PERFORMANCE EVALUATION OF ROUTING PROTOCOLS IN FINDING STABLE PATHS IN VANET

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ABSTRACT

Performance Evaluation of Routing Protocols in Finding Stable Paths in VANET

By

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With the increase in technology, many developers have advanced their knowledge in improving road safety by designing various devices such as Vehicular AD Hoc Networks (VANETs). These VANETs are important in ensuring there is a continuous vehicle-to-vehicle communication along the roads while at close range in order to prevent road accidents. Similarly, VANETS are meant to ensure vehicles are alerted of events occurring at their surrounding through information sharing between vehicles to other vehicles (V2V) and vehicles to stationary objects built along the roads (V2I). However, MAC sub-layer protocol is common when designing VANET devices; this is because VANETs are ineffectual in preventing road accidents when messages cannot get to the other party. The path breaks causes delay of inconsistency and packet delays from source to destination. There are several improvement measures that can be taken to VANET is effective and efficient in improving road safety through inter vehicle communication and vehicle to stationary VANET devices installed along the roads. Since VANET operates in a wireless environment, there are other interferences from wireless devices such as mobile phones, laptops and other operational devices installed in vehicles. This thesis evaluated the performance of multiple routing protocols on MANET to assess their ability in finding stable paths. The evaluation led to practical suggestions on how to design better routing protocols for VANET.

Keywords*:* MAC sub-layer, VANET, RTS, CTS, PASTA, TDMA and V2V/V2I

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CHAPTER 1

Introduction

Vehicular Ad Hoc Network, abbreviated as VANET, is a system where vehicles like cars have the possibility of digitally communicating with one another, and communicating with a stationary object, for example a building or a traffic light. These communications are of short-range types. Concretely, the three types of communications provided in VANET are: inter-vehicle communication, vehicle-to-roadside communication and inter-roadside communication. In all these communications, there are no usage of a base station or any additional dedicated infrastructure like an access point to facilitate the digital communications. This is a unique property of VANET

Through VANET, vehicles may be able to communicate among one another about a collision or an obstacle on the road, without most of the vehicles having seen the said collision or obstacle. In this sense, VANET is a self-organizing traffic information system. In VANET, each vehicle is considered to be a node and each of them is capable of passing information from itself to another node, i.e. to another vehicle. The transmission of information from the source node to the destination node is a path, and its procedure to find a path to it can be guided through a routing protocol. The stability of a path is an important issue to study in VANET since each of the nodes in VANET is most likely a moving vehicle, and not stationary. The movement of vehicles can be quite fast so much so that a path can be broken when a vehicle is not within the transmission range of another.

In the recent past, technology has been advancing and developing. This has led to a simplified way of conducting duties and performing functions. There is several software that has been developed in the recent past and have assisted and simplified several functions in the modern world, for instance, NS-2 and SUMO among others. Security is a priority in the recent past considering that terrorism is a global crisis. Each state has been working on the most appropriate strategies to use in enhancing the security of their nation and territories.

The effect of wireless communication technologies is very large in making our lives easier. Wireless communication have done a great work in the field of inter vehicle communication (IVC), which is also known as the Vehicular Ad-Hoc Networks (VANETs).

Vehicular Ad-Hoc Network (VANET) has been structured in the form of mobile network. It helps in providing vehicle-to-vehicle communications within their vicinity. The VANET equipment is installed within the vehicle in order to deliver comfort and safety of all those on board. Small electronic devices are used to facilitate Ad-Hoc Network for passengers who are within the same vehicle. Server communication and other complicated devices such as routers, switches are not required in VANET installation [12]. Each vehicle installed acts as a node within the Ad-Hoc network, therefore, receives, and relays messages from and to other vehicles that are within the network and have been equipped with VANET installation.

Most vehicles have been installed with different types of VANET installations such as Wi-Fi IEEE 802.11b/g, Bluetooth, IRA, ZigBee, Wi-MAX IEEE 802.16 in order to have accurate, simple, and effective communication between the vehicles that are within the dynamic mobility. Intelligent transportation system (ITS) is the traditional system, which is installed on the side of roads for monitoring the traffic density and speed, while others have been installed within the vehicle. ITS are connected to some base station where it periodically sends the monitored data of the traffic for further processing, this traditional system is too much expensive due to which alternative to this system that is inter vehicle communication is used. VANET devices use sensors and storage facilities to ensure it works effectively. Other wireless devices such as mobile phones, I-pads, laptops can detect VANET devices installed in these vehicles or along the road.

Several cities and towns in the globe require adequate security protocols to simplify sending and receiving of safety messages to particular personalities at different times. The use of NS-2 and SUMO may solve this problem. Managing traffic within the town is also a challenge considering the number of individuals who are in a position to purchase vehicles in most towns and cities across the globe in the modern world. Secondly, the uses of vehicles have also increased in the previous past increased mobility need [42].

1.1 Background for VANET

Vehicular Ad-hoc Network (VANET) is a network in which Vehicles, equipped with wireless communication capability, are able to communicate with each other and with roadside infrastructures. The idea is then to create both safety applications and non-safety applications that enhance the driving experience of a driver, on top of the network. Communications in VANETs are divided into two categories': Vehicle-to-Vehicle (V2V) communication and Vehicle-to-Roadside Infrastructure (V2I) communication. In V2V, a vehicle exchanges message with other vehicles. In V2V communication, all the vehicles engaged in the communication are mobile. V2I communication refers to a type of communication that involves Road Side Units (RSUs). This communication is usually used to get in contact with other networks such as Internet. For V2I, technologies such as WLAN, DSRC, WiMAX, cellular and satellite can be used. Figure 2 depicts the communication schemes in VANETs.

Communication in VANET

Communication in VANET is divided into five categories according to the pattern of their communication.

Beaconing: In beaconing, a periodic transmission of packets is broadcast for the nearby vehicles or roadside units. The purpose is to inform all the neighbor vehicles about the status such as speed, direction of the sending car. Beaconing is typically a single hop communication.

Geo-Broadcasting: This type of communication is done for transmitting the information to the given geographical area. The sender attaches a destination to the broadcast message every user that receives this type of message forward it until it reaches to the destination.

Unicast: This type of technique is used when a vehicle wants to send a message to a specific vehicle or RSU that is the scenario where unicast messaging becomes useful. For example, Vehicular social network is one of the envisioned applications in VANETs. The idea is used to allow vehicles to form a trusted network. Unicast routing is essential in this type of applications. The communication will be single hop if the communicating vehicle are neighbors otherwise a proper routing mechanism will be required to deliver the message to the receiver.

Advanced information dissemination: Information dissemination is another challenging task in VANETs as due to the very high velocity of vehicles network topology changes more frequently moving. The main aim of this developing this type of communication pattern is to ensure that which vehicle is arrived late or not received the message. Single-hop broadcasts, store messages, and multiple forward is used in this communication pattern.

Information Aggregation: In this type, communicated data is processed and merged before being forwarded. The focus of this type of communication is to reduce overhead communication and to increase reliability of the exchanged data. For some applications like traffic, jam reporting information aggregation results in better accuracy.

Protocol architecture in VANET

VANET protocol architecture supports communication between nodes within a network setup. The design functionality is structured into two, layered and non-layered. For the layered, OSI and TCP/IP models have been used to obtain the design while for non-layered, is customized to meet all the requirements of a particular functionality or user. Layered VANET uses multi-hop and single-hop communication protocol where each layer is either an independent module or shared module. These modules are structured to restrict easy access to metadata or state of the protocol positioned at different layers. However, some VANETs cannot be accommodated in OSI model because of control and stability of their layers. The un-layered VANETs have accurate customizations as per user desire hence are safer compared to layered models. Therefore, all communication and applications are accommodated within a single logical block interfaced with sensors. This makes it more complex and inflexible because other systems cannot interact with it. This personalization helps secure the customized VANET from other unauthorized users to get access to it. The figures below show the distinction between layered and un-layered models.

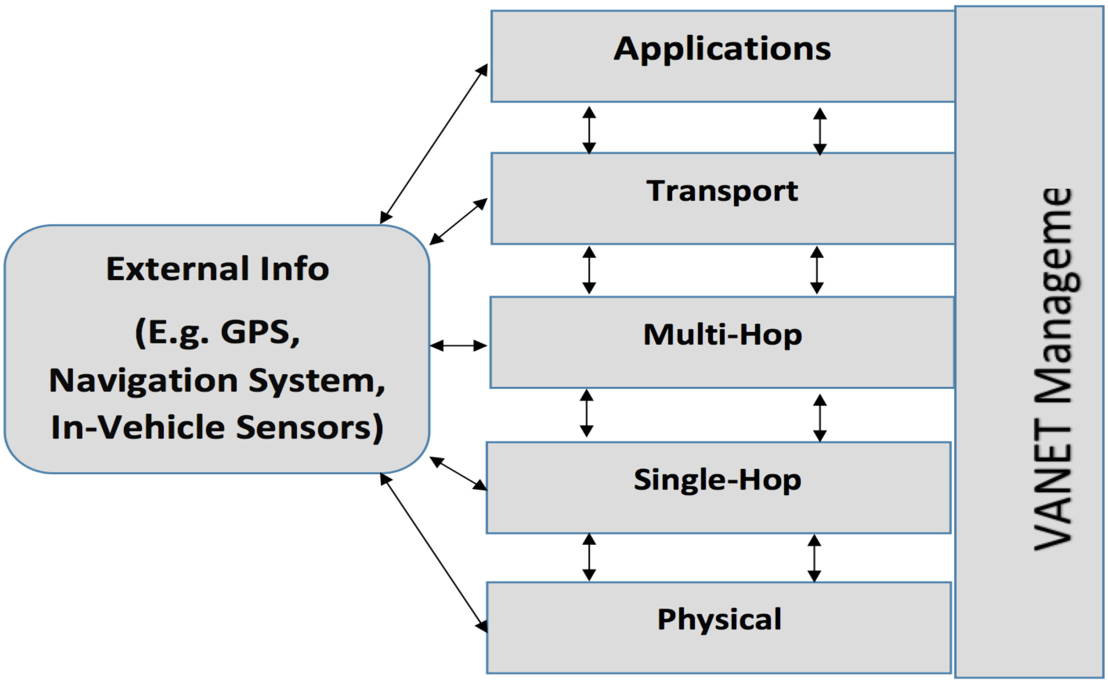

Figure 1. Layered VANETs.

