Optimized Routing Protocol for Data Dissemination in Vehicular Ad Hoc Networks

By

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DEPARTMENT OF COMPUTER SCIENCE AND ENGINEERING

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Optimized Routing Protocol for Data Dissemination in Vehicular Ad Hoc Networks

Major Project

Submitted in partial fulfillment of the requirements

For the degree of

Master of Technology in Computer Science and Engineering

By

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Declaration

This is to certify that

i) The thesis comprises my original work towards the degree of Master of Technology in Computer Science and Engineering at Nirma University and has not been submitted elsewhere for a degree.

ii) Due acknowledgement has been made in the text to all other material used.

Sutariya Dharmendra N.

Certificate

This is to certify that the Major Project entitled "Optimized Routing Protocol for Data Dissemination in Vehicular Ad Hoc Networks" submitted by Sutariya Dharmendra N. (09MCE016), towards the partial fulfillment of the requirements for the degree of Master of Technology in Computer Science and Engineering of Nirma University, Ahmedabad is the record of work carried out by him under my supervision and guidance. In my opinion, the submitted work has reached a level required for being accepted for examination. The results embodied in this major project, to the best of my knowledge, haven't been submitted to any other university or institution for award of any degree or diploma.

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Abstract

Vehicular Ad hoc Network (VANET) is a new communication paradigm that enables the communication between vehicles in the network about potential obstacles on the road ahead. This has opened door to develop several new applications like traffic engineering, traffic management, dissemination of emergency information to avoid hazardous situations and other user applications as a part of Intelligent Transport System (ITS). Various approaches of data dissemination in vehicular network is to inform vehicles about dynamic road traffic condition so that a safe and efficient transportation system can be achieved. Here, data dissemination techniques are extensively reviewed and concluded that data dissemination techniques depends on the type of application and data to be transmitted among vehicles. However, type of VANET applications and inherent characteristics such as different network density, fast movement of vehicles make data dissemination quite challenging.

Topology based routing protocols AODV, AOMDV, DSDV and DSR are evaluated with NS-2 simulator for highway and city scene, where in vehicle mobility is generated using MObility generator for VEhicular networks (MOVE). Simulation results shows that AODV has higher Avg. End-to-End delay and Dropped packets compare to other routing protocols in given scenarios with varying traffic concentration. However there is a scope to improve performance of AODV protocol in terms of Avg. End-to-End delay and Packet Loss Ratio in VANETs. Improvement is Limited Source Routing up to two hops with Backup route between Source node and Destination node in AODV protocol, which combines the routing mechanism of DSR and AOMDV protocol. Quantitative evaluation based on Vehicle Density, No. of Active connections and Vehicle Mobility is done for suggested evaluation metrics. Results indicate that the proposed improvement on AODV routing protocol is better compared to the existing data dissemination approach of AODV protocol.

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Abbreviations

AODV	Ad hoc On demand Distance Vector
AOMDV	Ad hoc On demand Multipath Distance Vector
CTS	Clear To Send
DSDV	Destination Sequence Distance Vector
DSR	Dynamic Source Routing
DSRC	Dedicated Short Range Communication
E2E	End-to-End
I2V	Infrastructure to Vehicle
IAODV	Improved AODV
ITS	Intelligent Transport System
MANET	Mobile Ad Hoc Network
MOVE	MObility model generator for VEhicular networks
NAM	Network AniMator
NRL	Normalized Routing Load
NS	Network Simulator
OTcl	Object-oriented Tcl
PDR	Packet Delivery Ratio
PLR	Packet Loss Ratio
RERR	Route Error
RREP	Route Reply

RREQ	Route Request
RTS	Request To Send
SUMO	Simulation for Urban MObility
TCL	Tool Command Language
TCP	Transmission Control Protocol
TIGER	Topologically Integrated GEographic Encoding and Referencing
UDP	User Datagram Protocol
V2I	Vehicle to Infrastructure
V2V	Vehicle to Vehicle
VANET	Vehicular Ad Hoc Network

Chapter 1

Introduction

Numerous local incidents occur on road networks daily, many of which may lead to congestion and safety hazards. If vehicles can be provided with information about such incidents or traffic conditions in advance, the quality of driving can be improved significantly in terms of time, distance and safety. VANETs have newly emerged as an effective tool for improving road safety through the dissemination of warning messages among the vehicles in the network about potential obstacles on the road ahead. Various approaches of data dissemination in vehicular network can be used to inform vehicles about dynamic road traffic condition so that a safe and efficient transportation system can be achieved. However, type of VANET applications and inherent characteristics such as unpredictable node density, movement at high speeds, constrained mobility and communication environment make data dissemination quite challenging. Increase safety of people from road accidents and help to solve traffic congestion problems can be achieved by giving timely and accurate information to driver in VANET. This dissertation work includes the survey of various data dissemination techniques and challenges associated with it. Highway scene and City scene are designed and implemented using MOVE for highlighting the topology based routing protocols performance in VANET using NS-2 simulator. Finally some modifications in AODV routing protocol in order to improve the performance of the AODV protocol in terms of Avg. End-to-End delay and Packet Loss Ratio, concluded from performance evaluation. The results were then analyzed based on the suggested evaluation metrics in order to verify their suitability for use in Vehicular Area Networks.

1.1 Objective of the Work

The objective of this research is to achieve safe and efficient transportation using data dissemination techniques in Vehicular Ad Hoc Networks.

Specific Objectives

- To study data dissemination techniques in VANETs.
- To evaluate topology based routing protocol's performance in Highway and City scenarios.
- To propose improvements on AODV protocol.
- To test and validate the effectiveness of proposed improvement.

1.2 Scope of the Work

The scope of this work is to optimize a topology based routing protocol for VANET based on data dissemination techniques with varying traffic concentration.

1.3 Motivation of the Work

- Increase safety - Hundreds of thousands of people are killed world-wide due to road accidents yearly and many more are injured.
- Traffic optimization - Congestion/traffic jams cost time and fuel.

Both these problems can be solved or mitigated by giving timely and accurate information to the drivers so safe and efficient transportation system can be achieved.

1.4 Thesis Organization

The rest of the thesis is organized as follows.

Chapter 2, *Literature Survey*, describes general overview of VANET, Characteristics and Data dissemination approaches in vehicular networks. Also, challenges and proposed solutions of data dissemination techniques are briefly explained.

Chapter 3, *Study of VANET Simulators*, includes study of various open source VANET simulation software. MOVE rapidly generates realistic mobility models for VANET simulations which is built on top of SUMO. NS-2 is a discrete event simulator useful for testing of networking environment.

Chapter 4, *Design and Implementation of VANET Scenarios*, includes implementation of mobility model of Highway and City scene for varying number of vehicles with MOVE.

Chapter 5, *Performance Evaluation of Routing Protocols*, includes the performance analysis of AODV, AOMDV, DSDV and DSR routing protocols in Highway and City scene and then results are analyzed in terms of four evaluation metrics: Packet Delivery Ratio, Avg. End-to-End Delay, Dropped Packets and Normalized Routing Load.

Chapter 6, *AODV and Related Work*, includes the detailed working of AODV protocol. Also related work for improvements on AODV protocol is defined.

Chapter 7, *Proposed Improved AODV Protocol*, includes proposed modification on basic AODV protocol in order to achieve the objective of the project work. It will also cover the comparison analysis of the results with respect to Vehicle Density, No. of Active Connection and Vehicle Mobility for data dissemination in manhattan city scenario of VANET.

Finally, in **chapter 8** concluding remarks and future work is presented.

Chapter 2

Literature Survey

2.1 Introduction

Many people lose their lives and/or are injured due to accidents or unexpected events taking place on road networks. Besides traffic jams, these accidents generate a tremendous waste of time and fuel. Undoubtedly, if the vehicles are provided with timely and dynamic information related to road traffic conditions, any unexpected events or accidents, the safety and efficiency of the transportation system with respect to time, distance, fuel consumption and environmentally destructive emissions can be improved. VANETs are self organizing networks established among vehicles equipped with communication facilities. The equipped vehicles are network nodes so that each node can act as the source of data, destination for data and a network router. In the envisioned applications, the equipped vehicles are able to communicate over the 5.9 GHz frequency band via a DSRC based device. DSRC with a range of up to 1000 m allows high-speed communications between vehicles for ITS related applications. Potential DSRC based applications for public safety and traffic management consist of intersection collision avoidance, warning messages, and approaching emergency vehicle warning etc.. VANETs have recently emerged as an effective tool for improving road safety through propagation of warning messages among the vehicles in the network about potential obstacles on the road ahead. VANETs and MANETs have some similar characteristics such as short range of transmission, low bandwidth, omni-directional broadcast and low storage capacity. In spite of these similarities, they have some different characteristics. VANET characteristics are defined as follows:

- **Highly Dynamic Topology :** The speed and choice of path defines the dynamic topology of VANET. If we assume two vehicles moving away from each other with a speed of 60 mph (25m/sec) and if the transmission range is about 250m, then the link between these two vehicles will last for only 5 seconds. This defines its highly dynamic topology.
- **Frequent Disconnected Network :** The above feature necessitates that in about every 5 seconds or so, the nodes needed another link with nearby vehicle to maintain seamless connectivity. But in case of such failure, particularly in case of low vehicle density zone, frequent disruption of network connectivity will occur. Such problems are at times addressed by road-side deployment of relay nodes.
- **Mobility Modeling and Prediction :** The above features for connectivity therefore needed the knowledge of node positions and their movements which as such is very difficult to predict keeping in view the nature and pattern of movement of each vehicle. Nonetheless, a mobility model and node prediction based on study of predefined roadways model and vehicle speed is of paramount importance for effective network design.
- **Communication Environment :** The mobility model highly varies from highways to that of city environment. The node prediction design and routing algorithm also therefore need to adapt for these changes. Highway mobility model, which is essentially a one-dimensional model, is rather simple and easy to predict. But for city mobility model, street structure, variable node density,

presence of buildings and trees that behave as obstacles to even small distance communication make the model application that very complex and difficult.

- **Hard Delay Constraints :** The safety aspect (such as accidents, brake event) of VANET application warrants on time delivery of message to relevant nodes. It simply cannot compromise with any hard data delay in this regard. Therefore high data rates are not as important an issue for VANET as overcoming the issues of hard delay constraints.

- **Interaction with onboard sensors :** This sensors helps in providing node location and their movement nature that are used for effective communication link and routing purposes.

Like most MANETs, data is propagated in VANETs through the exchange of messages between the nodes. Unlike MANETs, the restricted road topology imposes a directional nature to the message flow. Also due to higher node speeds and unstable connectivity among the nodes, it becomes necessary that data be transmitted in the most efficient ways and with minimal delay. A VANET system architecture consists of domains like in-vehicle, ad hoc, and infrastructure and many individual components as application unit, on-board unit, and roadside base station. Figure 2.1 defines VANET architecture where data dissemination among vehicles are done through inter vehicle communication and vehicle to roadside communication.

This chapter will cover the V2I/I2V and V2V data dissemination approaches, associated challenges and solution of them respect to the application types.

2.2 Data Dissemination Approaches

As defined in VANET architecture data dissemination between components is categorize as V2I/I2V and V2V. Data dissemination among vehicles depends on the type of assumed network architecture. In the presence of infrastructures or road side units, two data dissemination approaches are assumed: push based and pull based. In the

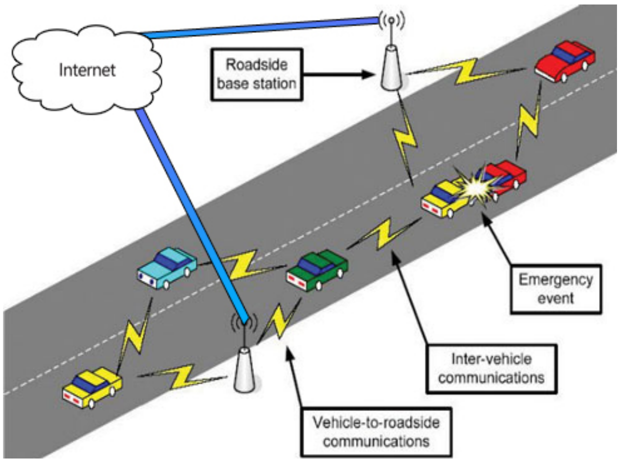


Figure 2.1: VANET Architecture

absent of infrastructure two dissemination approaches can be considered: Flooding and relaying.

2.2.1 Vehicle to Infrastructure (V2I)

Push based and Pull based approaches are considered for V2I/I2V data dissemination.

In the push based approach, the generated data is broadcasted to everyone. The drawback of this form of dissemination is that everybody may not be interested to the same data. Therefore is more suitable for applications supporting local and public-interest data such as data related to unexpected events or accidents causing congestion and safety hazards. It also generates low contentions and collisions for packet propagation.

However in the pull based approach, vehicles are enabled to query information about specific targets and responses to their queries are routed toward them. As it can be inferred, the pull based dissemination is useful for acquiring unpopular and individual-specific data. It generates a lot of cross traffics including contentions and collisions.

Reference [1] is a research effort which considers information source (data center) to disseminate data to many vehicles on the roads. It is noted that periodically pouring data on the road is necessary since vehicles receiving the data may move away quickly, and vehicles coming later still need the data. Reference [2] is a research effort which focuses on the decentralized discovery of parking places. The proposed model consists of communication between vehicles and fixed infrastructures named as parking automat and also between vehicles.

2.2.2 Vehicle to Vehicle (V2V)

Flooding and relaying are two approaches that can be considered for vehicle to vehicle data dissemination.

The basic idea in the first approach is that generated or received data is broadcasted to all neighbours. In other words, every node participates in dissemination. As it can be inferred it is suitable for delay sensitive applications and also for sparsely connected or fragmented networks. Flooding in general generates high message overhead and consequent broadcast storm problem. The problem can be more severe when the node density is high in urban area and extremely dense during rush hours or traffic jams. Therefore, there are several solutions proposed in order to avoid broadcast storm problem. These solutions are discussed in details in Section 2.3.

In relaying, instead of disseminating the message to all neighbors, a relay node is selected. The relay node is responsible to forward the packet further and so on. As it is clear contention is less in compared with the first approach and it is scalable for dense networks. This is due to the less of number of the nodes participating in forwarding message and consequently generated overhead is less. However, selecting relay node and ensure reliability are two challenges that need to be addressed and are discussed in section 2.4.

2.3 Broadcast Storm Problem Suppression Techniques

Flooding is one of the approaches that can be used for data dissemination in a pure VANET which does not have any infrastructure support for communication. Because of the shared wireless medium, blindly flooding the data packets leads to frequent contention and collisions among neighboring nodes. This problem is sometimes referred as broadcast storm problem. There are two main approaches that are considered in the literature: 1) Simple forwarding restricted by the timer and number of hops; 2) Map based/Geographic forwarding exploiting the map or geographic information such as directed flooding and aggregation. The details are described in subsections.

