Simulation and Analysis of AODV, DSDV, ZRP in VANETs

Thesis submitted in partial fulfillment of the requirements for the award of degree of

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in
Software Engineering

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CERTIFICATE

I hereby certify that the work which is being presented in the thesis entitled, ***"Simulation and Analysis of AODV, DSDV, ZRP in VANETs"***, in partial fulfillment of the requirements for the award of degree of Master of Engineering in *Software Engineering* submitted in Computer Science and Engineering Department of Thapar University, Patiala, is an authentic record of my own work carried out under the supervision of *Dr. Anil K.Verma* and refers other researcher's work which are duly listed in the reference section.

The matter presented in the thesis has not been submitted for award of any other degree of this or any other University.

Signature:

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This is to certify that the above statement made by the candidate is correct and true to the best of my knowledge.

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ABSTRACT

Vehicular networks are emerging class of wireless networks that have emerged because of recent advances in wireless technology. *V*ehicular *A*d-hoc *NET*work (VANET) is an enhanced form of *M*obile *A*d-hoc *NET*work (MANET), where communicating nodes are replaced by moving vehicles. VANETs promises many improvements in terms of accident avoidance and in better utilization of roads and resources such as fuel and time. Because of many applications, VANETs have fascinated many research authorities and automotive industries. Recognizing its importance, IEEE has approved a standard 802.11p for Wireless Access in Vehicular Environment (WAVE).

As the need of such network increases the implementation many challenges associated with it are being taken into account. They are broadcasting, routing, priority scheduling, security and privacy. In this thesis, routing is considered as the research factor.

Usually in VANETs nodes are moving with very high speeds and, thus, the topology is unpredictable and frequently changing. In this thesis, attempt has been done to analyze behavior of proactive routing (DSDV), reactive routing (AODV) and hybrid routing (ZRP) in such high mobile scenario, by simulating them on simulators which allow users to generate real world mobility models for VANET simulations. For this purpose, simulation tools such as NS-2, MOVE and SUMO has been used. MOVE tool is built on top of SUMO which is open source micro-traffic simulator. Output of MOVE is a real world mobility model and can be used by network simulator NS-2. In this thesis performance of DSDV, AODV and ZRP has been analyzed and evaluated under different node densities and connections. Four different sets of node density would be used to compare the performance of the said protocols. Simulation results obtained in the form of graphs are then compared under various parameters like normalized routing protocol, average throughput, average end to end delay and packet delivery fraction.

Keywords VANETs, AODV, DSDV, ZRP, NS-2, SUMO, MOVE

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List of Abbreviations

AODV	**A**d-hoc **O**n-**D**emand **D**istance **V**ector
AU	**A**pplication **U**nit
DSDV	**D**estination **S**equenced **D**istance **V**ector **R**outing
DSR	**D**ynamic **S**ource **R**outing
DSRC	**D**edicated **S**hort-**R**ange **C**ommunications
DREAM	**D**istance **R**outing **E**ffect **A**lgorithm for **M**obility
FSR	**F**isheye **S**tate **R**outing
GPSR	**G**reedy **P**erimeter **S**tateless **R**outing
IARP	**I**ntr-**A**zone **R**outing **P**rotocol
IEEE	**I**nstitute of **E**lectrical and **E**lectronics **E**ngineers
IERP	**I**nt-**E**rzone **R**outing **P**rotocol
LABAR	**L**ocation **A**rea **B**ased **A**d-hoc **R**outing
MANET	**M**obile **A**d-hoc **NET**work
MOVE	**MO**bility model generator for **VE**hicular networks
NS	**N**etwork **S**imulator
OBU	**O**n **B**oard **U**nit
OLSR	**O**ptimized **L**ink **S**tate **R**outing **P**rotocol
PDA	**P**ersonal **D**igital **A**ssistance
RERR	**R**oute **ERR**or
RREP	**R**oute **REP**ly
RREQ	**R**oute **REQ**uest
RSU	**R**oad **S**ide **U**nit
SUMO	**S**imulation of **U**rban **MO**bility
TCL	**T**ool **C**ommand **L**anguage
TORA	**T**emporally-**O**rdered **R**outing **A**lgorithm
VANET	**V**ehicular **A**d-hoc **NET**work
WAVE	**W**ireless **A**ccess in **V**ehicular **E**nvironment
ZRP	**Z**one **R**outing **P**rotocol

Chapter 1
Introduction

1.1 Wireless Networks

Wireless Networks refers to network of computer or nodes that uses radio waves to communicate. With the increasing use of small and portable devices/computers need of wireless network has increased. In the past it was believed that wired networks are more secure and fast as compared to wireless network but continuous enhancement in wireless network standard and technology have eroded that security and speed differences [1].

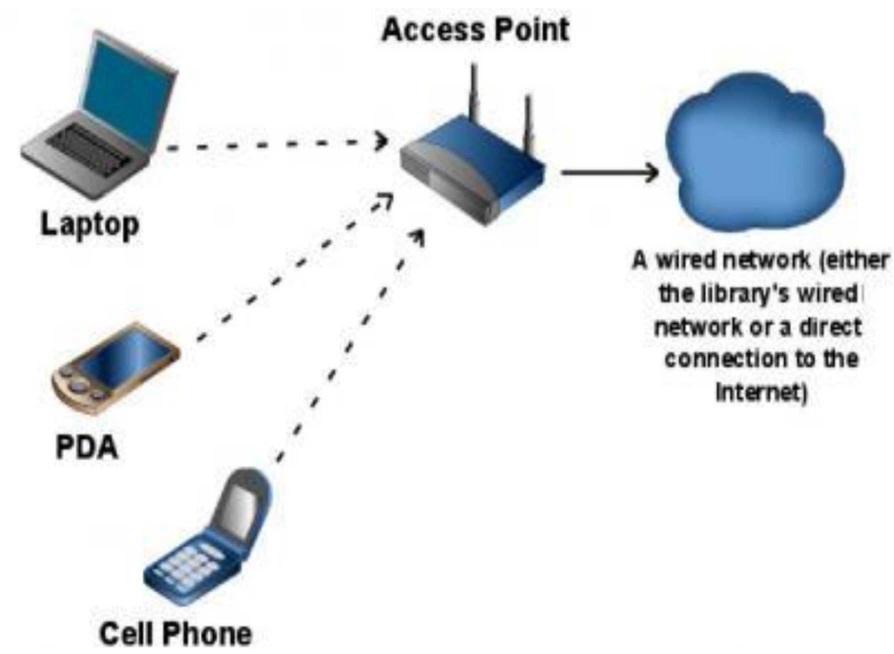


Fig. 1.1 Wireless Networks

1.2 Benefits of Wireless Networks

Small businesses can experience many benefits from a wireless network, including:

- **Convenience.** Access your network resources from any location within your wireless network's coverage area or from any Wi-Fi hotspot.
- **Mobility.** You're no longer tied to your desk, as you were with a wired connection. You and your employees can go online in conference room meetings, for example.

- **Easy setup.** You don't have to string cables, so installation can be quick and cost-effective.
- **Expandable.** You can easily expand wireless networks with existing equipment, while a wired network might require additional wiring.
- **Cost.** Because wireless networks eliminate or reduce wiring costs, they can cost less to operate than wired networks.

1.3 Types of Wireless Networks

Hierarchy of wireless network is same as wired network. Types of wireless networks are mentioned below.

- **WPAN (Wireless Personal Area Network)**
  This type of network provides connectivity within an area of about 10 meter. These network allows communication among the devices which are very close to each other for example connectivity between computer and printer which are placed very close to each other or connectivity between cell phone and cell phone's hand's-free headset. One important aspect of WPAN is that participating devices establish ad-hoc network.
- **WLAN (Wireless Local Area Network)**
  This type of network is setup to provide connectivity within finite area for example network in a university or office. WLANs use electromagnetic waves (typically radio or infrared), to enable communication between devices in a limited area
- **WMAN (Wireless Metropolitan Area Network)**
  This type of network is setup to provide connection of multiple networks in a metropolitan area such as different buildings in a city.
- **WWAN (Wireless Wide Area Network)**
  This type of network is setup for connectivity covering a large area, such as a country or continent via multiple satellite systems or antenna sites looked after by an ISP.

Table 1.1 Comparisons of Wireless Network Types

Type	Coverage	Performance	Technology
WPAN	Within reach of person	Moderate	Bluetooth, IEEE 802.15, and IrDa
WLAN	Within reach of building or campus	High	IEEE 802.11, Wi-Fi
WMAN	Within city	High	IEEE 802.16, and WIMAX
WWAN	World wide	Low	CDPD, TDMA, Cellular 2G, 2.5G, and 3G

1.4 MANETs

Rapid expansion in the field of wireless communication and need of new wireless devices to access computing and communication services on the move motivated the introduction of class of network, in which devices from a self creating, self-organizing and self-administering wireless network, called a MANET [3]. Unlike infrastructure wireless networks, where each node needs an access point or base station to communicate, a MANET doesn’t rely on fixed infrastructure for its operation. This network is group of mobile devices that can communicate to each other over wireless link. Nodes within each other’s range can directly transmit data and can discover each other dynamically. To enable the communication among the nodes that are not within each other’s range, intermediate nodes act as router and establish a route to send packet to destination. Applications of MANETs include the battlefield applications, rescue work at the time of natural disaster, as well as civilian applications like an outdoor meeting, or an ad-hoc class room.

1.5 VANETs

Absence of road traffic safety takes a toll of precious human lives and poses a dire threat to our environment as well. Other negative consequences are related to energy waste and environmental pollution. According to National Highway Traffic Safety Administration (NHTSA), following figures indicate some of the consequences of recent car accidents [4].

• 6.3 million Police reported traffic accidents

• 43,000 people were killed

• Millions of people were injured

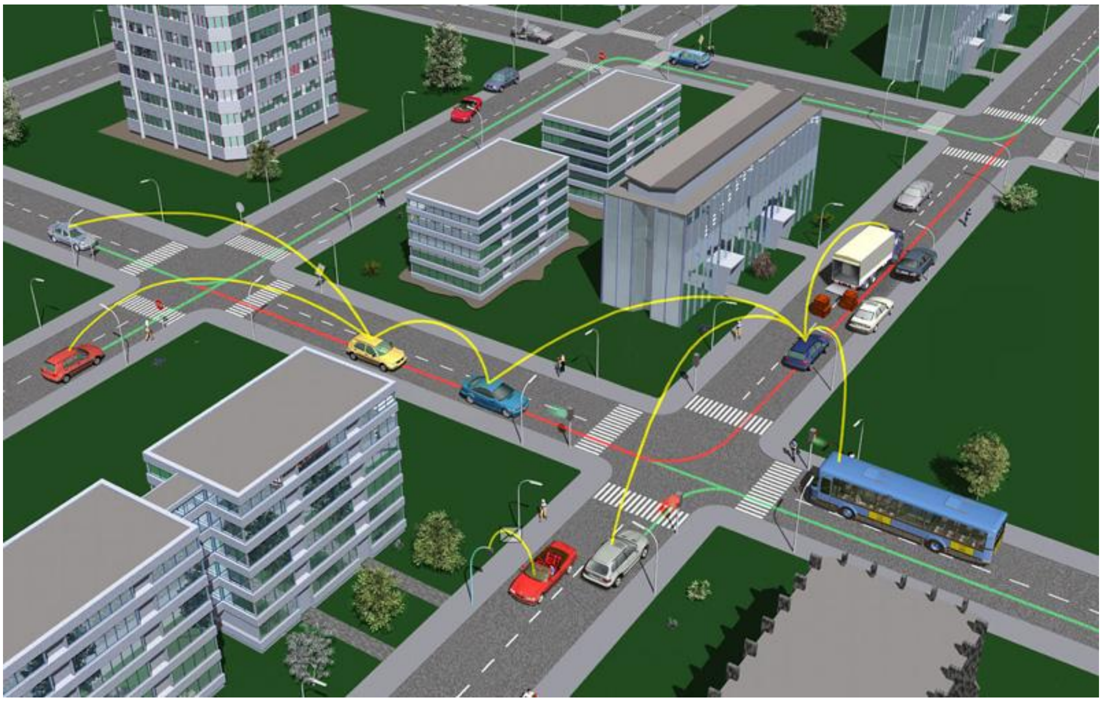


Fig. 1.2VANET Scenario [5]

Various precautions like seat belts and airbags are used but they cannot eliminate problems due to driver's inability to foresee the situation ahead of time .On a highway a vehicle cannot currently predict the speed of other vehicles. However, with use of sensor, computer and wireless communication equipment, speed could be predicted and a warning message sent every 0.5 seconds could limit the risk of potential accidents [6].

1.6 MANET vs. VANET

Although VANET is considered as form of MANET, but still there exist some differences between these two networks.

Table 1.2 MANET vs. VANET

Properties	**MANET**	**VANET**
Node's mobility	Mobility in MANET is random.	Mobility of nodes in VANET is well defined because of roadways.
Energy Constraint	Rely on batteries for their energy therefore energy conservation is an issue here.	Energy conservation is not an issue here because nodes (vehicles) can provide continuous energy
Connectivity	Connectivity among nodes is not an issue.	Because of highly dynamic nature results in frequent disconnected network.
Network Size	Limited Network size.	Very large network can extend over the entire road network.

Chapter 2

Literature Review

2.1 VANET Overview

Vehicular Network is an enhanced class of MANETs that has emerged because of recent growth in wireless technology and sensors. Vehicular network is also known as VANETs. VANETs are one of ad-hoc network real applications where communication among vehicles and nearby fixed equipment is possible. Introduction of VANET will significantly reduce both traffic congestion and vehicles crashes which are serious issues throughout the world. In recent days many countries have recognized the importance of VANET. In USA, the Federal Communication Commission (FCC) has allotted 75MHz of licensed spectrum at 5.9GHz as the DSRC for VANET. In Europe , the Commission of the European Communities has allotted 5875-5905MHz frequency band for road safety related applications. In Japan, the deployment of Electronic Toll Collection (ETC) has allotted 5.8GHZ spectrum.

2.2 VANET Architecture

VANET can be implemented through integration between operators, providers and governmental authority. Architecture of network must allow communication among vehicles and fixed road side equipments. One of the such architecture is proposed within C2C-CC [2]. Figure 2.1 illustrates this reference architecture

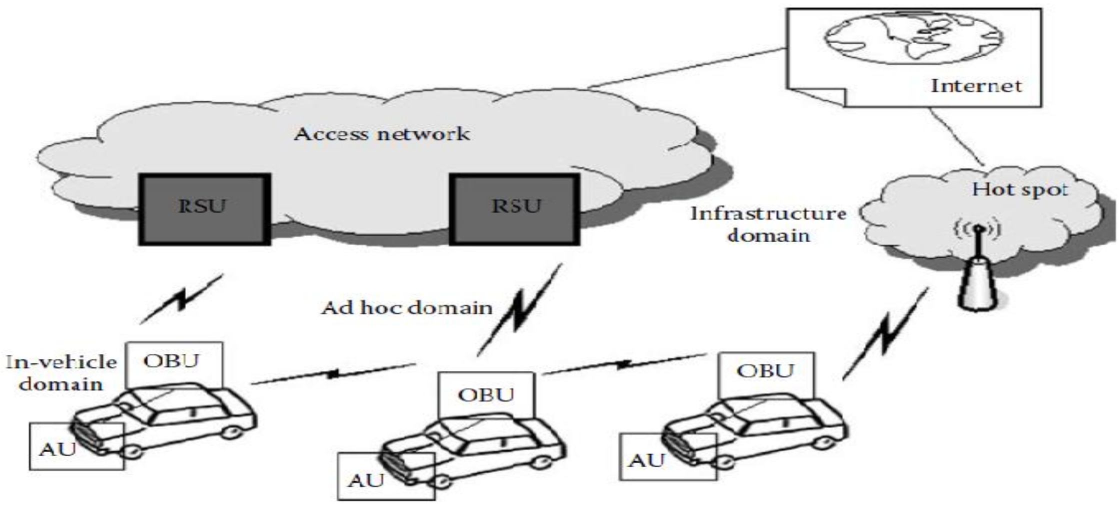


Fig. 2.1 C2C-CC reference VANET Architecture [2]

According to this architecture each vehicle composed of two types of units: (i) an on-board unit (OBU) and (ii) one or more application unit(s) (AUs). An OBU is a device in the vehicle having communication capabilities, including at least a short range wireless communication device dedicated for road safety while an AU is a device executing a single or a set of applications while making use of the OBU's communication capabilities. AU can be a portable device such as a laptop or PDA that can dynamically attach to (and detach from) an OBU. OBUs of different vehicles form a mobile ad hoc network (MANET). OBUs and road side units together will form ad-hoc network domain, road side units are stationary equipments fixed along side road. An RSU can be attached to an infrastructure network, which in turn can be connected to the Internet. RSUs can also communicate to each other directly or via multihop. RSUs allow OBUs to access infrastructure and internet.