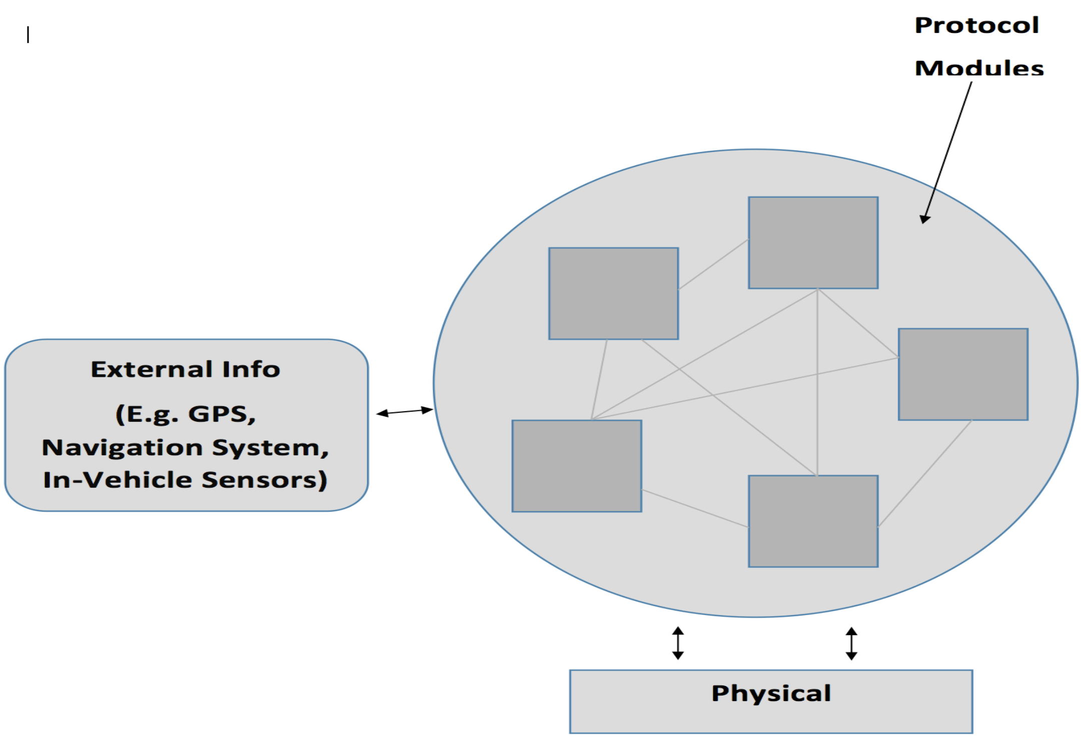

Figure 2. Un-layered VANETs.

Data link layer: All communication systems uses a protocol whose complexity depend upon the task of the communication system such as general web surfing, industrial control loops, mobile telephone systems. The MAC layer is a sub-layer of the data link layer of the OSI reference protocol, which is present in most of the communication networks. The MAC protocol decides who has to send on the channel for the moment. There are number of protocol, which can be selected on the base of conflict free, and contention. Examples of conflict-free protocols are time division multiple access (TDMA) and frequency division multiple access (FDMA).

The drawback with these protocols in their original design is that they generally require a central mechanism such as a base station or an access point that can share the resources among the users. Examples of contention-based protocols are Aloha and CSMA. In the simplest Aloha protocol, each transmitter sends its packet as soon as it is locally generated. CSMA is an improved Aloha protocol where the transmitter starts by sensing the channel before the transmission is initiated and only transmits if the channel is free, i.e., “listen before talk.” In order to reduce the probability that several transmitters starts sending immediately when the channel becomes free, each transmitter randomizes a back off time during which it defers channel access. The drawback is the possibility that two or more transmissions collide and collide many times and hence packets may suffer unbounded delays.

Transport Layer

Vehicles are fully equipped with the devices that are able to store and process the data that devices enable the vehicle to store and process data coming from other vehicles and access points. Enabled vehicles can then use on-board devices to develop on-demand ad hoc networks, which can be used to provide too many useful services.

By using this network vehicle can access Internet or enable inter-vehicular peer-to-peer applications. Many of these applications require the use of a reliable end-to-end transport protocol, the most common of which is Transmission Control Protocol (TCP). While there have been proposals to improve or replace TCP in wireless environments, the reason is so widely implemented in existing devices means that it will remain in use for quite some time. The researches of TCP have shown that TCP performance in VANET is very poor. Packet loss in TCP is a sign of network congestion.

In wireless networks, there are so many reasons of congestion, such as poor channel conditions or collisions. Because of a loss, TCP will unnecessarily reduce congestion window size, effectively decreasing throughput. In addition to this due to the ad hoc nature of VANET network, path symmetry is not guaranteed. This can also decrease TCP performance due to incorrect estimation of RTT times, resulting in unnecessary retransmissions.

1.2 Motivation for the Research

Providing the traffic safety is a primary challenge that needs to be addressed by automotive industries, governments and other liable entities. According to reports published by the World health Organization (WHO), about 4% of death is caused by traffic accidents in some industrialized countries. The number of road accidents has been increasing over the years. According to several researches conducted in the past and recently, it has been concluded that over-speeding and the road status are the contributors of the high numbers of accidents and deaths [9].

Vehicle crashes have been the major cause of many deaths and injuries globally even though different technologies have been implemented to prevent the occurrence of these accidents. Some of the technologies include the use of seatbelts and airbags. These technologies have, however, not been effective in preventing accidents as they concentrate on after the crash conditions. Most of the vehicle crashes can be prevented if vehicles are familiar with their surroundings.

The Dedicated Short Range Communication (DSRC), standard permits vehicle-to-vehicle (V2V), and Vehicle to Roadside (V2R) communication via wireless channels hereby presents us with the technologies that can be used to make vehicles familiar with their surroundings [42]. VANET can be used to prevent vehicle crashes and enhance improved road safety by sending routine messages and emergency messages. These routine and emergency messages are vital in avoiding road accidents [35].

These vehicles send routine messages that are delivered to nearby vehicles thereby reducing the risk of collision. The vehicle at the receiving end of the message can determine the future speed and the sender's position as it waits for the updated information from the sender. The accuracy of the receiver's estimates about the status of the sender depends on how often the status data are sent. Emergency safety messages are sent when a dangerous situation is detected. For instance, the messages are sent if there is an accident in the highway.

The emergency messages are sent to all vehicles within a distance that may be dangerous. Unlike routine messages, emergency messages are sent to multiple hops. Routine and emergency messages can enhance road safety if they are sent within a specific deadline. Path stability issues in MAC layer protocol, in VANET, make it hard to send routine and emergency messages and prevent accidents. The motivation for this research is the path stability problems in MAC layer protocol, in VANET. Examining the path stability problems in MAC layer protocol, in VANET will help in identifying possible solutions to enhance route stability. Routine and emergency messages will be sent effectively and on time to prevent road crashes [35].

The path stability issues include delay of packets and congestion. The current MAC protocol of DRSC belongs to the IEEE 802.11 family [42]. The protocol utilizes a CSMA/CA approach, which is conflict-based. Vehicles compete for popular channels and hence mar the data transmission from the sender to receiver. Packet delay and congestion increase significantly as the number of vehicle's increases [22]. The channels used to control packets are RTS and CTS. Consequently, vehicles are not able to transmit safety data needed to improve safety on time. Vehicles find it challenging to communicate and understand their surroundings because of congestion and packet delay. Other issues include longer latency and high levels of jitters. Latency implies how efficiently data packets are transmitted from the source to destination. Vehicles are not able to efficiently transmit data packets from the source to destination because of delays. Packet delays are common in high-density networks [22].

Vehicles in high-density networks are unable to transmit packets efficiently, which causes delay in communication. Jitter increases in dense environments because of longer paths. Increase in traffic load and traffic demand increases the jitter. Therefore, vehicles are not able to continuously transmit data packets in dense environments.