2.3.1 Timer-Based (Simple Forwarding)

A role-based multicast protocol is proposed in [3, 4] that suppresses broadcast redundancy by assigning shorter waiting time prior to rebroadcasting to more distant receivers. It should be noted that the primary objective of this study is to achieve maximum reachability in a sparsely connected network. By knowing its own position, the system determines a waiting time WT depending on the distance d to the sender such that the waiting time is shorter for more distant receivers as shown below:

$$WT(d) = -\frac{MaxWT}{Range} * \widehat{d} + MaxWT$$

$$\widehat{d} = Min\{d, Range\}$$

where MaxWT = Maximum Waiting Time, Range = Transmission range and d = Distance from sender

Three probabilistic and timer-based broadcast techniques are proposed by the authors in [5]. These techniques are used at network layer which are listed and described in the following:

- Weighted p-persistence (Vehicles located further have higher probability for retransmission)
- Slotted 1-persistence (Vehicles have to retransmit with probability 1 at the assigned time slot and shorter waiting time will be assigned to the vehicles locate further)
- Slotted p-persistence (Vehicles have to retransmit with probability p at the assigned time slot and shorter waiting time and higher probability will be assigned to the vehicles locate further)

Slotted 1-persistence and slotted p-persistence scheme can reduce broadcast redundancy and packet loss ratio up to 70 percent while still offering acceptable end-to-end delay for most multihop VANET applications.

2.3.2 Hop Limited (Simple Forwarding)

The basic idea of this approach is to avoid broadcast storm problem by simply limiting the number of hops the message gets propagated. However, determining the number of hops can be challenging.

Reference [6], is a research work that deploys strategy in which query disseminations are limited by the number of hops. The research discusses design issues relevant to a system for targeted ad delivery mechanisms for vehicles. AdTorrent searches for relevant ad-content using a hop-limited query broadcast. Since setting large hop-limit queries more nodes, a larger hop-limit improves the probability of finding the desired content and will likely increase the number of sources from which the content may be downloaded. There is an inherent trade-off between the reliability/effectiveness of the search and the flooding overhead. Thus, the hop limit in the query flood is a key design issue. Therefore, an analytical model is presented in this research to estimate the performance impact of key design parameters such as the scope of the query flooding (determined by the number of hops) on the query hit ratio in epidemic query dissemination. The analytical model can achieve 80 percent hit ratio with query hit limit value 4.

2.3.3 Directed Flooding (Map-based or Geographic Forwarding)

As indicated by its name, the flooding of data is restricted to specific directions or geographic areas. Therefore, by deploying this strategy, flooding of data in directions that does not benefit dissemination is limited.

Costa et al. [7] defined dissemination based on propagation function for inter-vehicular networks. Propagation function encodes destination region and trajectory with using map. They propose several flooding schemes as basic, probabilistic, function driven. Protocols defined below are designed to take decision in receiver based fashion so eliminate the need to collect neighbor information.

- One Zero Flooding (OZF) - Messages broadcasted only towards areas where propagation function returns the lower value.

- Distance Driven probabilistic diffusion (DDPD) - Extension of OZF with addition of a probabilistic decision.

- Function Driven Probabilistic Diffusion (FDPD) - Use values return by function in order to calculate forwarding probability.

- Feedback Augmented Store,Forward Diffusion (FSFD) - Deploy store and forward techniques.

2.3.4 Aggregation (Map-based or Geographic Forwarding)

Aggregation is a technique proposed in some research works in order to avoid broadcast storm problem. Penetration and scalability as two major challenges that can be faced in V2V based applications. It is believed that with low market penetration rate, in the majority of the time there is no or only a very limited number of communication partners available within transmission range. Therefore, the average range in which information can be distributed is small. Furthermore, scalability becomes an issue once a higher market penetration is reached. In order to avoid overload conditions the amount of data transferred needs to be restricted.

To solve these two challenges, Segment-Oriented Data Abstraction and Dissemination (SODAD), a method for data dissemination for comfort applications, is proposed in [8]. Vehicle sensing data for on-board traffic information system and data dissemination is reached by abstracting the map into adaptive segments and aggregation information (aggregation function) by restricting the method to the dissemination of map/position-based data, scalability is achieved. Self Organizing Traffic Information System (SOTIS) is an example application of SODAD. SOTIS system architecture [8] is defined in fig. 2.2.

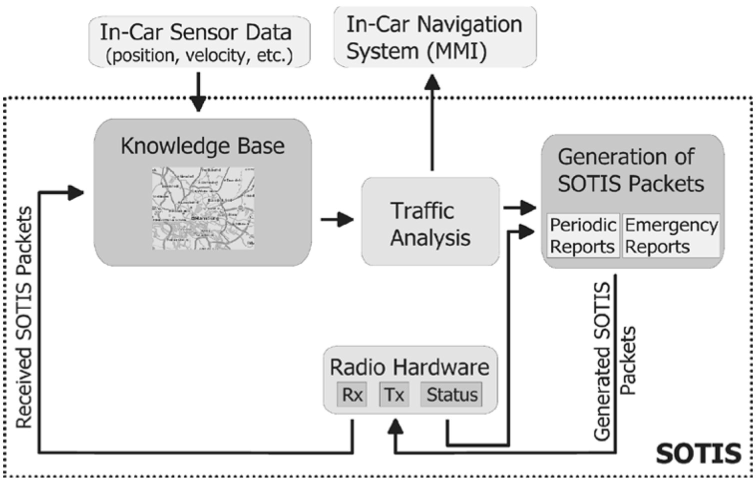


Figure 2.2: Structure of SOTIS

Traffic information is collected and updated in the knowledge base which contains traffic information of all segments of local area. Using the information stored in the knowledge base, a traffic analysis is continuously calculated in each car. From this analysis information is determine to be included for next broadcast data packet.

Adaptive broadcast intervals is defined based on provocation and mollification events to favor traffic conditions.

In decentralized discovery of free parking places [2], proactive dissemination scheme is used to inform drivers about parking place situation under urban traffic conditions. Periodic broadcast interval is used to disseminate received atomic and aggregated information which takes spatio-temporal character of parking places into account. Map is subdivided to overlay grids and information is classified into different levels for data dissemination.

2.4 Relaying and Associated Challenges

Relaying is an approach assigning the duty of forwarding a packet to specific node or nodes that satisfy some criteria. As it can be inferred it generates less contention and it is scalable for dense network condition. The main challenges faced in the relay-based approaches include selecting the relay node/nodes and ensuring reliability. Basically, the relay-based data dissemination approaches can be divided into two categories: 1) Simple forwarding and 2) Map-based forwarding exploiting digital map information and GPS. With respect to the second challenge, ensuring reliability, several solutions such as RTS /CTS and ACK mechanisms are suggested. The research efforts deploying these techniques are described in following subsections.

2.4.1 Relaying (Simple Forwarding)

With respect to the research proposed in [9], a new efficient IEEE 802.11 based protocol, Urban Multi-hop Broadcast protocol (UMB), is proposed for VANET. The node farthest from the sender of the packet is selected as relay point. UMB is designed to address the broadcast storm, hidden node and reliability problems in multi-hop broadcast. It is composed of two phases: 1) Directional broadcast and 2) Intersection broadcast. In the first phase, sender nodes try to select the furthest node in the broadcast direction to assign the duty of forwarding and acknowledging the packet

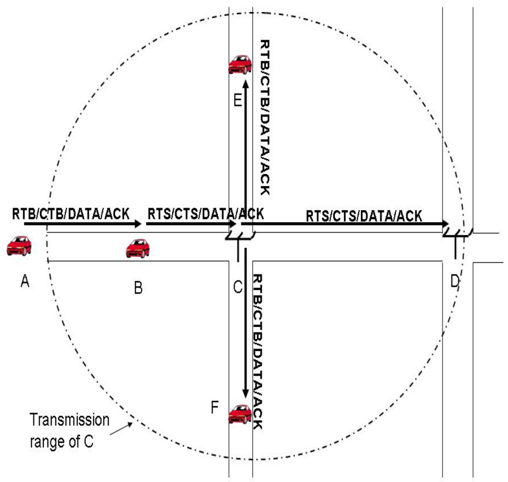


Figure 2.3: UMB Protocol [9]

without any apriori topology information i.e., sender selects the furthest node without knowing the ID or position of its neighbors. In the second phase, there are some repeaters installed at each intersection to disseminate the packets in all directions. When a node is selected to forward a packet and it is outside the transmission range of a repeater, it continues with the directional broadcast protocol. If the node is inside the transmission range of a repeater, the node sends the packet to the repeater using the point-to-point IEEE 802.11 protocol. RTS/CTS like mechanism RTB/CTB is used between node and repeater to forward the data. ACK packet provides reliability of broadcast. After receiving this broadcast packet, the repeater initiates a directional broadcast in all road directions except the direction from which the packet was received.

An example of intersection handling is illustrated in Figure 2.3 [9], which shows that vehicle A uses the directional broadcast to reach B. Note that A is out of the transmission range of the repeater C. On the other hand vehicle B is in the transmission range of repeater C; therefore vehicle C uses IEEE 802.11 protocol to communicate with repeater C. Once repeater C receives the message, it initiates directional broadcasts to the north and south directions. Since the repeater D is in the transmission range of repeater C, it also sends the packet to repeater D using IEEE 802.11 protocol.

With respect to the research carried out in refrence [1], data pouring and buffering dissemination scheme is proposed where disseminate data from center to many vehicles. Each nodes maintain neighbor list and select farthest node as relay. Here dissemination zone defined as rectangle area and expiration time are attached as data delivery information. Ibers (Infostation) are deployed at intersections to broadcast data to the cross roads vehicles. They developed analytical model for dissemination capacity and broadcast interval.

2.4.2 Relaying (Map-based or Geographic Forwarding)

With respect to the research carried out in reference [10], the relaying is used. The relay point that forwards the message further is called “message head” which is defined as massage holder closest to the destination region. The proposed algorithm is called MDDV (Mobility-centric Data Dissemination for Vehicular Networks). MDDV is designed to exploit vehicle mobility for data dissemination, and combines the idea of opportunistic forwarding, trajectory based forwarding and geographical forwarding. Opportunistic forwarding is used when the network is fragmented and end to end connectivity does not exist. As suggested in such cases messages are stored and forwarded as opportunities present themselves. Trajectory based forwarding directs messages along predefined trajectories. Generally, MDDV can be divided into two phases: Forwarding phase and Propagation phase. In the first phase, the data is forwarded to reach the destination region and in the second phase, the data is propagated to reach all the receivers in the region.

Research carried out in refrence [11], geographical routing is used to forward the query to the query region. Each nodes maintain a neighbor list and once query region is reached, nodes do flooding in that region. Reply is sent back to the source via flooding. All theses tasks are done with use of four phases as dispatch-query, VAHS-computation, dispatch-reply and reply delivery.

2.5 Opportunistic Forwarding

Network fragmentation may happen due to the low market penetration rate at least at the early stages of introducing the technology or due to low traffic density periods. Therefore, this issue is addressed in some of research efforts and data dissemination approaches are proposed such that continuous network connectivity can be guaranteed.

With respect to the role-based muliticast protocol proposed in [3, 4] the main objective is to achieve maximum reachability in a sparsely connected network. In the proposed approach, each node keeps a set named at neighboring set and retransmissions are based on changes in the neighbor sets.

With respect to the research carried out in reference [12], an opportunistic packet relaying is proposed for disconnected VANET named as OPERA. In OPERA the packet progresses towards destination opportunistically, by a combination of data muling and local routing with the help of both co-directional and oncoming clusters. Cluster refers to the group of vehicles that are in a direct radio transmission with one another and have the same direction. In this research, some mathematical expressions are proposed such as the expected slot for a specific car, the probability of having disconnected periods and expected cluster size, both as a function of traffic density and communication range. Beacon message is sent for cluster formation and cluster maintenance. Head and tail vehicles in a cluster play an especial role in data dissemination.

Most of the proposed routing protocols suggest that the message needs to be delivered to the cluster in the opposite direction and this process continues until the packet is reached to its destination. However, OPERA offers a different approach as shown in Figure 2.4 [12]. It believes that there are some cases may rise such as the one depicted in case (b) in which sending the packet in opposite direction not

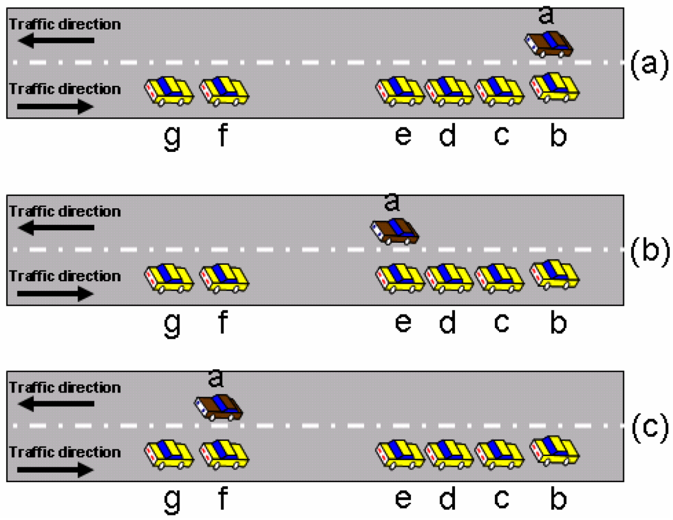


Figure 2.4: OPERA Example [12]

only is not beneficial but also a lot of resources may be wasted at no gains. As an example, it would have been much better for car a not to send the packet to car b at all and carry the packet for some time and send the packet to g when they are in a direct radio contact. OPERA attempts to speed up the packet delivery time by opportunistically selecting a locally-optimal route towards the destination using only local connectivity information. A packet may hop between clusters or cars moving in opposite lanes until eventually it reaches its destinations. In this sense, OPERA is actually a hybrid protocols it alternates between applying proactive routing and data muling.

In Fleanet [13] an architecture is proposed for buy/sell queries dissemination on vehicular networks. Dissemination is basically by contacts, vehicles that receive queries store it in their database and see if there is a local match with it. Source node broadcasts queries periodically to its neighbors (opportunistic). Last Encounter Routing (LER) is used to send notifications from buyers to sellers.

Research [14] shows the feasibility of information dissemination w.r.t. penetration ratio in city. With analytical model they show that connectivity decreases with length.

They Propose installing SSUs (InfoStations) in networked and stand-alone to improve dissemination by re-broadcasting the information. Vehicles periodically broadcast information to neighbors with use of Locomotion and Wireless propagation.

2.6 Summary

Push based and pull based are two approaches considered in V2I/I2V. In the push based approach, data is disseminated to anyone and it is suitable for popular data which is in the interest of anyone. In the pull based approach, the network entities are able to query the required information and this approach is suitable for unpopular data propagation. Therefore, generated cross traffic can cause interference and collisions among propagating data packets.

Flooding and relaying are the two proposed approaches for V2V. In the flooding, reliable and quick data propagation is its advantages but not suitable for dense network condition due to its high message overhead. In the relaying approach, the duty of forwarding is assigned to less number of vehicles and generated overhead is less. Therefore, although it is suitable for dense networks, selecting the relay points and ensuring reliability are its disadvantages.

Opportunistic data dissemination approach proposed for data dissemination in sparsely connected network is store and carry mechanism in which the data will be stored at the node until some nodes are available. This is the only applicable strategy in a sparsely connected network as there is no other option available.