2.3 Standards, Regulations & Layered Architecture

For vehicular network it is mandatory that all participating institutes or authorities agree on common standard. A standard is a set of rules that promote interoperability among equipment developed by different groups for example IEEE or Society of Automotive Engineers (SAE). To create a common standard IEEE has introduced IEEE 802.11p [7], it is amendment to the IEEE802.11a standard to assist the progress of wireless access in vehicular network (WAVE). Being variant of IEEE 802.11a, IEEE 802.11p additionally covers the specifics of vehicular network for example dynamic and mobile environment, message transmission in an ad-hoc manner, low latency. Another IEEE 1609 work group are developed providing necessary services on higher layer within the payload of IEEE 802.11p.

The WAVE technology is classified into dedicated short range communication (DSRC). The US FCC has allocated 75 MHz of spectrum for DSRC communication from 5.850 GHz to 5.925 GHz. This spectrum consist of 5 MHz guard band and seven 10MHz channels to support both safety applications and non-safety applications [8]. DSRC enables the communication among OBU(On Board Unit) and RSU (Road Side Unit). DSRC composed of both IEEE 802.11p and IEEE 1609 standards, fig. 2.2 illustrates the layered architecture of DSRC .Short overview of 1609 work group deployed in layered architecture has been given below:

- **IEEE 1609.1** defines a resource manager that should allow multiple applications run on roadside units to communicate with the on-board units of multiple vehicles. It serves on the application layer [8].
- **IEEE 1609.2** defines security services for communication such as authentication of devices and encryption of messages [8].
- **IEEE 1609.3** specifies networking services for communication, including a specific stack and protocol to handle WAVE short messages (WSM) [8].
- **IEEE 1609.4** provides enhancements to the IEEE 802.11p MAC to support multi-channel operation [9].

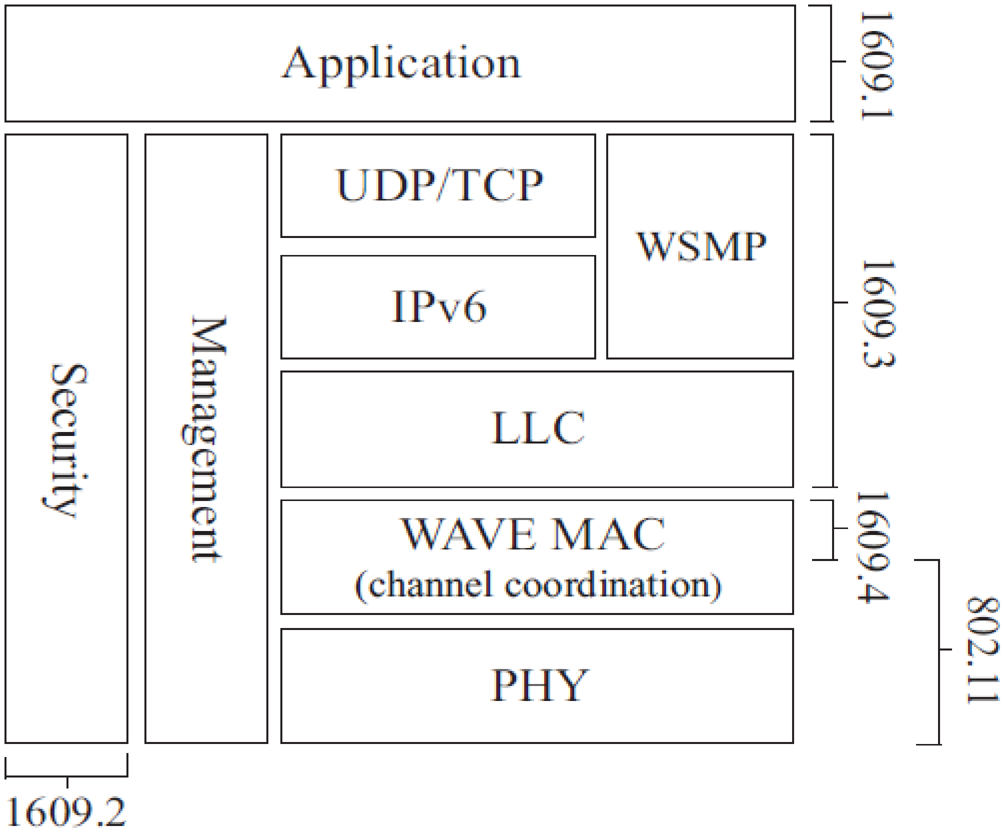


Fig. 2.2 layered Architecture [9]

2.4 Applications

The roadway system touches the life of every person. Absence of road traffic safety takes a toll of precious human lives and poses a dire threat to our environment as well.

Other negative consequences are related to energy waste and environmental pollution. With the deployment of VANET , the number of accidents will decrease and human lives will be saved. Along with public safety and road management numerous other applications have also been proposed, various applications of vehicular network has been discussed as follows.

- Public safety applications or systems would increase the protection of the people in the vehicle, the vehicle itself as well as pedestrian. The systems shall save lives by avoiding or minimizing the effects of an accident.
- Resource Efficiency refers to stable traffic fluency. With the growth of industrialization, people and businesses rely more on roadways which ultimately increase the traffic congestion, since traffic congestion is becoming an increasingly severe problem. Better traffic efficiency results in less congestion and lower fuel consumption, which will result in efficient use of resources.
- Advanced Driver Assistance Services provide numerous services to drivers and passengers. This makes driving more comfortable by providing access to different services such as easy toll payment without stopping, internet access while traveling.
- Vehicular communication will also help in improving the Police services; because of it vehicles of cop can coordinate in better way while following criminals.
- Vehicular communication will help in detecting the position of vehicle; it would be of great use specially if vehicle has met with an accident at anonymous place.

2.5 Challenges

Even though Vehicular network seems conceptually straightforward yet design and deployment of VANET is very challenging technically as well as economically. Some of the challenges are described as follows.

- It would be difficult to make efficient use of available bandwidth of the wireless channel in decentralized and self-organizing network. Lack of an entity able to synchronize and manage transmission rate of different nodes might result in less efficient usage of channel and in large number of packet collision [8].

- Because of inherent characteristics of radio channel, multiple reflecting objects can degrade the strength and quality of the received signal.
- High mobility, scalability requirements and excessive variation in environmental conditions presents a challenge in designing a optimized routing algorithm.
- Security and privacy needs are concerns. There is a challenge in balancing security and privacy needs. On the one hand, the receivers want to make sure that they can trust the source of information. On the other hand, the availability of such trust might contradict the privacy requirement of sender.

2.6 Routing Protocols

Routing is a mechanism to establish and to select a specific path in order to send data from source to destination. There are various routing algorithm designed for ad-hoc networks. Classification of various routing protocols has been shown below in figure 2.3

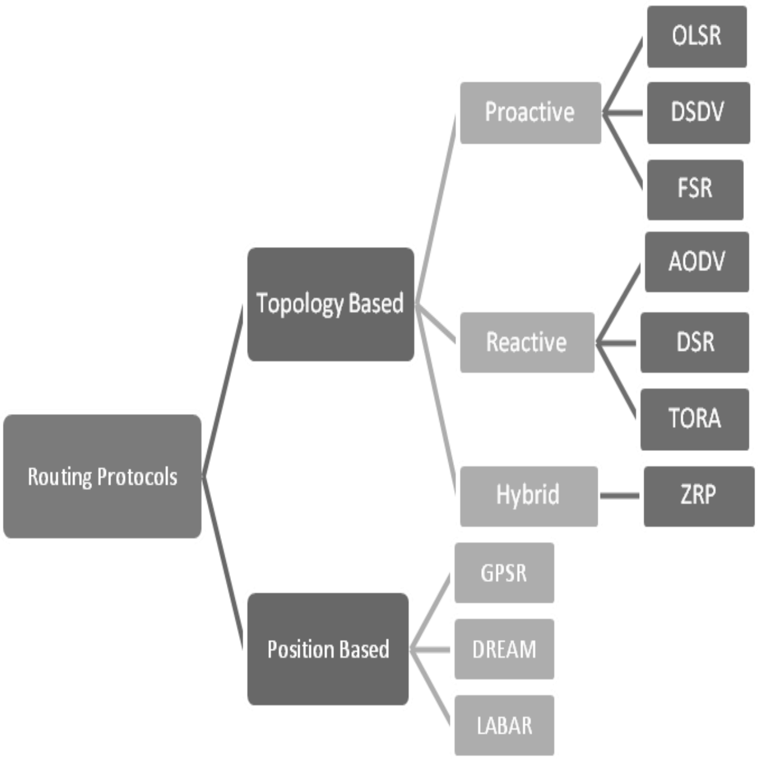


Fig. 2.3 Routing Protocols

2.6.1 Topology Based

Topology based routing protocols use link's information within the network to send the data packets from source to destination.

2.6.1.1 Proactive Routing

These types of protocols are table based because they maintain table of connected nodes to transmit data from one node to another and each node share its table with another node. Different types of proactive routing protocols are Destination Sequence Distance Vector Routing (DSDV), Optimized link state routing (OLSR), Fisheye State Routing (FSR).

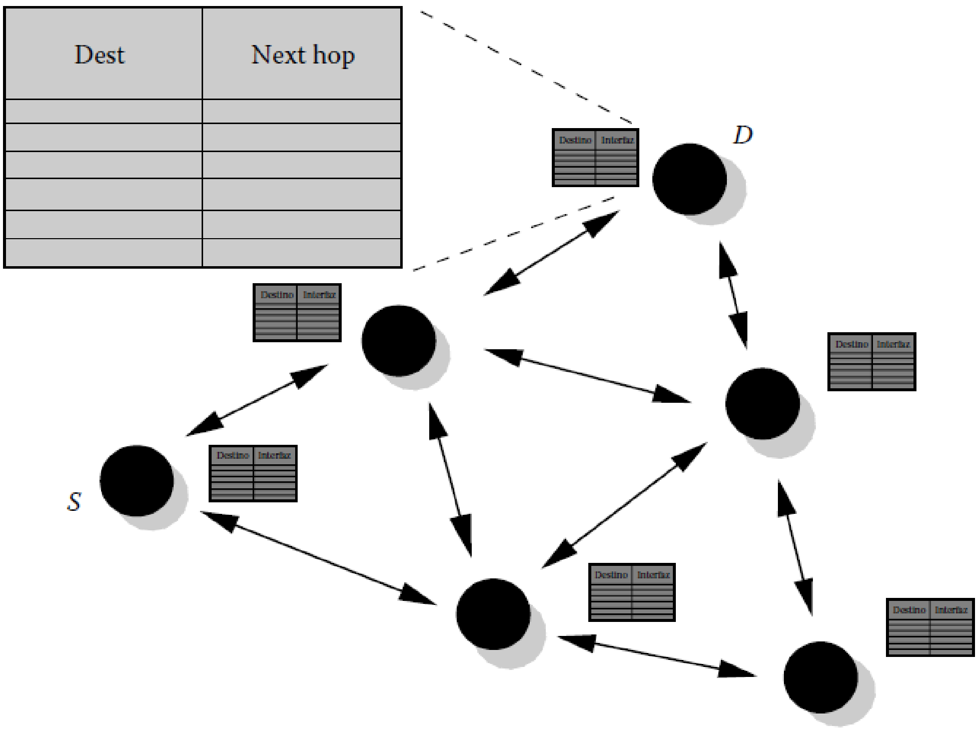


Fig. 2.4 Proactive routing protocols routing scheme [24]

Destination Sequence Distance Vector Routing[10] is a table driven routing protocol for MANET based on Bellman-Ford algorithm. Every node in the network share packet with its entire neighbor. Packet contain information such as node's IP address, last known sequence number, hop count. Whenever there is topology change in network each node advertises its routing status after a fixed time or immediately.

Optimized link state routing (OLSR)[11] protocol is an optimization of the classical link state algorithm. In OLSR every node use "HELLO" message to know about their neighbors. Flooding of message to sense the neighbor node is very expensive process therefore to reduce the cost of flooding to sense neighbors OLSR use multipoint relay (MPR) technique [12].

Fisheye State Routing (FSR)[13] uses the fisheye technique proposed by Kleinrock and Stevens. In FSR link state packets are not flooded but it allows sharing link state message at different intervals for nodes within different fisheye scope distance and thus reducing the size of link state message size.

2.6.1.2 Reactive Routing

It is also called On Demand routing because it establish a route to destination whenever a node has something to send thus reducing burden on network. Reactive routing have route discovery phase where network is flooded in search of destination. Different types of Reactive routing protocols are AODV, DSR, TORA

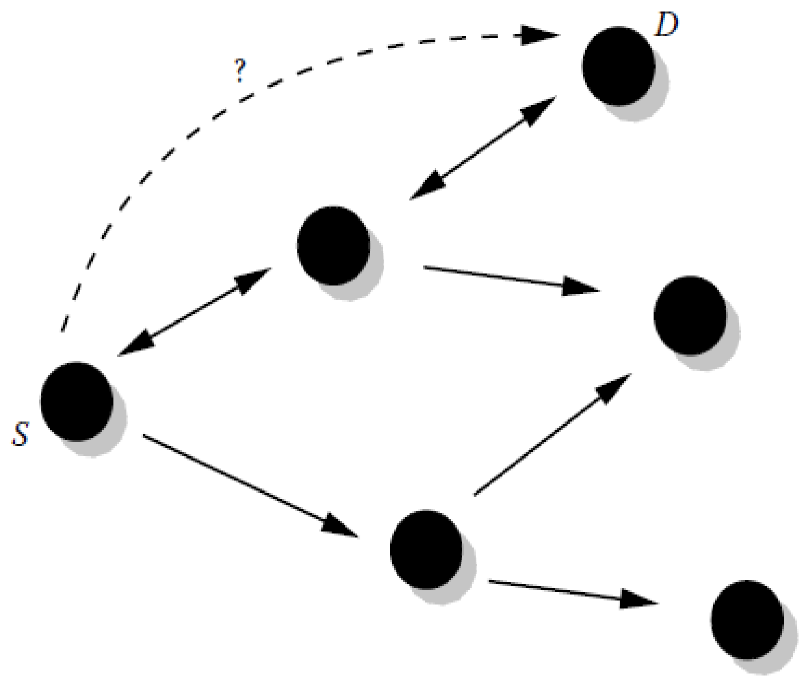


Fig. 2.5 Reactive routing protocols routing scheme [24]

Ad Hoc On Demand Distance Vector (AODV) [14] is an reactive routing protocol which capable of both unicast and multicast. In AODV, like all reactive protocols, topology information is only transmitted by nodes on-demand. When source has something to send then initially it propagates RREQ message which is forwarded by intermediate node until destination is reached. A route reply message is unicasted back to the source if the receiver is either the node using the requested address, or it has a valid route to the requested address.