Path breaks are also a major path stability issue in MAC layer protocol. Drivers believe that there are vehicles that are consistently near them. However, the distance between the vehicles is not constant as it changes. The discontinuity causes regular path breaks that negatively affect network performance [32].

In this thesis, I will evaluate the performance of AODV, DSR and DSDV based connection with different pause time, speed time and also different network parameters and measured performance metrics such as packet delivery ratio, loss packet ratio and average end-to-end delay of this two routing protocol and compare their implementation. The rest of the thesis is organized as chapter two describes literature review to performance evaluation of AODV, DSR and DSDV. In chapter 3 examines the methodology and the analysis about the routing protocols AODV, DSDV and DSR of VANET. Chapter four will have the result of the evaluation of the three protocols.

CHAPTER 2

Literature Review

Research Topic

This chapter reviews existing research evolving around Vehicular Ad-hoc Network (VANET), its mechanism, processes involved in it, its limitations, and delimitations and how they can be approved. VANET has been given due importance in recent and more and more technological advances are being added to it for improved performance and efficiency. It is however difficult to design and formulate effective routing protocols to route data among vehicles thus making more challenges in development. Frequent disconnection and rapid technology changes add more to the problem. Current routing protocols used in VANET such as Vehicle to vehicle communication (V2V) and Vehicle to roadside infrastructure (V2I), are not much efficient in order to meet everyday traffic scenario. Significant effort and research is underway to design an efficient protocol for VANET.

Key academic areas

Inter-vehicle communication uses a self-organizing and autonomous wireless communication network and it works on MANET, which is basic form of VANET used in vehicle & vehicle roadside wireless communication network. Information is exchanged and shared among clients and servers through nodes in VANET. Further three categories define the network architecture of the VANET system, which are pure ad hoc, pure cellular/WLAN, and Hybrid. Vehicle collision warning, Cooperative driving, Map location, Dissemination of road information, Driver assistance, Driverless vehicles, Cooperative cruise control, Automatic parking, Security distance warning and Internet Access are some of useful VANET applications.

As I have established earlier that VANET are center of attention and continuous research was done in the past to increase the efficiency and reduce the technical barriers attached to it. There are also some other barriers, which needed to be resolved. In order to understand the requirements of an improved and developed protocol for VANET, we will examine pros and cons of existing protocols and focus on studies done on detection and correction of these pros and cons and other maliciousness in VANETs. Distinguished research projects studies carried around the world on and in relation to VANETs include; Car TALK 2000, FleetNet, COMCAR, CarNet, NoW (Network on Wheels) and DRIVE etc. Government and private sector is working hand in hand to synchronize latest technologies in the VANETs, academia is aimed at finding gaps in the system, and collective effort of both will eventually increase efficiency of the system [6].

The proposed cross-layer design is popular among wireless devices due to its high performance and QoS delivery. The cross-layer schemes in VANETs only work where there are multiple layers, more so, on Multi-Hoc. It endorses information flow across layers through a specialized interface. The figure below shows how the existing system functions [5].

The system works within the Cities and small towns because it has been designed to manage traffic. Inter vehicle VANET works for vehicles that have installed VANET system while roadside VANET operates between vehicles and roadside installations making it more efficient even along highways. Both V2I and V2V are applicable both within the city and along highways [3]. The limitations are based on route stability.

2.1 Characteristics of VANET

VANETs are distinguished from MANET on unique characteristics and on challenges of developing VANETs applications. Below is short description of characteristics of VANETs

High dynamic topology: When vehicles move at a high speed, it alters the VANETs topology. Speed by which two cars are moving will yield the radio range that can further establish the link between two cars.

Mobility Modeling: Different circumstances like traffic environment, behavior of driver, speed of other vehicles and road structure accumulate to vehicles' mobility pattern and they are important to be considered.

Frequent Disconnected Network: Frequent disconnection between two cars occurs when information is being exchanged which we discussed in highly dynamic topology. This disconnection was observed especially in sparse networks.

Storage capacity and battery power: In old cars, storage and battery power is limited as compare to modern cars. Most MANET systems worked with less modern cars thus limited computing power is available. To make routing decisions and an effective communications, modern cars with VANETs will be most helpful.

Communication environment: Dense networks and sparse networks define the different communication network in two vehicles. Trees, buildings and other objects are the obstacles in dense networks and such things are absent on highways (sparse networks). Therefore, we use different routing approaches for dense networks and sparse networks

Interaction with attached sensors: GPS devices and other onboard sensors could greatly help in sensing the movement and current position of the nodes. When we achieve that, effective communication will also be achieved.

Inter-vehicle communication and VANET applications: Several studies discuss the key requirements in VANETs with a focus on the broadcast mechanisms. Various application types and their characteristics were examined and communication paradigms were employed to determine such applications. According to Vehicle Safety Communications Project (2005), there are number of applications that were envisioned for the VANETs and range up to 75 application scenarios. High benefits could be achieved if such applications are employed effectively. Research study by on "Automotive Networking and Applications" [2] classified VANET applications based on their effectiveness as below.

Applications for the convenience in traffic management: Different means of communications are used in this application to increase the comfort on roads and driving efficiency etc. Driving efficiency applications usually intend to adjust the traffic flow on road by distributing the information regarding road and traffic flow conditions thus decreasing the travel time. Vehicles could periodically combine and exchange information, which they receive from neighboring vehicles. The information attained by own sensors can further be aggregated together and new information could be distributed among all vehicles in proximity. In this way, travel time estimation can be achieved for different road segments and help of these applications can do traffic jam detection. Drivers can always have traffic jam and other information in advance and they can choose alternative routes in advance. This will greatly reduce their travel time. Successful deployment and employment of such applications will therefore greatly decrease the fuel consumptions, which would have immense effect on vehicle expenses and other cost reduction as well as a decrease in the CO_2 emission. These comfort applications can assist the drivers in number of situations. For example, locating free parking spots and aligning with traffic flow etc. These applications can be delay-tolerant. They do not impose tight time problems or constraints, which safety applications pose. They mostly require exchanging desired information into directed neighborhood periodically.

Safety applications: Most important VANET application is active safety application. The objective of safety applications is to decrease the number of fatalities and injuries on road in case of an accident. If we access data of accidents when use of safety application was comparatively low than the time when more people were using it, we can safely interpret those accidents ratio was decreased. The potential benefit of employing this application is very high and this goal can be achieved by distributing the information about each hazardous situation including post-crash warning and abnormal road condition through the safety application. Vehicles can greatly benefit from this application to prevent accidents and other mishaps. Therefore, this form of application relies on dissemination of data into particular geographic location and a geographically limited broadcast. GeoCast is one effective example of that [3].

It should be noted that safety applications are usually delay critical meaning the information about any accident on road must be passed on to other vehicles immediately. Special cases of such broadcast are one-hop MAC-layer broadcast, which is also known as beaconing. Beaconing is the process in which a communication range is used to disseminate the information between neighbors. Position and speed of the car can be exchanged through beaconing effectively. All information could help users of safety application in scenarios like cooperative collision warning [13].

Commercial applications: Communication services like web access, advertisement and entertainment is provided through communication applications. Examples of this type of application are vehicle diagnostic, map download for navigation and video streaming. In contrast to applications mentioned above, commercial applications mainly rely on the unicast communication. Much higher bandwidth is required in commercial application than other two applications.

Link Reliability: The most challenging aspect of VANET communications is when one of the communicator, also known as a node, is a moving vehicle. With moving nodes, the communication links between nodes are relatively unstable due to a fast changing topology in the vicinity of the moving node. Kirtiga in 2014 proposed a measure of a probabilistic link reliability r(l) between two vehicular nodes. This measure is computed as an integral with respect to an input quantity known as a transmission link between node i and node j over a certain time length which can be denoted as T. The integral kernel is a Gaussian-like probability density function. Mathematically, the link reliability r(l) can be expressed as follow:

$$r(l) = \int \frac{4H}{T^2 \sigma \sqrt{2\pi}} \, e^{-\frac{(\Delta v)^2}{2\sigma^2}} \, dT, \qquad (1)$$

where $\Delta v = v_r - \mu_{v_r}$, v_r is the magnitude of the relative velocity between two mobile nodes, μ_{v_r} is the mean of v_r, σ is the standard deviation of the distribution of the relative velocity, and H is the typical communication range in the VANET system, which was taken to be 300 meters by Kirtiga [17]. In this approach as proposed by Kirtiga[17], the variation in the velocity of the moving nodes, as well as the direction of the moving nodes are taken into account, as reflected in Equation (1). Prior to this, techniques calculating the linkage between two mobile nodes failed to take the aforementioned factors into account.

The modeling of the movement of vehicles is done with the assistance of graphs. Here, each node in a graph represents a vehicle. The linking between two nodes is timeordered. There can be more than one path that links a source node and a destination node. Kirtiga [17]. assigns each link which links two intermediate nodes along a path connecting the source and the destination node with a reliability value r(l). The total reliability value R of an entire route linking a source and a destination node is the product of all the reliability values along the route. Mathematically, this can be written as follow:

$$R = \Pi \, r(l_{ij}), \qquad (2)$$

where i and j are two nodes found along a route linking the source and the destination node. However, the reliability link is relatively mute on the issue of security attacks, malicious nodes and hackers. The quantity assumes that the reliability value can take into account how malicious nodes for example, can alter the connection between the source node and the destination node, and hence alter the path's total reliability value.

