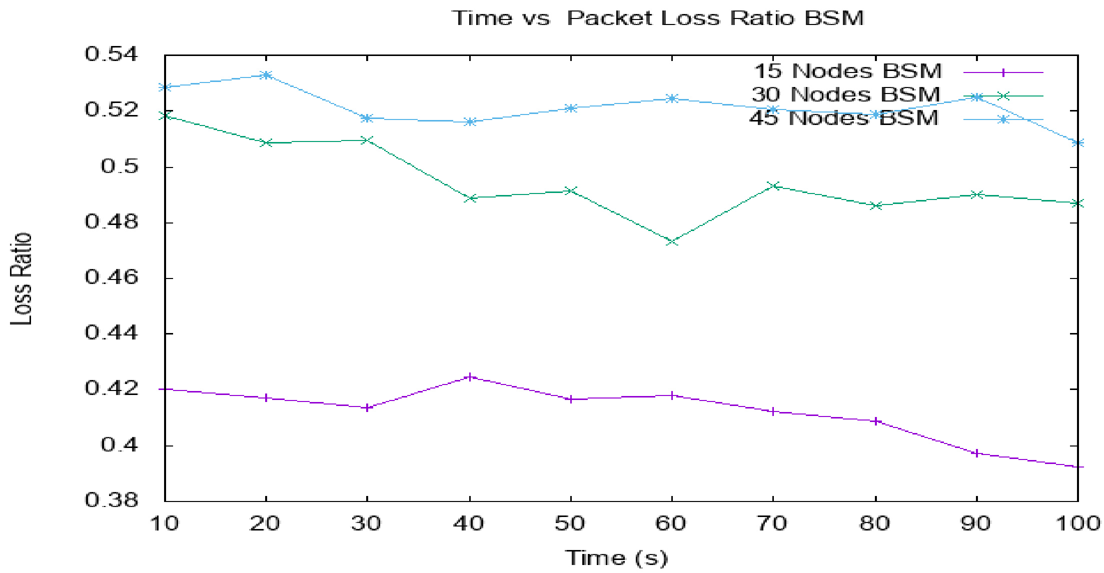


Fig 20. Packet Loss Ratio for BSM messages for different time

For this purpose, we have kept the inter vehicle distance constant to 200 meters and increase the transmission duration for each vehicle. We find small variation in the packet loss ratio. As it is evident that the re increase in number of packet loss as the number of nodes are increased, it could be due to congestion or more number of packet collisions taking place, this happens when the vehicles approach closer to each other.

V.3 Scenario 2 Non-BSM (OLSR)

Non BSM messages are IP based messages, and we shall use topology-based routing protocols that are able to utilize the information about the number of links that exists between nodes for the routing the packets.These messages contain non safety related related information which are transmitted by using service chaneel SCH.The non safety information is either ued for comfort or commercial applications. Some of the applications include electroic toll collection, weather information, search of nearest parking place, fuel pump and shopping mall etc. We shall use one proactive routing protocol known as optimized link state routing protocol OLSR that create routing tables before transmission of data packets. The data packets are forwarded hop by hop basis. It uses the multipoint relays to send topological information to other nodes periodically.

Some of the additional features of the OLSR include the sensing of neighbour, HELLO and control messages (TC). The multipoint relay offers some of the benefits when used in topology which include decrease in number of control messages in the network which decreases the control overhead information.It uses control messages on periodic basis for advertising the information about the status of the links to the other nodes present in the network.

V.3.1 Traffic generation for Routing message

For generating routing messages, we have used the library used in NS-3 OnOffHelper and OnOffApplication for generating traffic to a single destination according to an OnOff style. The duration of each of these states is obtained by the onTime and the offTime random variables. During the "Off" state, traffic is not generated on the other hand during "On" state, CBR or constanst bit rate traffic is generated. This CBR traffic is characterized by the specified "data rate" and "packet size".

We have used data rate 8kbps and packet size 256 bytes. We used **for** loop for our platoon scenario which means 1st node will receive packets from 2nd node and 2nd node will receive from 3rd … N-1 node will receive from N. We can also stop routing messages just change value in protocol = 0

We have used OnOffTrace to Trace the receipt of an on-off-application generated packet, and we have used ReceiveRoutingPacket to Process a received routing packet. We have used base IP address “10.0.1.0” and port 80.

In order to calculate the metrics, we have used processoutput method in which we apply different formula to calculate PDR, loss packets, loss ratio, throughput, we have used flowmonitor library for calculating end to end delay. Processoutput method is used after simulation is completed to generate the graphs.

V.3.2 Packet delivery ratio for different intervehicle distances

The Fig 21 shows the behaviour of vanet protocol known as optimized link state routing protocol based on packet delivery ratio for different distance ranges. Three different set of vehicles are used to check the performance 15, 30 and 45 vehicles. The result implies that PDR is in the direct variation with distance and it is much stable level for 500 meters but as the distance increase more than 500 meters the value of PDR starts decreasing significantly. The contention flows are increased and interreference rate is increased above 500 meters that leads to decrease packet delivery ratio. We have selected the intervehicle distance as 200 meters to calculate the packet delivery ratio for the routing messages at the total range of 1200 meters. The PDR is normalized to one, it takes range from 0.1 to 0.9. when total number of nodes are 15 the PDR takes the maximum value of 1 for the distance 200 meters but as the distance increases the PDR starts decreasing and it is down to its lowest value of 0.6 at 1000 meters, similarly for the 30 nodes PDR reaches to 0.4 as the vehicles go farther 1000 meters, but it gets to zero value for the 45 nodes as they approach to 1000 meters, it due to fact that there is increased congestion and collision for the packets are also higher.

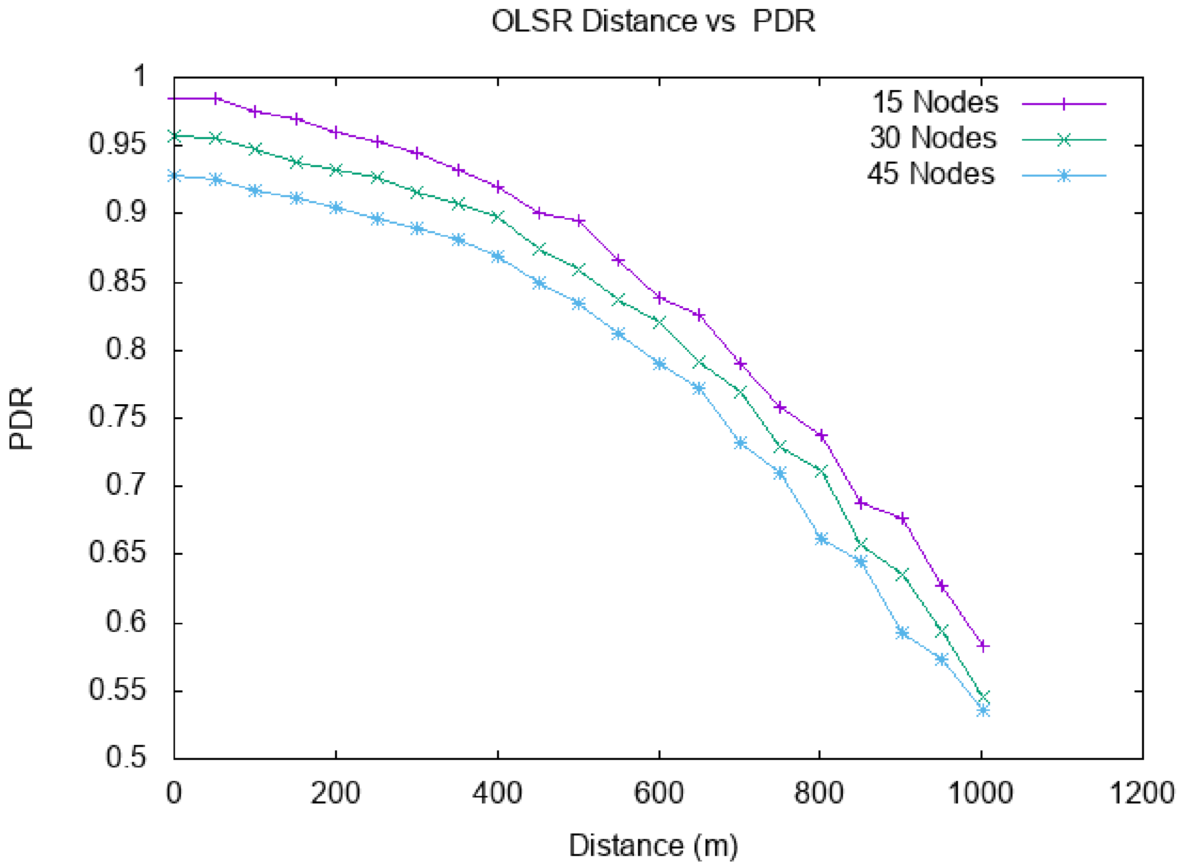


Fig 21. Packet delivery ratio for non-BSM messages for different nodes (OLSR)