Use of one or more data dissemination techniques depending on the type of application considered and type of data to be transmitted among vehicles. Inherent VANET characteristics makes data dissemination quite challenging for different type of application and data to be transmitted. As identifying problem from above studies, next task is to find effective data dissemination technique for topology based routing protocol in varying VANET scenarios.

Chapter 3

Study of VANET Simulators

The goal for any simulator is to accurately model and predict the behavior of a real world environment. Developers are provided with information on feasibility and reflectivity important for the implementation of the system without investing significant time and money. Deploying and testing VANETs involves high cost and time. Simulations of VANETs often involve large and heterogeneous scenarios. Mobility behavior of node in VANET significantly affects simulation results. In a vehicular network, nodes (vehicles) can only move along streets, prompting the need for a road model. In VANETs nodes do not move independently of each other but they move according to well established vehicular traffic models.

VANET mobility generators are used to generate traces of the vehicle's motion that can be usually saved and subsequently imported into a network simulator in order to study the performances of the protocol/application. It is important to generate realistic movement traces in order to thoroughly evaluate VANET protocols because in general performances depend on the vehicles movement traces. The inputs of the mobility generator include the road model, scenario parameters like maximum vehicular speed, vehicle arrivals and departure rate etc.. The output of the trace contains the location of each vehicle at every time instant for the entire simulation time and their mobility profiles. Examples are SUMO, MOVE, FreeSim and VanetMobiSim .

Network simulators allow researchers to study how the network would behave under different circumstances. Users can then customize the simulator to fulfill their analysis needs. Network simulators are relatively fast and inexpensive compared to cost and time involved in setting up an entire experiment containing multiple networked computers, routers and data links. They allow researchers to test scenarios that might be difficult or costly to emulate with real hardware, especially in VANETs. Network simulators perform detailed packet level simulation of source, destinations, data traffic transmission, reception, route, links, and channels. Network simulators are particularly useful to test new networking protocols or to propose modifications on it. Examples are NS-2, GloMoSim and JiST/SWANS. Most existing network simulators are developed for MANETs and hence require VANET extensions before they can be used to simulate vehicular networks.

Simulation is therefore, the most common approach to developing or testing new protocol for a VANET. Choosing a right simulation tools has been a key step to get accurate prediction of real world environment. This chapter will cover the MOVE and NS-2 with its architecture.

3.1 MObility model generator for VEhicular networks(MOVE)

MOVE is built on top of an open source micro-traffic simulator SUMO [15]. Simulation of Urban MObility (SUMO) is a microscopic, space continuous and time discrete traffic simulator written in C++ capable to provide accurate and realistic mobility patterns. The project started as an open source project in 2001 with the goal to support the traffic research community with a common platform to test and compare models of vehicle behaviour, traffic light optimization, routing etc. In SUMO, each vehicle has an own route and is simulated individually according to a fast but still accurate car following model called as SUMOKrauβ.

MOVE [17] is an extension to SUMO that adds a GUI for describing maps, defining vehicle movement and allows the user to import real world map databases such as TIGER [16] and Google Earth. The output of MOVE is a mobility trace file that contains information of realistic vehicle movements which can be immediately used by popular simulation tools such as NS-2 or Qualnet. In addition, by providing a set of graphical user interfaces that automate the simulation script generation, MOVE allows the user to quickly generate realistic simulation scenarios without the hassle of writing simulation scripts as well as learning about the internal details of the simulator. The architecture of MOVE is shown in Figure 3.1 [17]

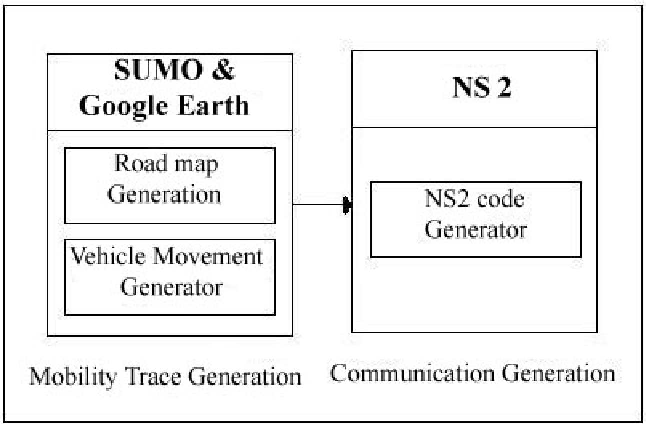


Figure 3.1: An Architecture of MOVE

3.1.1 MOVE Modules

Figure 3.2 shows MOVE modules and defines flow how we can create mobility and then simulate it with netwok simulators. Users input information of Map Editor and Vehicle Movement Editor is then fed into SUMO to generate a mobility trace which can be immediately used by a simulation tool such as ns-2 or qualnet to simulate realistic vehicle movements. Users can also visualize the generated mobility trace with SUMO by clicking on the “Visualization” button, as shown in Figure 3.3. MOVE

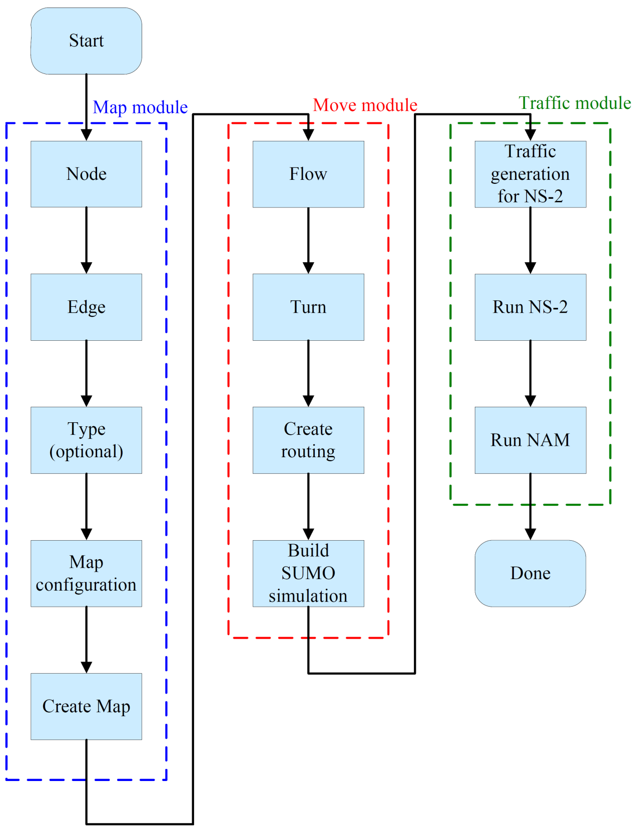


Figure 3.2: Modules of MOVE [17]

consists of two main components: Map Editor and Vehicle Movement Editor, as shown in Figure 3.3.

3.1.2 MAP Editor

The Map Editor is used to create the road topology. It provides three different ways to create the road map – the map can be manually created by the user, generated automatically, or imported from existing real world maps such as publicly available TIGER database from U.S. Census Bureau. Manual generation of the map requires inputs of two types of information, nodes and edges. A "node" is one particular point on the map which can be either a junction or the dead end of the roads. The junction nodes can be either normal road junctions or traffic lights. The edge is the road that

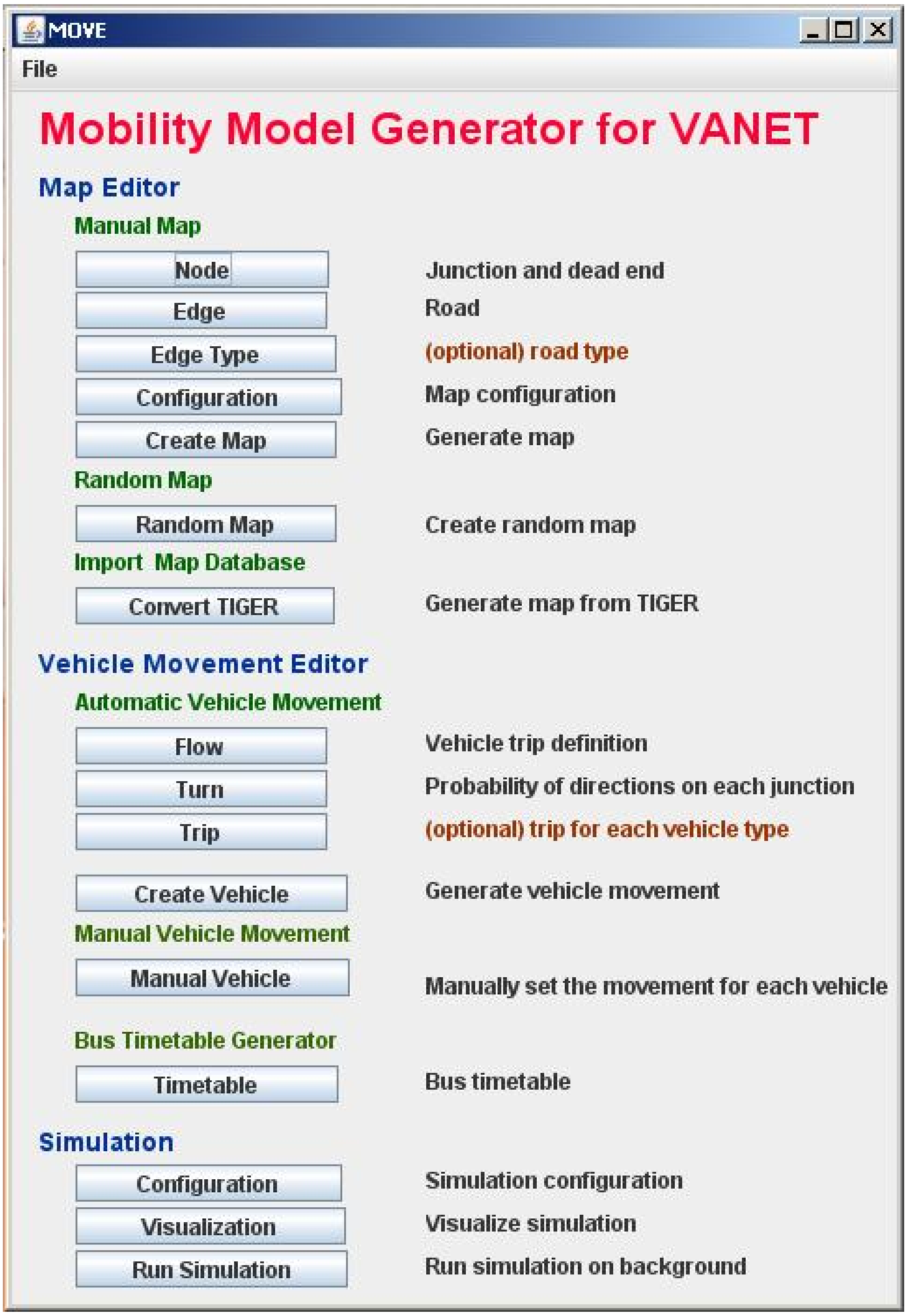


Figure 3.3: Mobility Editor of MOVE

connects two points (nodes) on a map. The attributes associated with an edge include speed limit, number of lanes, the road priority and the road length.

The road map can also be generated automatically without any user input. Three types of random maps are currently available as grid, spider and random networks. There are some parameters associated with different types of random maps such as number of grids and the number of spider arms and circles. Also we can generate a realistic map by importing real world maps from publicly available database from internet.

3.1.3 Vehicle Movement Editor

The Vehicle Movement Editor allows the user to specify the trips of vehicles and the route that each vehicle will take for one particular trip. It support three different methods to define the vehicle movements the vehicle movement patterns can be manually created by the user, generated automatically or specified based on a bus time table to simulate the movements of public transportation. To generate vehicle movement automatically we have to first define a vehicle flow which describes vehicles toward the same direction. The parameters of each flow consist of the starting road and destination of the flow, the time to start and end the flow, the number of vehicles in the flow and the interdeparture time of the vehicle originating from the starting road. In addition, a MOVE user can define the probability of turning to different directions at each junction in the editor.

We can also generate vehicle movement manually using the Vehicle Movement Editor which allows users to specify several properties of vehicle routes including the number of vehicles in a particular route, vehicle departure time, origin and destination of the vehicle, duration of the trip, vehicle speed (including acceleration, deceleration and maximum speed) etc. In addition to simulating V2V communication, it is also useful for simulations of V2I. For creating infrastructure or roadside unit a static node can be created in MOVE by assigning the vehicle with a maximum speed of zero in the Vehicle Movement Editor. MOVE allows users to enter the bus time table to simulate the movements of public transport.

3.2 Network Simulator-2

The Network Simulator-2, as its name suggests, is a simulation tool for replicating real life networking environment and their working and adjoining standards respectively. It works with the combinations of different development tools and languages because of open source environment. Mainly by default, the backend is object oriented and scripting languages used by this simulator are the C++ and TCL. C++ is used for the development and implementation of low level operations and algorithms, whereas, TCL is used for the actual scripting codes for the simulations output scenarios. NS-2 is basically an OTcl script interpreter with network simulation object libraries. NS-2 has a simulation event scheduler, network component object libraries and network setup module libraries. To use NS-2 for setting up and running a network simulation, a user writes a simulation program in OTcl script language. Such an OTcl script initiates an event scheduler, sets up the network topology and tells traffic sources when to start and stop transmitting packets through the event scheduler. There are some associated tool with NS-2 like NAM is majorly used for visualization purposes.

3.2.1 Architectural Overview

The NS-2 architecture is composed of five parts:

- Event scheduler
- Network components
- Tclcl
- OTcl library
- Tcl 8.0 scipt language

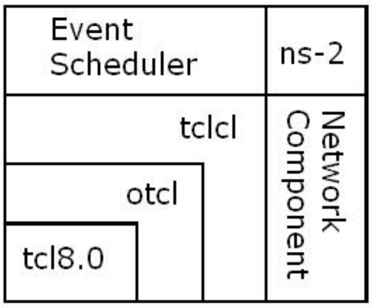


Figure 3.4: Architectural view of NS-2

Figure 3.4 shows a graphical overview of the NS-2 architecture [18]. A user can design and run simulations in Tcl using the simulator objects in the OTcl library. The event schedulers and most of the network components are implemented in C++ because of efficiency reasons. These are available to OTcl through an OTcl linkage that is implemented using tclcl. These five components together make up NS-2, which is an object-oriented extended Tcl interpreter with network simulator libraries.

3.2.2 Simulation Components

There are some very basic and generic components used by NS-2 to establish various special and diverse simulation scenarios. The most common (but not limited) are the Nodes, Agents and Links. The nodes are the participating objects within the simulation environment. Vehicles are the appropriate example in case of simulation scene for VANET. These nodes can further be classified with the attributes of source and sink depending on their traffic generator and/or receptor functions respectively. Agents on the other hand are the dependent elements. They rely on nodes for specifying the traffic type between their communication processes. And finally, links are used to specify the medium of connection i.e. wired or wireless between the participating nodes.

3.2.3 Simulation Operations

The simulation operations performed by the NS-2 after employing the components (mentioned above) can be broadly categorized as following [19].