2.2 Communication Paradigms

When we consider all three groups of applications from the network perspective then we can state that foundational paradigms for all three applications are GeoCast/broadcast, unicast communication, and beaconing. Bai [2] stated that broadcast could be divided further into scheduled, on-demand fractions and event driven. Letter is used in road hazard situations warning by the delay-critical applications in which information is distributed into particular geographic region over multiple hops. Scheduled broadcast is employed for applications similar to cooperative collision warning and other traffic management applications. Information is being exchanged periodically needed by these applications and are sent in form of MAC-layer broadcast. Such information is only disseminated to neighbors in close communication range. Applications that require multi-hop distribution require applying some effective aggregation techniques and protocols to solve the limited bandwidth problem. Unicast is effective and important for entertainment and commercial applications [6].

Requirements analysis: Special network characteristics and diversity of the VANETs applications impose various requirements to all broadcast protocols. These requirements are lowered from previous subsections and being summarized in the following.

Scalability: In order to execute safety applications correctly in traffic jams and other such scenarios, broadcast protocols have to deal with very dense networks.

Effectiveness: To ensure that all nodes or fraction of nodes received disseminated information effectively that application defines in a particular region.

Efficiency: The broadcast protocol usually needs to eliminate the message redundancy due to limited available bandwidth. Forwarding rate is minimized in order to achieve this, but still obtaining a reception of an informatory message by all nodes lying in specific geographic region. This greatly helps in avoiding the broadcast storm problem and coexistence of multifold VANET application is enabled.

Dissemination delay: Immediate communication of information is basic requirement of safety applications and that too without delay.

Delay-tolerant dissemination: Vehicle networks are usually subject to regular partitioning therefore caching information is desirable in such scenarios and they can be propagated when new vehicles come in the vicinity. Important information could be lost otherwise when network is not fully connected in destination region.

Robustness: The communication is prone to error over the wireless medium; however, the broadcast has to bear with packet losses so that vital safety applications can function correctly. Some requirement can be contrary so it is highly unlikely that all requirements will be achieved fully. For example, when we tend to achieve the high frequency by minimizing forwarding ration, the requirement robustness fails to work anymore because dissemination nodes show single point of failure. Therefore, when dissemination node cannot forward a message (wireless communication channel could be probable cause of this) overall reception rate drops significantly. An elaborate tradeoff is needed between such requirements in such situations.

2.3 Routing Protocols

An important consideration for VANET prior to a large-scale implementation of it in the real world is its speed of information exchange while at the same time, respecting the security and the safety of the data transmission. Asif et al. in 2010 introduced a mechanism to preserve these two factors in VANET, without compromising too much of one for the other, at a conference for communication software and networks. Prior to this, proposed techniques by others have resorted to sacrificing one of the factor for the other, mostly at increasing the speed of information exchange, but unfortunately with a side effect of reducing the security standard of the transmission. At the moment, the standard security mechanism used in the VANET community is known as the PKI/ECDSA security mechanism. Asif 2010 has criticized this. as needing too high a computational cost, thus reducing its practical usage in emergency situations, where information exchange, especially safety messages between vehicle nodes should be fast.

The core of the idea from a study [19] is that the vehicles and nodes in their immediate vicinity form a trusted group relationship, thereby enhancing group communication with security standards. This framework used by them is a hardware-based one, and the trusted group relationship is build based on an important module, coined as Trusted Platform Module or TPM for short. The group entity can be formed based on which cell in the geographical location that a vehicle node belongs to. These cells are imaginary boxes that divide a road into segments. In each group, there will be a group leader and a number of group members. The group leader can be selected via its node position.

In the grouping method as proposed by the study [19], the hardware used is a TPM chip, which will be embedded in each vehicle. The chip contains not only the core TPM module, but an additional four sub-modules, known as an asymmetric module or ECC, a symmetric module, a random number generator or RNG, and a hash module. The TPM module functions to ensure that there is security during the transmission of messages, and that each component has not been tempered. The ECC module functions by generating a digital signature. This signature has a public key and a private key. The private key is burned into the TPM chip during manufacturing stage. The public key is widely distributed to the users in a VANET system. The random number generator generates seed numbers for the keys. The hash module using the Secure Hash Algorithm or SHA1 technique provides the hash value. The hash value is used when selecting a group leader within a vehicular trusted group.

The symmetric module functions similarly to the EEC module, but is used primarily in event-driven information transfers. Event-driven information is usually safety and alarm-related messages to alert other vehicles in the vicinity of a hazard that one of the node, usually the group leader node has encountered. The other type of information transfer involves periodic safety messages, which transfers information like the speed of the node, and its location and direction. This will be transferred using the EEC module, which has a slower transfer rate than the symmetric module, due to its slower generation of digital signature generation and verification.

Any node can leave the trusted group, for example when it leaves the cell that specifies the group. Likewise, any external node can be linked to the trusted group, and be a member of it at any time when it is within the vicinity of the trusted group. To check the feasibility of the trusted group technique applied in the real physical world, it is imperative that this study [19] conducted simulations and presents their results thereof in the future.

Another type of cellular group-style wireless networking is the Vehicular Mesh Network, or VMESH for short, which was proposed by Zang [43]. Here, vehicles, which are within the transmission range of one another, will form a group-like structure in VANET, also known as a mesh. If one of the nodes in a mesh has information, it is assumed that all other nodes in the said mesh will also carry the same information via broadcasting the data from the initial node, which receive that information to the other nodes. This is a useful and resource-saving networking method. As an example, if a mesh contains node A, B and C, and A happens to encounter an obstacle on the road. This information about an obstacle will be broadcasted to B and C, and a resolution to the obstacle will be determined, for example, with B and C slowing down or B and C completely avoid the obstacle altogether by diverting from their original course. Hence, it is not necessary that B and C experience the encounter like what A did.

In VANET, a temporary event such as the occurrence of an obstacle on the road, which is assumed that it will be removed from the road after a certain period of time, is known as a transient event of interest or EOI for short. In addition, the information stored in a node within a mesh that has an encounter with an EOI is in the form of a region of interest information or ROI for short. ROI defines the physical region that encloses the EOI, for example the exact location in coordinates and the size of the obstacle.

Information that is stored in one mesh can be passed to another mesh if both meshes are within a distance d from one another. This distance is not a distance set in stone, but is rather tunable. However, this distance d is calculated based on the location of where an obstacle has occurred for example, if the said information is about the obstacle itself. Suppose there is no other mesh within that region defined by the distance d, information loss occurs when the initial mesh that first encounter the EOI has travelled out of the said region. Hence, if there is a mesh within the region, the information about the EOI is still available when the initial mesh that first encounter the obstacle has travelled out of the region containing the EOI.

Study in 2010 [21] has performed a simulation of a VANET scenario, which utilized the VMESH protocol. The simulation lasted for three hours. Several assumptions were made which formed the inputs to the model. Firstly, a Poisson distribution described the arrival time of a vehicle to a certain location. Secondly, free flow traffic was assumed. Thirdly, EOI could randomly appear on the road at any given time. Fourthly, the information about an EOI can be transmitted instantaneously to other nodes within a mesh. As Liu et al. used the VGSim software to perform their simulation, the vehicle nodes travel following the Nagel-Schreckenberg model, which was a model, introduced by Nagel and Schreckenberg in 1992.

From the simulation, the study [19] extracted the mean time to information loss. This quantity was defined as the average duration of time where the ROI is still stored before it is lost. The calculation was done through taking the difference between the time from the moment the EOI was captured and the ROI stored by the first vehicle node, which encountered the EOI to the time that the last vehicle in the mesh that stored the ROI travelled out of the EOI region. Liu et al. found that the mean time to information loss correlated positively with the vehicle arrival rate for a one-way highway traffic and a two-way highway traffic. In addition, the mean time to information loss for a two-way highway traffic was about a factor of two higher than that of a one-way highway traffic. The reason was because vehicle nodes from the opposite lane in a two-way highway traffic could also store the ROI even though the EOI did not occur on their lane. This implies that in VMESH, a path is much more stable in a two-way highway lane compared to a one-way highway lane.

The routing protocol of VANET can be broadly categorized into two, which are, the topology based routing protocol and the geography based routing protocol, as described by [30]. The topology based routing protocol can be further divided into the proactive routing and the reactive routing protocols. In a proactive routing protocol, each node keeps a table of information about other nodes that are connected to it. An example of a proactive routing protocol is the Fisheye State Routing also known as FSR. The drawback to this is that the network load is tremendously large. Furthermore, the time needed to process the routing tables is large.

The reactive routing protocol avoids the problems face by the proactive routing protocol. In this protocol, nodes only start a route discovery if it requires information or need to communicate with another node. Consequently, the network load is tremendously reduced. An example of a proactive routing protocol is known as the Ad Hoc On Demand Distance Vector routing protocol. In this protocol, routing can be done in a unicast or a multicast mode. The drawback to this protocol is that there is, on average, a need for more time before an initial connection between two nodes can be established.