V.3.3 Throughput for different intervehicle distances

We have calculated the throughput for the different set of vehicles 15, 30, 45 for distance range 1200 meters in Fig 22. We observe that throughput is higher for the higher density of nodes 45, the maximum throughput obtained is 70 kbps for initial 50 meters which tends to decreased to value of 40 kbps when the distance to the vehicles approaches to 1000 meters. For the node density of 30, the maximum throughput is 45 kbps which reaches to 30 kbps when the distance approaches to 1000 meter, we observe small variation in the throughput at 800 meters it is 30 kbps but increased to 40 kbps at 850 meters, it could be that vehicles range is more increased at that point. We observe almost constant throughput for smaller density of vehicles round 23 kbps that is decreased to 11 kbps when the distance range is 1000 meters. In case of 45 nodes, we observe decrease in the throughput after the intervheicle distance has crossed the limit of 600 meters, which means the receiving vehicles are not receiving all the transmittted packets from the source vehicles, and network impairments may cause decrease in the data packets, the lowest throughput is observed as 50 Kbps for the distance of 1000 meters, similarly it is further decreased to 30 Kbps for the 30 vehciles when their intervheicle distance is approached to 1000 meters.

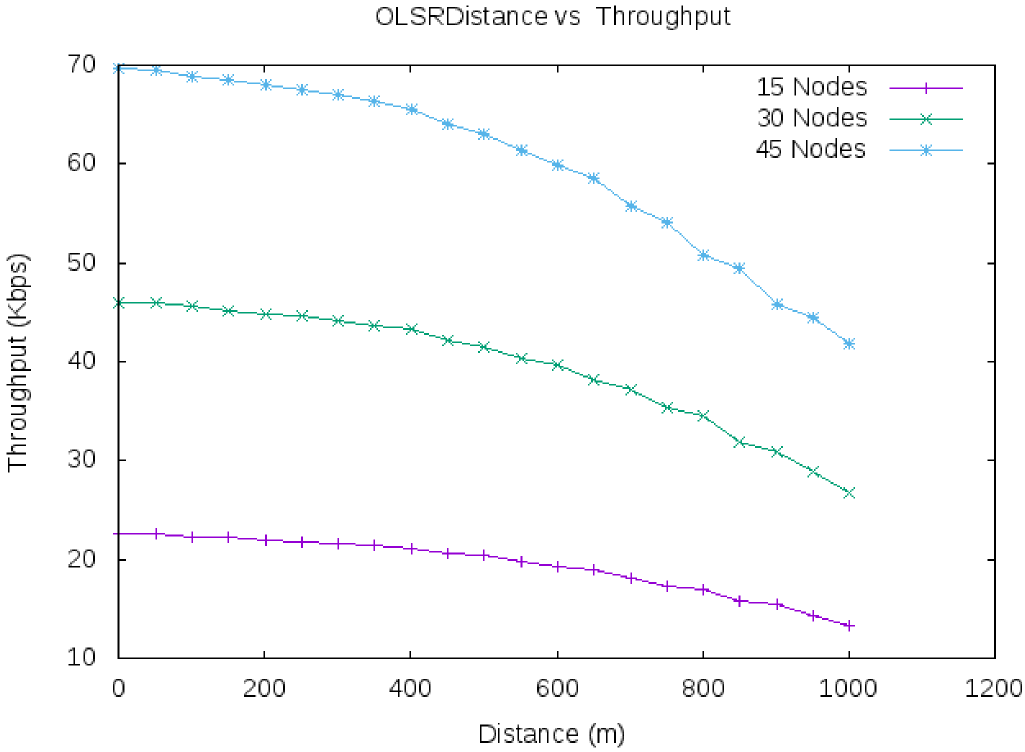


Fig 22. Throughput for non-BSM messages for different nodes (OLSR)

The maximum throughput acheived, when the vehicle density is 15, is 22 Kbps which is further reduced to 10 Kbps at the distance of 1000 meters. The Optimized Link State Routing Protocol being proactive in its nature gives more throughput when it is compared to its reactive counterpart. It is due to the fact, no bnadwidth is wasted for path discovery process, since the paths are already defined.

V.3.4 Packet Loss Ratio for different intervehicle distance

The packet loss ratio is described as the number of lost packets to the number of packets were transmitted, it is found that when number of nodes in Fig 23, are 45 the maximum packet loss ratio approaches to 0.5 when the distance approaches to 1000 meters, the most suitable explanation for this increased loss is that CSMA/CA is limited to the number of channel to be assigned for the transmission, therefore as the traffic congestion increased the number of lost packets are also increase. To avoid this type collision among the packets other alternative sensing can be used. Similarly, when vehicle density is 30, there is .05 lost of packets is observed in the begning which reaches to maximum level of 0.45 at 1000 meters, which means 55% of total transmitted packets are received successfully at the destination, this loss of packets is further reduced when the number of vehicles are kept 15 for the same disance. Some of the issues with Optimized Link State Routing Protocol could be, the routing loop which can occur when interface state is changed. In case if interface is down there may need of adjusting the routing table mannually and other routes can be used but they could take some time to transfer the data from source to destiantion which may result into routing loop problem and in case of link failure it takes time to discover the alternating routes.

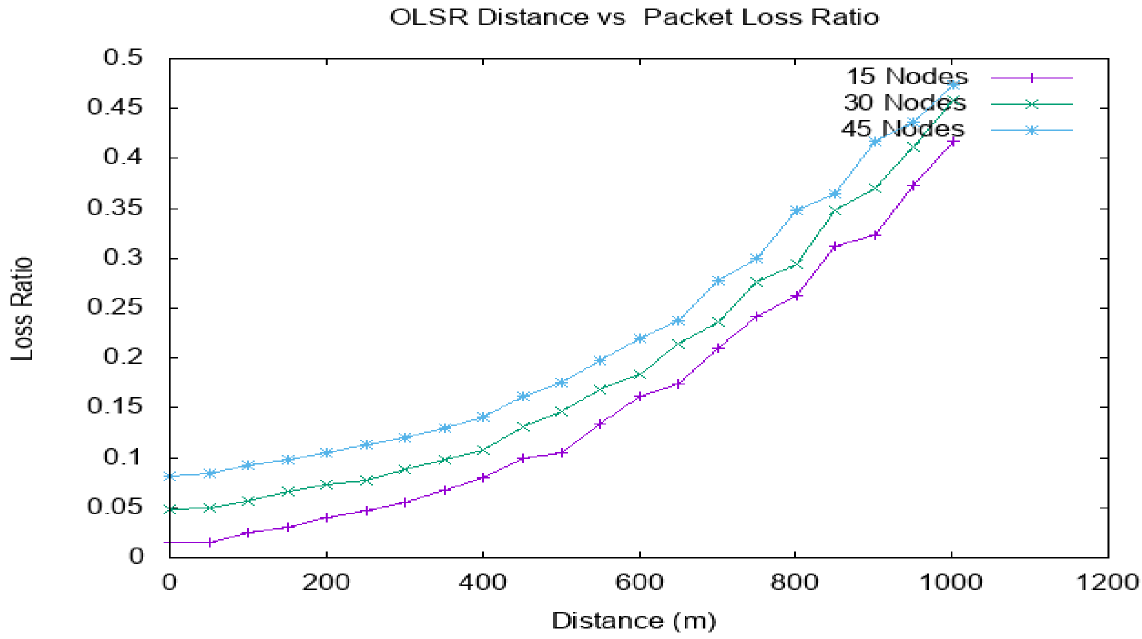


Fig 23. Packet Loss Ratio for non-BSM messages for different nodes (OLSR)