Dynamic Source Routing (DSR) [15] is also an reactive routing protocol it uses source routing. When a node has something to send it broadcast a rout request message to its 1-hop neighborhood if receiver is not a valid destination then it forward the updated RREQ message in which they add their address in this way all the intermediate node update RREQ message with their address and thus message along with updated route reach to destination. When RREQ reach to destination it returns a route reply message to source.

Temporally Ordered Routing Algorithm (TORA) [16] it belongs to a class of algorithm called the link reversal algorithm. TORA attempt to build DAG(Directed Acyclic Graph) towards destination is based on the height of the tree rooted at the source. TORA performs three tasks.

- Creation of a route from a source to destination
- Maintenance of rout
- Removing route if it is no longer valid.

2.6.1.3 Hybrid Routing Protocol

To make routing more scalable and efficient Hybrid routing combines the characteristics of both reactive and proactive routing protocols. Mostly Hybrid Routing protocols are zone based i.e whole network is divided in to number of zones.

Zone Routing Protocol (ZRP) [17] It is based on the concept of zone. Each routing zone has radius 'ρ' which mean a zone include all the nodes whose distance from node is at most 'ρ' hops. Nodes inside the zone whose minimal distance from centre node is 'ρ' hops are known as peripheral nodes and rest are known as interior nodes. Proactive routing protocols is used to route packet within a zone which is known as Intra-Zone routing protocol whereas reactive routing protocol is used to route packet outside zone which is termed as Inter-Zone routing protocol.

2.6.2 Position Based Routing

Work on position-based routing protocol started in 1980s. In position-based routing protocols, forwarding decisions are made based on the position of destination node and source's one-hop neighbors. Nodes that are within the coverage of source's node are called 1-hop neighbors. If destination is outside source's coverage area, then source has to select one of its neighbors as 1-hop neighbor as next relay for the message. This information can be obtained by GPS technology and local services (Vehicle to infrastructure).Unlike topology based routing protocols, position based routing protocols do not exchange routing table to establish route. Some of the famous position based routing protocols are Distance Routing Effect Algorithm for Mobility (DREAM), Location Area Based Ad-hoc Routing (LABAR), Greedy Perimeter Stateless Protocol (GPSR).

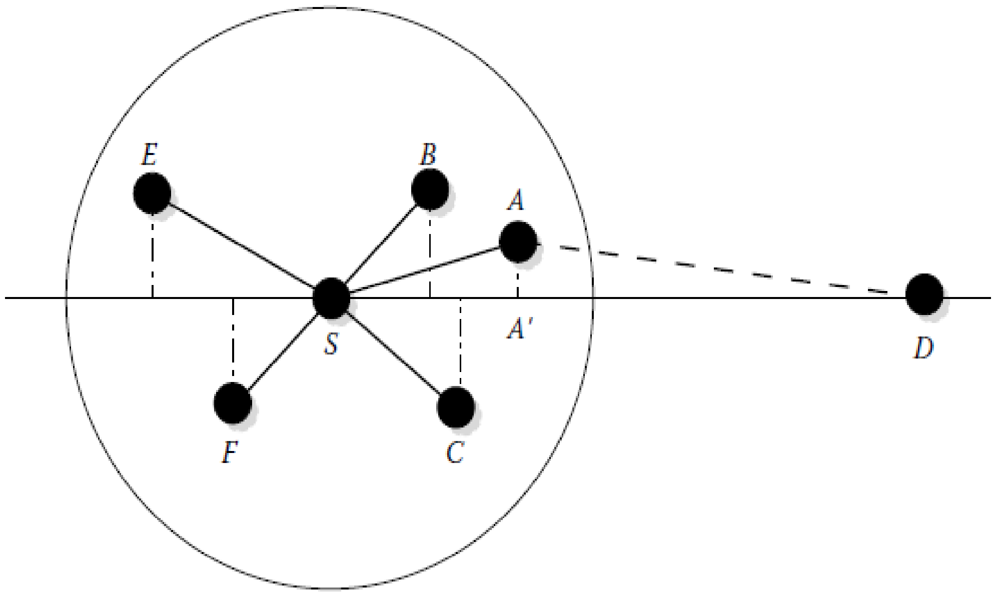


Fig 2.6 Position-based geographic routing scheme [24]

GPSR [18], is a responsive and efficient routing protocol for mobile, wireless networks. GPSR uses the positions of nodes to make packet forwarding decisions. GPSR uses greedy forwarding approach to forward packets to nodes that are always increasingly closer to the destination. In regions of the network where such a greedy path does not exist, GPSR recovers by forwarding in perimeter mode, which transfers the connectivity graph into a planar graph by eliminating redundant edges in order to get out of local maximum.

Distance Routing Effect Algorithm for Mobility (DREAM)[19] forwards packet to several next-hop nodes in order to reach the destination. DREAM restricts the number of broadcasts by forwarding the packets to specific regions and thus it reduces the overhead. Every node uses GPS to take the position of each node in the network. With the help of this information it measures the region that is possible the destination belongs to and broadcast the packet to this region, which is called expected region.

Location Area Based Ad-hoc Routing (LABAR)[20] It aims to perform routing with a relaxation of the GPS equipment in sensor nodes. It therefore considers that GPS can be found only in certain nodes (G- nodes), the rest having no location information. Assumptions are made about an open propagation environment and of equal node range for all nodes. It makes use of two types of nodes (G-nodes and S-nodes) - with and without geographical knowledge of their own positions. This protocol consists of 3 steps: zone formation, virtual backbone formation and directional routing. The main idea is that G-nodes form a virtual backbone of the network. S-nodes are requested to belong to certain zones attached to a G-node. As soon as the S-node joins a certain G-node zone, his ID becomes known to that certain G-node. The G- node then maps the IP address to the geographical location. Zones are connected through a G-node called root. The source node uses the associated G-node to map the destination IP address and to calculate the vector from the G- node to the destination. The vector's direction is compared to each of the adjacent zones' direction and distance to determine the route with the least number of hops.

2.7 Mobility Models

In order to achieve good result from VANET simulations, there is need to generate a mobility model that is as realistic as an actual VANET environment. The usage of mobility model signifies the movement of mobile node that will consume the protocol. Mainly mobility models are separated into two levels [21]: macroscopic level and microscopic level. The mobility of cars, roads, buildings, etc. is comes under macroscopic model. The movement of vehicles and their behavior are classified as Microscopic Model. Different types of mobility models have been used in VANET simulations. They are classified according to the level of details they generate. The mobility patterns can be generated from various models. These models are described below.

Survey Model Survey models represent realistic human behavior in urban mesh environments. The model relies on data collected through surveys performed on human activities. The survey was recorded for the human performance, tasks, and activities. E.g. UDel mobility model is a tool for simulating urban mesh networks.

Event driven model Event driven models, also called trace models, they are used to observe the movement of human beings and vehicles, this model generate traces based on the mobility of human beings and vehicles. Event driven models could be gathered to develop a probabilistic mobility model that reflects the real movement on the map. The problem with this model is that only the characteristics of mobile nodes with access points were considered; no relationship between the nodes was considered. As a result, probabilistic models cannot support the ad hoc mode of VANET [22].

Software Oriented Model Various simulators like VISIM , CORSIM and TRANSIM can generate the traces of urban microscopic traffic. VANETMobiSim uses TIGER database and Voronoi graphs to extract road topologies, maps, streets etc for the network simulators. The problems with such simulators are that they can only operate at traffic level and cannot generate realistic levels of details. Moreover the inter-operability with network simulators and the generated level of details seems insufficient for network simulators.

Synthetic Model This model has fascinated lot of researchers and lot of work has been carried out in synthetic model. Mathematical equations are used by all models in this category for the development of realistic mobility models. Synthetic model is further classified in to five main categories:

- Stochastic model: deals with totally random motion.
- Traffic Stream model: examines the mechanical properties of mobility model.
- Car Following model: monitors the behavior of car-to-car interaction.
- Queue model: considers cars as standing in queues and roads as queue buffers.
- Behavioral models: examines how movement is influenced by social interaction.

2.8 Working of DSDV

Bellman and Ford designed a centralized algorithm to compute shortest paths in weighted graphs. Bertsekas and Gallager designed it to be executed in a distributed fashion, which is called Distributed Bellman–Ford (DBF) algorithm [25]. In distributed Bellman-Ford (DBF), each and every node maintains a cost to reach to every known destination. Thus, the routing table consists of a entries <*destination*, *distance*, *next-hop*>.In the beginning all the routing tables are empty, and each node starts issuing periodic broadcast messages to its 1-hop neighborhood. Main disadvantage of DBF is that it suffer from a bouncing problem that leads to the *count-to-infinity* and looping issues. Loops can appear if out-of-date information is used to compute the shortest path.

The main objective behind the designing of DSDV [10] is to maintain simplicity and to avoid loop formation. In DSDV, packets are transmitted between the nodes of the network by using these routing tables which are stored at each nodes of the network. Each routing table at each of the nodes lists all available destinations and the number of hops to reach. To maintain consistency in dynamically varying topology, each node share its routing entries with its neighbor either periodically or immediately when significant new information is available. Each mobile node will contain its new sequence number and the following information for each new route :

- The destination's address
- The number of hops required to reach the destination
- The sequence number of the information received regarding that destination as originally marked by the destination.

DSDV add a sequence number that indicates the newness of the information to the routing table and the messages. Routes with the latest sequence number are always preferred for forwarding the message, in case of same sequence number route with lower distance is preferred. Every destination increments its sequence number up to the next even number before sending a routing message. Working of DSDV is given below.

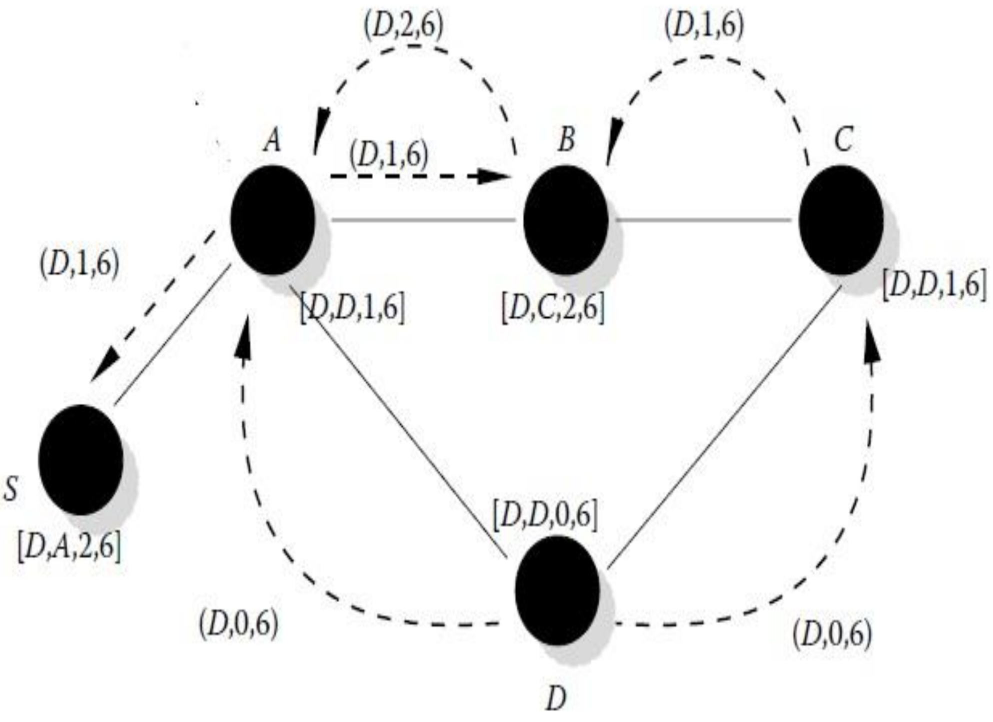


Fig. 2.7 Example of DSDV operation. The figure shows the exchanged messages (Destination, Distance, Sequence No.) and the routing table entries [Destination, NextHop, Distance, Sequence No.] related to node *D* [24].

2.8.1 Routing in DSDV

Consider *D* in figure 2.7, table 2.1shows a structure of routing table entries which is maintained at *D* and table 2.2 shows the exchanged messages.

Table 2.1 Routing table entries maintained at *D*

Destination	NextHop	Distance	Sequence No.
A	A	1	6
B	C	2	6
C	C	1	6
D	D	0	6
S	A	2	6

Table 2.2 Exchanged message by *D*

Destination	Distance	Sequence No.
A	1	6
B	2	6
C	1	6
D	0	6
S	2	6

In the beginning, node *D* sends a message in which it broadcast its routing entries to its neighborhood, *A* and *C*. These nodes update their routing tables and broadcast a new message to inform their neighbors that destination *D* can be reached through them. Next, *A* receives a message from *B*, which announces *D* at distance 2 and sequence number 6. As *A* already has a routing entry for *D* with the same sequence number and lower distance, it will ignore this message because both information are equally fresh, but the first provides a shorter route. Therefore, finally, *S* can set up a route to *D* with distance 2 and *A* as the next hop.

Now let's take a scenario where node *D* moves and is no longer in the neighborhood of *A* and *C*, but is in neighborhood of *S* as given in figure 2.8. The new exchangeable entries at *D* might then appear as shown in table 2.3

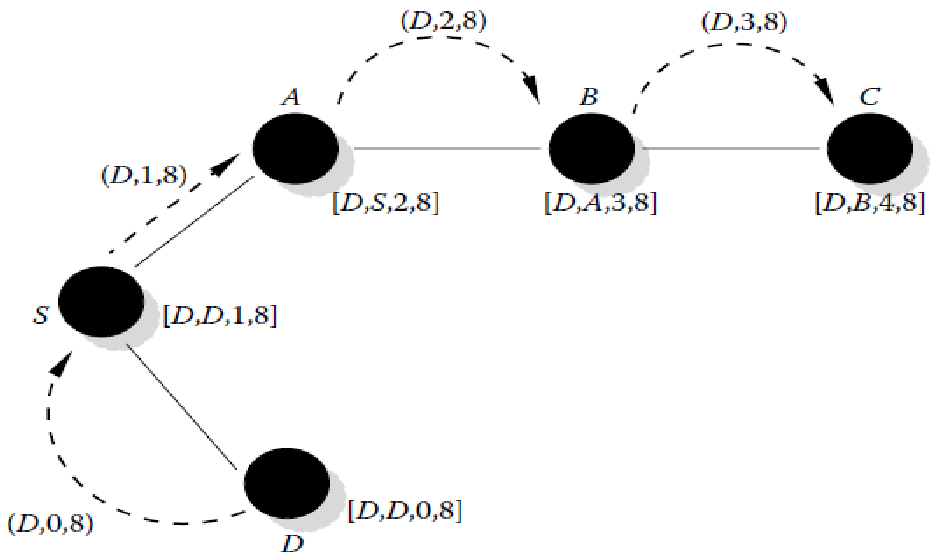


Fig.2.8 Node *D* moves and the network topology changes accordingly. The figure depicts how sequence numbers avoid the use of stale information [24].