The geography-based protocol does not keep any routing tables. Rather, it relies on the Global Positioning System also known as the GPS device to decide on routes.

Nonetheless, the GPS is not available at all times, particularly when the vehicle node is in a tunnel, as the signal from the GPS is obstructed by the density of matter above the tunnel. In order to solve this problem, a system known as the Delay Tolerant Network (DTN) can be used. In this system, when a node is disconnected from other nodes, the data packet, which should be sent to the other nodes, is recalculated based on some metrics, and forwarding to other nodes is done thereafter. Another way is to drop completely the node from the contact list kept by each neighboring nodes. Here, each node has a beacon that transmits a short data packet to other nodes at each specified time interval. If no data is received from a node after a certain time period, the node is considered not within the vicinity of the neighboring nodes. To combine the advantages of both the geography based routing protocol and the topology based routing protocol, Lochert [20] proposed a new protocol known as the Geographic Source Routing protocol, also known as the GSR

The design of effectual VANETs routing protocols become challenging because of characteristics of increased dynamic topology. We classify routing protocols of VANETs into two different categories including Position-based routing protocols and Topology-based routing protocols. Figure given below will help in overall classification of routing protocols of VANETs [34].

Data Broadcasting and Transmission: Broadcasting of data in a consistent manner to the environment in VANET can be quite costly and inefficient, particularly when the data is large in size. Furthermore, since vehicles are mobile nodes and thereby the topology of the network can be very dynamic, this type of communication between nodes is not effective at all. Janech [11] proposed a solution to this based on the concept of a distributed database system. Their proposal also addressed the possibility of disconnection of nodes momentarily in a VANET, which can be high in a dynamic network topology. It was proposed that communications be done in one of two methods. The first method is known as a pull method, and the second one is known as a push method.

In the pull method, a query node will first enquire for a piece of information from a data node. The data node then checks to see if it possesses the necessary information, or nodes in its immediate vicinity may have. The data node will connect the query node to the respective node having the necessary information. If partial information can only be retrieved from any of the nodes the data node has searched from, the data node will return the query node with the partial information. It then waits for further instruction from the query node. Upon acquiring further instruction from the query node, the data node will connect the query node with another possible node. This new node is decided based on the possibility that it may be able to assist in providing the necessary remaining information that the query node requires.

In the push method, a response is sent out via a broadcasting message from the data node at a certain specified time interval. This broadcast can be received by whichever node that may be in its vicinity. This response is information based on a query that has been preprogramed. Any node upon receiving the broadcast will check if the information contained in it is a data that is needed. If affirmative, the data will be processed accordingly.

For these methods, Janech [11] introduced three algorithms. They are the Simple Pulling Algorithm (SPA), Independent Replication Algorithm (IRA) and the Dependent Replication Algorithm (DRA). The SPA algorithm is the simplest of the three. This algorithm starts with a query by a node to a list of data nodes, and then receives a response from them.

The IRA algorithm does similar to the SPA algorithm, but also additional steps. The IRA also collects data that a node may not require at that particular time, but deemed possibly useful in the future. The node also broadcasts, at a specified time interval, information regarding its local database to its environment. Based on the information contained in this local database, all other nodes in the vicinity will update their own local databases respectively.

The DRA algorithm is the most complicated of the three. It combines the techniques in both the IRA and the SPA algorithm. A key feature of the DRA algorithm is that each data that is available in a local database of a node is assigned a timestamp and an identifier. The timestamp will be used to determine if the data should be retrieved in any future queries. The identifier is used to identify the node that has sent the broadcasting signal to it.

Janech [11] had done a simulation on the feasibility of the methods. The simulation was done using a tool known as adhocsim.fri. Each vehicle node was assigning a travel speed. The vehicles were simulated to move in a uniform linear motion manner. When encountering a road section, the vehicles were simulated to slow down before continuing at the initially assigned speed at a new road section. In addition, the simulation had included the possibilities of buildings forming obstacles that may block the propagation of the broadcasting signal. For building corners, Janech [11] have assigned a degree of tolerance that the broadcasting signal may propagate successfully. This is an effect of diffraction of the radio signal wave, which allows the signal to bend slightly when it encounters any obstacles.

Furthermore, Janech [11] have set a high number of cars on the road per simulation to reflect the possibility of a road during busy hours. The number was set to as high as 400 per simulation, and may change in any intermediate stages based on an exponential distribution. The broadcasting range of the signal was set to a maximum distance of 800 m.

All three algorithms, that is, the SPA, IRA and DRA algorithms were tested. Not surprisingly, the SPA algorithm, which is the simplest of the three algorithms, required the least amount of bytes for a transmission of data. The DRA algorithm required more amount of bytes than that of SPA. The IRA algorithm required the most amounts of bytes among the three algorithms. In IRA, the nodes collectively produced the largest amount of replicas of data. Furthermore, in the IRA, the nodes distributed and shared the most amounts of data. Due to this, it contributes a drawback in that the network load is high in the IRA compared to the other three algorithms. Given the helpful results that Janech [11] obtained from IRA, the focus will be on the IRA algorithm, and will attempt to reduce the network load to improve the applicability of the said algorithm.

Position-based routing protocol: Geographic routing is used in position-based routing protocol in which each node uses position determining services such as GPS to determine geographic position of vehicle's and it's neighbor's node. However, it does not exchange link state data with neighbor nodes or maintain the routing table. Routing decisions are made with the help of GPS in this protocol.

Topology based routing protocols: Link's information is being used to send the data packets within the network from source to destination. Reactive (on-demand) routing and proactive (table-driven) are two approaches used in topology based routing protocols that have their own pros and cons.

Pros and Cons of position-based routing protocol: Geographic routing has its pros and cons, which add to the efficiency or deficiency of the routing protocol. Main pros include non-requirement of discovery and management of the route, scalability, and suitability of high node mobility pattern. Main setback of geographic protocol is it requires GPS and other position determining services, which can stop working in particular circumstances such as tunnels where vehicles can lose satellite signals.

Pros and Cons of topology-based routing protocol: Proactive routing employed in the topology based routing protocol works on algorithms of the shortest path. We retrieve table-based protocols as all connected nodes are kept in table form. Furthermore, this information in tabular way can be shared with neighbors. They will be informed of any change that occurs in the network topology as routing table keeps updating its nodes updates. This protocol does not also require route discovery. In addition, real time applications have low latency in topology-based protocols. Significant setback is that unused path usually occupies considerable available bandwidth.

As we have observed, special network characteristics and the versatility of VANET applications make designing of an effective broadcast a very challenging task. The simplest way in this regard is the usage of naïve flooding to implement the broadcast mechanism. Every node broadcasts the information exactly once in flooding situation if it is situated inside that destination region. Therefore, whole information is flooded throughout the region. The inefficiency is the considerable downsize of this simple flooding method. Limited bandwidth related to wireless medium and inefficient information distribution e.g. naïve flooding results in contention, collision and redundancy. According to [26], all this referred to broadcast storm problem.

To reduce such problems and other similar situations, research community has proposed many improved and enhanced broadcast protocols. Classification of various broadcast as stated in previous section needs to be understood carefully to identify and evaluate the problems more efficiently. This will lead to novel broadcast mechanism that can be designed to execute well in VANETs and other highly dynamic environments. Understanding the mechanism and protocols of mobile ad-hoc networks greatly help in overviewing VANET protocols and identification of barriers become easy and saves a lot of time. This method can be applied to multiple domains.

Deterministic broadcast approaches: Tropology based protocols have a subclass, which are, imposed decision protocols. In this subclass, sender as to specify in broadcast dissemination which receiving neighbors will have to further broadcast. This type of protocols is referred as deterministic broadcast approaches. Such approaches explicitly choose a small subsection of neighbors to be forwarding nodes, which can be sufficient to connect to same terminuses as all nodes together.

DTMC-CA: DTMC-CA uses the cellular communication resources of automaton freeway model for the traffic. The estimate for the time taken for the connectivity in the given vehicular networks. The figure below summarizes the DTMC-CA algorithm. The estimation is carried out by the basic principle of Markov chain in the discrete subspace. It is worth noting that the connectivity is maintained until all the sub nodes in the connectivity can be found. This is a fundamental consideration for multi hop network. The intermediate vehicles are independent from the connectivity of the elements. In addition, the distance between the consecutive nodes in the network should be equal to or greater than the range of transmission denoted by R. It is the basic criteria for the list to be maintained for the communication between the nodes of the network.