V.3.5 End to end delay for different intervehicle distance

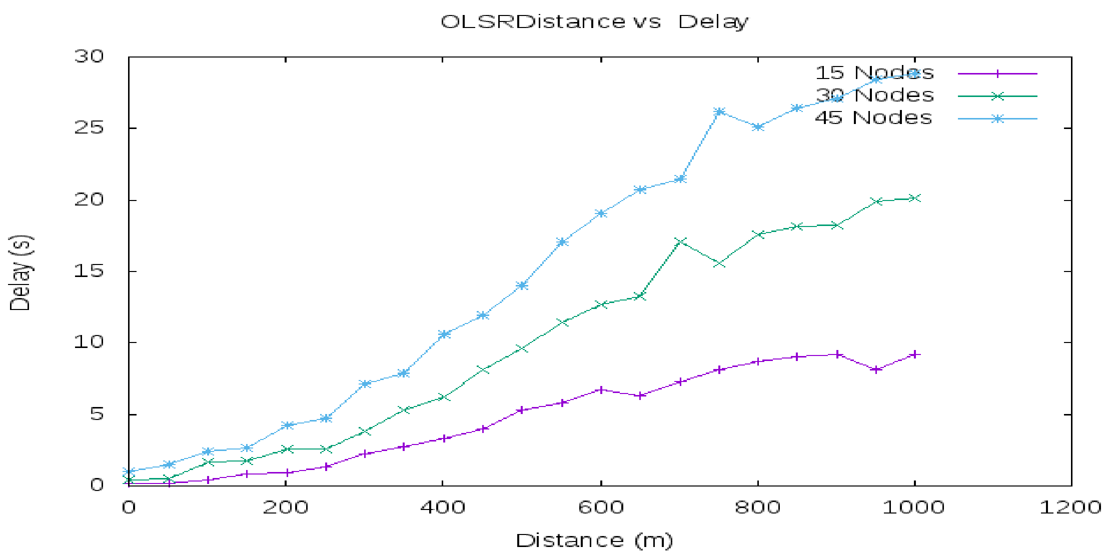


Fig 24. End to End Delay for non-BSM messages for different nodes (OLSR)

End to end delay is defined as the total time duration packets takes from source to destination. As the distance between the vehicle increases the end to end delay tend to increase too. The optimized link state routing protocol is proactive in nature, which means the routes to send the data packets are predetermined, therefore there it does not find the new routes when sending data packets, therefore end to end delay is less than AODV protocol which is reactive nature and has to find new route each time it has to transmit the data packets therefore observing more delay than OLSR protocol.

It is clear from the Fig 24 that as the number of nodes are increased, the end to end delay also increases, hence we can assume that OLSR protocol is not suitable for the urban environment where node density is high, but it can produce low latency for rural environment where node density is less. The maximum amount of delay is notices at the distance of 1000 meters when number of nodes are 45, there could be number of reasons for this delay one of them is the link failure between the nodes and it takes time rediscover the alternative path for the transmission.

V.3.6 Packet delivery ratio for different experimental simulation time

The packet delivery ratio is calculated with different nodes for the different experimental simulation times in Fig 25, where the intervehicle distance is kept constant to 200 meters. When node density is 45, the PDR remains 0.86 for transmitting time duration of 10 seconds and reaches to 0.89 when simulation time is reached to 20 seconds but as the time is increased beyond 30 seconds

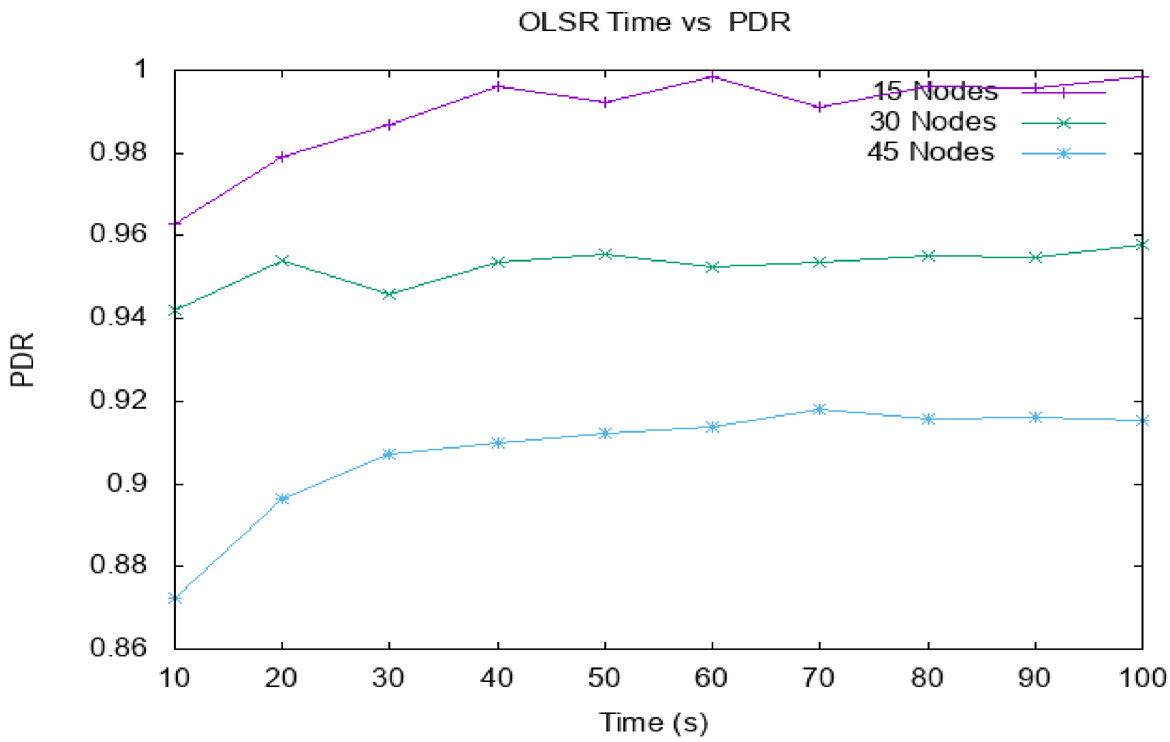


Fig 25. Packet Delivery Ratio for non-BSM messages for different time (OLSR)

the packet delivery ratio remains constant for entire duration resulting 10% loss of total transmitting data packets, when node size is reduced to 30, the PDR gives constant result to be 0.95 for entire simulation time, except some variation till 30 seconds. When node size is reduced more to 15, we observe the packet delivery ratio to be at the maximum level of 0.99% beyond the simulation time of 30 seconds.

V.3.7 Throughput for different experimental simulation time

The Fig 26 shows the throughput result which is calculated for different experimental simulation times, in our previous results this number was kept constant to 20 secnods but now we keep changing the transmission time of each vehicle and keep the intervehicle distance same. Every node transmits single packet which is of size 256 bytes to its neighbour node, we start with 15 nodes and assign 10 seconds to calculate the cumulative throughput, then we increase the simulation time 20 seconds to 100 seconds, similarly we perform the same operation for the rest of 30 and 45 nodes and find the average throughput for them. We find the received bytes which are stored in RoutingStats class by calling GetRxBytes methods and then we calculate throughput in Kbps

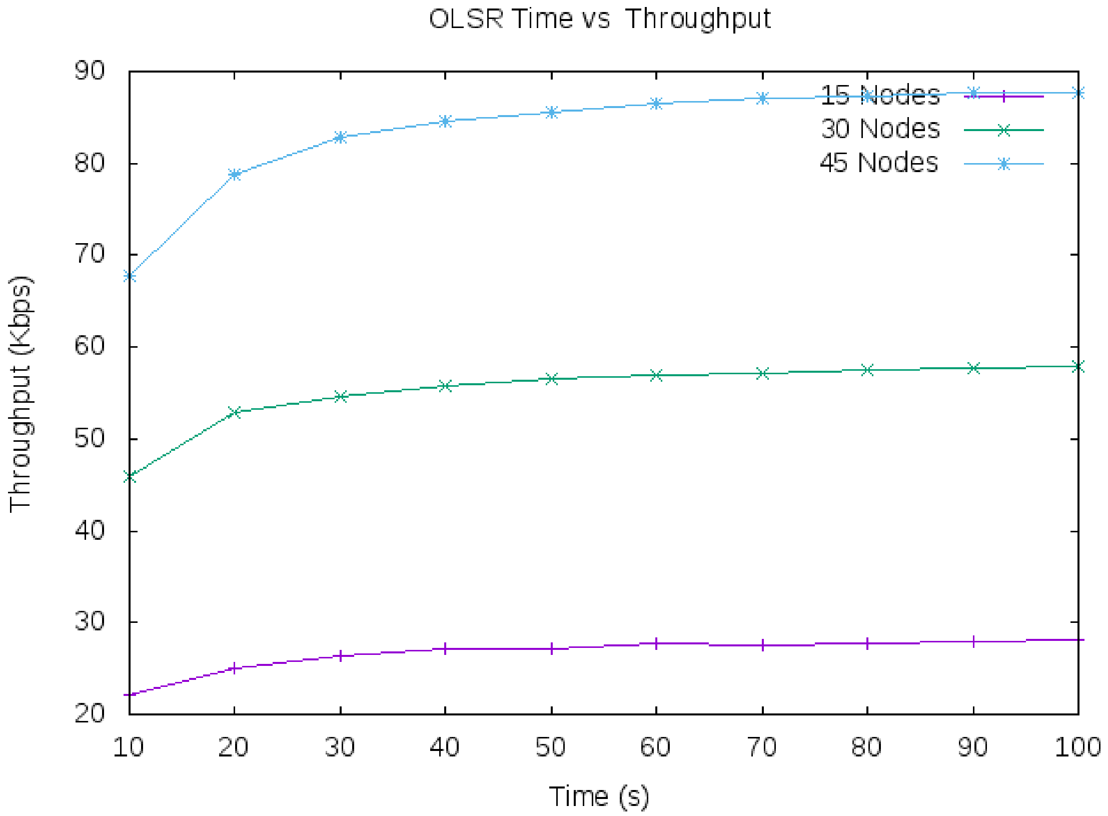


Fig 26. Throughput for different experimental simulation time (OLSR)