- **Creating the event scheduler:**In this operation different event related activities being done. For example: create scheduler, schedule event(s) and start scheduler.
- **Creating network:** In this operation the required nodes with their linkage and queuing operations are created.
- **Creating connection:** In this operation the actual connection scheme e.g. TCP or UDP is given.
- **Creating traffic:** In this operation traffic flow is being mentioned i.e. how much traffic is needed for the simulated network. The common traffic creation criterion is Constant Bit Rate (CBR) where constantly bits of traffic are supplied to the network.
- **Tracing:** This is the crucial operation which reads the NS-2 simulation generated output file and shows different output results in the form of text or graph.

3.3 Simulation Methodology

According to the objectives of the research simulation methodology is defined in Figure 3.5. The movement and traffic files are generated and compiled separately before associating with NS-2 simulation, which would then be in the receiving format for NS-2 to amalgamate with the body of actual TCL.

The TCL file is the scripting representation for coding and developing the desired networking scenarios (wired/wireless). These scenarios are based on various parameters and their settings of generated traffics along with their mobility, reliability, and

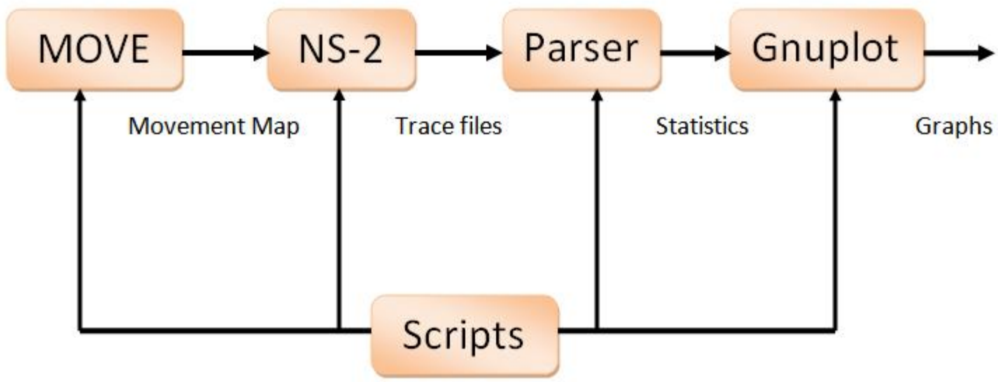


Figure 3.5: Simulation Methodology

likewise constraints. Initializing the routing protocol within a TCL file as inputs in association of particular traffic and movement files, the NS-2 simulates accordingly. Ultimately, as a result, it generates two files i.e. a NAM File (*.nam) and a Trace files (*.tr) as the outputs.

The NAM file consists of all the operations to be performed at the time of simulation with all the positioning and graphical information and their defined parameters. This NAM file then can be called or executed by its built-in nam command from the operation component of NS-2 itself. The trace files contains all of the data e.g. how many packets are sent, received, dropped and with what sequence number, type, size, etc.. The trace file is simply available in a text format and could be called as a log file of the simulation with all the information logged in columns format.

Text analyzer is use to analyze the trace file(s). This could be done by mean of various analyzing methods and scripting codes, for example: PERL (Practical Extraction and Reporting Language), AWK (named after their writers, Alfred Aho, Peter Weinberger, and Brian Kernighan) and some other third parties text search software. Statistics generated by text analyzer are given to gnuplot to generate the graphs.

3.4 Summary

This chapter presented MOVE which is specifically designed for VANET to generate vehicle mobility on road topology and NS-2 which is discrete event simulator for simulating VANET scenarios.

Chapter 4

Design and Implementation of VANET Scenarios

In this chapter simulation models used for VANET scenarios are classified into two pragmatic scenes: 1) Highway Scene and 2) City Scene. A realistic vehicular mobility scenario for a highway and city scene are generated using MOVE. A vehicular mobility pattern defines vehicle motions within the road segment during a simulation time, which reflects, as close as possible, the real behavior of vehicular traffic such as traffic jams and stop at intersections.

4.1 Highway Scene

Figure 4.1: Highway Scene

Mobility scenario for highway traffic which is modeled as 2×2 scenario, viz. bidirection two lanes in each side as shown in Figure 4.1. Vehicles can move along road-

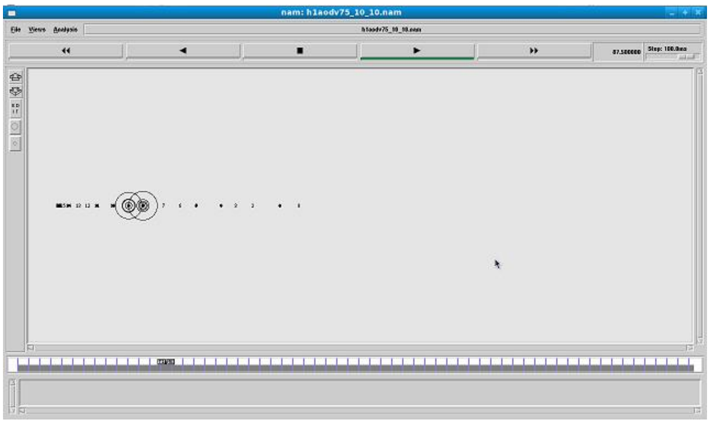
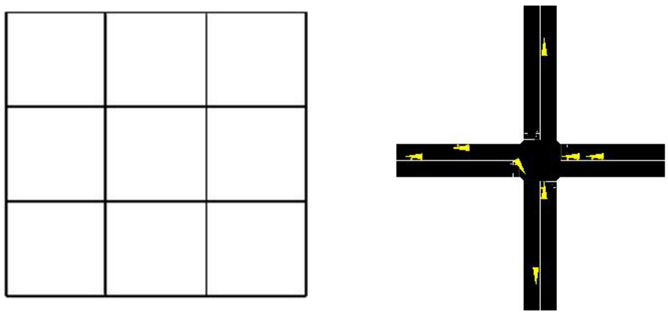


Figure 4.2: Highway Scene with Network AniMator

ways with high speed towards the two opposite directions. for this scenario vehicles can move with maximum speed of 90 km/h and vehicle flow is determined from left to right direction on 10 km highway. To make comparative study of selected routing behavior in their respective scenes, an approach of density formulation among traffic flow is reused. The highway model is further sub-classified on the basis of their participating vehicles and number of TCP connection used for established path. Figure 4.2 defines Highway scenario with Network AniMator. Table 4.1 shows common variable defined for highway scene.

Table 4.1: Common variables for Highway Scene

Variable	**Value**
Simulation Time	400 second
Tology Size	10 km
Max speed of Vehicles	90 km/h
No. of Vehicles	25, 50, 75, 100



(a) City Roadway (b) Intersection Structure

Figure 4.3: City Scene

4.2 City Scene

As shown in Figure 4.3(a), City scene consist of eight vertically and horizontally oriented streets as well as 12 crossings. Figure 4.3(b) defines view of crossing in road network. Each modeled street has a total length of 1500 m, where as parallel streets are separated by a distance of 500 m with bidirectional two lanes in each side. Vehicles can move with maximum speed of 40 km/h and vehicle flow is determined from upper left corner to bottom right corner and upper right to bottom left of the city map. Traffic lights to be placed at each crossing and vehicles stops at intersection and also make a turn at each crossing. To make comparative study of selected routing behavior in their respective scenes, an approach of density formulation among traffic flow is reused. The city model is further sub-classified on the basis of their participating vehicles and number of TCP connection used for established path. City scene with Network AniMator is shown in Figure 4.3. Table 4.2 shows common variable defined for city scene.

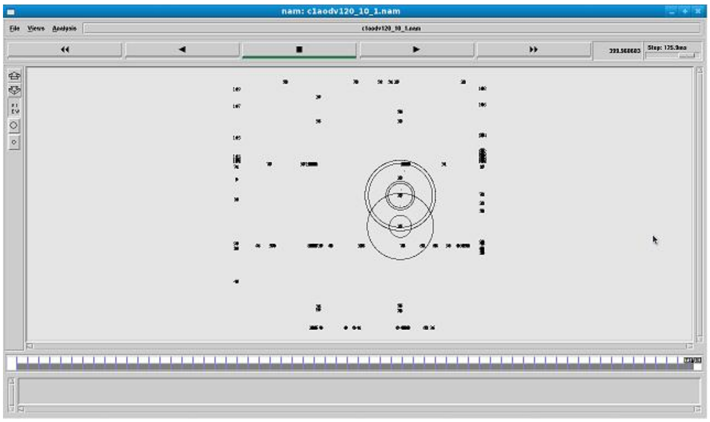


Figure 4.4: City Scene with Network AniMator

Table 4.2: Common variables for City Scene

Variable	**Value**
Simulation Time	400 second
Topology Size	1500 m x 1500 m
Max speed of Vehicles	40 km/h
No. of Vehicles	24, 48, 120, 280

4.3 Summary

The chapter presented the design and implementation of Highway and City scene with use of MOVE which was further used as mobility of vehicles in order evaluate protocols performance.

Chapter 5

Performance Evaluation of Routing Protocols

This chapter describes performance of topology based routing protocols along their effectiveness and underlying limitations within certain density levels of city and highway scenarios. Ad hoc routing protocols: AODV, AOMDV, DSR, and DSDV are separately incorporated by simulation models of varying vehicle concentration along with the precise parametric values of defined scenes and simulations are carried out with NS-2.34. The evaluative metrics for the examination of these protocols are measured by Packet Delivery Ratio (PDR), Average End-to-End delay, Dropped packets and Normalized Routing Load (NRL) respectively.

5.1 Routing Protocols

Various ad hoc network routing protocols have been proposed in recent years, whereas two main classes of protocols can be distinguished as : location based (position based) and topology based protocols. These protocols enable the exchange of data between distinct pairs of nodes, using intermediate network participants for forwarding packets on their way to the destination. Location based routing protocols use additional information on the nodes geographical positions to find suitable routes. These positions may be e.g. the nodes GPS coordinates. However, when using location based protocols, there is always a need for location services and servers. For that reason, we focus on topology based routing protocols that do without these additional mechanisms. Topology based routing protocols can be further classified as proactive, reactive and hybrid approaches. Following protocols are some chosen ones for the exploration of city and highways traffic scenarios:

- DSDV: Destination Sequence Distance Vector [20] is a proactive routing protocol where every node maintains a table of information (which updates periodically or when change occurred in the network) of presence of every other node within the network. Any change in network is broadcasted to every node of the network.

- AODV: Ad hoc On demand Distance Vector [21] is an improved version of DSDV, as its name suggest, establishes the route only when demanded or required for the transmission of data. By this mean, it only updates the relevant neighboring node(s) instead of broadcasting every node of the network i.e. it does not make source routing to the entire node for the entire network.

- AOMDV: Ad hoc On demand Multipath Distance Vector [22], an extension of AODV with an additional feature of multipath route discovery which prevents this on-demand routing protocol to form any loop or alternative paths.

- DSR: Dynamic Source Routing [23] is an on demand routing protocol like AODV. It maintains the source routing, in which, every neighbor maintains the entire network route from source to the destination.

5.2 Evaluation Metrics

The following metrics are chosen for evaluating the protocols:

- Packet Delivery Ratio (PDR): This metric gives the ratio of the total data packets successfully received at the destination and total number of data packets generated at source.

$$PDR = \frac{\Sigma \ Data \ \ Packets \ \ Received \ \ by \ \ Destination}{\Sigma \ Data \ \ Packets \ \ Generated \ \ by \ \ Source} \times 100 \tag{5.1}$$

  As of relative amount, the usual calculation of this system of measurement is in percentage form. Higher the percentage, more privileged is the routing protocol.

- Average End-to-End Delay (E2E Delay): It is the calculation of typical time taken by packet (in average packets) to cover its journey from the source end to the destination end. In other words, it covers all of the potential delays such as route discovery, buffering processes, various in-between queuing stays, etc, during the entire trip of transmission of the packet. The classical unit of this metric is millisecond (ms). For this metric, lower the time taken, more privileged is the routing protocol.

- Dropped TCP packets: It defines a total number of TCP packets dropped during transmission of packet from source end to destination end. For this metric lower the dropped packet, more privileged the routing protocol is considered.

- Normalized Routing Load (NRL): Normalized Routing load is the number of routing packets transmitted per data packet send to the destination. lower the value of metric, more privileged is routing protocol.

$$NRL = \frac{\Sigma \ Sent \ \ received \ \ and \ \ forwarded \ \ routing \ \ packets}{\Sigma \ Sent \ \ received \ \ forwarded \ \ data \ \ packets} \tag{5.2}$$

5.3 Simulation Parameter

For all scenarios mobilty of vehicle is generated with MOVE which work on SUMO, which is open source software. Traffic patterns are based on TCP which is generated with the help of cbrgen.tcl script of NS-2. Ten different traffic files are generated with use of cbrgen.tcl with varying number of traffic connection and then integrate with TCL script for both scenarios. The randomly chosen source-destination pairs are spread in the network. Table 5.1 shows Simulation parameters for highway scene and Table 5.2 shows for city scene which are used for creating TCL script. TCL scripts are then simulate with NS-2.34.

Table 5.1: Simulation parameter for Highway Scene

Parameter	**Simulated Value**
Channel Type	Wireless Channel
Antenna Model	Omnidirectinal antenna
Radio Propogation Model	Two Ray Ground
Transmission Range	250 m
MAC Type	IEEE 802.11
Interface Queue Type	priority Queue (50 Packtes)
Routing Protocols	AODV,AOMDV,DSDV,DSR
Simulation Time	400 Second
X Dimension	10 km
No. of Vehicles	25, 50, 75, 100
No. of TCP Connections	5, 10

Table 5.2: Simulation parameter for City Scene

Parameter	**Simulated Value**
Channel Type	Wireless Channel
Antenna Model	Omnidirectinal antenna
Radio Propogation Model	Two Ray Ground
Transmission Range	250 m
MAC Type	IEEE 802.11
Interface Queue Type	priority Queue (50 Packtes)
Routing Protocols	AODV,AOMDV,DSDV,DSR
Simulation Time	400 Second
Dimension	1500 X 1500 m
No. of Vehicles	24, 48, 120, 280
No. of TCP Connections	10, 20

5.4 Result and Analysis

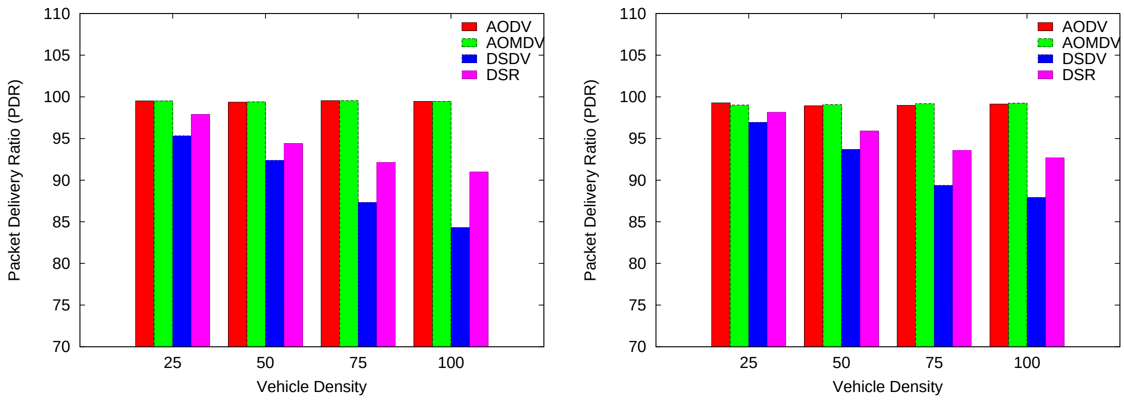
In this section results for Highway scenes and City scenes are analyzed to evaluate performance metrics as defined in subsections for routing protocols.