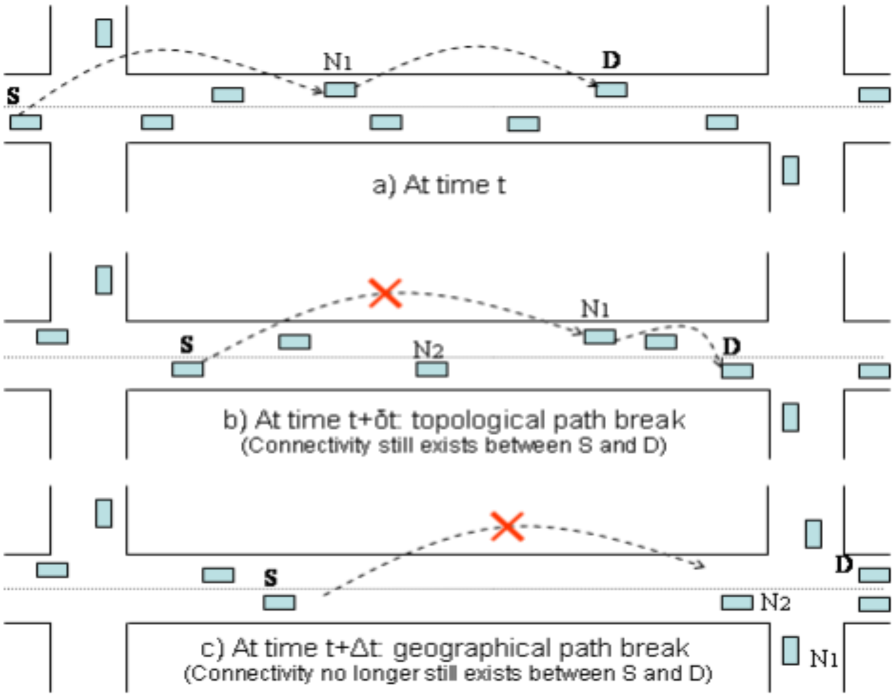

Figure 3. DTMC-CA [28].

System Model for DTMC-CA: According to Nzouonta [28] if we consider a traffic model in which the respective velocities of the vehicles are denoted by vector **V.** If we wish to communicate between two vehicles and the distance of the road is divided into k number of cells. It should also be noted that the cells formed are of equal length lets denote by L. Each cell is assigned a value corresponding to the vehicle. The value depends on the simple fact that whether the vehicle is moving towards the cell or away from the cell. A positive value is assigned if the vehicle is moving within the cell. The mobility of the vehicle is shown by the absolute value. It can be inferred that if the vehicle is stationary the value will be equal to zero. In addition, the cell will be assigned a value of ∞ if no vehicle is present within the cell.

The corresponding cells form a Markov chain with the state space denoted by **S.** A probability transition matrix is also constructed based on the relative values of the probabilities in the specific cell. The starting state is chosen randomly from the Markov chain as the stationary nodes are considered. The transitional probability matrix shows the probability that a node moves from state **I** to state **J**. It is clear that only a few entries of the matrix will have the valid values because only a handful of transitions are possible from any arbitrary state to other. The probability transition matrix is used to measure the probabilities of interest for the communication. The discrete state space is divided further into two subspaces S_1 and S_2. The subspace S_1 contains all the states in which the connection between vehicles is maintained while the subspace S_2 is used to show the disconnected state of the vehicles.

Connectivity Window Model: The connectivity model is a generalization of the DTMC-CA model discussed above. It is valid for any type of vehicular traffic at the microscopic model. The connectivity patterns depend largely on the model of the traffic generator. The idea behind the use of connectivity model is to estimate the movements of the vehicle along with the number of vehicles present in the range **R**. A vector is calculated for the locations and arrangements of the vehicles in the consecutive cells [28]. The transition probability matrix for this method is carried out in two steps. In the first step, the probability for the space of the number vehicles to the space of the location of the vehicles in the cell is found. The transitions probabilities are calculated for the mapping of these subspaces.

The basic objective for the use of both the DTMC-CA and the connectivity window model is the RBVT protocol. It calculates the density of the traffic in each cell in particular and the whole region in general. The density of the traffic can be determined from the signals taken from the sensors used in the existing transportation sensors. These sensors mostly present on the roadside can generate the traffic on the hourly basis. Secondly, the respective velocities of the vehicles can also be determined. These values can be saved either on the cars or saved in a database and can be taken from the vehicles or from the database. A possible drawback of this method is that it cannot adapt to the continuously changing traffic conditions. In addition, the traffic values of the matrix should also be shared among the vehicles present in the cell to compute it dynamically.

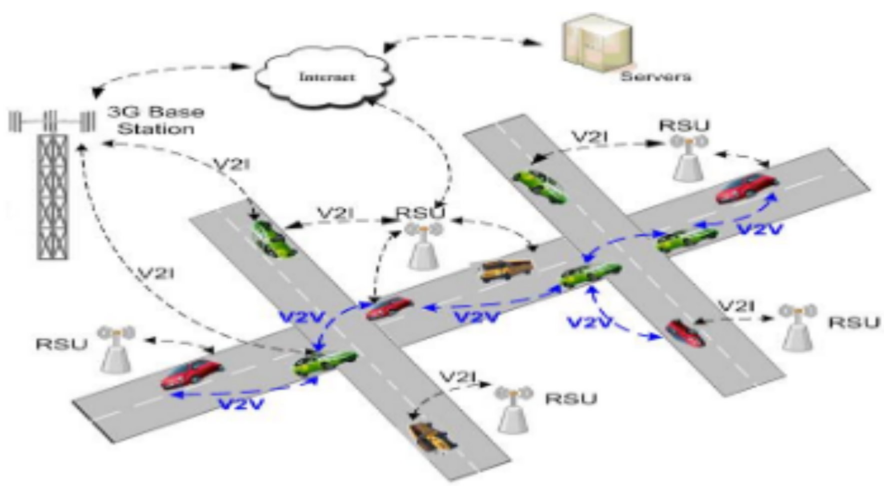

Figure 4. VANET Application [5].

AODV is a reactive routing protocol that works on hop-by-hop array. In VANET, the nodes are vehicles. Vehicles have random mobility and travels in different speeds. The Ad hoc On-Demand Distance Vector (AODV) strategy allows active, self-starting, multi-hop routing between joining mobile nodes wanting to start and maintain a network. AODV permits mobile nodes to increase routes quickly for new destinations; however, AODV does not need nodes to provide routes to destinations that are not in effective communication. The type of the messages expressed by AODV Route Requests (RREQs), Route Replies (RREPs), and Route Errors (RERRs).

In AODV routing, upon receiving (RREQ), the nodes record the address of the node sending the query. This process of recording its preceding hop is called *backward learning*. Upon received at the destination, the reply packet (RREP) is sent. Whenever it stops, the node will record its preceding hop, therefore creating the *forward path* from the source. After the path has been founded, it is supported as long as the source is using it. A link failure will be reported to the source and then different query response will be created to find a new route.

The Dynamic Source Routing (DSR) protocol uses source routing & keeps active routes. It has two stages route discovery & route maintenance. DSR does not use periodic routing message. DSR will generate an error message if there is any link breaks. All the intermediate nodes ID are kept in the packet header of DSR. If there are multiple paths to go to the destination DSR stores multiple path of its routing information.

AODV and DSR have some major differences. In AODV when a node sends a packet to the destination then data packets only contains destination address. Instead in DSR when a node sends a packet to the destination data packets carry the full routing information, which causes more routing overhead than AODV.

DSDV stands for Destination Sequenced Distance Vector. DSDV is a Proactive routing protocol that use evidence stored in the routing table to take routing choices. In DSDV, each node keeps route to all identified destinations in the form of table. The table has records as destination node, next hop, and cost metric, sequence number assigned by destination to avoid loops, number of hops to destination, and install time. Time when entry was made that is used to delete the staling entries. The topology alterations are restructured by immediate messages to the neighbors. The tables are updated by full update in which a node sends all information to other nodes, in which a node sends only changed entries to other nodes.

DSDV has its advantages and disadvantages. DSDV protocol are not complicated, the path has no loops because it uses a sequence of numbers and no latency as the path is taken from the routing table maintained by the nodes. However, the disadvantages of the protocol are overhead as some of the information is never used and tables need to be updated the consumed amount in a significant amount of bandwidth.

2.4 Security Issues

In any wireless system such as VANET, security issues need to be addressed. If information to a vehicle node is tampered with, the vehicle node in question may be given mischievous instructions that could lead to road accidents. The security goals of VANET can be broadly categorized into five main components or criteria, which are, the authentication, the confidentiality, the integrity, the availability and the non-repudiation of a data.

Study in 2013 [23] described the authentication criteria as the assurance that the nodes in a communication link are the correct nodes matched in identity to the supposed nodes in a database. Therefore, for this to happen, each vehicle should have been registered and be uniquely identified with an authority prior to being driven on the road. The confidentiality criteria of a data are due to the fact that all data should remain private and confidential, and not be disclosed to unauthorized figures. Disclosure of this information may lead to leakages of vital information about the nodes in a communication link, thereby allowing tampering and hacking of information to occur. Accidents can happen if the hackers intend to overwrite the information with new instructions that may cause the nodes to behave in a hazardous manner.

The integrity criteria of a data describes the fact that each data that has been received is assured to be exactly the same as the data that was sent out by a node, which has been authorized to do so by an authority. No modifications or compression of a data is allowed that renders the data sent being not the same as the data received.

The availability of a data should be guaranteed by a working system. Checks should be ensured that no battery power that generates the signal, sending and receiving one is drained. In addition, the routing protocol should be ensured not to be jeopardized by any hackers.

The non-repudiation criteria of a data are described by Matthew and Kumar [23] as one that ensures that the vehicle node that has sent a piece of information cannot not be in denial that it was the sender. Likewise, the vehicle node that has received a piece of information is not allowed to be in denial that it has received the information.