We observe in the above graph, higher density of nodes produces higher throughput, for example when simulation time is 10 seconds throughput for 45 nodes is 70 kbps and it is increased to 85 kbps at 40 seconds and remains same till the simulation time approaches to 100 seconds. It appears to be of no effect of how long the connectivity is available, the throughput gives the same result for more duration of simulation time. When the number of vehicles are reduced to 30 the throughput is maintained to the level of 55 Kbps which is dropped to 25 Kbps when node density is further reduced to 15. OLSR protocol maintains the Multipoint Relays which are able to control the flooding mecahanism and therefore OLSR protocol gives more throughput than its counterpart.

V.3.8 End to end delay for different experimental simulation times:

The end to end is calculated with reference to different experiment simulation time for various node densities 15, 30 and 45. We find that as we increase the experimental simulation for transmission of data packets the end to end delay is also increased, higher number of node observe large amount of delay as compared with lower node size.
As we have observed that OLSR outperforms in terms of delay as compare with AODV protocol when there is low speed of the nodes in the network which results into less number of topological changes which strengthen the performance of the proactive protocol, moreover MPR used by the OLSR are able sent control messages only which reduces the overhead and decreasing the delay.

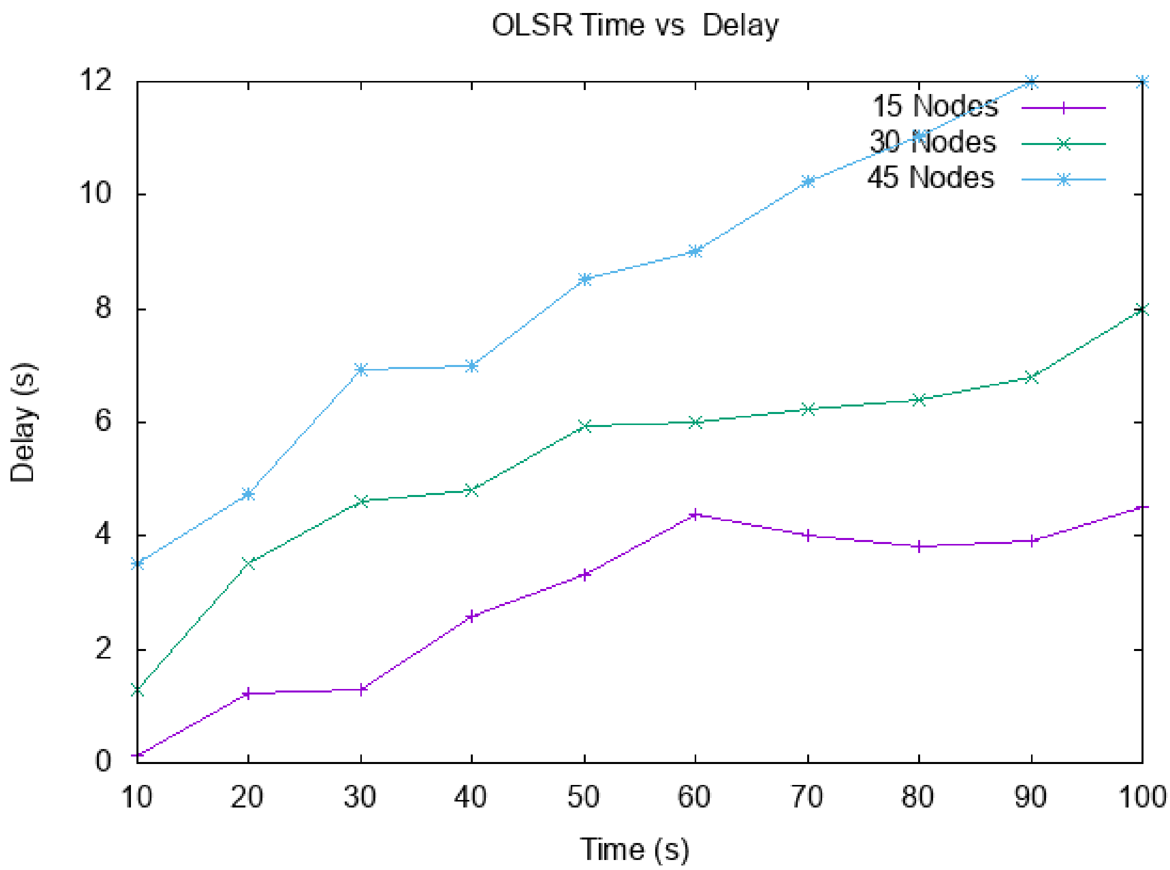


Fig 27. End-to-End delay for non-BSM messages for different time (OLSR)

The Fig 27 illustrates the effect of end to end delay when the transmission time of each vehicle is increased, we observe the maximum delay for the arrival of the packets for 45 nodes and minimum amount of delay has observed for the node density of 15.

V.3.9 Packet loss ratio for different experimental simulation time:

Fig 28, shows the packet loss ratio for the non-BSM messages is calculated for different experimental simulation time for various nodes, the intervehicular distance between the vehicles is kept 200 meters, at initial stage when nodes are assigned 10 seconds for transmitting the data packets the packet loss ratio is found to be 0.15 which is decreased to 0.11 when time duration is increased to

30 seconds and remains the same till the experimental simulation duration approaches to 100 seconds, it is because nodes have enough time for transmitting the data packets. In case of node size of 30 the loss ratio is significantly reduced to 0.07 and remains constant for the entire duration of transmission, similarly when node size is further reduced to 15, the packet loss ratio is found to be 0.03 which is further reduced to 0.01 and very small variation is noticed till it the experimental simulation time approaches to 100 seconds.

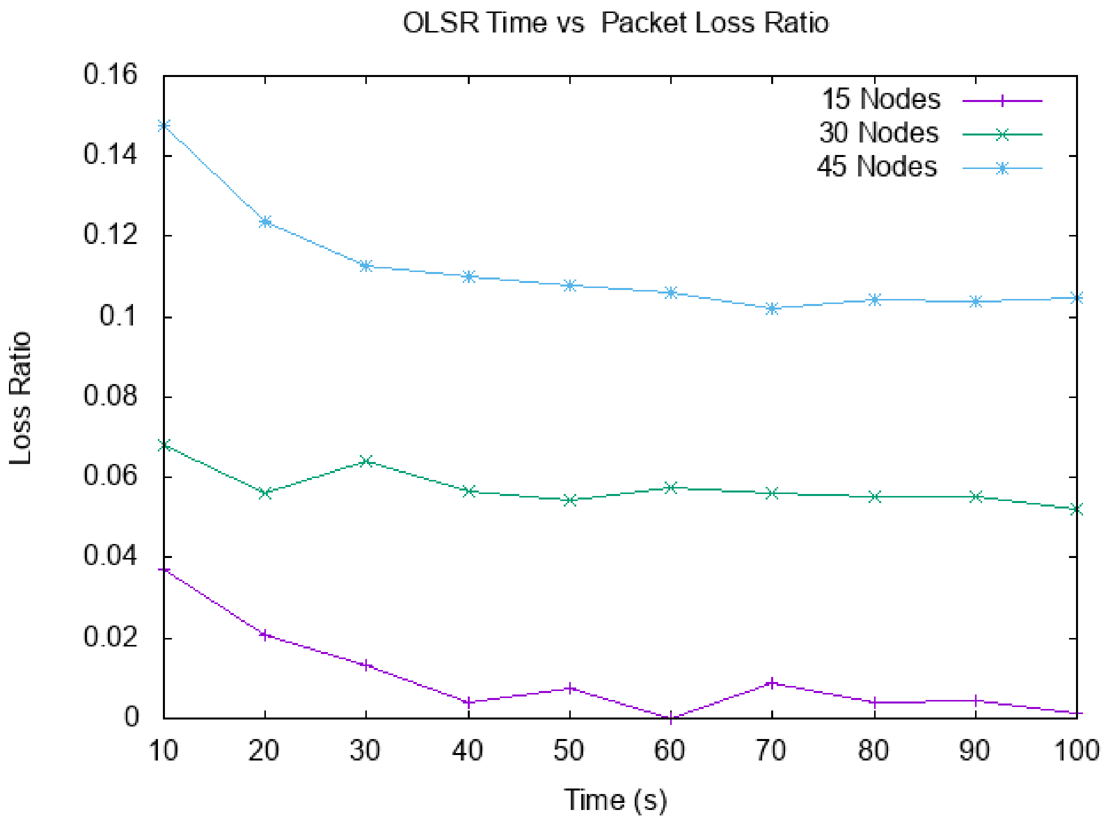


Fig 28. Packet Loss Ratio for non-BSM messages for different time (OLSR)

When the node density is increased to 45, the initial packet loss is 0.15 which remains 0.12 till the time is increased to 100 seconds. We can observe that packet loss ratio is independent of the experimental simulation time, which means, it does not matter how long the vehicle is transmitting the data packets but it must be in the reach of another vehicle.