5.4.1 Packet Delivery Ratio (PDR)

In order to evaluate PDR, for each case ten different simulation are carried out for highway scene and city scene with varying vehicle density. Table 5.3 and 5.4 shows average resultant values for highway and city scene. Higher the value, more privileged is the routing protocol.

Table 5.3: PDR Measurement for Highway Scene

Protocol	**No. of Vehicles**	**Packet Delivery Ratio**	
		5 TCP Connection	**10 TCP Connection**
AODV	25	99.5144	99.2778
	50	99.3570	98.9261
	75	99.5480	98.9810
	100	99.4526	99.1273
AOMDV	25	99.5088	99.0195
	50	99.3985	99.0713
	75	99.5475	99.1931
	100	99.4533	99.2532
DSDV	25	95.3295	96.9385
	50	92.3778	93.6906
	75	87.3328	89.3779
	100	84.3077	87.9302
DSR	25	97.8905	98.1630
	50	94.4029	95.9009
	75	92.1226	93.5474
	100	91.0019	92.7114

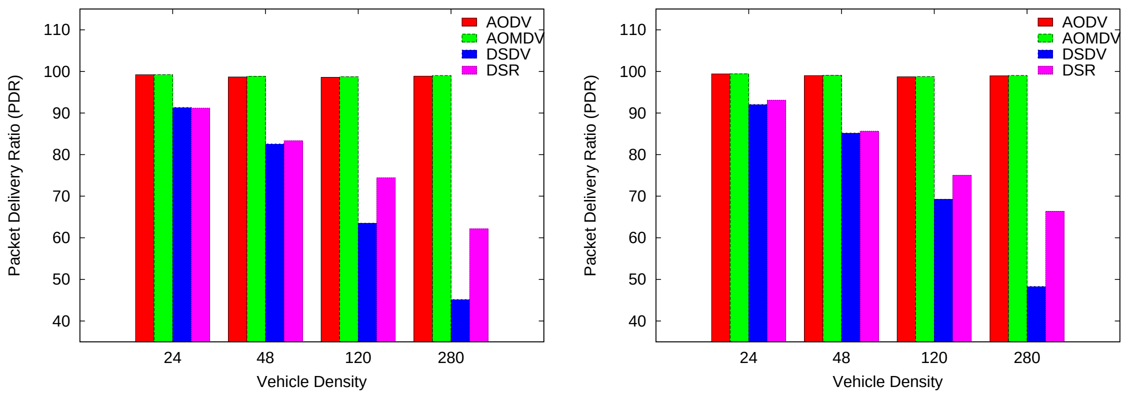


(a) For 5 TCP connection (b) For 10 TCP Connection

Figure 5.1: Packet Delivery Ratio in Highway Scene

Table 5.4: PDR Measurement for City Scene

Protocol	**No. of Vehicles**	**Packet Delivery Ratio**	
		10 TCP Connection	**20 TCP Connection**
AODV	24	99.2063	99.4000
	48	98.6675	98.9888
	120	98.5786	98.7012
	280	98.8654	98.9444
AOMDV	24	99.2277	99.4217
	48	98.8266	99.0698
	120	98.7313	98.7553
	280	99.0172	99.0374
DSDV	24	91.3398	92.0517
	48	82.5559	85.1915
	120	63.5284	69.2802
	280	45.1705	48.3113
DSR	24	91.2012	93.1023
	48	83.3271	85.6504
	120	74.4105	75.0508
	280	62.1587	66.3567



(a) For 10 TCP connection (b) For 20 TCP Connection

Figure 5.2: Packet Delivery Ratio in City Scene

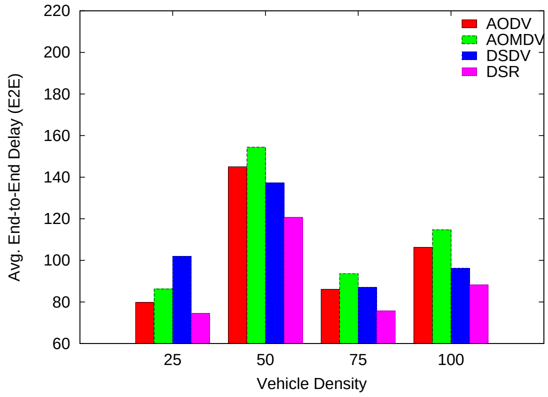
Figure 5.1 and 5.2 shows the corresponding graphs for highway scene and city scene respectively. From this results it is clear that Packet Delivery Ratio is better for AODV and AOMDV then DSDV and DSR for both scenarios.

5.4.2 Average End-to-End Delay (E2E Delay)

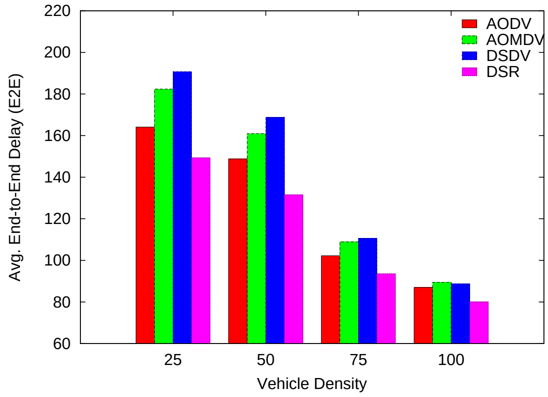
In order to evaluate Average E2E delay, for each case ten different simulation are carried out for highway scene and city scene with varying vehicle density. Table 5.3 and 5.4 shows average resultant values for highway scene and city scene. For given metric Lower the value, more privileged is the routing protocol.

Table 5.5: Average E2E Delay Measurement for Highway Scene

Protocol	**No. of Vehicles**	**Average End-to-End Delay**	
		5 TCP Connection	**10 TCP Connection**
AODV	25	79.7853	164.0963
	50	145.0189	148.7605
	75	86.1402	102.2308
	100	106.2508	86.9786
AOMDV	25	86.2474	182.3790
	50	154.4302	160.9330
	75	93.6284	108.6133
	100	114.6640	89.4158
DSDV	25	101.9454	190.7578
	50	137.2051	168.7052
	75	87.0970	110.5461
	100	96.2928	88.7432
DSR	25	74.5404	149.3111
	50	120.7641	131.5408
	75	75.6844	93.5336
	100	88.2212	79.9880



(a) For 5 TCP connection

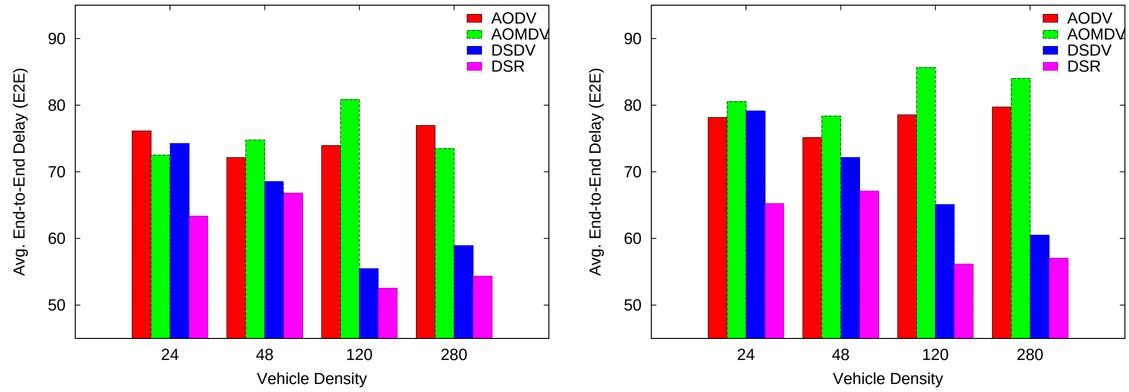


(b) For 10 TCP Connection

Figure 5.3: Average End-to-End Delay in Highway Scene

Table 5.6: Average E2E Delay Measurement for City Scene

Protocol	**No. of Vehicles**	**Average End-to-End Delay**	
		10 TCP Connection	**20 TCP Connection**
AODV	24	76.1536	78.1524
	48	72.1520	75.1167
	120	73.918	78.5668
	280	76.9709	79.7077
AOMDV	24	72.5244	80.5164
	48	74.7855	78.3654
	120	80.8348	85.6506
	280	73.4792	84.0174
DSDV	24	74.2564	79.1741
	48	68.5496	72.1664
	120	55.4513	65.0865
	280	58.9488	60.4869
DSR	24	63.3162	65.2087
	48	66.8091	67.1268
	120	52.5369	56.1806
	280	54.3522	57.0186



(a) For 10 TCP connection

(b) For 20 TCP Connection

Figure 5.4: Average End-to-End Delay in City Scene

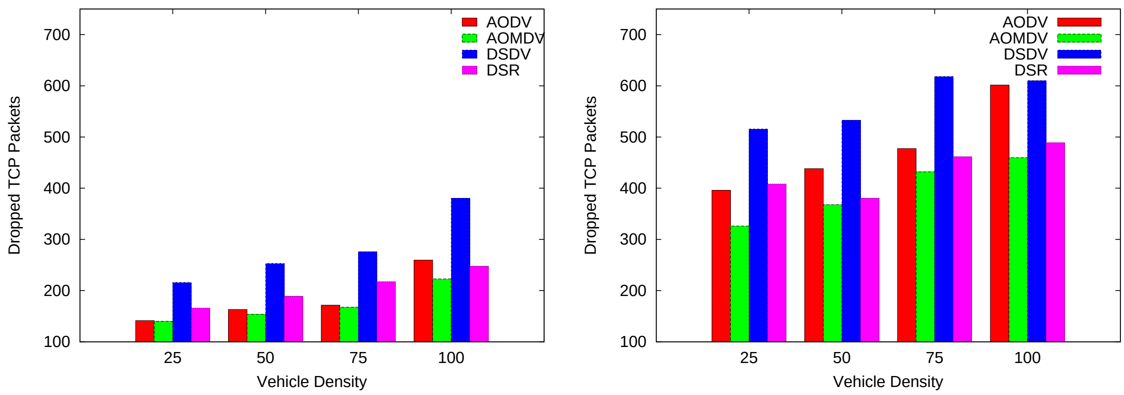
Figure 5.3 and 5.4 shows the corresponding graphs for Highway scene and City scene respectively for Avgerage E2E delay. From this results it is clear that Average End-to-End Delay for DSR is better then AODV, AOMDV and DSDV.

5.4.3 Dropped TCP Packets

In order to evaluate Dropped packets, for each case ten different simulation are carried out for highway scene and city scene with varying vehicle density. Table 5.7 and 5.8 shows average resultant values for highway scene and city scene. Lower the value, more privileged is the routing protocol.

Table 5.7: Dropped TCP Packets Measurement for Highway Scene

Protocol	**No. of Vehicles**	**Dropped TCP Packet**	
		5 TCP Connection	**10 TCP Connection**
AODV	25	141.40	395.8
	50	163.2	438.2
	75	171.6	477.4
	100	259.6	601.6
AOMDV	25	140.2	326.2
	50	153.6	367.7
	75	167.6	432.0
	100	222.8	459.8
DSDV	25	216.00	515.7
	50	253.2	532.7
	75	275.6	618.3
	100	380.2	610.1
DSR	25	166.00	408.4
	50	188.8	380.6
	75	217.4	461.3
	100	247.6	488.8

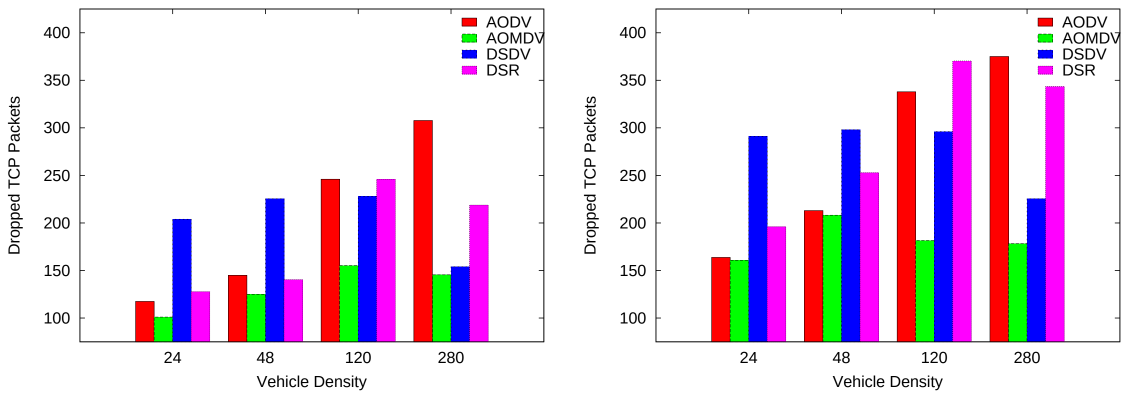


(a) For 5 TCP connection (b) For 10 TCP Connection

Figure 5.5: Dropped TCP Packet in Highway Scene

Table 5.8: Dropped TCP Packets Measurement for City Scene

Protocol	**No. of Vehicles**	**Dropped TCP Packet**	
		10 TCP Connection	**20 TCP Connection**
AODV	24	117.5	163.8
	48	144.9	213.0
	120	246.0	337.9
	280	307.8	375.1
AOMDV	24	101.0	160.7
	48	125.0	208.1
	120	155.2	181.5
	280	145.4	178.3
DSDV	24	203.9	291.1
	48	225.4	297.9
	120	228.1	296.1
	280	153.9	225.4
DSR	24	127.6	195.9
	48	140.3	252.7
	120	245.8	370.4
	280	218.8	343.6



(a) For 10 TCP connection

(b) For 20 TCP Connection

Figure 5.6: Dropped TCP Packet in City Scene

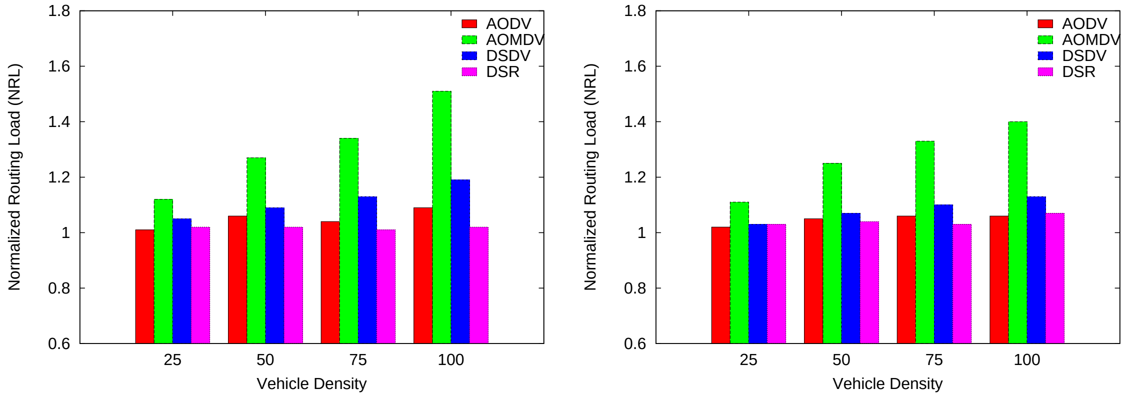
Figure 5.5 and 5.6 shows the Dropped TCP packets for highway scene and city scene respectively. From this results it is clear that Dropped TCP Packets variation is more in AODV and DSR as number of vehicles increases compare to DSDV in City scene. Dropped packets are increases with increase in TCP connections for both scenario. AOMDV has lower Dropped packets because it establishes multiple path from source node to destination node. In highway Scene AOMDV is also looks better then others.