Security attacks in VANET can be abundant, and are broadly categorized into several types by Matthew and Kumar [23]. The categories include Sybil attack, denial of service (DoS), sinkhole attack, illusion attack, position attack, selective forwarding and misbehaving and faulty nodes.

In a Sybil attack, the mischievous node creates a multiple identity of itself. Concretely, there is only one node mapping to one vehicle in the physical world, but in the digital world, there are multiples of this one vehicle node. Consequently, other nodes, which may receive information from one of these duplicate nodes, might be misled into thinking that there is traffic congestion ahead, and thereby will choose alternative routes to reach their respective destinations. In this situation, the mischievous node is a selfish one, since no other nodes will be near it, thus having the entire road for itself. In order to prevent a Sybil attack from succeeding, a node can observe other nodes for a certain time interval, and the data from neighboring nodes are compared with the information gathered by itself. Any anomalies from the comparisons will be flagged as a potential attack.

In a DoS attack, the aim is to block nodes from accessing services and resources in the VANET network. This can be done through jamming the network, akin to spamming in emails. Consequently, nodes under DoS attack will lose connection with the network, which without information received from other nodes, may cause accidents next. The sinkhole attack acts differently from a DoS attack, but has similar intention. In this attack, the attacker node forces all information to pass through itself. Consequently, the attacker node who is now capable of controlling the information traffic, and thereby the traffic on the road, may be able to selectively reroute other vehicle nodes, or create malicious data packets to be sent to others, thereby causing accidents.

In an illusion attack, the malicious node deliberately create false signals or alter the signal originating from its own vehicle, before broadcasting it to other nodes. Consequently, other neighboring nodes fail to see the physical traffic but an imaginary traffic created by the malicious node.

An attack can also be in the form of a deliberate alteration of the distance information in the network, such that a transmission of data can be forced to pass through the node under malicious attack. Lu [21] described that the attacker will attempt to change the information on the distance value between the destination node and itself as less than other neighboring nodes. Through such modification, one of the hops on the routing will always be through the malicious node. Not only is the security of the data information in transmission compromised, the network routing overhead is also increased. It is important the overhead is not increased, as it can cause traffic accidents due to information not reaching the destination node in a fast enough manner.

Similarly, Lu [21] remarked that the azimuth information can also be tempered. The azimuth information is the information on the angle between an imaginary line connecting two nodes, and an imaginary line drawn on the road. To transmit azimuth information, the law of right hand is used in protocols, such as VANET GPCR and GeoDTN+Nav, to transfer the information from the source node to the destination node. When a malicious attack occurs, the law of right hand is no longer obeyed. Instead, the information is forwarded to another series of nodes, which some of them are not in the supposed route as determined by the law of right hand, and one of the nodes in the series is that of the malicious node.

CHAPTER 3

Methodology and Analysis

3.1 Performance Analysis Methodology

Using a reactive routing protocol, the connection between the nodes is recognized only when desired; no need to pre-define connections between the nodes. If a node in a network needs to connect with any of its adjacent nodes, the sender node sends a Route Request Message (RRM) to all the nodes in the network, and it is received to the destination node, a Reply Message (RM) is sent back to the sender node. That is how the route is created between the sender and receiving nodes.

There are numerous protocols that fit in this category of reactive routing protocols. Two of the most commonly used protocols that fit the reactive routing in VANET scenarios are Ad hoc on-Demand Distance Vector Protocol (AODV) and Dynamic Source Routing (DSR). AODV experiences less delay as connection is established only on demand.

According to Nzouonta [28] Patch determination and messaging can be determined using a routine algorithm. The algorithm indicates the absence or presence of a route through a given code. Route maintenance process in either MAC sub-layer protocol or TCP/IP protocol is done after link breaking even is completed. The delays that exist in new path determination raises a problem that can lead to accidents taking place before messages are sent or received. The algorithm helps in estimating the number of nodes required, the frequency and data rates being transmitted. The estimation depends on the method of data transfer and the standard being used. The table below describes the estimated frequency alongside the data rates. Although many protocols have been proposed for the implementation of VANETs applications, but a requirement of standard in the optimal sense is ever increasing. VANETs use various modes for the communications of the vehicles for traffic control and avoid circumstances of accidents. These include the existing 2G, 3G mobile communication standards, Bluetooth and ZigBee. In the past various standards used different modes of transmission like Direct Sequence Spread Spectrum (DSSS) or Orthogonal Frequency Division Multiplexing (OFDM).

The data rates are also varied depending on the choice of the transfer method. The methods can be adopted based on the requirement of the application and the resources available. For example, if the priority of a traffic accident mechanism is high then one can allocate a high bandwidth and data rate resource for it. On the other hand, if the objective is to reduce the latency of the overall system OFDM can be selected. A list of the standards previously used for VANETs is listed in Table below.

Table 1

Physical Layer IEEE 802.11

Standard	Transfer method	Data rates (Mbps)	Frequency (GHz)
802.11b	HR-DSSS, DSSS	1, 2, 5, 11	2.4
802.11a	OFDM	6,9,18, 24, 48, 54	5.1 to 5.6
802.11g	OFDM	1,2, 5.5, 6,9, 18, 24,36,48,54	2.4
802.11	DSSS, FHSS, IR	1,2	IR and 2.4
802.11g+	OFDM	1,2, 5.5, 6, 9, 11, 18, 24 ,36 ,48 ,54,	2.4
802.11b+	HR-DSSS,DSSS	1,2,5,11,22,33,44	2.4

Recently, IEEE has finalized the standard IEEE 802.11p for the purpose of vehicular networks along with the medium access control. The aim of the standard is to provide robustness together with mobility and low latency. The physical layer for IEEE 802.11p makes use of the short-range communication with the bandwidth of 75MHz. The operating frequency is in the range of 5.9 GHz. These are subdivided into seven 10 MHz channels that make use of the OFDM method for communication. The table below summarizes the specifications of the IEEE 802.11p.

Table 2

Specifications of the IEEE 802.11p

Parameter	IEEE 802.11p	IEEE.802.11a
Rate (Mbps)	3,4,5,6,9,12,18.24 and 27	6,9,12,18,14,36,48 and 54
Modulation	BPSK, QPSK 16-QAM and 64-QAM	BPSK, QPSK 16-QAM and 64-QAM
Codification Rate	1/2, 1/3 and 3/4	1/2, 1/3 and 3/4
Sub-carriers Number	52	52
OFDM symbol duration	8μs	4μs
Guard Interval	1.6μs	0.8μs
FFT period	6.4μs	3.2μs
Preamble duration	32μs	16μs
Sub-carriers Spacing	0.15625 MHz	0.3125 MHz

In case of emergencies like congestion or accidents, it is desired that information be communicated to other vehicles not only successfully but also in time. Vehicular Ad hoc networks establish the communication without the need of any resources like base stations. In certain scenarios, the transmission quality exhibits high variations, which in return downgrades the performance. Previously, various studies have been performed which depicted lower throughput for TCP protocol especially for multi hop network communications. The reasons behind the reduced performance are the procedure of congestion control. As a case scenario, TCP detects the errors in transmission as the congestion. This considerably reduces the overall throughput of the system. Although, many improvements in the original TCP have been made, the algorithms have high delay which is not acceptable in the VANET. Moreover, local information is used in most of the improvements for the prediction of congestion situations. However, these improvements are unable to detect the current state of the VANET. In short, the use of TCP in VANETs gives poor results that are undesired. When packets get lost, they are treated as congestions hence in wireless it cannot be the same case. It is also not possible to use TCP because it cannot reduce congestion or window size or even effectively decrease the throughput. Therefore, for VANETs established on a wireless network, MAC sub-layers are recommended.

3.2 Simulation Design

Simulation VANET can be done in a variety of ways. By doing research I figured that NS-2 would suit my simulation. It is open source software for research purposes. It is an event-driven simulator and I will be using it for my simulation. I will also use SUMO-GUI to create the VANET topology. NS-2 is another object-oriented simulator; the code used in NS-2 is C++ or OCTL. Using C++ would have been unnecessarily complicated and time consuming; therefore I will be using OCTL codes. NS-2 has two main tools, the network simulator, which contains all the commonly used IP protocols, and the network animator, which is used to visualize simulations. Regarding SUMO abbreviation of Simulation of Urban Mobility, it is an open source software same as NS-2; it helps to implement large road networks.

Various performance metrics will be used to examine the performance of the three routing protocols in various network atmospheres. In my thesis I have chosen throughput, end-to-end delay, packet delivery ratio and jitter for the distinctive number of vehicles to examine the performance of VANET routing protocols. These metrics were chosen to check the performance in high mobility network. In addition, these metrics will help me decide which protocol will be more effective and how the packets will be delivered and the delay between them. The metrics for routing protocols evaluation are explained below.

Packet delivery ratio is the portion of produced packets by successfully received packets. It is the ratio of packets received at the destination to those of the packets made by the source. For example, the typical calculation of this system of measurement is in percentage form; the bigger the percentage, the more advantage the routing protocol.