V.1 Scenario 2 Non-BSM (AODV)

V.1.1 Ad-Hoc On-Demand Distance Vector Routing (AODV)

The AODV is type of reactive routing protocol in which route from source to destination is established whenever the node intends to send some data packets. It is able to support both unicast as well as multicast types of traffic in the network. Since it is reactive protocol it uses some control types messages in order to discover the route from source to destination.

It uses the RREQ control message whenever the node has some data to transfer, the route request message (RREQ) is broadcasted to its neighbour nodes, and intermediate nodes forward this message until the destination of the message is reached. The information contained in the RREQ message is the IP address of source and destination, source and destination sequence number. When intermediate noes receive the RREQ message they send back the unicast route response to the source provided they are the valid destination, or its path is established with the destination, this packet has the information about the hop count, destination sequence number and source and destination IP addresses. If any of the link is failed, failure route error message RERR is generated that contains the information about IP address and unreachable destination sequence number.

V.1.2 Packet Delivery Ratio for non-BSM messages for different nodes at different intervehicle distance ranges

The packet delivery ratio for the AODV protocol is calculated in the Fig 29, we can observe that initial when the number of nodes approach to the lowest distance the packet delivery is found to be at maximum value, as in case of 15 nodes the total number of transmitted packets are received at the receiver

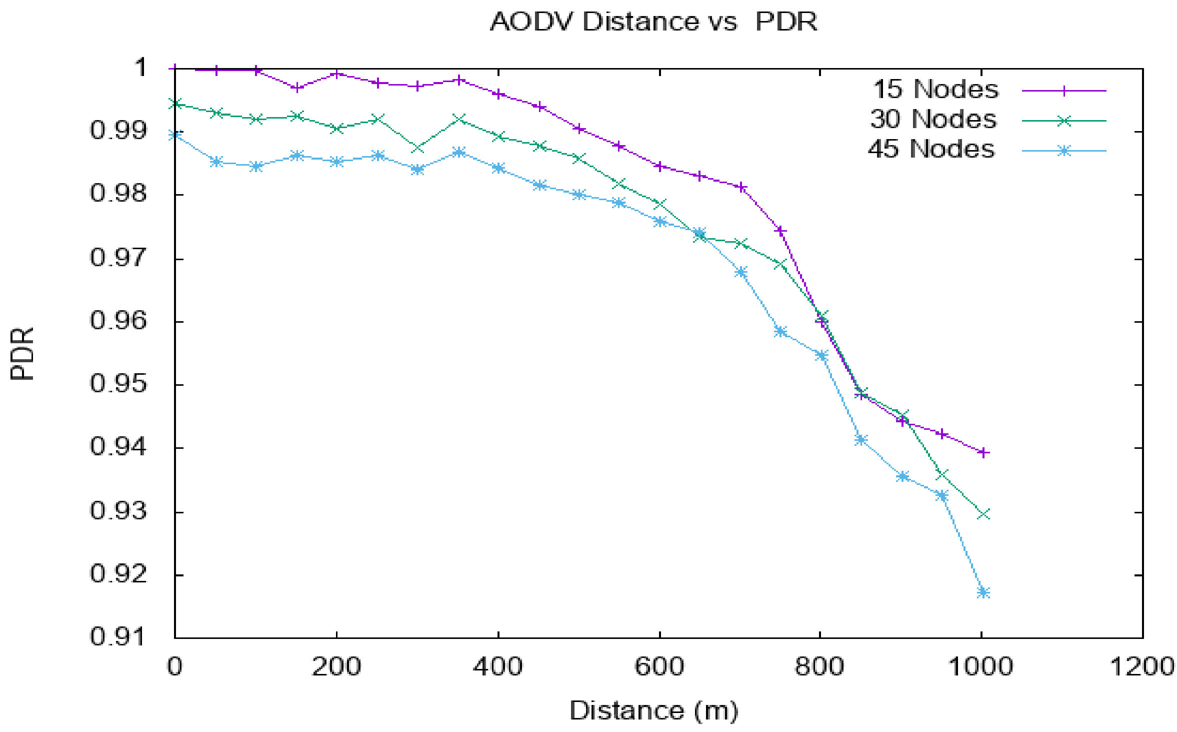


Fig 29. Packet Delivery Ratio for non-BSM messages for different nodes (AODV protocol)

node and PDR value reduces to 0.998 for the same distance when node density is increased to 30 resulting some loss of packets, the loss packets increases to 10% more if the node density is increased to 45, and we also observe that PDR has more stable value up to the distance 400 meters but as distance increased the packet delivery ratio starts decreasing and it results 0.93 when the distance approaches to 1000 meters for 45 nodes. When we compare the PDR resulted from AODV protocol for low density network we find its maximum value as 0.99 at the close distance between the vehicles and 0.92 for highest distance, which in case of OLSR routing protocol is better result, AODV also outperforms in terms of PDR for the incresed vehicle density of 30 and 45.

V.1.3 Throughput for non-BSM messages for different nodes at different intervehicle distance ranges:

We have calculated the throughput for the different set of vehicles 15, 30, 45 for distance range 1200 meters in Fig 30. We observe that throughput is higher for the higher density of nodes 45, the maximum throughput obtained is 71 kbps for initial 50 meters which tends to decreased to value of 40 kbps when the distance to the vehicles approaches to 1000 meters. Similarly, when the number of nodes in the network are reduced to 30 the throughput at the initial stage is found to be 46 kbps which is reduced to 46 kbps later at the distance of 1000 meters. The results also show the small amount of variation in the throughput when the node density is further reduced to 15 nodes the throughput approaches to 19 kbps.

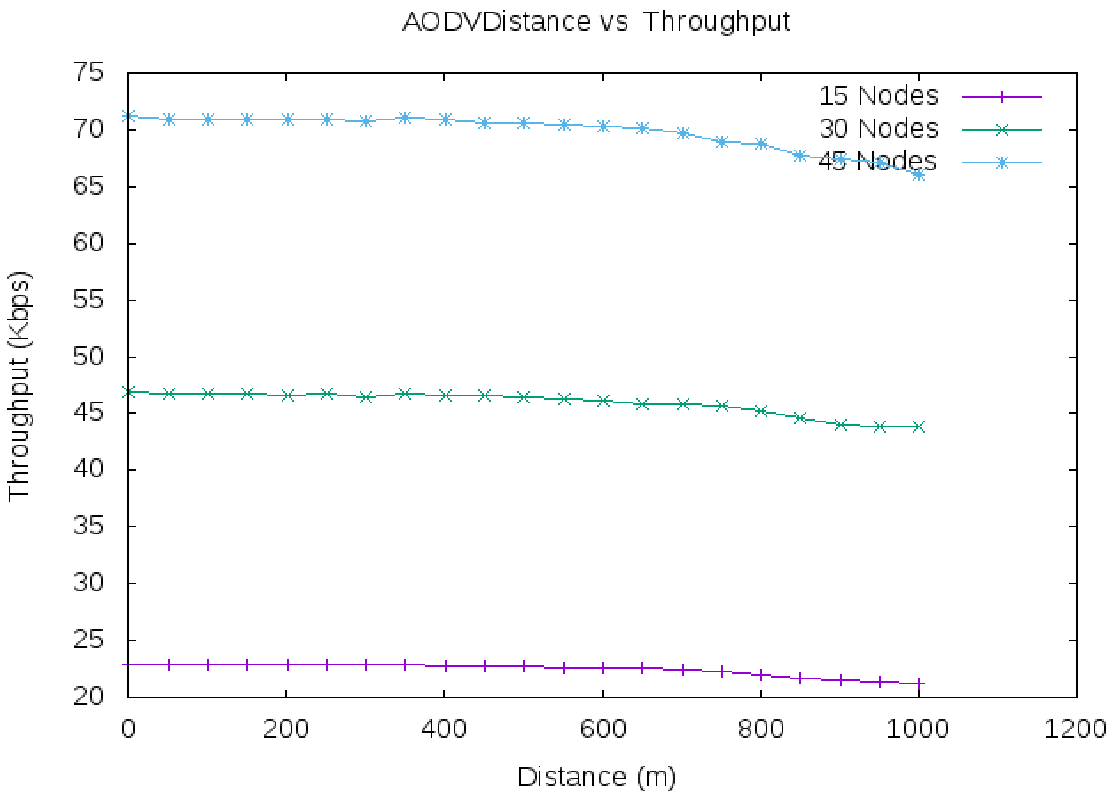


Fig 30. Throughput for non-BSM messages for different nodes (AODV protocol)

We can observe that AODV protocl has better throughput result for increased number of vehicles such as 45 which is considered as urabn enviroment, for lower traffic densities they both perform at same level for this given speed.