Table 2.3 Exchanged message at *D*

Destination	Distance	Sequence No.
A	2	8
B	3	8
C	4	8
D	0	8
S	1	8

D issues a new message with a higher sequence number, 8. This nullifies the routing entries for *D* in every node of the network, as the new sequence number is higher. The information is propagated until all the nodes in the network gain knowledge of a new route to *D*. In this way, sequence numbers are used to avoid the use of old information, which might cause the formation of loops or non-optimal routes.

When a link breakage occurs, the destination marks with distance ∞ (any value greater than the maximum allowed metric) all the routes that used that neighbor as their next hop. This situation is immediately advertised by a protocol message, and the receiving nodes update those routes with the next odd number. So, whenever the route is reestablished, the destination will generate an even sequence number bigger than the one that indicated a broken link and the routes will be restored.

2.9 Working of AODV

The Ad hoc On-Demand Distance Vector (AODV) [14, 23]is a reactive routing protocol which enables dynamic, self-starting, multihop routing between participating mobile nodes wishing to establish and maintain an ad hoc network. It allows the communication between two nodes through intermediated nodes, if those two nodes are not within the range of each other. To establish a route, there is route discovery phase in AODV, along which messages can be passed. AODV makes sure these routes do not contain loops and tries to find the shortest route possible. AODV allows mobile nodes to respond quickly to handle changes in route. When links break, AODV causes the affected set of nodes to be notified so that they are able to invalidate the routes using the lost link. Distinguish feature of AODV is that it uses destination sequence number for each route entry, which ensures lop free route. In case there are two routes to a destination, a requesting node selects the one with greatest sequence number.

For route discovery and maintenance purposes control messages are defined in AODV. Different control messages are defined as follows.

- **RREQ** When node has data to send it broadcast route request message (RREQ) to its neighbors. This message is forwarded by intermediate nodes until destination is reached. RREQ packet contain information RREQ id, destination i.p address, destination sequence number, originator IP address, originator sequence number.

- **RREP** On receiving RREQ message intermediate nodes unicast route reply message (RREP) to source if it is valid destination or it has path to destination and reverse path is constructed between source and destination. RREP packets contain information hop count, destination sequence number, destination IP address, originator IP address.

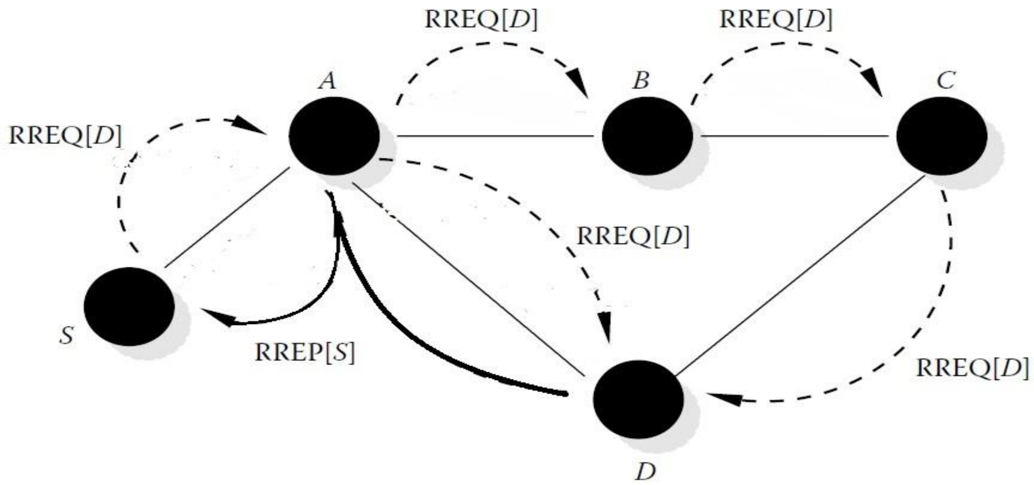
- **RERR** Whenever there is link failure route error message (RERR) is used. RERR contain information Unreachable Destination IP Address, Unreachable Destination Sequence Number.

An additional feature of AODV is the generation of gratuitous RREPs. When an intermediate node replies an RREQ on behalf of the destination, it also sends an RREP to the destination in order for this to create a route to the source. This avoids the need of future route discoveries to establish the reverse route.

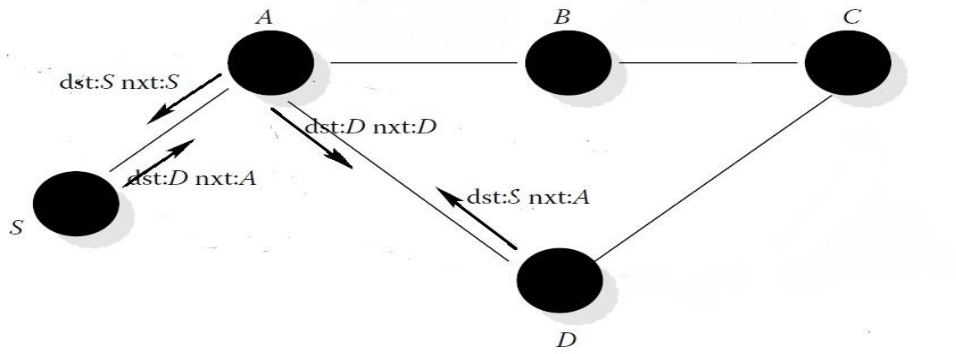
2.9.1 Routing in AODV

Fig. 2.9 shown below illustrates the different phases of AODV routing. There are various mechanisms which are followed in AODV routing approach. These are as follows:

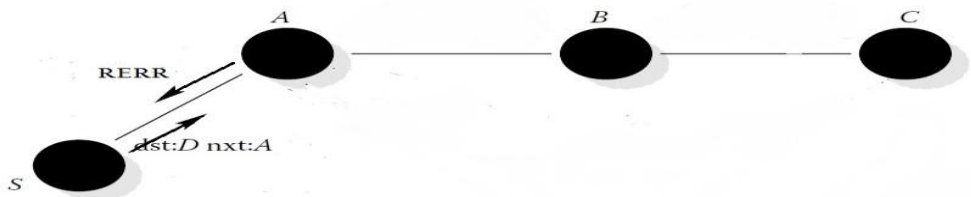
a) AODV Route Discovery The need for basic route discovery arises when a source has a packet to send to destination. AODV uses route discovery mechanism by broadcasting RREQ to all its neighboring nodes. The broadcasted RREQ contains addresses of source and destination, their sequence numbers, broadcast ID and a counter, which counts how many times RREQ has been generated from a specific node.



Phase 1- Source node broadcast RREQ message, Destination unicast RREP message



Phase 2- Route established between Source and Destination



Phase 3- Destination is down, its neighbor unicast RERR message to Source

Fig. 2.9 Working of different phases AODV

When a source node broadcast a RREQ to its neighbors it obtains RREP either from its neighbors or that neighbor(s) rebroadcasts RREQ to their neighbors by increment in the hop counter. If node receives multiple route requests from same broadcast ID, it drops repeated route requests to make the communication loop free. RREQ is generated from one source towards different destinations in order to reach at particular destination. If RREP is not received by the source node, it automatically setups reverse path to the source node. A reverse path is created only when each node keeps the record of its neighbor from which it gets the RREQ. Reverse path is used to send a reply to source node, if any intermediate node does not satisfies the RREQ, moreover reverse path is settled for only the limited period of time. All intermediate nodes stored the particular destination sequence number information and compare it with the RREQ destination sequence number. If RREQ sequence number is greater than or equal to stored sequence number of the intermediate node. Then the RREP is generated to source node following the same route from destination node to source node. This method is also known as the forward path discovery. And in this way a route is discovered for two nodes that need to communicate.

b) AODV Route Table Management Routing table management in AODV is needed to avoid those entries of nodes that do not exist in the route from source to destination. Managing routing table information in AODV is handled with the destination sequence numbers. The need for routing table management is important to make communication loop free. The following are characteristics to maintain the route table for each node .

- IP address of the particular destination.
- Total number of hops to the destination.
- Next hop: It contains information of those nodes that are used to forward data packets by using the current route.
- Destination sequence numbers.
- Active neighbors: Those nodes that currently using the active route.
- Expiration time: It contains information for the total time that route is being valid.

c) AODV Route Maintenance When nodes in the network detects that a route is not valid anymore for communication it delete all the related entries from the routing table for those invalid routes. And sends the RREP to current active neighboring nodes that route is not valid anymore for communication. AODV maintains only the loop free routes, when the source node receives the link failure notification it either start the process of rebroadcasting RREQ or the source node stop sending data through invalid route. Moreover, AODV uses the active neighbor's information to keep tracking of currently used route. AODV reduces several problems that occurred in proactive routing protocols. AODV provide support by reacting at on demand needs for communication for such ad hoc network where large numbers of nodes. And this can help when the sudden change in topology happens.

So, AODV is an on demand algorithm, meaning that it maintains routes as long as they are needed by the sources. It uses sequence numbers to ensure the freshness of routes. These routes are loop-free, self-starting, and scale to large numbers of mobile nodes.

2.10 Working of ZRP

Zone Routing Protocol (ZRP) [17] is a hybrid protocol which is designed by combining the best properties of both proactive routing protocol as well as reactive routing protocol. The Zone Routing Protocol is based on the concept of zones. For each node routing zone has been defined. The radius of the routing zone can be defined as ρ which is expressed in hops. The zone thus includes the nodes, whose distance from the from that specific node is at most ρ hops. In Fig. 2.10 an example routing zone is shown where the routing zone of S includes the nodes A–I, but not J.

Two types of nodes are exist in zone, peripheral nodes and internal nodes. Peripheral nodes are nodes whose minimum distance to the central node is exactly equal to the zone radius ρ (*D, G, I, H* in Fig. 2.10). The nodes whose minimum distance is less than ρ are interior nodes (*A, B, F, E, C* in Fig. 2.10). Since, it can be assumed that that the largest part of the traffic is directed to nearby nodes. Therefore, proactive routing protocol is executed within a zone while node outside a zone can be reached by reactive routing protocol.

ZRP refers to the locally proactive routing section as the IntrA-zone Routing Protocol (IARP). The globally reactive routing section is named IntEr-zone Routing Protocol (IERP). IARP is responsible for maintaining routing information for nodes that are within the routing zone of the node. Correspondingly, IERP is a family of reactive routing protocols that offer enhanced route discovery and route maintenance services by using the topology knowledge provided by IARP to deliver the route request directly to the peripheral nodes, this concept is called bordercasting, and is implemented by the Bordercast Resolution Protocol (BRP).

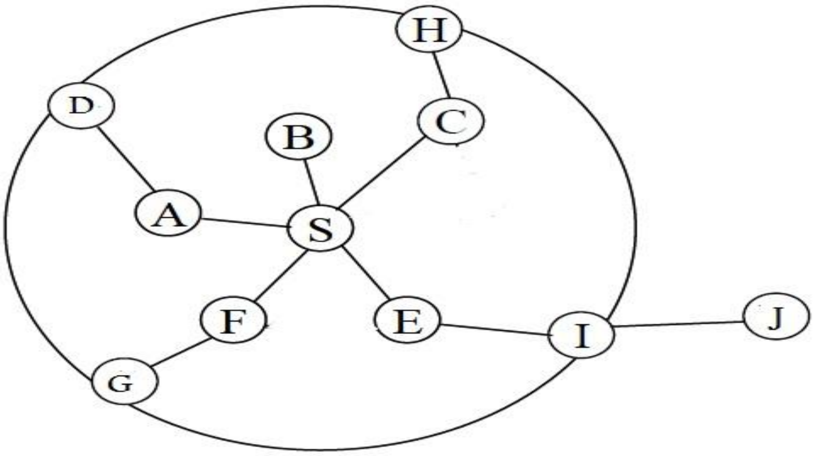


Fig 2.10 Example of routing zone with ρ=2

2.10.1 Routing in ZRP

Routing in ZRP is shown in fig 2.11. A node that has a packet to send first checks whether the destination is within its local zone using information provided by IARP.

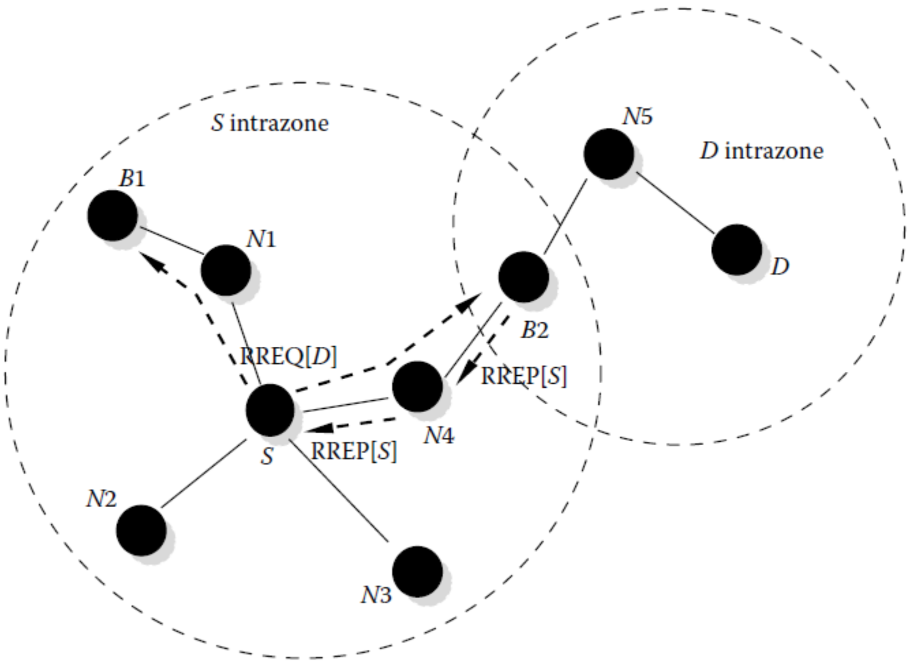


Fig. 2.11Routing in ZRP with ρ=2 [24]

In that case, the packet can be routed proactively. Reactive routing is used if the destination is outside the zone. For example *'S'* has a packet to send to destination *'D'*. *S* first checks whether destination is within its local zone using IARP. But *'D'* is not within its *'S'* zone. *'S'* sends a RREQ to its peripheral nodes B_1 and B_2 using multicast. Because B_2 is within *D's* zone, it knows a proactive route to *'D'* and sends a RREP back to *'S'* using unicast.

3.1 Problem Statement

Because of many applications vehicular network has fascinated many research institutes and automotive industries. Various types of challenges in vehicular communications have been identified and addressed. Main issue of concern is implementation of an appropriate routing protocol because of several issues. Routing protocol is an algorithm used to determine an appropriate path to destination along which messages can be forwarded. VANET routing protocol is classified in to topology based and position based. It will be interesting to evaluate the performance of AODV (reactive routing), DSDV (proactive routing), ZRP (hybrid Routing) with realistic mobility model for VANET. Analysis of these three protocols from different category will help in better understanding of these three categories (proactive, reactive, hybrid).

The performance of the different protocols can be evaluated using simulation tools, mainly -Network Simulator (NS2) [26] and MOVE (MObility model generator for VEhicular networks) [32] over SUMO (Simulation of Urban MObility) [33].

3.2 Objectives

The primary objective of this thesis is the simulation and analysis of DSDV, AODV, ZRP routing protocol with realistic mobility model for VANETs. The variation in the number of nodes is done as 10 nodes,20 nodes, 40 nodes and 80 nodes. The results are evaluated in all cases and compared with each other.

- To simulate AODV, DSDV, ZRP protocols for VANETs
- To compare and analyze their performance under different scenarios
- Report and analysis of the result obtained.