5.4.4 Normalized Routing Load (NRL)

In order to evaluate NRL, for each case ten different simulation are carried out for highway scene and city scene with varying vehicle density. Table 5.9 and 5.10 shows average resultant values for highway scene and city scene. Lower the value, more privileged is the routing protocol.

Table 5.9: NRL Measurement for Highway Scene

Protocol	**No. of Vehicles**	**Normalized Routing Load**	
		5 TCP Connection	**10 TCP Connection**
AODV	25	1.01	1.02
	50	1.06	1.05
	75	1.04	1.06
	100	1.09	1.06
AOMDV	25	1.12	1.11
	50	1.27	1.25
	75	1.34	1.33
	100	1.51	1.40
DSDV	25	1.05	1.03
	50	1.09	1.07
	75	1.13	1.10
	100	1.19	1.13
DSR	25	1.02	1.03
	50	1.02	1.04
	75	1.01	1.03
	100	1.02	1.07



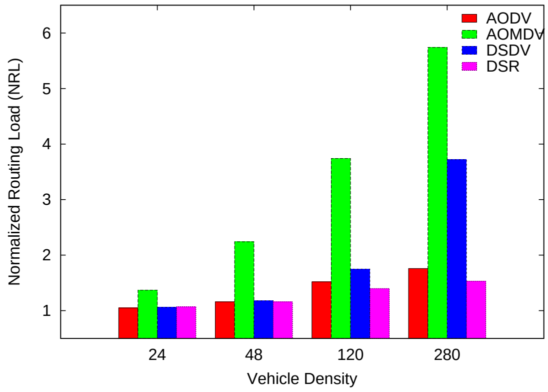
(a) For 5 TCP connection

(b) For 10 TCP Connection

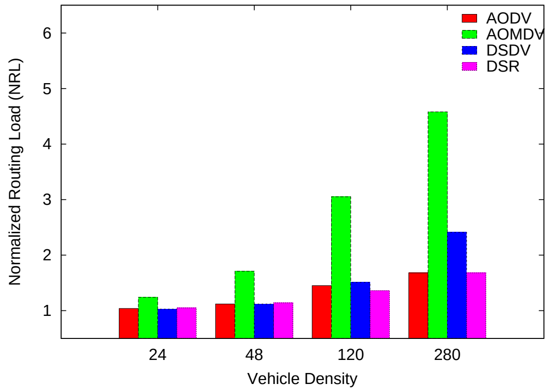
Figure 5.7: Normalized Routing Load in Highway Scene

Table 5.10: NRL Measurement for City Scene

Protocol	**No. of Vehicles**	**Normalized Routing Load**	
		10 TCP Connection	**20 TCP Connection**
AODV	24	1.05	1.04
	48	1.16	1.12
	120	1.52	1.45
	280	1.76	1.68
AOMDV	24	1.37	1.24
	48	2.24	1.71
	120	3.74	3.05
	280	5.74	4.58
DSDV	24	1.06	1.03
	48	1.18	1.12
	120	1.75	1.51
	280	3.72	2.41
DSR	24	1.07	1.05
	48	1.16	1.14
	120	1.4	1.36
	280	1.53	1.68



(a) For 10 TCP connection



(b) For 20 TCP Connection

Figure 5.8: Normalized Routing Load in City Scene

Figure 5.7 and 5.8 shows graphs for highway scene and city scene for NRL respectively. From this results it is clear that NRL is more in AOMDV and then DSDV, AODV and DSR. Results shows that NRL is decreases as more vehicles are participating in data dissemination for highway scene and city scene.

5.5 Summary

Simulation results show that AODV and AOMDV are preferable for Packet Delivery Ratio while DSR has lower Avg. End-to-End delay. AODV has higher value while AOMDV has less for Dropped packets. AOMDV and DSDV has Higher Normalized Routing load compare to other protocols. AODV has higher End-to-End delay and number of Dropped packets compare to other routing protocols in given highway and city scenarios. AODV is found most appropriate selection compare to other protocols at the network layer of given cases, i.e. city and highway models in VANETs with varying traffic concentration. Extensions of AODV protocol can overcome the problem of End-to-End delay and Drop Packets for Data dissemination in VANET. The next chapters of this thesis describes the working of AODV protocols, research improvements on AODV protocol and then proposed technique to improve performance of AODV protocol for effective data dissemination in VANETs.

Chapter 6

AODV and Related Work

Concluded from previous chapter AODV is preferable for Packet Delivery Ratio and Normalized Routing Load but higher Avg. End-to-End delay and Dropped packets compare to other topology based routing protocols. To make AODV a better choice for effective data dissemination in VANET scenarios it is required to improve Avg. End-to-End delay and Dropped packets. In this chapter working of AODV protocol and research achievements in the field of improvements for AODV for Ad Hoc Networks are described.

6.1 Working of AODV

Ad hoc On demand Distance Vector (AODV) is a reactive protocol consists of two main phases: Route Discovery and Route Maintenance. AODV uses a distributed approach which means that a source node is not required to maintain a complete sequence of intermediate nodes to reach the destination. It is also an improvement from DSR by addressing the issue of high messaging overhead and large header packets in maintaining routing tables at nodes, so that packets do not have to store much routing information in the headers. AODV uses a routing table in each node and keeps one to two fresh routes. The incorporated features of AODV include features of DSDV, like the use of hop by hop routing, periodic beacon messaging and sequence numbering. A periodic beacon message is used to identify neighboring nodes. The sequence numbering guarantees a loop free routing and fresh route to destination. AODV has the advantage of minimizing routing table size and broadcast process as routes are created on demand. AODV specifies three types of routing packets for discovering and maintaining routes: Route Request (RREQ), Route Reply (RREP), Route Error (RERR) packets [21].

6.1.1 Route Discovery

When a source node needs to send data packets to a destination, it first checks the routing table to see whether it already has a valid route to that destination. If not, the node performs route discovery to find a route to the destination. First, the source node creates a RREQ packet. Source node broadcasts a route request packet (RREQ) to its neighbors, which is uniquely identified by the pair (source address, broadcast id). The RREQ packet includes the IP address of the destination node, the last known sequence number for the destination, its own IP address, its current sequence number, and the hop count which is set to zero. If the source node has no knowledge of the sequence number for the destination, it is set to zero. Each node also has a RREQ ID, which is a unique number incremented every time a node sends a route request. This RREQ ID is included in the RREQ packet to identify each route request sent by the source node. The source node broadcasts the RREQ packet to its neighbors. When a node receives the RREQ packet, it first increases the hop count value in the RREQ and creates a reverse route entry in its routing table for both the source node and (if applicable) the neighbor node from which it received the request. The intermediate node can use this reverse route to forward a RREP packet to the source node if it later receives a RREP packet. After creating the reverse route, the node sends a RREP packet to the source if it is either the destination, or has a ”fresh enough” route to the destination. Otherwise, it just rebroadcasts the RREQ packet to its neighbors. Figure 6.1 shows an example of AODV route discovery, where node

S is the source node and node D is the destination node. Links in this figure represent RREQ packet broadcasting.

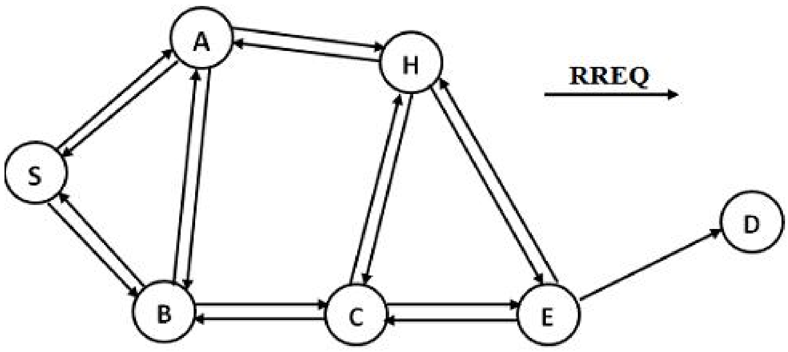


Figure 6.1: AODV Route Request

A RREP packet contains the IP address of the destination node, the destination sequence number, the source IP address, the hop count to the destination node (if it is the destination node, it is set to zero, otherwise it is the hop count of the routing entry for the destination node), and the lifetime value of the RREP packet. A RREP packet is unicast to the source node from the destination node or intermediate node. When a node receives the RREP packet, it first increments the hop count value in the packet, and then creates a forward route entry for both the destination node and the neighbor node from which it received the RREP packet. The forward route entry is used to forward data packets during transmission. The node then forwards the RREP packet to the next hop towards the source node according to the reverse route entry, and so on, until the RREP packet reaches the source node. After the source node receives a RREP, it can use the route for data packet transmission. If the source node receives multiple RREPs along different paths, it will select the route with the greatest destination sequence number. Figure 6.2 shows an example of AODV route reply.

Each node records the RREQ packets that it has received. When it receives duplicate RREQs (with the same RREQ ID and source address) from neighbor nodes, they

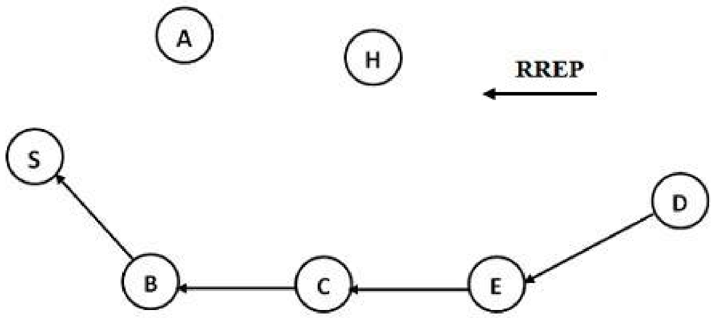


Figure 6.2: AODV Route Reply

are discarded and not rebroadcast, which reduces the routing overhead caused by ”flooding” broadcasts. The RREQ information recorded in each node must be kept a certain amount of time to ensure that no other node in the network is still processing request packets resulting from the same route discovery.

6.1.2 Route Maintenance

In an ad hoc network, links in active routes may break due to the nature of mobile nodes, so a method is needed to notify other nodes associated with this link in the network that the link is broken. An active route in AODV is defined as a route that has recently been utilized for data transmission. When a broken link is discovered, the upstream node of the link, which is closer to the source node, invalidates all the active routing entries in its routing table that use the downstream node of the broken link as the next hop. Then it creates an RERR packet, in which it lists all the unreachable destinations and their known sequence number. Each routing entry includes a precursor list, which records those neighbor nodes to which a route reply was generated or forwarded. If there is only one precursor in the routing entry, then the RERR packet is unicast towards the source node along the reverse route. Otherwise the node broadcasts the RERR to all its neighbors. When a node receives an RERR packet, it first checks whether it is the next node in the route to one of the destinations listed in the packet. If it is, the node invalidates the related routes in its routing table and then retransmits the RERR packet as before. In this manner, the

RERR packet is forwarded to the source nodes. After the source node receives the RERR packet, it may initiate route discovery if it still needs a route.

Each routing entry has a lifetime value. This value is assigned when a route is created, and is based on the information contained in the RREQ, RREP or Hello packet for the destination node. Each time a route is utilized in the routing table, whether it is forwarding a data packet or transmitting a routing packet, the lifetime value for that destination is updated. Receiving a Hello packet from a neighbor node results in an update of the lifetime of that neighbor's route table entry. If a route to a destination is not utilized within the lifetime, the routing entry for that destination will expire.

6.2 AODV Improvements

Following are the research achievements in the field of improvements for AODV in Adhoc networks.

- Baozhu Li. et al. [24] ,in 2010 proposed a routing protocol AODV_BD for vehicular Adhoc networks that improves the AODV routing protocol by making it reduce the packet delay. AODV_BD establishes a routing to the destination node by broadcasting data packets when local repair is going on. Means data packets broadcasted is not only the request packets, but also the data packets. This will not only setup the routing but also reduce the delay.
- Baozhu Li. et al. [25] ,in 2010 proposed a routing protocol AODV_OBD that induces the packet delay to a certain extent compare to AODV. mechanism was based on reference [24] with limited hop count for RREQ, so when the RREQ can not find the destination node, it can only go through very small count. also new method is used by replying a reply packet which can tell the node that the next node is active and decided whether the node get a RREP or not.

- Yongjun Hu. et al. [26] ,in 2010 proposed an improvement of the route discovery process in AODV (IMAODV)to decrease the delay and routing overload. IMAODV combines the route discovery process of AODV and DSR with append second node's address on RREQ.

- Noor Azlam Ahmad et al. [27] ,in 2008 proposed lifetime ratio (LR) to reduce unnecessary packets in the rebroadcast of AODV. The formula for LR is lifetime of an intermediate node divided by the time to live of the route.

- Fei Jiang and JianJun Hao [28] ,in 2010 proposed an improved routing protocol based on AODV for adhoc network, which optimize Hello mechanism, Local repair mechanism and provide multi-backup pathway for the source node.

- Luo Chao and Li Ping'an [29] ,in 2010 proposed scheme suggest that each source node maintains an alternative route to the specified destination node. when the primary route fails, the source node will use the backup route to send packets which improve the Packet Delivery Fraction, reduce the Avg. end-to-end delay, routing overload and route discovery frequency.

- Abdulsalam Alammari et al. [30] ,in 2009 utilized Multiple paths in Intermediate nodes in AODV protocol (MIAODV) and multiple paths at source and destination nodes in AODV (NMIAODV). The performance was evaluated in terms of routing packet overhead, Avg. end-to-end delay and packet delivery fraction.

6.3 Summary

Without source routing, AODV relies on routing table entries to propagate a RREP back to the source node and subsequently to a route data packets to the destination. The advantages of AODV are Loop free routing, optional multicast, reduced control overhead and a quick response to link breakage. The disadvantages are delay caused by route discovery process and the bidirectional connection needed in order to detect a unidirectional link. One of the challenges AODV face is the large delay during route construction. Link failures can also initiate another route discovery, therefore creating extra delays and consuming more bandwidth, when the size of network increases. Immediate nodes can lead to inconsistent routes if the sequence number is very old and has a higher but not the latest destination sequence number thereby having stales entries. Combination of route discovery process of DSR and AOMDV routing can be used in AODV protocol such that it gives efficient performance for data dissemination in VANETs.