V.1.4 Packet loss Ratio for non-BSM messages for different nodes at different intervehicle distance ranges:

The Fig 31,depicts the packets loss ratio with different node densities for the AODV protocol, initially the number of lost packets for the 15 nodes is negligible, while the packets loss ratio for higher of nodes like 45 is 0.01, and it is also reflected in the packet delivery ratio where 99% transmitted packets are received correctly, but as the distance goes on increasing the drop in the number of packets also increased, as the inter vehicle distance is approached to 1000 meters the packets loss ratio is at its maximum value.
We can observe that end to end delay is varying slowly till the distance of 700 meters is reached but we notice abrupt enhancement in the delay after 750 meters which is also inconsistence with the packet delivery ratio graph where we get decrease in the packet delivery at this distance

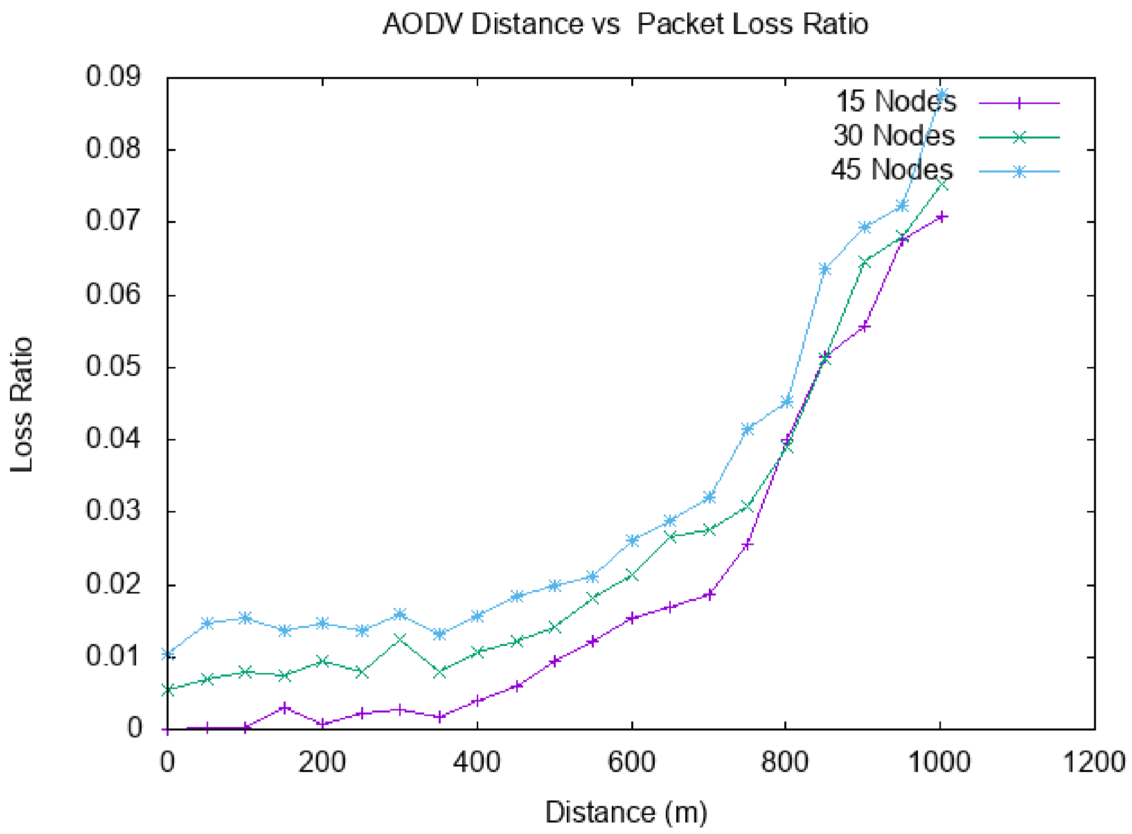


Fig 31. Packet Loss Ratio for non-BSM messages for different nodes

Comparing the packet loss ration of AODV protocol to the OLSR, it gives better results in terms of packet loss, more number of packets are succesfully recieved at the destination with it which due to the fact that establishing the route with AODV is more faster than its counterpart.

V.1.5 End to End delay for non-BSM messages for different nodes at different intervehicle distance ranges

As we have already defined the end to end delay, it is the average time the data packets takes form its sender to the receiver, it includes multiple types of such as delay observed due to time takes spent to discover the route for transferring the data packets, queuing and propagation delay, as the results in the Fig 32 reflects the fact, AODV protocol consumes significant amount of time for the route discovery of the packets, because the routes to send the packets are not established in advance but they are created whenever they are requested, therefore if node density is high, as in case of 45 nodes the average delay goes to the peak, the end to end delay is much greater in AODV than observed for the OLSR protocol, therefore OLSR outperforms in this metrics.

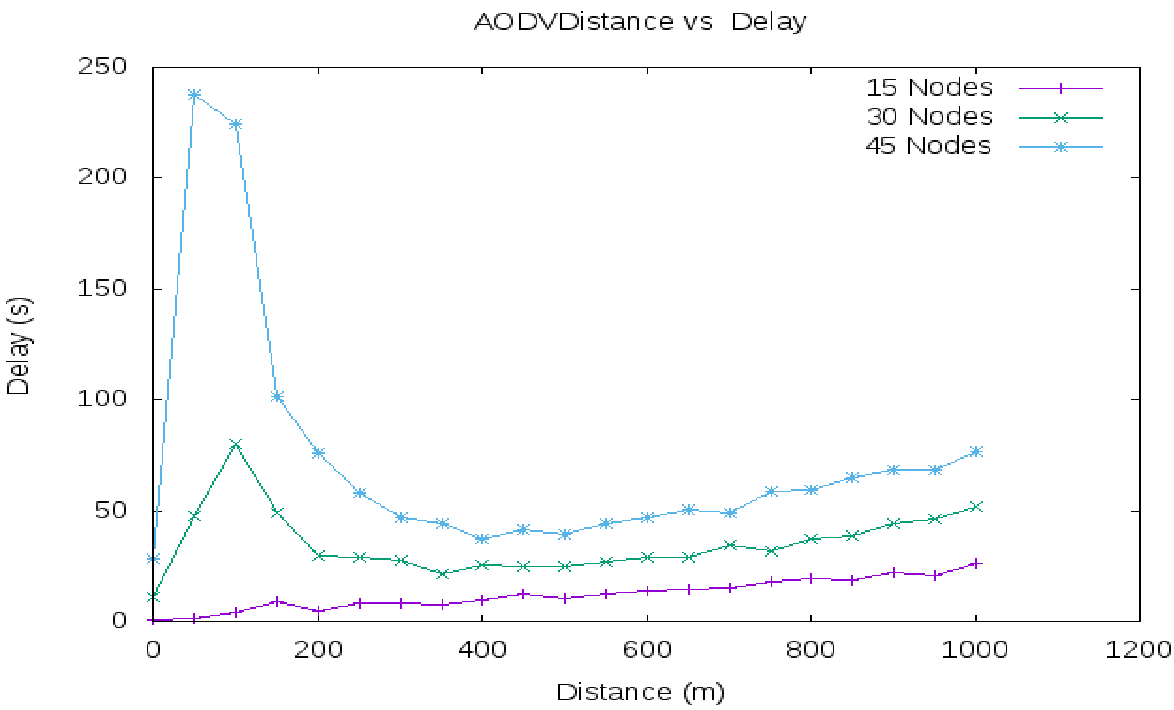


Fig 32. End-to-end delay for non-BSM messages for different nodes (AODV protocol)

We observe that end to end delay has greater value when reactive protocol such AODV is used when compared with proactive protocol OLSR, it is due to the fact that reactive type topology uses the route discovery packet for finding its destination therefore it takes some time for reaching the desired destination, on the contrary the destination is known to the proactive type routing protocols.
Due to fast moving nature of the vehicles it is not suitable to use such type of reactive protocol in vehicular adhoc networks.