3.3 Methodology

i) Firstly, simulation environment is to be setup. MOVE tool is used for rapid generation of realistic mobility model along with SUMO and NS2.

ii) The performance comparison is made with different number of nodes. Four different sets of node density would be used to compare the performance of the said protocols.

iii) Awk scripts are used to get the value from trace file and ms-excel is used to generate graphs.

iv) Results are compared under various parameters like throughput, End to End delay, Packet delivery ratio etc.

Chapter 4
Simulation & Implementation

4.1 Simulation

According to Shannon [34], simulation is “the process of designing a model of a real system and conducting experiments with this model for the purpose of understanding the behavior of the system and/or evaluating various strategies for the operation of the system.”

Developing a VANET in practical application is too costly therefore to test and to evaluate the protocols simulators are used .Simulation of protocol is the initial step of implementation of VANET protocols. Several communications network simulator already exist to provide a platform for testing and evaluating network protocols, such as NS-2[26], OPNET [27] and Qualnet [28].Several simulation tools available such as PARAMICS [29], CORSIM [30] and VISIM [31], MOVE[32], SUMO[33], NS-2, etc that have been developed to analyze transportation scenarios at the micro and macro-scale levels. Node mobility is the most important parameter in simulating ad-hoc network. It’s important to use real world mobility model so that the results from the simulation correctly reflect the real-world performance of a VANET.

In this thesis, to generate real world mobility models for VANET simulations a tool MOVE (MObility model generator for VEhicular networks) has been used . MOVE is a java based tool with GUI and built on top of micro traffic simulator SUMO. It does the interpretation between NS2 and SUMO. The output of MOVE is a mobility trace file that contains information of real world vehicle movements which can be used by NS-2 or Qualnet. In addition, MOVE provides a set of GUI that helps the user to generate real-world simulation scenarios.

A brief introduction of used simulators has been given in below sections.

4.1.1NS-2

Network Simulator (Version 2), widely known as NS2, is simply an event driven simulation tool that has proved useful in studying the dynamic nature of communication networks. Simulation of wired as well as wireless network functions and protocols (e.g., routing algorithms, TCP, UDP) can be done using NS2. Ns2 also implements multicasting and some of the MAC layer protocols for LAN simulations. In general, NS2 provides users with a way of specifying such network protocols and simulating their corresponding behaviors. Due to its flexibility and modular nature, NS2 has gained constant popularity in the networking research community since its birth in 1989. The NS project is now a part of the VINT project that develops tools for simulation results display, analysis and converters that convert network topologies generated by well-known generators to NS formats.

4.1.1.1 Basic Architecture

Figure 4.1 shows the basic architecture of NS2. NS2 provides users with an executable command ns which takes on input argument, the name of a TCL simulation scripting file. Users are feeding the name of a TCL simulation script (which sets up a simulation) as an input argument of an NS2 executable command ns. NS2 consists of two key languages: C++ and Object-oriented Tool Command Language (OTCL). While the C++ defines the internal mechanism (i.e.,a backend) of the simulation objects, the OTCL sets up simulation by assembling and configuring the objects as well as scheduling discrete events (i.e., a frontend). The C++ and the OTCL are linked together using TCLCL. Mapped to a C++ object, variables in the OTCL domains are sometimes referred to as handles. Conceptually, a handle (e.g., n as a Node handle) is just a string in the OTCL domain, and does not contain any functionality. Instead, the functionality (e.g., receiving a packet) is defined in the mapped C++ object (e.g., of class Connector). In the OTCL domain, a handle acts as a frontend which interacts with users and other OTCL objects. It may defines its own procedures and variables to facilitate the interaction.

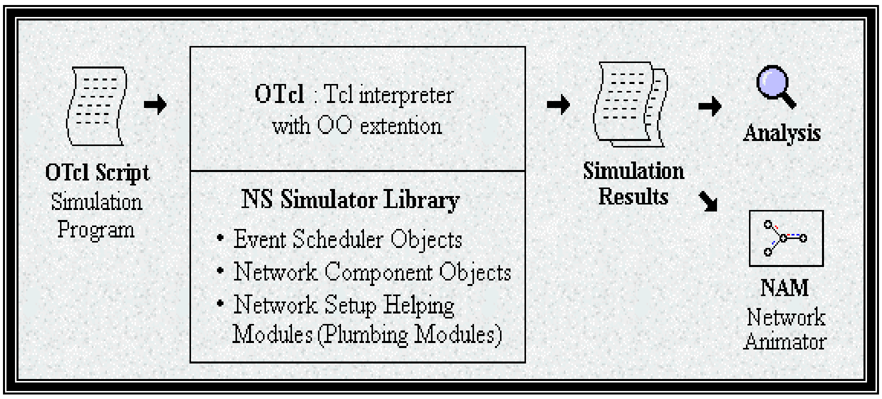


Fig. 4.1 Architecture of NS

After simulation, NS2 outputs either text-based or animation-based simulation results. To interpret these results graphically and interactively, tools such as NAM (Network AniMator) and XGraph are used. To analyze a particular behavior of the network, users can extract a relevant subset of text-based data and transform it to a more conceivable presentation.

4.1.1.2 NAM

NAM provides a visual interpretation of the network topology created. The application was developed as part of the VINT project. Figure 4.2 displays the NAM Visualization.

Fig. 4.2 NAM Generated for 80 nodes

4.1.1.3 Trace File

The trace file is an ASCII code files and the trace is organized in 12 fields as in Figure 4.3

Event	Time	From node	To node	Pkt type	Pkt size	Flags	Fid	Src addrs	Dst addrs	Seq num	Pkt id

Fig. 4.3 Field of Trace

The trace file data explanation is given below starting from the first field as number 1.

1. Operation performed in the simulation, given by one of four available symbols r, s, and d which correspond respectively to receive, enqueued, dequequed and dropped

2. Simulation time of event occurrence

3. Input node of link at which the events takes place.

4. Output node of link at which the events takes place.

5. Packet type like CBR or TCP.

6. Packet size

7. Flags

8. IP flow identifier

9. Packet source node address

10. Packet destination node address

11. Sequence number

12. Unique packet identifier

Depending on the user's purpose for an OTCL simulation script, simulation results are stored as trace files, which can be loaded for analysis by an external applications or scripts.

4.1.1.4 Installation

NS2 is a free simulation tool, which can be obtained from [26]. It runs on various platforms including UNIX (or Linux), Windows, and Mac systems. Being developed in the Unix environment, with no surprise, NS2 has the smoothest ride there, and so does its installation. Unless otherwise specified, the discussion in this book is based on a Cygwin (UNIX emulator) activated Windows system. NS2 source codes are distributed in two forms: the all-in-one suite and the component-wise. With the all-in-one package, users get all the required components along with some optional components. This is basically a recommended choice for the beginners. This package provides an “install” script which configures the NS2 environment and creates NS2 executable file using the “make” utility.

The used all-in-one suite consists of the following main components:

- NS release 2.33,
- TCL/Tk release 8.4.18 ,
- OTCL release 1.13, and
- TCLCL release 1.19.

and the following are the optional components:

- NAM release 1.13: NAM is an animation tool for viewing network simulation traces and packet traces.
- Zlib version 1.2.3: This is the required library for NAM.
- Xgraph version 12.1 : This is a data plotter with interactive buttons for panning, zooming, printing, and selecting display options.

The all-in-one suite can be installed in the Unix-based machines by simply running the install script and following the instructions therein. The only requirement is a computer with a C++ compiler installed. The following commands show how the all-in-one NS2 suite can be installed

- **$ ./install**
- **$ ./validate**

4.1.2 SUMO

"*S*imulation of *U*rban *MO*bility", or "SUMO"[33] is a highly portable microscopic road traffic simulation package designed to handle large road networks.The major reason for the development of an open source, microscopic road traffic simulation was to support the traffic research community with a tool into which own algorithms can be implemented and evaluated.

It is script based tool. It allows users to create a road topology with vehicles movement according to his requirement. It also allows user to define the departure and arrival properties, such as the lane to use, the velocity, or the position can be defined. These all properties are defined when the vehicle is created and its flow definitions are set.

4.1.2.1 Features

- Complete workflow (network and routes import, DUA, simulation)
- Simulation
  - Collision free vehicle movement
  - Different vehicle types
  - Multi-lane streets with lane changing
  - Junction-based right-of-way rules
  - Hierarchy of junction types
  - A fast openGL graphical user interface
  - Manages networks with several 10,000 edges (streets)
  - Fast execution speed (up to 100,000 vehicle updates/s on a 1GHz machine)
  - Interoperability with other application on run time using TraCI
  - Network-wide, edge-based, vehicle-based, and detector-based outputs
- Network
  - Many network formats (VISUM, Vissim, Shapefiles, OSM, Tiger, RoboCup, XML-Descriptions) may be imported
  - Missing values are determined via heuristics
- Routing
  - Microscopic routes - each vehicle has an own one
  - Dynamic User Assignment
- High portability
  - Only standard c++ and portable libraries are used
  - Packages for Windows main Linux distributions exist
- High interoperability through usage of XML-data only

4.1.2.2 Miscellaneous Applications

SUMO is not only the name of the simulation application, but also the name of the complete software package which includes several applications needed for preparing the simulation. The package includes:

Application Name	Short Description
SUMO	The microscopic simulation with no visualization; command line application
GUISIM	The microscopic simulation with a graphical user interface
NETCONVERT	Network importer and generator; reads road networks from different formats and converts them into the SUMO-format
NETGEN	Generates abstract networks for the SUMO-simulation
DUAROUTER	Computes fastest routes through the network, importing different types of demand description. Performs the DUA
JTRROUTER	Computes routes using junction turning percentages
DFROUTER	Computes routes from induction loop measurements
OD2TRIPS	Decomposes O/D-matrices into single vehicle trips
POLYCONVERT	Imports points of interest and polygons from different formats and translates them into a description that may be visualized by GUISIM
Additional Tools	There are some tasks for which writing a large application is not necessary. Several solutions for different problems may be covered by these tools.

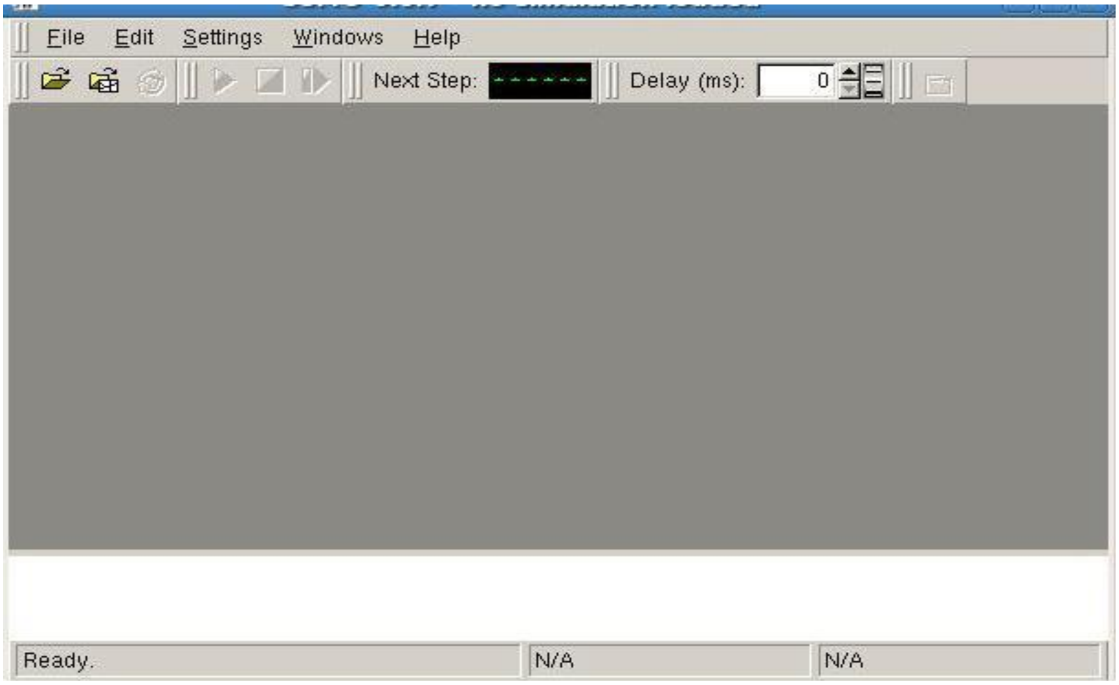


Fig. 4.4 SUMO GUI

4.1.2.3 Installation steps on Ubuntu

Sumo 0.12.3 has been installed on our system. Its installation steps are as follows:

1. Downloaded sumo-src-0.12.3.tar.gz
2. Extracted it to home folder, here we extracted to /home/abhishek/Downloads
   root@ubuntu:/home/abhishek/Downloads# tar xvzf sumo-src-0.12.3.tar.gz
3. Installed important libraries
   root@ubuntu:/home/abhishek/Downloads# apt-get install gfortran libproj-dev libxerces-c-dev libfox-1.6-dev

Then installed sumo by following commands.

4. **root@ubuntu:/home/abhishek/Downloads#** cd sumo-0.12.3
5. **root@ubuntu:/home/abhishek/Downloads/sumo-0.12.3#**./configure
6. **root@ubuntu:/home/abhishek /Downloads/sumo-0.12.3#** make
7. **root@ubuntu:/home/abhishek/Downloads/sumo-0.12.3#** make install

With these steps sumo-0.12.3 got installed for use.

4.1.3 MOVE

MOVE (MObility model generator for VEhicular networks)[32] is a Java-based application built on SUMO (Simulation of Urban Mobility) with a ability of GUI. In this thesis, a tool MOVE (MObility model generator for VEhicular networks) has been used to allow the users to generate realistic mobility models for VANET simulations. MOVE is built on top of an open source micro-traffic simulator SUMO. The output of MOVE is a mobility trace file that contains information of realistic vehicle movements which can be used by popular simulation tools such as NS-2.

MOVE consists of two main components: Mobility model and traffic model generator.

1. **Mobility Model Generator** It provides a user friendly interface for generating mobility model for simulations using SUMO. It allows the user to create customized topology or import maps.
2. **Network Traffic Model generator** It takes the SUMO trace file as the input and generates the network traffic model as required by either NS2 or Qualnet. It provides all the configurable option of NS2 TCL files, like specifying MAC, routing protocol to use, etc.