Chapter 7

Proposed Improvements on AODV Protocol

In this chapter modification in basic AODV protocol is based on the combination of routing mechanism from DSR and AOMDV protocol and inspired from methodology proposed by Yongjun Hu. et al. [26] and Luo Chao and Li Ping'an [29] which is given for the Ad hoc network with random mobility model. The proposed IAODV (Improved AODV) protocol can ensures giving timely and accurate information to driver in V2V data dissemination compare to AODV protocol in city scene. The performance of the proposed IAODV is compared with basic AODV protocol in terms of Average End-to-End delay, Packet Loss Ratio, Packet Delivery Ratio and Normalized Routing Load.

7.1 Proposed IAODV

Proposed IAODV is defined as "Limited Source Routing up to two hops with Backup route between Source node and Destination node". Proposed method is divided into two sub parts as change in route discovery mechanism and route maintenance mechanism. During the route discovery mechanism of IAODV protocol route request phase is modified for limited source routing up to two hops and route reply phase is modified to create backup route between source and destination node. Route maintenance mechanism is modified such a way that if primary route is failed then source node uses the backup route for transmission of data and if backup route itself failed then new route discovery procedure is performed.

7.1.1 Route Request Procedure

AODV can gather only a limited amount of routing information, route learning is limited only to source node. This usually causes AODV to rely on a route discovery flood more often, which may carry significant network overhead [26]. Combination of route discovery process of AODV and DSR routing protocol has lower delay and lower routing load than original AODV. However, it has set up too many reverse routes, this would bring in DSR's disadvantage and results in limited performance so only append second node's address on RREQ. Design a new packet structure of RREQ packet by addition of two field as shown in Figure 7.1. Modification in Route Request Procedure of AODV protocol is as shown Algorithm 7.1.

Type	Reserved	Hop Count
RREQ ID		
Destination IP Address		
Destination Sequence Number		
Source IP Address		
Source Sequence Number		
Second Node IP Address		
Second Node Sequence Number		

Figure 7.1: RREQ Packet Structure

Algorithm 7.1 Modification in Route Request Procedure

```
Node i receives a RREQ packet
if node i is the destination node then
  Reply RREP Packet
else
  if node i is second node then
    Building a reverse link in routing table for source node
    Append its node ID and sequence number
    Rebroadcast the Packets
  else
    if exists a route in table then
      if check for better route then
        Update existing route in table
      end if
      Discard Packet
    else
      Build a reverse link in routing table for source node
      Build a reverse link in routing table for second node
      Rebroadcast the Packets
    end if
  end if
end if
```

7.1.2 Route Reply Procedure

Each source node maintain an alternative route to the specified destination node like AOMDV protocol where multiple path established between source node and destination node. For proposed improvement modify the Route Reply Procedure of AODV protocol as shown in algorithm 7.2. Also add two function in route table class for addition and finding alternative route in route table and addition of one field as flag in route table entry to check for backup path.

Algorithm 7.2 Modification in Route Reply Procedure

```
Node i receives a RREP packet
if node i is the source node then
  if exist an alternative route in table then
    if check for better route then
      Update route in routing table
    end if
  else
    if exist a primary route then
      if check for better route then
        Add route as backup path
      else
        Add route as primary route
      end if
    end if
  end if
  Discard RREP
else
  if primary route exists then
    if check for better route then
      Update route
      Forward RREP
    else
      Discard RREP
    end if
  else
    Add the route in table
    Forward RREP
  end if
end if
```

7.1.3 Route Maintenance Procedure

During route maintenance procedure node perform local repair to forward the data packets. When node detecting link failures it notify link failure to source node. If backup route exists in routing table of source node data packets are send with new path. The route discovery process will be re-initiated only when alternative route is failed at source node. Algorithm 7.3 shows the route maintenance procedure of proposed protocol.

Algorithm 7.3 Modification in Route Maintenance Procedure

```
Node i receives a RERR packet
if the entry of the unreachable destination exists then
  Remove entry in the routing table
  Node i start local repair
  if node i detecting link failure then
    Notify link failure to source node
    if Backup path exists in routing table then
      Forward data with new path
    else
      Initiate route discovery procedure
    end if
  else
    Forward the data
  end if
end if
```

7.2 Simulation Parameter

For all scenarios mobility of vehicle is generated with MOVE which work on SUMO, which is open source software. Traffic patterns are based on TCP connections which are generated with the help of cbrgen.tcl script of NS-2. Cbrgen.tcl file is modified in a way such that traffic connections are established after 20 sec of simulation start. Twenty five different traffic files are generated with use of cbrgen.tcl with varying number of traffic connection and then integrate with TCL script for scenarios. The randomly chosen source-destination pairs are spread in the network. We had integrate AODV protocol as new name IAODV in NS-2.34 and implementing proposed improvement on it. This chapter includes the simulation parameters for test cases which are carried out on the NS-2 for varying Vehicle Density, No. of Active Connections and Vehicle Mobility. Table 7.1 shows simulation parameters used in the city scene for varying Vehicle Density, No. of Active Connections and Vehicle Mobility.

Table 7.1: Simulation parameter for City Scene

Parameters	**Simulated Values**
Antenna Model	Omnidirectinal antenna
Radio Propogation Model	Two Ray Ground
Transmission Range	250 m
MAC Type	IEEE 802.11
Interface Queue Type	priority Queue (50 Packets)
Routing Protocols	AODV, IAODV
Simulation Time	400 Second
Dimension	1500 X 1500 m
For Varying Vehicle Density	
No. of Vehicles	20, 30, 50, 80, 120, 170, 230
No. of TCP Connections	20 % of Vehicle Density
Mobility of Vehicles	40 km/h
For Varying Active Connection	
No. of Vehicles	100
No. of TCP Connections	10, 20, 30, 40, 50
Mobility of Vehicles	40 km/h
For Varying Vehicle Mobility	
No. of Vehicles	100
No. of TCP Connections	20
Mobility of Vehicles	25, 30, 35, 40, 45 km/h

7.3 Results and Analysis

The performance of the proposed IAODV is compared with basic AODV protocol in terms of Average End-to-End delay, Packet Loss Ratio, Packet Delivery Ratio and Normalized Routing Load. All experiment results presented in this section are average of twenty five simulation runs for all the three different parameters for performance metrics. The performance metrics measurements are with respect to Vehicle Density, No. of Active Connection and Vehicle Mobility.

The following metrics were chosen for evaluating the performance of protocols:

- Average End-to-End delay (E2E delay): It is the calculation of typical time taken by packet (in average packets) to cover its journey from the source end to the destination end.

- Packet Loss Ratio (PLR): It is the ratio of data packets lost over number of data packets sent during simulation.
- Packet Delivery Ratio (PDR): This metric gives the ratio of the total data packets successfully received at the destination and total number of data packets generated at source.
- Normalized Routing Load (NRL): Normalized Routing Load is the number of routing packets transmitted per data packet send to the destination.

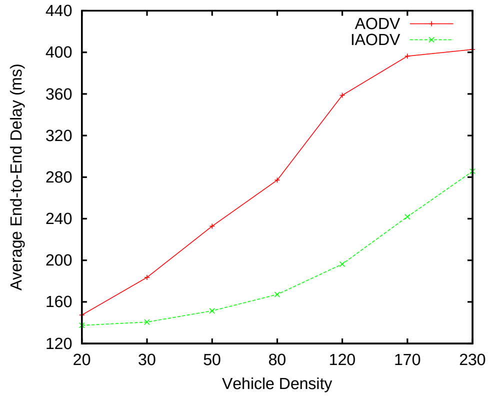
Routing protocol is more privileged for lower value of E2E Delay, PLR and NRL metrics while higher value of PDR metric.

7.3.1 Vehicle Density

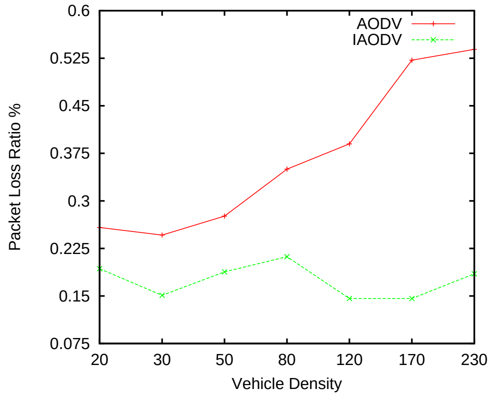
Table 7.2 and Figure 7.2 shows the simulation results for varying Vehicle Density with 20 % of vehicle density communication pair with maximum speed of 40 km/h.

Table 7.2: Simulation Results for Vehicle Density

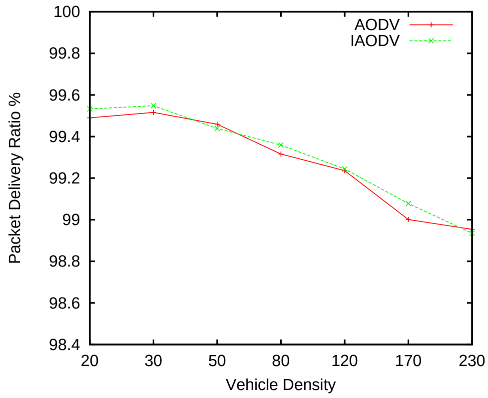
Vehicle Density	**AODV**				**IAODV**			
	E2E (ms)	**PLR (%)**	**PDR (%)**	**NRL**	**E2E (ms)**	**PLR (%)**	**PDR (%)**	**NRL**
20	147.365	0.258	99.490	2.047	137.465	0.193	99.533	2.025
30	183.583	0.246	99.516	2.059	140.641	0.151	99.548	2.038
50	232.807	0.276	99.459	2.124	151.391	0.188	99.439	2.096
80	277.091	0.350	99.316	2.141	167.134	0.212	99.359	2.146
120	358.659	0.390	99.236	2.286	196.347	0.146	99.244	2.263
170	369.274	0.522	99.001	2.401	241.885	0.146	99.078	2.460
230	402.774	0.539	98.954	2.529	285.612	0.185	98.935	2.784



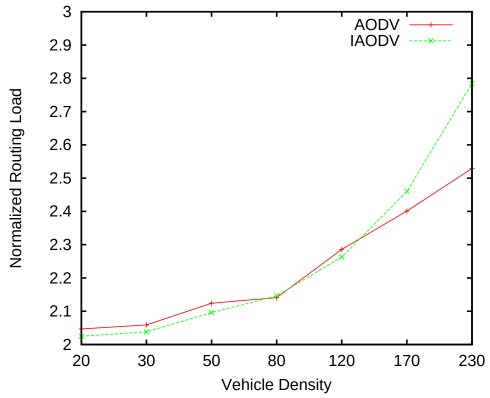
(a) Avg. End-to-End Delay



(b) Packet Loss Ratio



(c) Packet Delivery Ratio



(d) Normalized Routing Load

Figure 7.2: Performance metrics for Vehicle Density

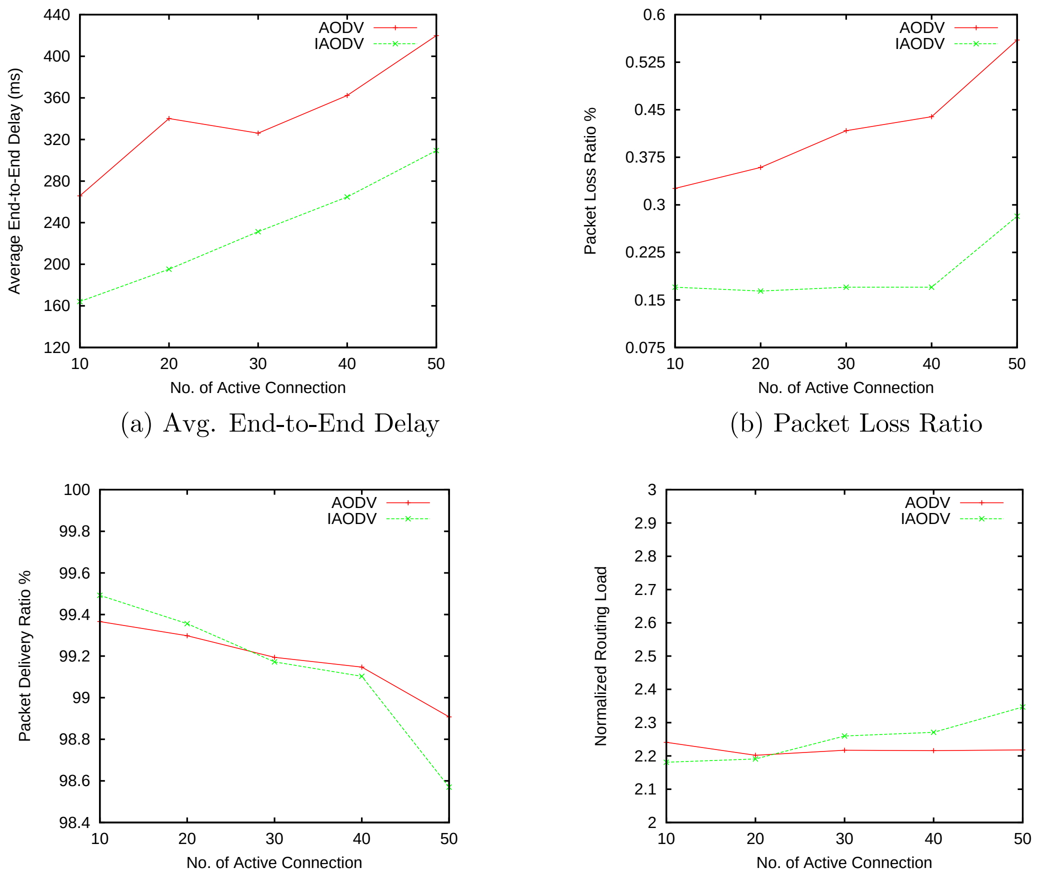
By analyzing results of city scene with varying vehicle density as shown in Figure 7.2 performance improvement in Avg. End-to-End delay is 33.928% and Packet Loss Ratio is 52.655% without much affecting Normalized Routing Load or decreasing Packet Delivery Ratio. As number of vehicle increases beyond 120 NRL is increases for IAODV with 20 % vehicle density communication pair.

7.3.2 No. of Active Connection

Table 7.3 and Figure 7.3 shows the simulation results for 100 vehicles with varying No. of Active Connection and maximum speed of 40 km/h.