VI Chapter 6. Conclusion

We have studied the vehicle to vehilce to communication used for the platoon case for both safety and non safety messages. We used network simulator NS-3 for simulating the different parameters such as packet delivery ratio, throughput, packet loss ratio and end to end delay for both safety and non-safety messages used in vehicular ad-hoc neworks. We used the packet size of 200 bytes for the basic safey messages with data rate of 6 Mbits/sec. Three different types of vehicular ranges were used, 45 vehicles to represent urban enviroment, 30 vehicle representing the sub-arban enviroment and 15 vehicles used to represent rural eniviroment. The resutls for the packet delivery ratio for the basic safey messages which produces favourable results for the urban enviroment and moderate results for sub-urban areas. Similarly throughput level is better in urban enviroment due to close tranmission ranges of vehicles, but the chances of packet collosion are also increased hence resulting inot increase in packet loss ratio. We have also noticed that increased transmission time of vehicle does not affect any of the parameters we discussed.

In the next level of study, we used two different classes of routing protocol that were initially developed for the mobile ad-hoc networks,to check their performance in vehicular adhoc networks. One of them is Optimised Link State Routing Protocol OLSR which is proacitve type routing protocol in which routes for sending data packets are already established and other is known as Ad-hoc On-Demand Distance Vector Routing AODV protocol which is type of reactive protocol in which routes from source to destination are established whenever the node intends to send data packet supporting both unicast and multicast traffic. The metrcis used for the simulations are, packet delivery ratio, throughput, end to end delay and packet loss ratio. The packet size for the nonsafety messages is kept 256 bytes whereas the data rate is kept as 8 kbps. Thre different vehicle ranges were used for the total distance of 1000 meters. We have evaluated performance of both protocols and found that AODV protocol present good perforamce in terms of throughput specifically in urban enviroment where AODV maintians the level of throughput of 71 kbps for the distance upto 700 meters and it is decreased to 66 kbps when the distance of 1000 meters is reached whereas in case of OLSR the throughput is continously in declined state, it gives the value of 60 kbps when the intervehicle distance is 400 meters which in case of AODV is 70 kbps, the level of throughput is further decreased to 50 kbps at the distance of 1000 meters where as AODV still maintians 65 kbps for the same distance, both protocol maintain throughput at moderate level for sub-arban and rural enviroment. Similarly packet delivery ratio for AODV is better resutls than its counterpart. For example when the interdistance between the vehicle is 500 meters the PDR results for AODV at level of 97%, which is maintained to 94 % till the distance of 1000 meters is reached,where as OLSR gives results into 90% of PDR value for urban areas when total number of vehicles are 45, at 500 meters and rapidly decreased to 56% at the distance of 1000 meters. Where as AODV protocol has much higher end to end delay hence consuming more time for transmitting packtes from source to destination, it is due the reason its being reactive in nature where there are no any pre established link before the transmission starts and in case of link failure it takes lot of time for the link to be established again. To best of understanding both protocols are not suitable for the safety applications for vehicular ad-hoc networks.

VII Future Work

In future we shall implement the modified version of the Optimized Link State Routing Protocol OLSR in which some tuning parameter has been used as reported in [27].

It can be performed by coupling the Network Simulator NS-3 with optimization algorithm (GA). The validation of optimized parameters can be performed by comparing it with standard tuning. Tuned-OLSR results are predicted to be much better than conventional OLSR routing protocol, with increase in throughput, packet delivery ratio as well as decreased end to delay.

It can be achieved by using simulate annealing algorithm as well as particle swarm algorithm

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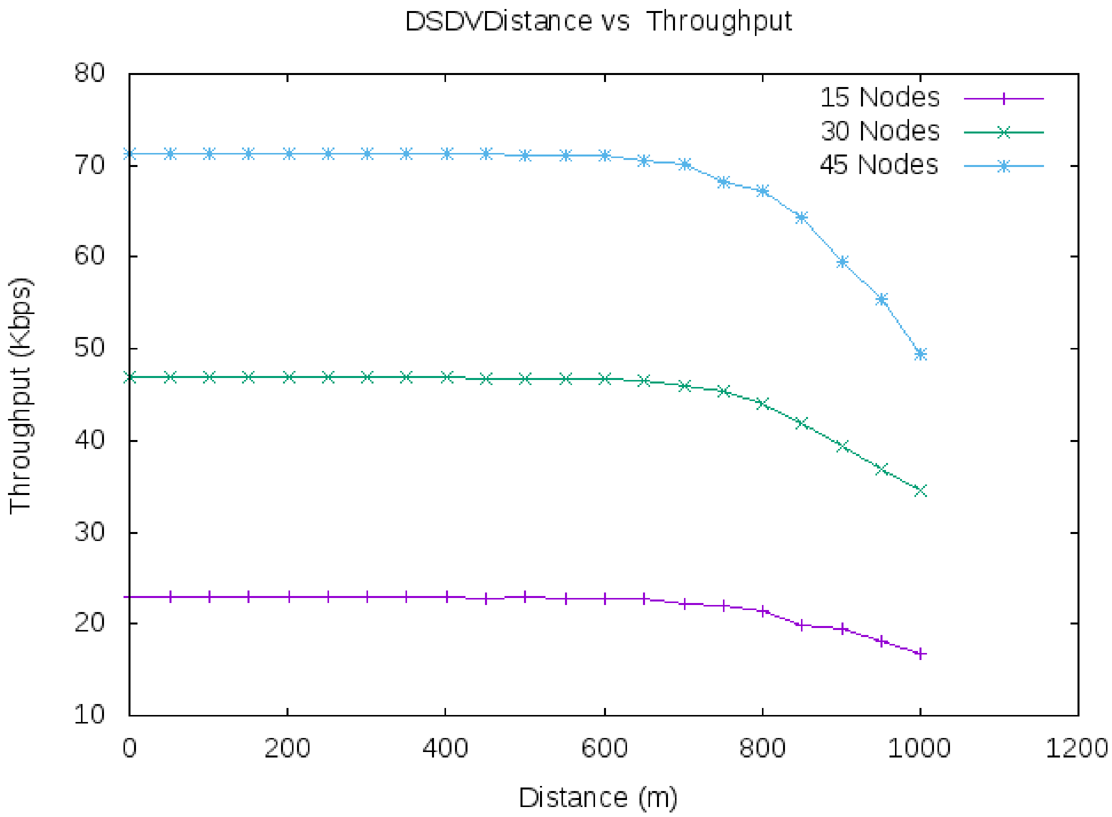
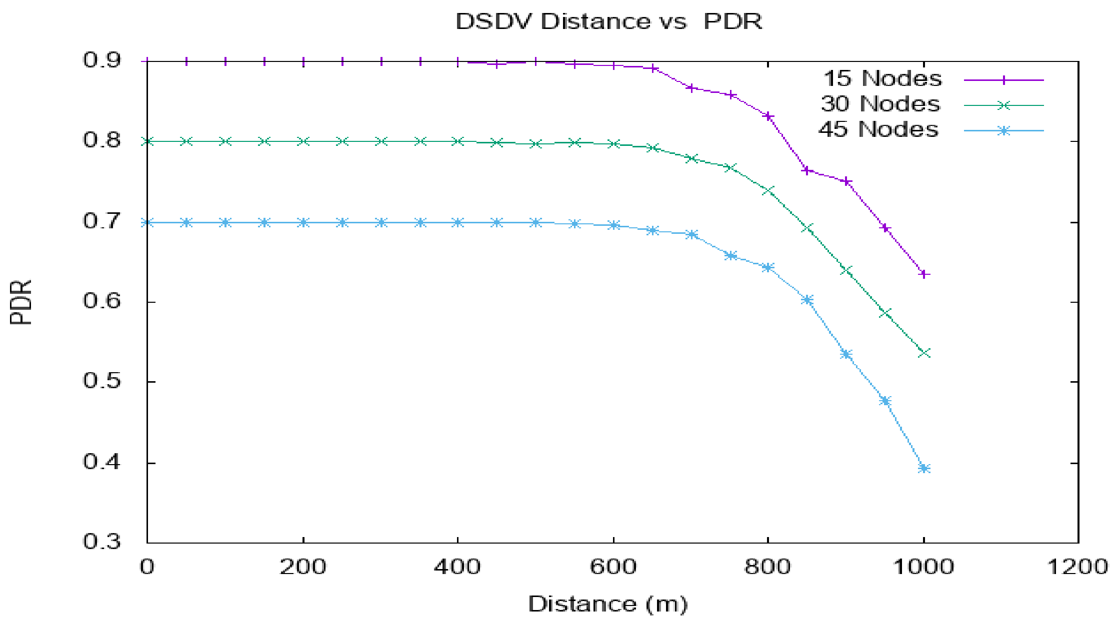
IX ACRONYMS