4.1.3.1 Installation steps of MOVE

First install java sdk 1.6 and NS-2 Version 2.33

a) openjdk-6-jdk

- SUMO version: 0.12.3
- Xerces (XML-parser)
- FOX-Toolkit (GUI Toolkit)
- PROJ (Cartographic Projections Library)

GDAL (Geospatial Data Abstraction Library)

b) NS2 version: 2.33

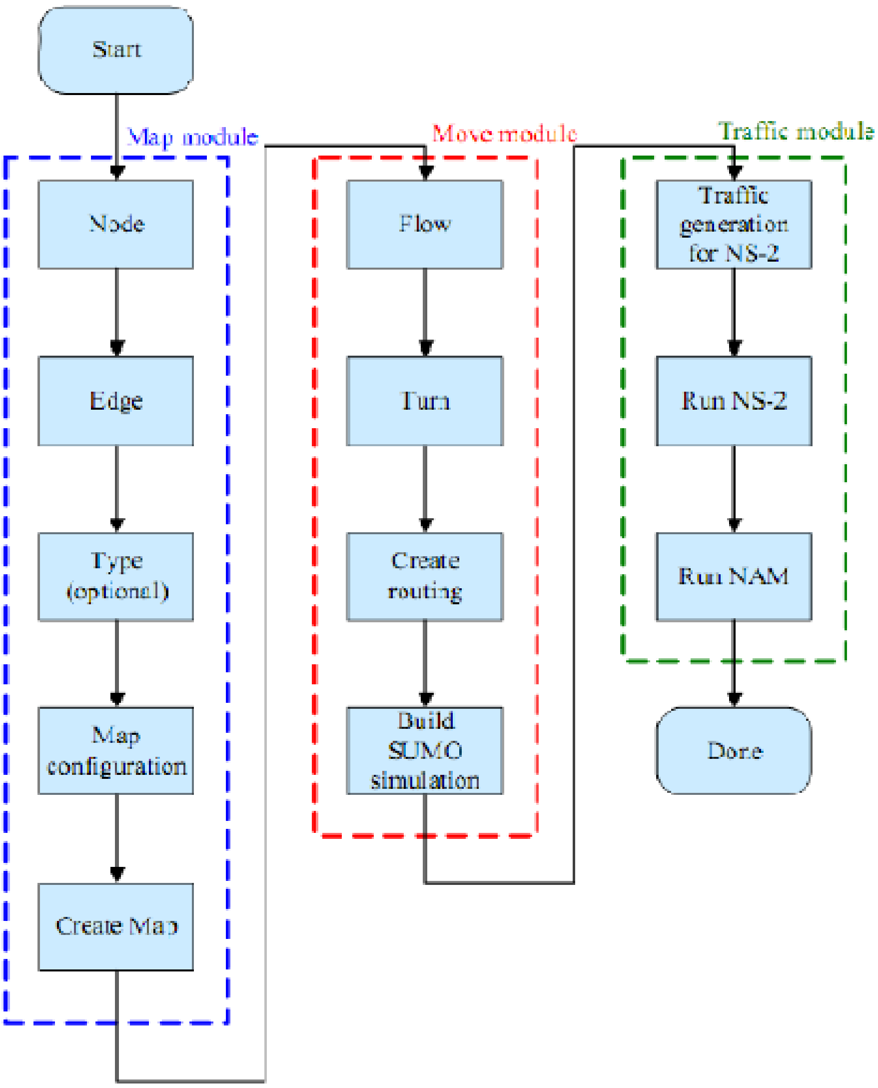


Fig. 4.5: This is the roadmap in the VANET manual

Here OpenJDK Development Kit (JDK) is a development environment for building applications, applets, and components using the Java programming language. The packages are built using the IcedTea build support and patches from the IcedTea project.

Following commands are needed to install openjdk-6-jdk on ubuntu:
root@ubuntu:/home/abhishek# apt-get update
root@ubuntu:/home/abhishek# apt-get install openjdk-6-jdk
Executed MOVE jar file with following command:
root@ubuntu:/home/abhishekk# java -jar MOVE.jar

4.2 Implementation

MOVE and SUMO are used to generate a realistic mobility model for VANETs. With the help of MOVE, scripts for SUMO have been generated. These scripts help in generating realistic mobility model. Routing protocols (AODV, DSDV, ZRP) have been implemented over the generated realistic mobility model to analyze their behavior and performance. Following steps are involved in the implementation process:

4.2.1 Mobility Model Generation

Firstly select "Mobility Model "on the main top level menu . This part of the software (called MOVE - MObility model generator for VEhicular networks) will generate the mobility model created by SUMO. It has three main modules: map editor, vehicle movement editor, simulation. Map editor is used to generate the map, here one has to specify nodes, which act as junction or dead ends and edges which represent roadways, one can either create new topology manually or can generate any random maps. Vehicle movement is used to create vehicles this module is responsible for defining number of vehicles, flow of vehicles that will specify the groups of vehicle movements flow on the simulation and turning ratio that will defines the probability of directions on each junction. Simulation module is used to visualize the configured topology and also specify the beginning and end time of simulation.

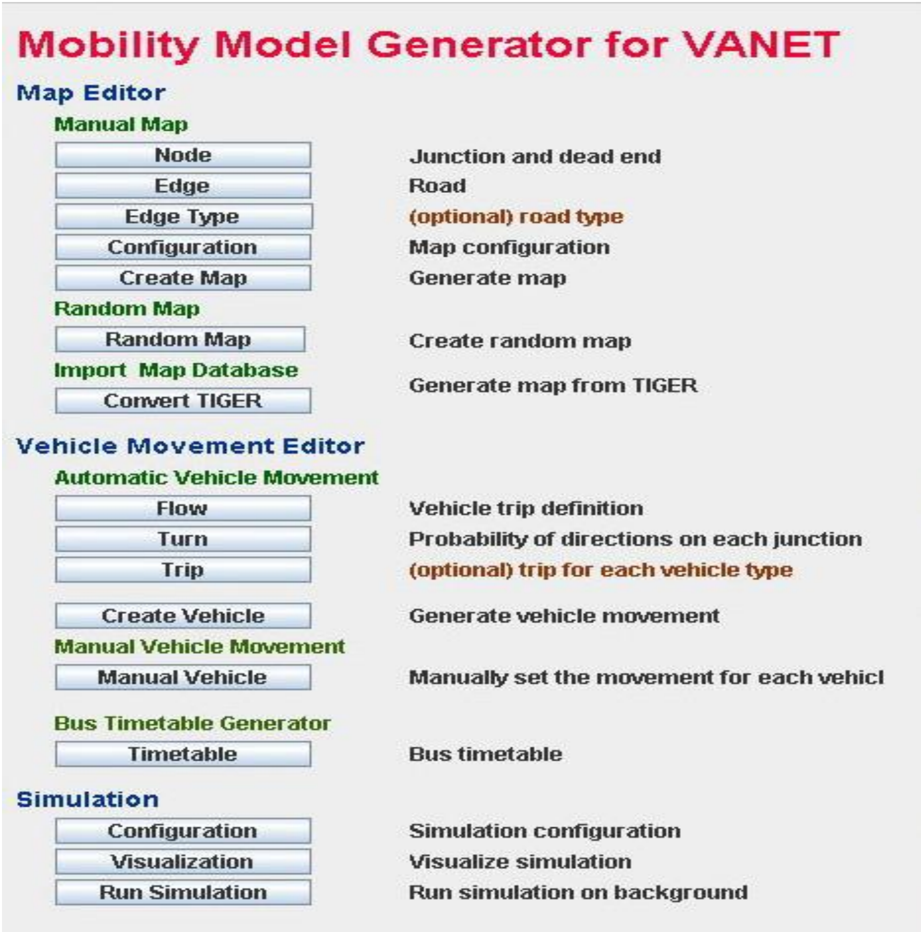


Fig. 4.6 Mobility Model Generator

(a) Map generation

(i) Manually created map

Manually create your own map by specifying the nodes, edges and configuration. Save the file as <name>.net.xml.

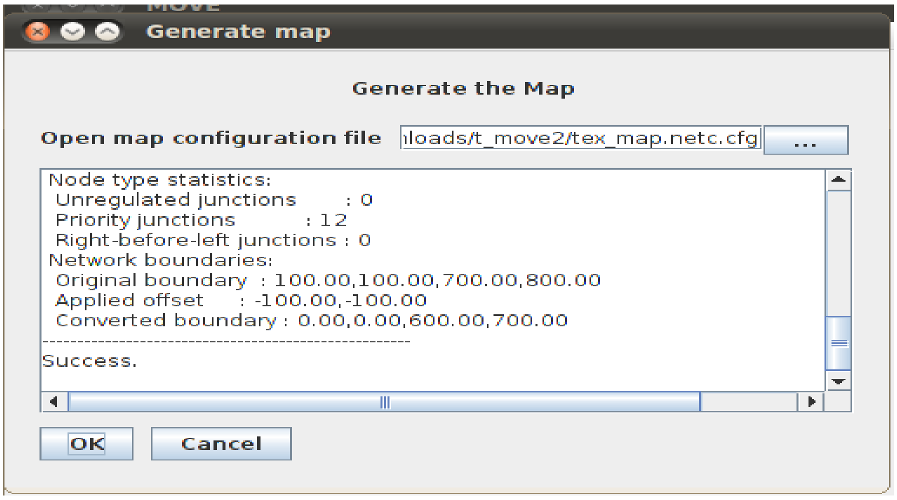


Fig. 4.7: Generating the map by configuring nodes and edges.

(ii)Automatically generated map

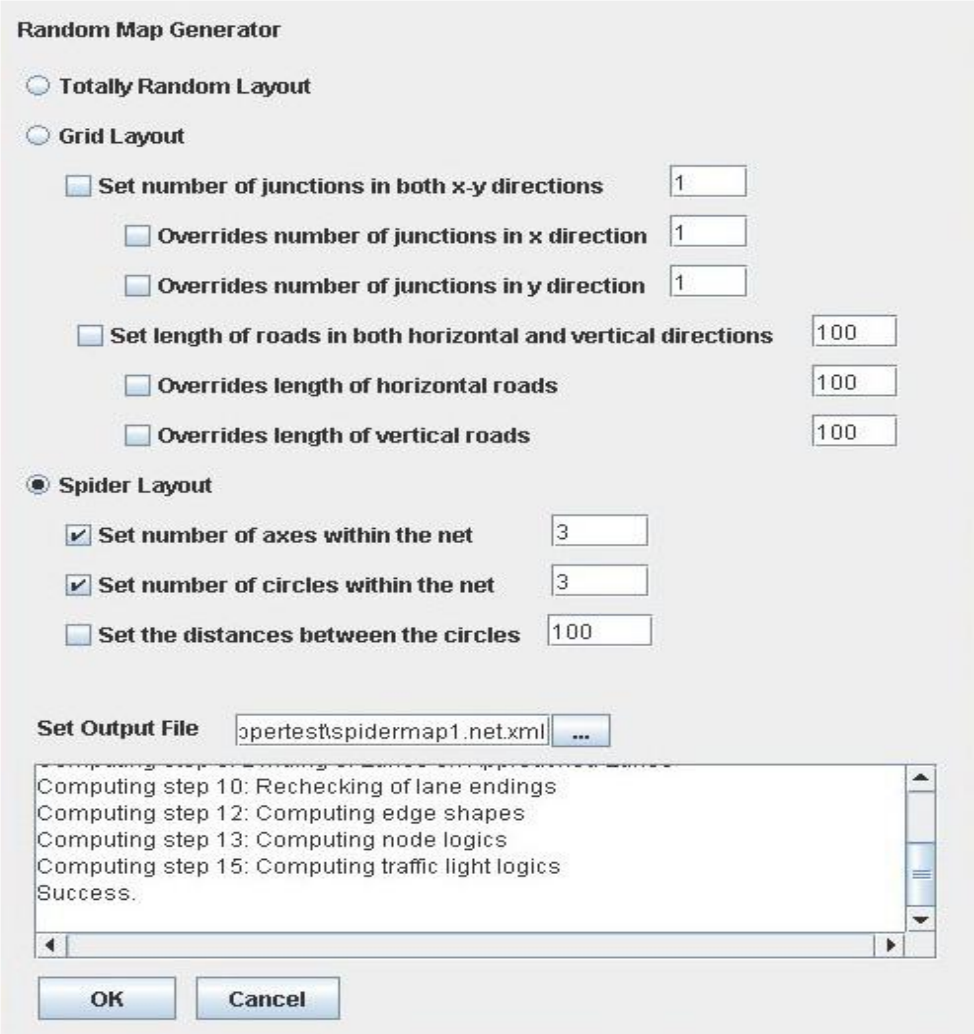


Fig.4.8: Creating random maps

Choose "Random Map" from figure 4.6, MOVE mobility generator menu to do this figure 4.8 shows that any of the three layouts of the map are possible whether it can be grid, spider or totally random. The output file is set by the user by giving any name, and the map will be generated by that name.

Three types of maps can be created using this;

- Grid
- Spider
- Totally random

(b) Vehicle Movements Generation

After the map is created, it is time to generate the movements.

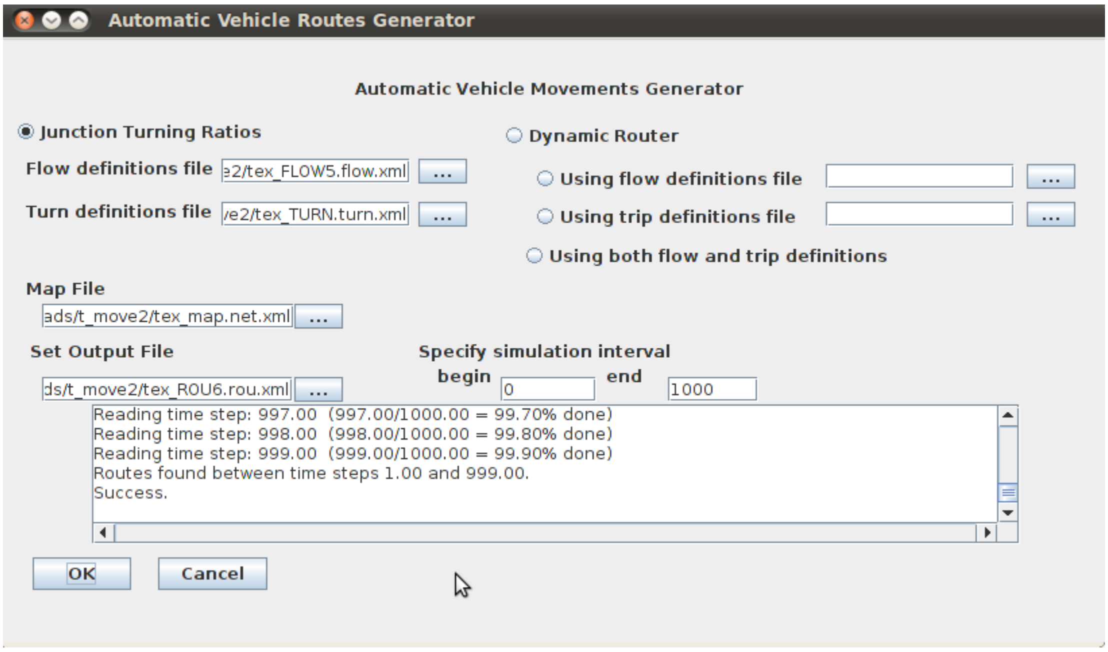


Fig. 4.9 : Creating Vehicles

To Create Flow and Turn of the Vehicles.