Table 7.3: Simulation Results for No. of Active Connection

No. of Active Connection	**AODV**				**IAODV**			
	E2E (ms)	**PLR (%)**	**PDR (%)**	**NRL**	**E2E (ms)**	**PLR (%)**	**PDR (%)**	**NRL**
10	265.770	0.326	99.366	2.241	164.172	0.170	99.492	2.181
20	340.159	0.359	99.298	2.202	195.239	0.164	99.356	2.191
30	326.063	0.417	99.194	2.217	231.342	0.170	99.172	2.260
40	362.310	0.439	99.147	2.216	264.746	0.170	99.103	2.271
50	419.877	0.560	98.908	2.218	309.352	0.282	98.570	2.347



(a) Avg. End-to-End Delay

(b) Packet Loss Ratio

(c) Packet Delivery Ratio

(d) Normalized Routing Load

Figure 7.3: Performance metrics for No. of Active Connection

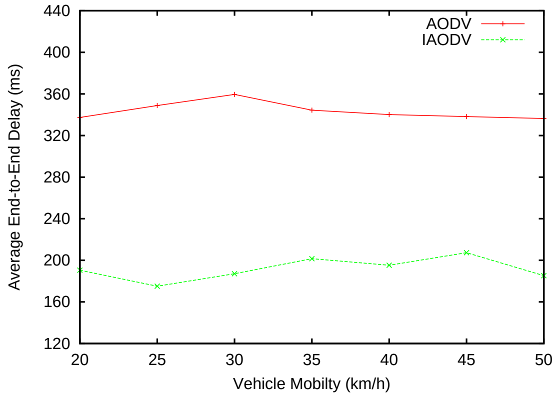
By analyzing results of city scene with varying no. of active connection as shown in Figure 7.3 performance improvement in Avg. End-to-End Delay is 32.046% and Packet Loss Ratio is 54.517% without much affecting Normalized Routing Load or decreasing Packet Delivery Ratio. As number of active connection increases NRL for IAODV increases but overall increment is only 1.38% for IAODV.

7.3.3 Vehicle Mobility

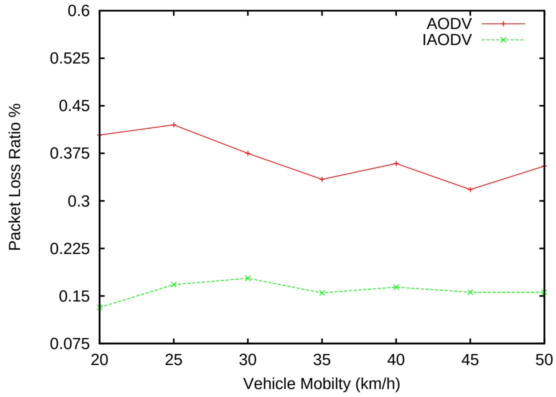
Table 7.4 and Figure 7.4 shows the simulation results for 100 vehicles and 20 communication pairs with varying Vehicle Mobility.

Table 7.4: Simulation Results for Vehicle Mobility

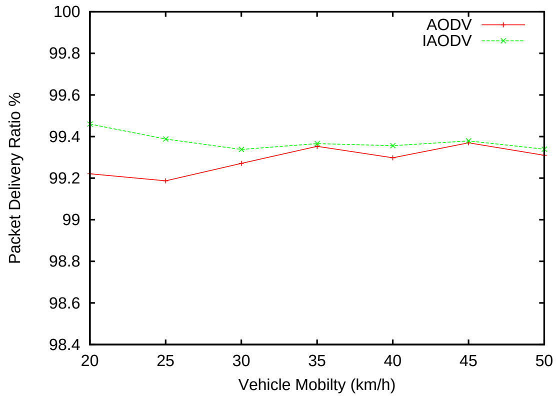
Vehicle Mobility	**AODV**				**IAODV**			
	E2E (ms)	**PLR (%)**	**PDR (%)**	**NRL**	**E2E (ms)**	**PLR (%)**	**PDR (%)**	**NRL**
20	337.356	0.404	99.221	2.182	190.456	0.132	99.460	2.173
25	348.815	0.420	99.187	2.207	175.080	0.168	99.388	2.181
30	359.540	0.375	99.271	2.203	187.075	0.178	99.338	2.193
35	344.356	0.334	99.353	2.172	201.547	0.155	99.366	2.188
40	340.159	0.359	99.298	2.202	195.239	0.164	99.356	2.191
45	338.202	0.318	99.370	2.168	207.291	0.156	99.379	2.207
50	336.374	0.355	99.310	2.204	185.266	0.156	99.339	2.186



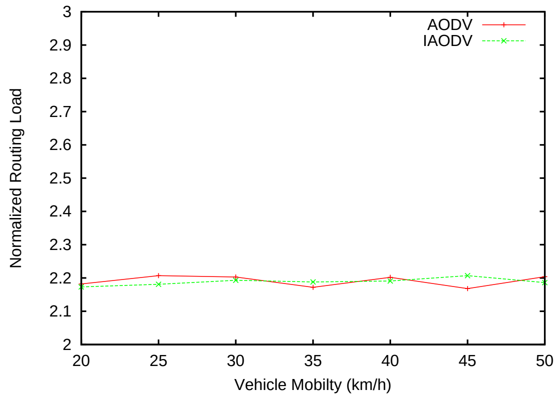
(a) Avg. End-to-End Delay



(b) Packet Loss Ratio



(c) Packet Delivery Ratio



(d) Normalized Routing Load

Figure 7.4: Performance metrics for Vehicle Mobility

By analyzing results of city scene with varying vehicle mobility as shown in Figure 7.4 performance improvement in Avg. End-to-End delay is 44.197% and Packet Loss Ratio is 56.729% without affecting Normalized Routing Load or decreasing Packet Delivery Ratio.

7.4 Summary

Results indicate that the "Limited Source Routing with Backup path between Source node to Destination node" approach reduces Average End-to-End Delay and Packet Loss Ratio without degrading the network performance in terms of Packet Delivery

Ratio and Normalized Routing Load compared to the existing data dissemination approach of AODV protocol with respect to Vehicle Density, No. of Active Connection and Vehicle Mobility.

Chapter 8

Conclusion and Future Work

8.1 Conclusion

Inherent VANET characteristics makes data dissemination quite challenging for different type of application and data to be transmitted. For implementing effective data dissemination technique with different application and VANET scenarios, performance evaluation of topology based routing protocols are performed.

The simulation test beds for highway and city scene are deployed by NS-2 along with their injecting level of densities defined by the number of participating vehicles within the projected scene of city and highway. Simulation results show that AODV and AOMDV are preferable for Packet Delivery Ratio while DSR has lower End-to-End delay. AODV has higher value while AOMDV has less for Dropped packets. AOMDV and DSDV has higher Normalized Routing Load compare to other protocols. AODV has higher Avg. End-to-End delay and Dropped packets compare to other routing protocols in given scenarios. AODV is found most appropriate selection compare to other protocols at the network layer of given cases, i.e. city and highway models in VANET with varying traffic concentration. Extension of the AODV protocol with combined routing mechanism of DSR and AOMDV for data dissemination can overcome the problem of Avg. End-to-End Delay and Dropped Packets in Vehicular Ad Hoc Network.

"Limited Source Routing with Backup path between Source node and Destination node" approach reduces Average End-to-End delay and Packet Loss Ratio without degrading the network performance in terms of Packet Delivery Ratio and Normalized Routing Load compared to the existing data dissemination approach of AODV protocol. IAODV reduces Avg. End-to-End delay by around 34% and Packet Loss Ratio by 52% with respect to Vehicle Density with 20% communication pair. Avg. End-to-End delay is reduced by 32% and Packet Loss Ratio by 54% with varying Active Connection for 100 vehicles. With respect to Vehicle Mobility reduction in Avg. End-to-End delay is 44% and Packet Loss Ratio is around 57% for 100 vehicles. Proposed IAODV protocol provides timely and accurate information in V2V data dissemination to achieve safe and efficient transportation compare to AODV protocol in manhattan city scene.

8.2 Future Work

IAODV performs better compared to AODV protocol in given manhattan city scene. IAODV improvement can be verified for other type of road topologies because in real world road topology is different for different areas of city and highways.

The DSRC standard is adopted by ASTM and IEEE to provide a secure, reliable, and timely wireless communication component as an integral part for the intelligent transportation system (ITS) by supporting multichannel communication. The next improvement possible is at the MAC layer assumptions. We have considered 802.11 for communication requirements which can be replaced with 802.11p (DSRC) communication standard.

Appendix A

List of publication

1. Dharmendra Sutariya, Shrikant Pradhan, "Data Dissemination Techniques in Vehicular Ad Hoc Network", *International Journal of Computer Applications (ISSN no: 0975-8887)*, vol. 8(10), pp. 35–39, October 2010. Available at `http://www.ijcaonline.org/archives/volume8/number10/1240-1725`

2. Dharmendra Sutariya, Shrikant Pradhan, "Evaluation of Routing Protocols for VANETS in City Scenarios", *International Conference on Emerging Trends in Networks and Computer Communications (ETNCC)*, April 2011, (IEEE Record Number 18690).

References

[1] J. Zhao, Y. Zhang and G. Cao, "Data pouring and buffering on the road: A new data dissemination paradigm for Vehicular Ad Hoc Networks", *IEEE Transactions on Vehicular Technology*, vol. 56(6), pp: 3266–3277, 2007.

[2] M. Caliskan, D. Graupner and M. Mauve, "Decentralized discovery of free parking places", *International conference on mobile computing and networking, in Proceedings of the 3rd International Workshop on Vehicular ad hoc network*, pp. 30–39, 2006.

[3] L. Briesemeister , L. Schafers and G. Hommel, "Disseminating messages among highly mobile hosts based on Inter-vehicle Communication", *in Proceedings of the IEEE Intelligent Vehicles Symposium*, pp. 522–527, 2000.

[4] L. Briesemeister and G. Hommel, "Role-based multicast in highly mobile but sparsely connected ad hoc networks", *First annual workshop on Mobile and Ad Hoc Networking and Computing(MobiHOC)*, pp. 45–50, 2000.

[5] N. Wisitpongphan, O. K. Tonguz, J. S. Parikh, P. Mudalige, F. Bai and V. Sadekar, "Broadcast storm mitigation techniques in Vehicular Ad hoc Networks", *IEEE Wireless Communications*, vol. 14(6), pp. 84–94, 2007.

[6] A. Nandan, S. Tewari, S. Das and L. Kleinrock, "Modeling epidemic query dissemination in Adtorrent Network", *in Proceedings of IEEE CCNC*, pp. 1173–1177, 2006.

[7] P. Costa, D. Frey, M. Migliavacca and L. Mottola, "Towards lightweight information dissemination in Inter-vehicular Networks", *International conference on mobile computing and networking, in Proceedings of the 3rd International Workshop on Vehicular ad hoc networks*, pp. 20–29, 2006.

[8] L. Wischhof, A. Ebner and H. Rohling, "Information dissemination in self-organizing inter-vehicle networks", *IEEE Transactions on Intelligent Transportation Systems*, vol. 6(1), pp. 90–101, 2005.

[9] G. Korkmaz, E. Ekici, F. zgner and . zgner, "Urban multi-hop broadcast protocol for Inter-vehicle communication systems", *in Proceedings of the 1st ACM International Workshop on Vehicular Ad hoc Networks*, pp. 76–85, 2004.

[10] H. Wu, R. Fujimoto, R. Guensler and M. Hunter, "MDDV: A mobility-centric data dissemination algorithm for Vehicular Networks", *in Proceedings of the 1st ACM International Workshop on Vehicular Ad hoc Networks*, pp. 47–56, 2004.

[11] M. Dikaiakos,S. Iqbal,T. Nadeem and L. Iftode, "VITP: An Information Transfer Protocol for Vehicular Computing", VANET05, September 2, 2005.

[12] M. Abuelela, S. Olariu and I. Stojmenovic, "OPERA: Opportunistic Packet Relaying in Disconnected Vehicular Ad Hoc Networks", *5th IEEE International Conference Mobile Ad Hoc and Sensor Systems (MASS 2008)*, pp. 285–294, 2008.

[13] U. Lee, J.-S. Park, E. Amir and M. Gerla, "Fleanet: A virtual market place on vehicular networks", *Proc. of V2VCOM*, pp. 1–8, July 2006.

[14] C. Lochert, B. Scheuermann, M. Caliskan and M. Mauve, "The feasibility of information dissemination in vehicular ad-hoc networks", *In Proc. of WONS*, Jan. 2007.

[15] Krajzewicz D and Rossel C, "Simulation of Urban MObility (SUMO)". German Aerospace Centre, 2007. `http://sumo.sourceforge.net/index.shtml`.

[16] TIGER Topologically Integrated GEographic Encoding and Referencing. `http://www.census.gov/geo/www/tiger/`.

[17] MOVE (MObility model generator for VEhicular networks):"Rapid Generation of Realistic Simulation for VANET", 2007. `http://lens1.csie.ncku.edu.tw/MOVE/index.htm`.

[18] J. Chung and M. Claypool, NS by Example. Worcester Polytechnic Institute (WPI). `http://nile.wpu.edu/NS/purpose`.

[19] The Network Simulator ns 2. "http://www.isi.edu/nsnam/ns/index.html".

[20] C. E. Perkins and P. Bhagwat, "Destination Sequenced Distance-Vector Routing (DSDV) for Mobile Computers", *Proc. ACM SIGCOMM Conf. Commun. Architectures, Protocols and Apps.*, pp. 234–244, Aug. 1994.

[21] C. Perkins, E. Belding-Royer and S. Das, "Ad hoc On-Demand Distance Vector (AODV) Routing", *in IETF RFC 3561*, July 2003. `http://www.ietf.org/rfc/rfc3561.txt`.

[22] Mahesh K. Marina and Samir R. Das, "Ad hoc on-demand multipath distance vector routing", *Wireless Communications and Mobile Computing*, vol. 6, pp. 969–988, 2006.

[23] D. Johnson, D. A. Maltz and Y. C. Hu, "The Dynamic Source Routing Protocol for Mobile Ad Hoc Networks (DSR)", *IETF Internet Draft, work in progress, draft-ietf-manet-dsr-09.txt*, April 2003.

[24] Baozhu Li,Yue Liu and Guoxin Chu, “Improved AODV routing protocol for vehicular Ad hoc networks”, *International Conference on Advanced Computer Theory and Engineering (ICACTE)*, pp. 337–340, Aug. 2010.

[25] Baozhu Li,Yue Liu and Guoxin Chu, “Optimized AODV routing protocol for vehicular Ad hoc networks”, *Global Mobile Congress (GMC)*, pp.1–4, Oct.2010.

[26] Yongjun Hu,Tao Lu and Junliang ShenD, “An Improvement of the Route Discovery Process in AODV for Ad Hoc Network”, *International Conference on Communications and Mobile Computing (CMC)*, pp. 458–461, April 2010.

[27] Ahmad N.A.,Subramaniam S.K. and Desa J.M., “Increasing packet delivery in Ad Hoc On-Demand Distance Vector (AODV) routing protocol”, *International Conference on Computer and Communication Engineering, (ICCCE)*, pp. 505–509, May 2008.

[28] Fei Jiang and JianJun Hao, “Simulation of an improved AODV algorithm for ad hoc network”, *International Conference on Computer and Automation Engineering (ICCAE)*, Vol. 1, pp. 540–543, Feb. 2010.

[29] Luo Chao and Li Ping’an, “An efficient routing approach as an extension of the AODV protocol”, *International Conference on Future Computer and Communication (ICFCC)*,Vol. 1, pp. 95–99, May 2010.

[30] Alammari A.,Zahary A. and Ayesh A., “Multipath contribution of intermediate nodes in AODV extensions”, *International Conference on Computer Engineering & Systems (ICCES)*, pp. 347–352, Dec. 2009.

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