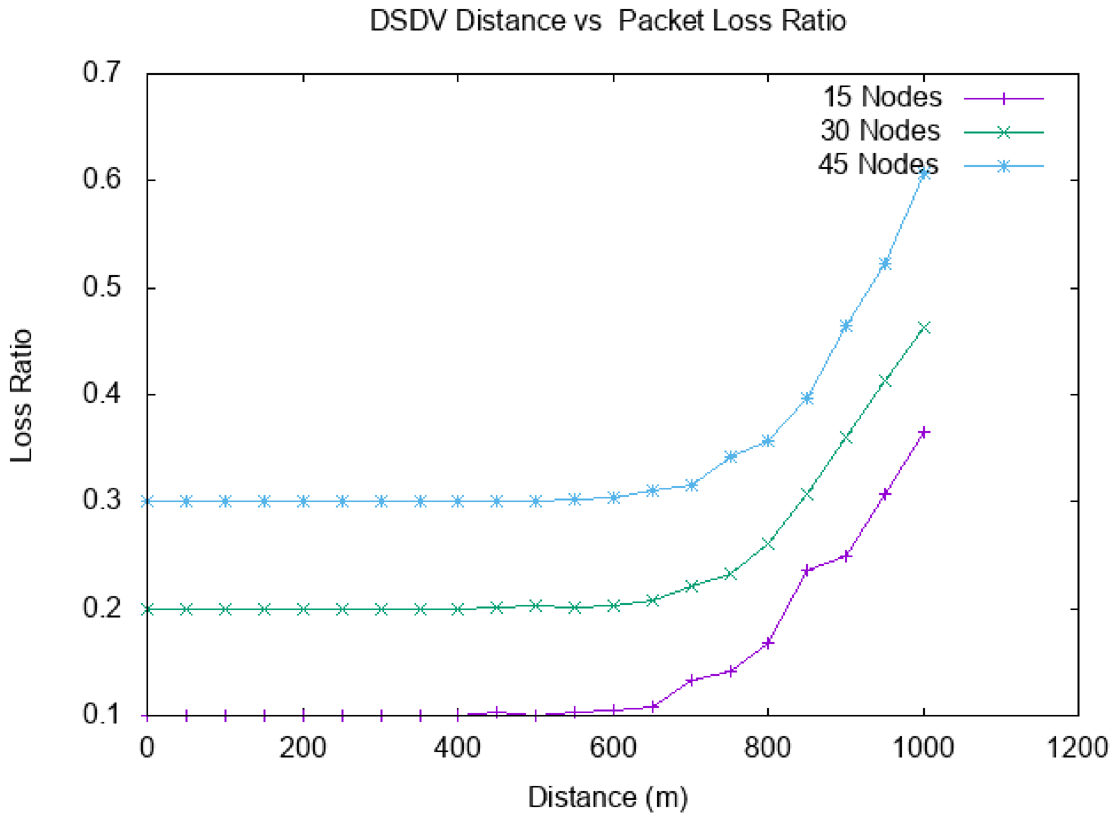
VANET	Vehicular Ad-hoc Networks
MANET	Mobile ad-hoac Networks
V2V	Vehicle to Vheicle Communication
V2I	Vehicle to Infrastructure Communication
BSM	Basic Safety Messages
DSCR	Dedictated Short Range Communication
ITS	Intelligent Transportation System
CCH	Control Channeñ
SCH	Service Channel
CA	Coopeartive Awareness
CDA	Cooperative Driver Assistance Applications
ACC	Adaoptive Cruise Control
CACC	Cooperative Adaptive Cruise Control
CVT	Connected Vehicle Technology
GPS	Global Positioning System
CAM	Cooperative Awareness Message
DENM	Decentralized Enviromental Notification Messages
OFM	Orthogonal Frequency Divsion Multiple Access
OLSR	Optimized Link State Routing
AODV	Ad-hoc On-demand Routing
NS-3	Network Simulator-3
RSU	Road Side Units
OBU	On-Board Unit
WBSS	WAVE Basic Service Set wbss
WAVE	Wireless Access for Vehicular Environment
PCF	Point Coordination Function
ASTM	American Society for Testing and Materials
DGPS	Differential Global Position System
CVT	Connected Vehicle Technology
MPR	Multi-Point Relay
RREQ	Route Request Message
RERR	Route Error Message
QoS	Quality of Service
EDCA	Enhanced Distributed Channel Access
TCP/IP	Transport Control Protocol/Internet Protocol
MAC	Media Access Control
FCC	Federal Communication Commission

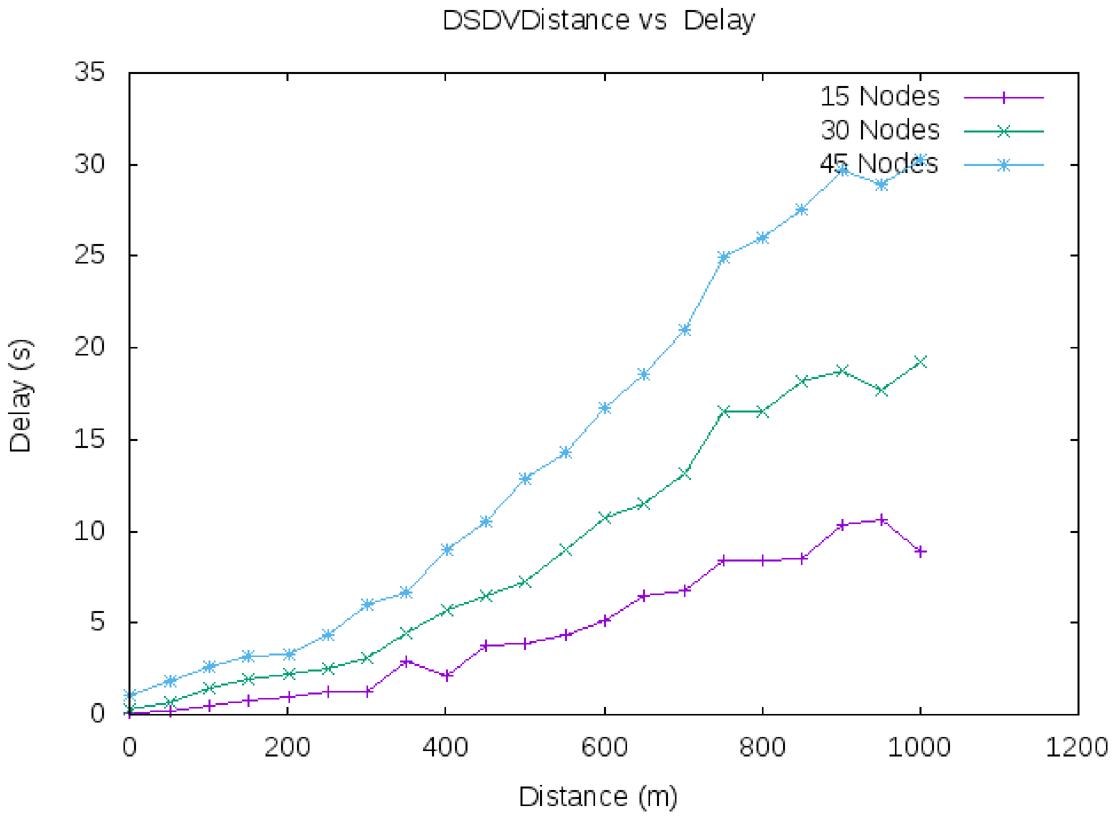
X Annexes

In the annexes, I have attached some results for Destination-Sequence Distance Vector DSDV protocol. The graphs include results for throughput, packet delivery ratio, packet loss ratio and end to end delay.






DSDV Distance vs Packet Loss Ratio
Loss Ratio
Distance (m)
15 Nodes
30 Nodes
45 Nodes
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0
200
400
600
800
1000
1200


DSDVDistance vs Delay
Delay (s)
Distance (m)
15 Nodes
30 Nodes
45 Nodes
0
5
10
15
20
25
30
35
0
200
400
600
800
1000
1200