Simply select "Flow" from figure 4.6, MOVE main menu. This editor will specify the groups of vehicle movements flow on the simulation. The IDs can be assigned automatically. Save the file as <name>.flow.xml

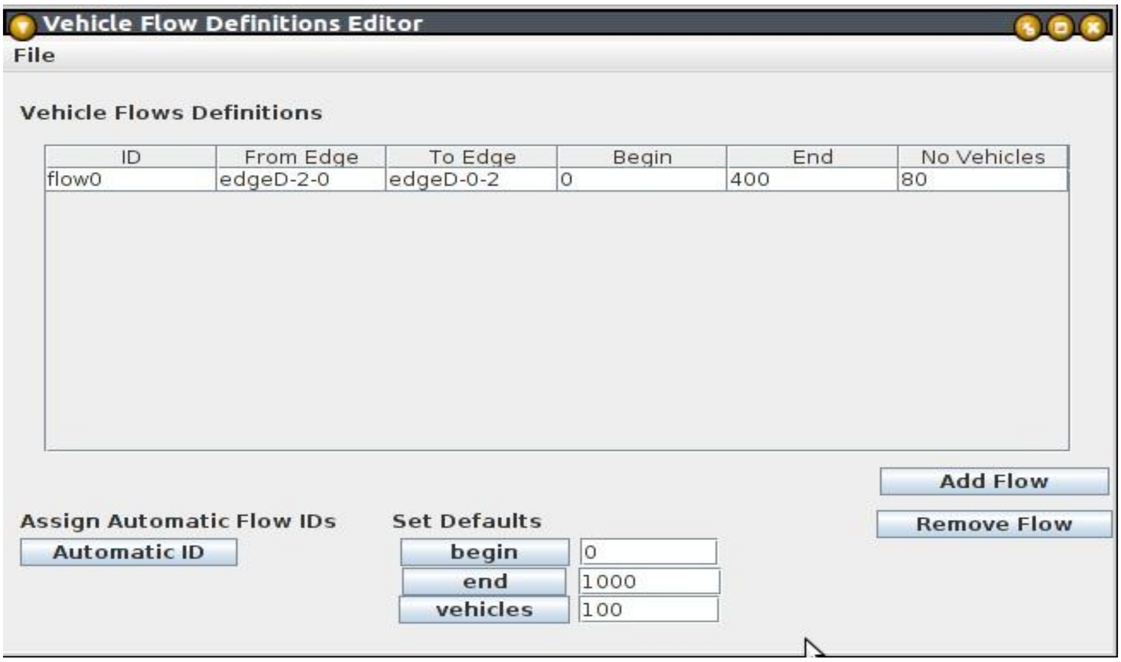


Fig. 4.10 : Vehicle Flows Definitions

Using Turn Definitions

In figure 4.9, when junction turning ratio is selected, turn file also need to be specified. It defines the probability of directions on each junction. Save the file as <name>.turn.xml. The turn definitions are specified in figure 4.11.

Create Vehicle

When create vehicle is selected from figure 4.6, MOVE main menu, there are two options in it in figure 4.9, either junction turning ratio can be selected in which both flow as well as turn definitions need to be specified. If dynamic router is specified, then only flow definition need to be defined. In junction turning ratio, the vehicles follow different paths along different directions whereas in dynamic router, all the vehicles follow the same path specified in flow definition.

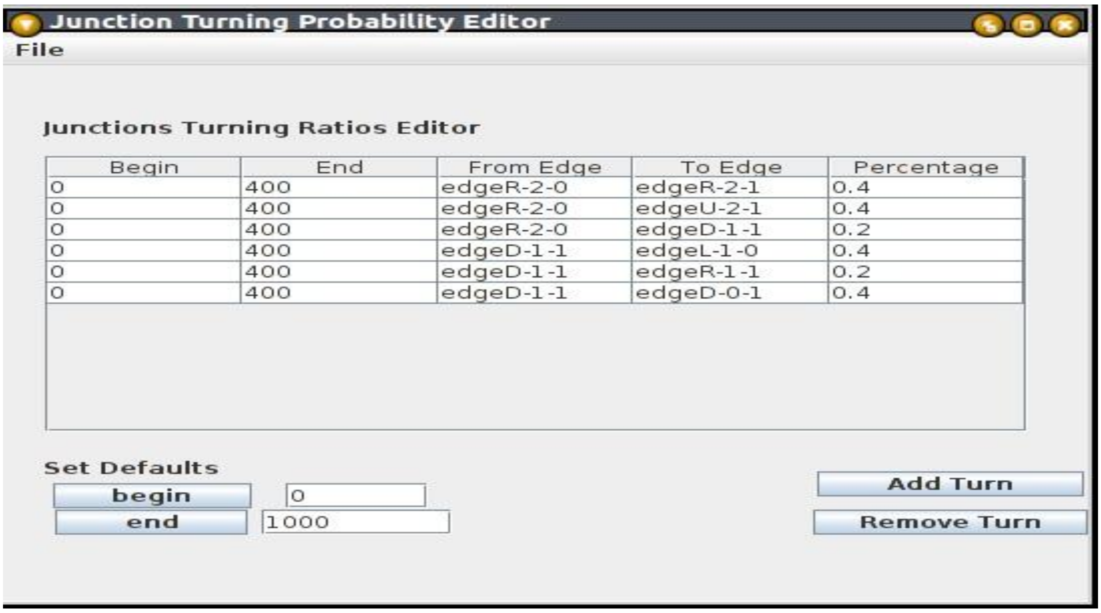


Fig. 4.11. Junction Turning Ratios Editor

(c) Simulation Scenario

After the map and movement is complete, there is need to specify the configurations of the simulation. Select "Configuration" at the bottom on figure 4.6, MOVE main menu. In figure 4.12, specify the <name>.net.xml (map) and <name>.rou.xml (movements) locations and specify the beginning and end time of simulation. If we want to create the trace file, don't forget to check the checkbox and specify your trace output name. Then save the file as <name>.sumo.cfg.

Fig. 4.12 Traffic Configuration

Now to visualize the actual movements of vehicles, select visualization at the bottom on figure 4.6. Resultant map is shown in figure 4.13

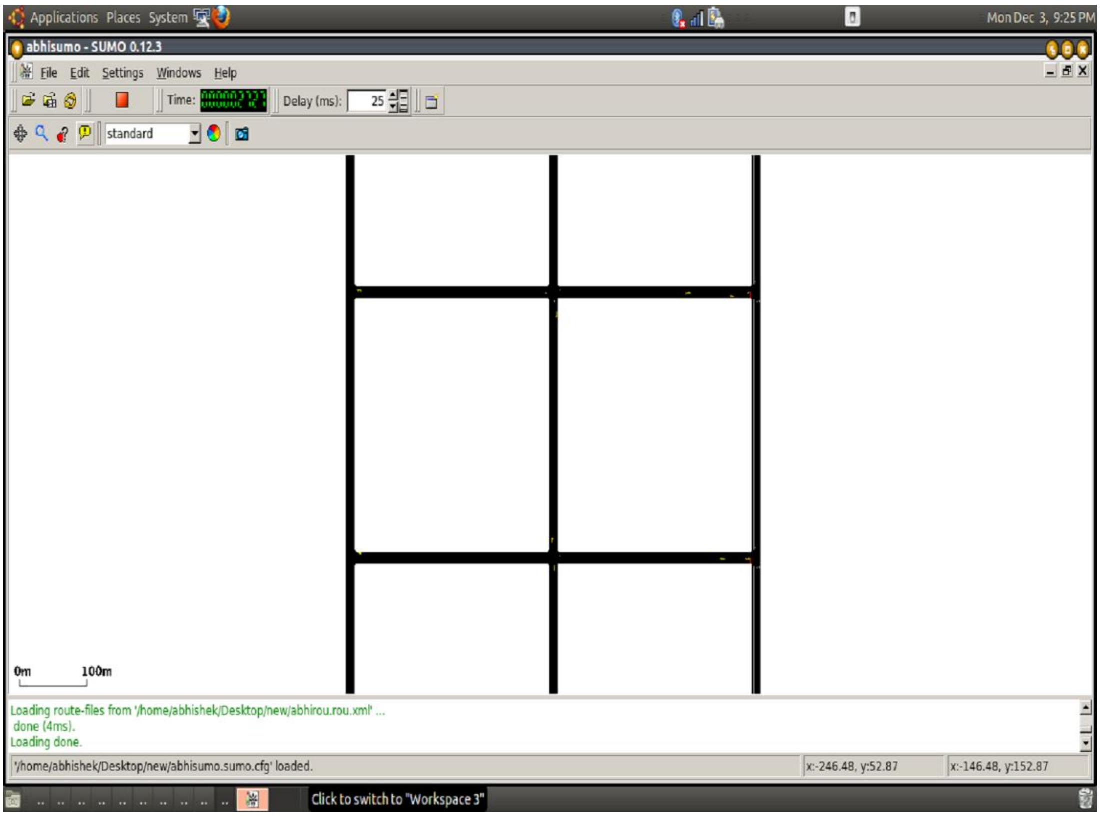


Fig.4.13 Generated map by SUMO

4.2.2 Network Traffic Model generator

It takes the SUMO trace file as the input and generates the network traffic model as required by either NS2 or Qualnet. It provides all the configurable option of NS2 TCL files, like specifying MAC, routing protocol to use, etc. On MOVE main menu , select the "Traffic Model" and traffic model generator will be generated.

To generate the NS-2 TCL script file, two files are needed: a MOVE trace file and its map file. First, select File->Import MOVE Trace then select <name>.move.trace file and <name>.net.xml file from the simulation directory.

Chapter 5

Results and Analysis

Results obtained by simulation is shown in this chapter. The analysis is being done on the basis of the results of *.tr file by executing TCL scripts. The .TCL files were generated for the following cases,

- 10 vehicle nodes
- 20 vehicle nodes
- 40 vehicle nodes
- 80 vehicle nodes

5.1 Simulation Setup

All tests have been performed on different scenarios having 10, 20, 40, 80 nodes with 5 and 10 connections for each scenario. With the help of simulators MOVE and SUMO a grid view map has been created which is shown in figure 5.1 with the total area 652 m x 752 m.

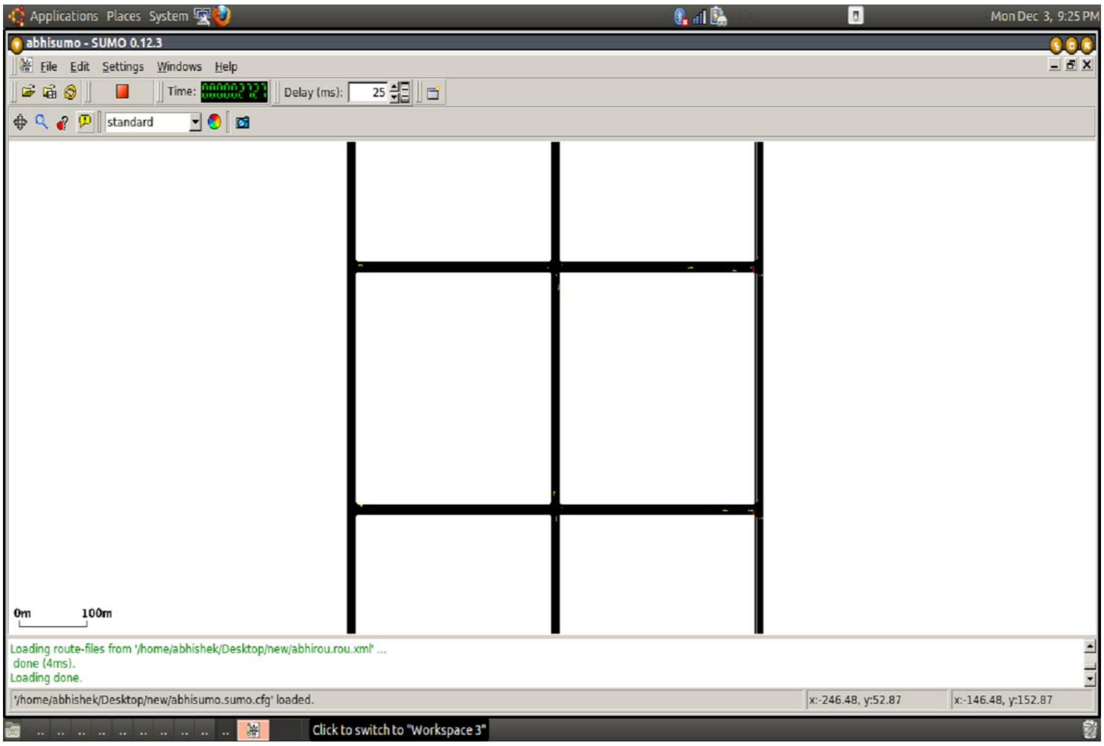


Fig. 5.1 Generated Map

Table 5.1: Simulation Setup

Routing Protocols	AODV , DSDV, ZRP
No. of nodes	10,20,40,80
Traffic type	TCP
Channel Type	Wireless Channel
MAC type	IEEE 802.11
Simulation Time	400 ms
Data packet size	512 bytes
Window Size	20
Scenario	Urban
Queue Length	50

5.2 Performance Metrics and Results

Routing protocols can be analyzed and compared by observing their behavior under some performance metrics. To analyze the behavior of AODV, DSDV, ZRP following performance metrics has been used. Simulation has been performed on each protocol for 10, 20, 40 and80 nodes with 5 and 10 connections in each scenario. Warm-up time for each simulation 10ms. Results obtained are mentioned below:

Normalized Routing Load- Normalized Routing Load (or Normalized Routing Overhead) is defined as the total number of routing packet transmitted per data packet. It is calculated by dividing the total number of routing packets sent (includes forwarded routing packets as well) by the total number of data packets received. It helps to understand the protocol routing overhead; i.e. how many control packets are needed (for route discovery/maintenance) to transport data packets to their destinations successfully.

The figure 5.2 (a) and figure 5.2 (b) shows the performance of DSDV, AODV and ZPR routing protocols with respect to routing load. Here the AODV has a lower network load than DSDV and ZRP. AODV's network load was dominated by more number of RREQ packets. Thus, all the routing load savings for AODV came because of RREQs. In DSDV, due to the mobility, the topology information is collected through by exchange of routing tables stored at each node. Routing tables are maintained by periodically broadcasting the tables stored in each node. Due to this reasons, a DSDV generates a more volume of control messages as compared to AODV and thus routing load increases. In ZRP, because of mobility lots of routes are broken that causes large number of packet drop and also as the number of nodes increases, route discovery becomes more complicated and large amount of overhead is introduced because of communication between IARP and IERP.

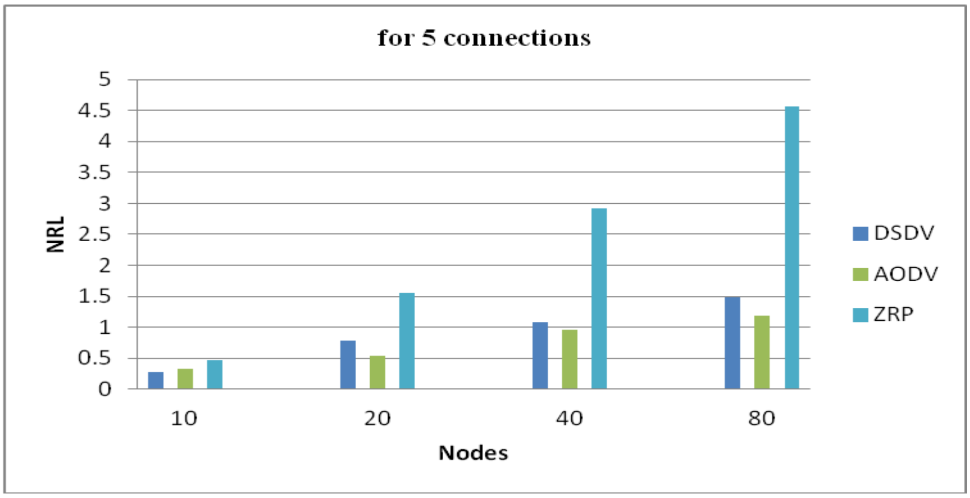


Fig. 5.2 (a) NRL vs. Nodes for 5 connections

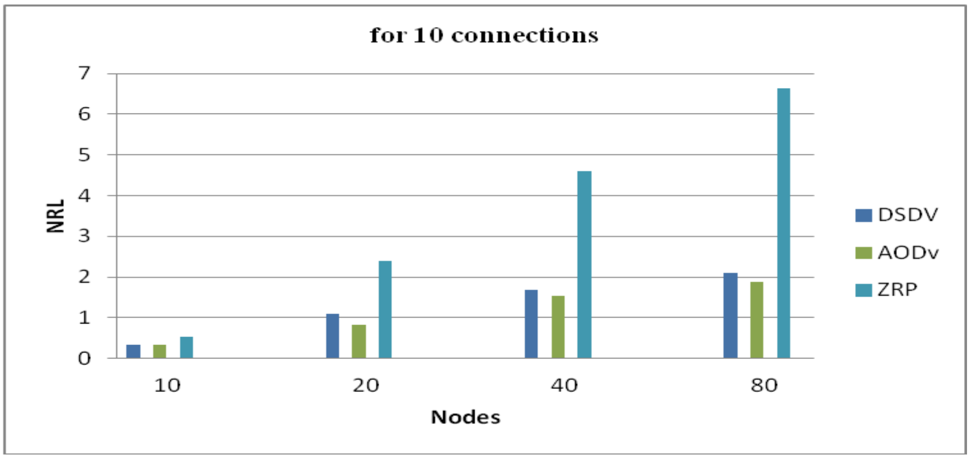


Fig.5.2 (b) NRL vs. Nodes for 10 connections

Average Throughput – It is defined as amount of data per unit time that has been delivered to one node from another. It is calculated in Kbps. Throughput include frequent topology changes, unreliable communication, limited bandwidth and limited energy. A high throughput network is desirable.

It can be concluded from the figure 5.3 (a) and figure 5.3 (b) that throughput being increased in AODV protocols. It is observed that the throughput remains almost same for 10 nodes and 20 nodes but rises appreciably for 40 nodes and 80 nodes, this fact can be attributed to the high node density in the simulation area leading to likelihood of better connectivity. It is also concluded that as the number of nodes increases , throughput of DSDV decreases, as DSDV uses table driven approach to maintain route which introduces extra overhead and its not adaptive to the route changes that occurs frequently under high mobility, thus its throughput decreases, whereas effect of more number of nodes is worse in ZRP (Zone Routing Protocol) as it can be observed from the figure 5.3 (a) and Figure 5.3 (b), this is because of mobility lots of routes are broken that causes large number of packet drop and also as the number of nodes increases, route discovery becomes more complicated and large amount of overhead is introduced because of communication between IARP and IERP.

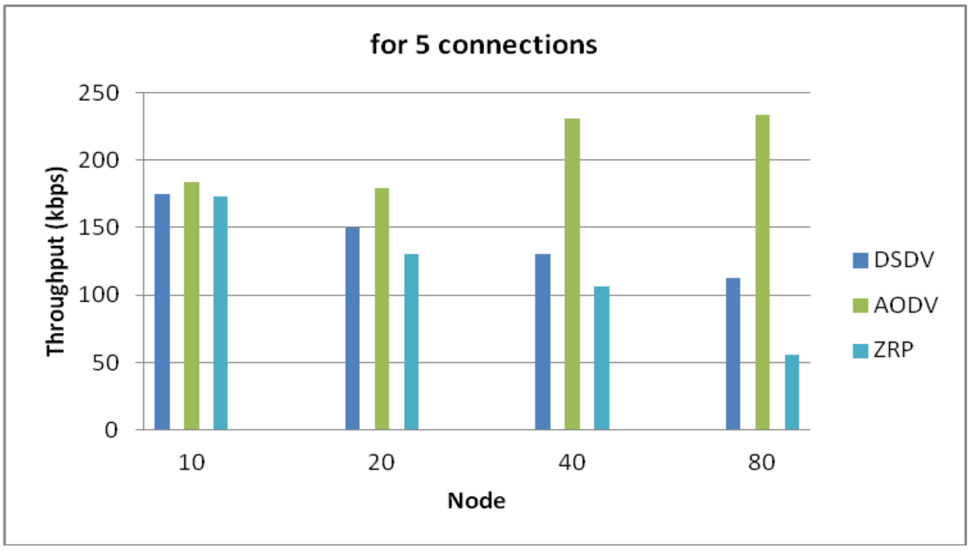


Fig.5.3 (a) Throughput vs. Nodes for 5 connections

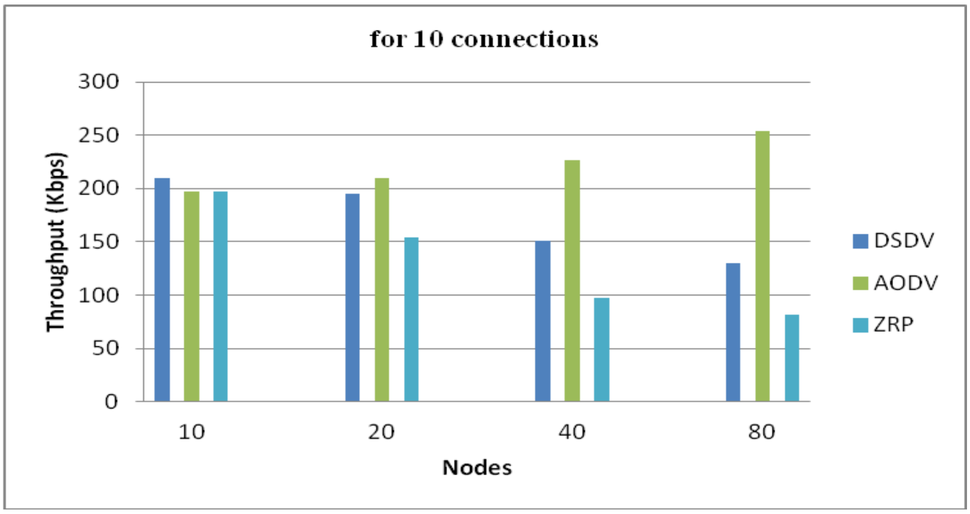


Fig.5.3 (b) Throughput vs. Nodes for 10 connection

Average End to End delay- It is defined as the average time taken by data packet to propagate from source to destination across network. It includes various delays introduced because of route discovery, queuing, propagation and transfer time. It can be concluded form the figure 5.4 (a) and figure 5.4 (b) that end to end delay in DSDV is less as compared to AODV and ZRP, although it increases as number of nodes increases but still end to end delay is better than AODV and ZRP, reason being DSDV is proactive routing protocol which maintain entire routing path to establish route at source, where as AODV is reactive routing protocol which means it request for the path only when a node has something to send, which introduce extra delay in AODV. In ZRP end to end delay is less than AODV for 10 nodes but as node increases end to end delay also increased, because of high mobility zone is not stable and it consumes more time to reconfigure the zone and route and also additional delay is introduced because of communication among IERP, IARP and BRP.

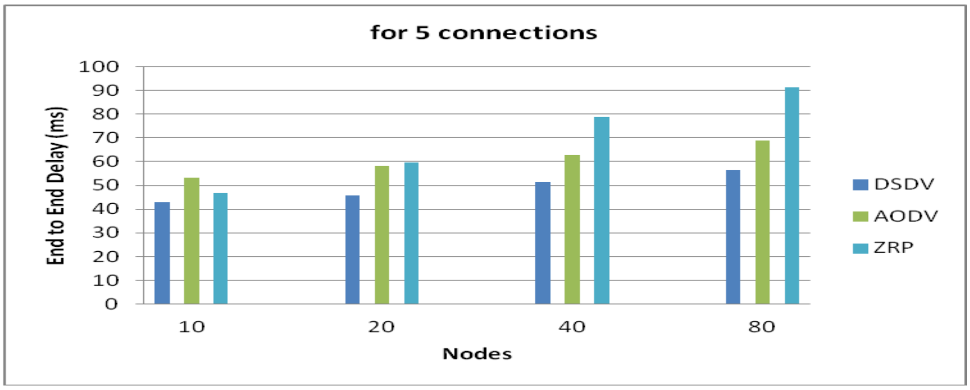


Fig. 5.4 (a) End to End Delay vs. Nodes for 5 connections

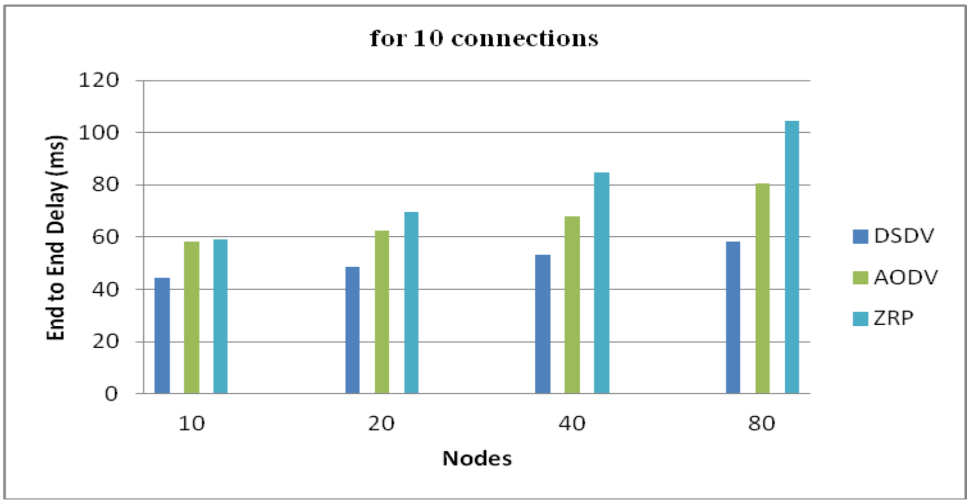


Fig. 5.4 (b) End to End Delay vs. Nodes for 10 connections

Packet Delivery Fraction- It is defined as the ratio of the data packets received by the destinations to those generated by the sources. With the help of PDF one can understand how well a protocol can transfer packet from source to destination.

From the figure 5.5 (a) and figure 5.5 (b), it can be concluded that packet delivery fraction of AODV is better than DSDV and ZRP in all scenarios. With the help of PDF one can understand how well a protocol can transfer packet from source to destination. More is the PDF more will be throughput, as it has been concluded from figure 5.3 (a) and figure 5.3 (b) throughput of AODV is better, it is all because of better PDF in AODV where as PDF of DSDV and ZRP is low. PDF of DSDV is good in scenario with 10 nodes and 20 nodes but for 40 nodes and 80 nodes it is poor, this is due to its characteristics of exchanging entire routing table periodically and also whenever there is topological changes that introduce appreciable overhead, that consume more bandwidth, and thus large amount of bandwidth is used in handling these overheads and its PDF suffers. In case of ZRP its worse, because of mobility lots of routes are broken that causes large number of packet drop and also as the number of nodes increases, route discovery becomes more complicated and large amount of overhead is introduced because of communication between IARP and IERP which leads to more packet drop.

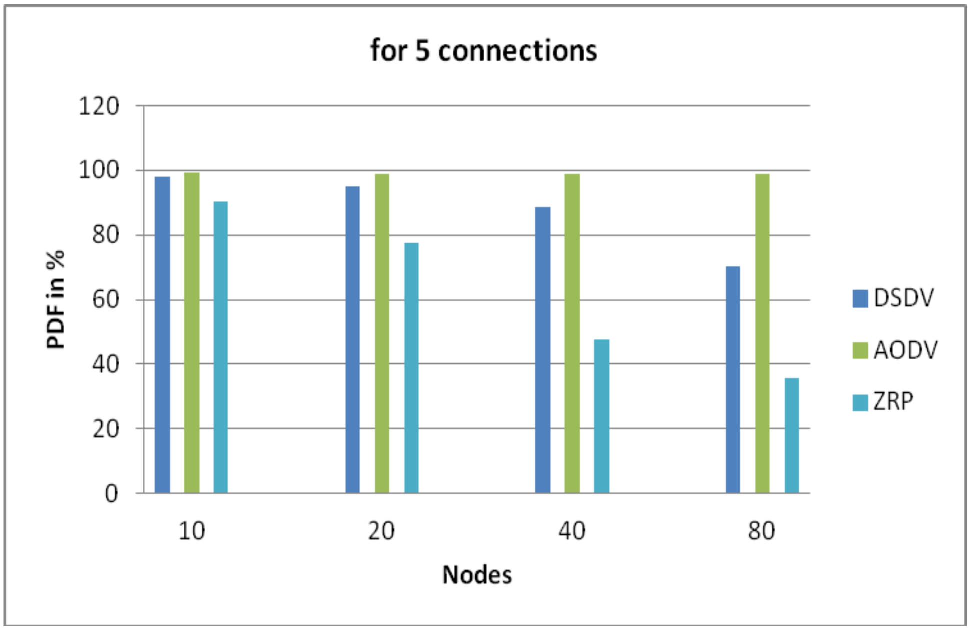


Fig. 5.5 (a) PDF vs. Nodes for 5 connections

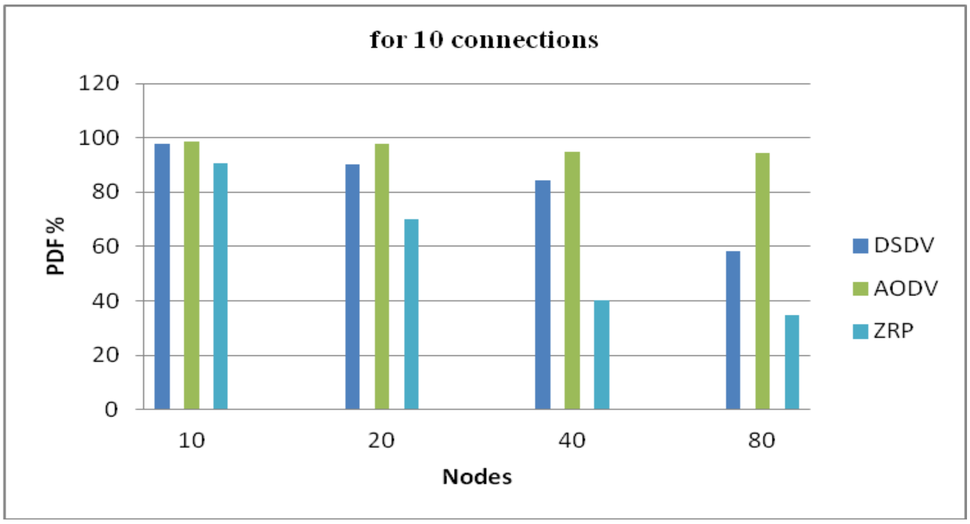


Fig.5.5 (b) PDF vs. Nodes for 10 connections

Chapter 6

Conclusion and Future Scope

6.1 Conclusion

In this thesis, behavior of reactive routing protocol (AODV), proactive routing protocol (DSDV) and hybrid routing protocol (ZRP) have been analyzed under the microscopic mobility model. The evaluations made on these protocols bring out some important characteristics of these protocols when they are used in VANET.

From the obtained results, it is observed that reactive protocol (AODV) performed well because mechanisms of route discovery, route maintenance and elimination of periodic broadcasting are used by AODV and by almost all reactive protocols. It is observed from the result that end to end delay of DSDV is least which is one of the main requirement in real time system, end to end delay in DSDV is less because of table driven approach used by almost all proactive protocols, but because of this approach extra overhead in the network is introduced which degrades it's performance with respect to NRL, Throughput and PDF. It is also observed that performance of hybrid protocol (ZRP) is considerably poor in all scenarios because of various issues that have been discussed in previous section.

6.2 Future Scope

The analysis of AODV, DSDV, ZRP in VANET environment in this thesis has been performed by using offline simulation. It would be interesting to simulate and analyze their behavior in realistic scenario by specifying acceleration, decceleration, maximum speed and other movement characteristic of vehicle under real map with large number of nodes and by generating a scenario where vehicles can exchange messages that will change their speed, lane etc, hence communication scenario can be totally different from offline.

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- Abhishek Singh, Anil K. Verma "Simulation and Analysis of AODV, DSDV, ZRP for VANETs" *International Journal in Foundations of Computer Science and Technology (IJFCST) ISSN: 1839:7662,* **(Communicated).**