Throughput is the amount of communications formed during the simulation. And also it is stated as the total capacity that application can grip. Likewise before starting the simulation it is mutual to have a throughput goal that the application needs to be able to handle a specific number of requests. Average End-to-End Delay (E2E Delay**)** is the calculation of the total time from the source end to the destination end taken by the packet. In other words, it covers all of the potential delays such as route discovery, buffering processes, variations in between queuing stays, etc. during the entire trip of transmission of the packet. For this metric, the lower the time spend, the more privileged the routing protocol.

Jitter is the difference between in the end-to-end delay and the packets received at the destination. In real time applications as video conferencing, and multiplayer video games, jitter is measured as vital of a metric as end-to-end delay.

The time the data packets take to be delivered to its source is called the average end-to-end delay. So, the time, which the first data packet gets to destination, is subtracted from the time, which the first packet sent by the source. The value of the average End-to-End delay indicates the time spent for all potential delays produced by buffering procedure at the same time as performing route discovery method.

In my research, I will also study the impact of mobility on the performance of different routing protocols in VANET. Mobility models define the design of nodes traveling in the wireless network scenario. Motion of nodes is very close real world scenario the only different is nodes instead of vehicles. These scenarios support the simulation of VANET. Essentially, the mobility models represent acceleration geographical position, velocity, and speed of vehicles.

The Random way point model is a node that randomly selects a destination point and moves to it. After reaching at destination, it stops for some amount of time, which is the pause time. Then after the pause time, the node will select another random point to move. This procedure will be repeated until the simulations ends.

City section model is the movement of nodes, when it is limited to a grid road topology, where the edges look bi-directional, and each node randomly selects one of the intersections as a destination. So, each node moves to the destination with a constant speed, taking the most horizontal and vertical way to the destination. The node decide which path to take and which is the shortest way to the destination. The Speed depends on the type of road the node chosen.

On the other hand in the Manhattan model, the movement of nodes is so close to be realistic and the motion of nodes is created based on probability values. The node moves only one step at a time. The probability of choosing the path will always be equal in all the ways.

I will be creating four different scenarios using various densities and different speeds. The first scenario will be simulation between AODV, DSR and DSDV in means of impact of traffic loads in terms of Packet ratio delivery, throughput and Average end-to-end delay for number of nodes 12, 24, 51, and 60 nodes. The network parameters are shown in table 3.

In the second scenario the total number of nodes in the network at a time remains fixed at 200 nodes but I will use changeable pause times of the network. Simulation parameters of scenario one are shown in table 4.

In the third scenario I will be testing the impact of mobility under varying speeds to observe how the network reacts. Comparison between AODV, DSR and DSDV but using a different topology using the speed time 5 to 25 m/s for number of nodes 30, 90, and 150 in means of packet delivery ratio, average end to end delay and loss packet ratio. Scenario three simulation parameters are shown in table 5.

Regarding Scenario four it is the impact of node distribution. This scenario consists of two parts. First part I will be using the fixed number of nodes and even distribution; however, the second part I will be using uneven distribution of the nodes to test the link breakage in different circumstances. Scenario four simulation parameters are shown in table 6. These scenarios encompass my thesis purpose in evaluating the protocols because I will be creating real world scenarios using Sumo software. This scenario has specific importance because it will be the closest scenario to realistic scenario because then in real life we cannot have all the nodes evenly distributed; therefore, I will be comparing between the evenly distributed and the unevenly distributed.

Table 3: Simulation Setup Scenario 1.

Parameters	Value
Number Of Nodes	12, 24, 51,60
Routing Protocols	AODV, DSR, DSDV
Simulation Model	TwoRayGround
MAC type	IEEE 802.11
Link layer type	LL
Interface Type	Queue
Packet Size	512

Table 4: Simulation Setup Scenario 2.

Parameters	Value
Number Of Nodes	200 with 100 connections
Routing Protocols	AODV, DSR, DSDV
Simulation Model	TwoRayGround
MAC type	802.11
Link layer type	LL
Interface Type	Queue
Packet Size	512
Queue Length	50
Pause time	10 sec, 30 sec, 50 sec, 70 sec, 90 sec
Node Speed	10 m/s

Table 5: Network Parameters For Scenario 3.

Parameter	Value
Protocols	AODV, DSR, DSDV
Simulation Time	200 s
Number of Nodes	30, 90 and 150
Speed/Time	5, 10, 15, 20 and 25m/s
Traffic Type	TCP
Network Simulator	NS 2.35

Table 6: Network Parameters For Scenario 4.

Parameters	Value
Number Of Nodes	5, 10, 20, 25
Routing Protocols	AODV, DSR, DSDV
Simulation Model	TwoRayGround
MAC type	802.11
Link layer type	LL
Interface Type	Queue
Packet Size	512
Queue Length	50

3.3 Simulation Tools and Environment

Due to the high cost to implement and to test a VANET system model, researchers often resort to simulations prior to carrying their results out into the real world on simulation software, such as MOVE. The software MOVE was developed by Vaishali and Pradhan as detailed by them in 2010. MOVE is add-on software built on top of open source micro traffic simulation software, known as SUMO.

MOVE uses the Java language, and is an attempt to model real-life traffic system into a user-friendly graphic user interface (GUI) display. The output of MOVE is a file containing the vectors of the directional movement of the vehicles. In MOVE, the user can manually create the road map, or allow MOVE to randomly generate one, or as a third option, import an existing real world road map from other programs, such as Google Earth.

In MOVE, a road map needs two main inputs, which are the nodes and edges. Here, nodes are different from the definition of a node in VANET. Nodes in MOVE refer to an element of the road, such as a junction or a traffic light. Meanwhile, edges refer to the road itself. Attributes associated to an edge include the speed limit and the length of the road.

The movements of vehicles in MOVE is specified in the Vehicle Movement Editor, either manually or generated automatically. The user can specify the values to properties, such as the speed, and the time of the vehicle at a certain location. A unique feature of MOVE is that the user can also simulate the movements of public transport, including buses by entering as an input, the arrival time and stopping duration of buses at each stop. This makes MOVE a good tool to use for policymakers to implement new routes for public transport, or to analyze the conditions of the existing routes.

Vaishali and Pradhan have demonstrated the functionality of MOVE by generating a 150 nodes scenario with a 4 square kilometers road map. Information exchange in VANET is done at a rate of 4 packets per second, where each packet contains 64 bytes of information. In addition, they found that the packet delivery ratio correlates positively with the number of vehicles. However, they cautioned that this increase is only up to a certain limit before radio interference factor starts to take over and thereby deteriorate the delivery capabilities.

Most drivers end up crashing or colliding with other vehicles too in some areas of the road, especially at bends and roads where respective drivers may not be familiar. This software is of great importance, as it will help in the reduction of collusions and crashes of vehicles. Drivers will be in a position to determine the characteristics of different roads as they travel. This will enable each driver to speculate what to expect along the road and determine the most appropriate speed limit to use at different junctures during a journey.

Some drivers end up crashing or colliding with other drivers after losing control, as they are not in a position to determine the acceleration of other drivers. This compromises the stability of other drivers on the road too. In some cases, a driver may be over speeding unknowingly. However, the software enables individual drivers to determine their acceleration and stability. When a driver is over speeding, he or she loses the path stability as any slight mistake can lead to an accident and or loss of lives. Solving such situations on the road is tricky as some drivers end up losing their lives yet it can be avoided [9].

According to the established traffic rules, drivers are expected to use specific speed limits in different areas while traveling depending on the characteristics of the road. When a driver is approaching a corner, legal speed limit is expected to be slightly lower to enable safety of the driver and the vehicle. Furthermore, reasonable speeding is expected of drivers in areas where children and other pedestrians are using for crossing the road in case there are no flyovers [9]. Determining such areas has been a challenge for several drivers in the recent past where the road signs are invisible. Some drivers end up colliding with other cars, as they are not in a position to determine the exact positions of the respective vehicles on the road leading to collusion. Collusion is one of the major causes of deaths in the roads in the recent past. This can be eliminated if different drivers and road users are in a position of determining the position of different vehicles on the road, for instance, vehicles behind them and those in front. Some accidents along the road are caused by the inability to determine the distance of the vehicle in front or vehicles coming from behind. Secondly, some accidents are caused by the inability in determining the precise location and speed of vehicles on the road. This software is of great importance as it has the capability of determining the exact locations of vehicles on the road. This will enable drivers to determine the position of vehicles in front and behind them [9].

Three routing protocols will be simulated using the Network Simulator, and SUMO a free implementing tool, which supports car-following model. SUMO is a traffic generator on the microscopic level and is a convenient package for the testing of the network protocols for mobile traffic. AODV is IEEE 802.11 MAC layer protocol, and the ns22.35 version is to be used. Input data of the SUMO would be one of the several road networks and a route file. The road network would be generated from varying input formats with the aid of the net-convert module. These input formats may be from any available database formats. A route file will be created that will describe both the characteristics of vehicles on the road and the path they take [14].

The SUMO module will simulate all the positions at several chosen times. These positions will be written in a dump file, which will be used in the generation of files in the format that the network simulator understands. In this case, this can be achieved with the extension known as trace exporter. The trace exporter is responsible for the implementation of the data flow diagram shown in Figure 5 below.

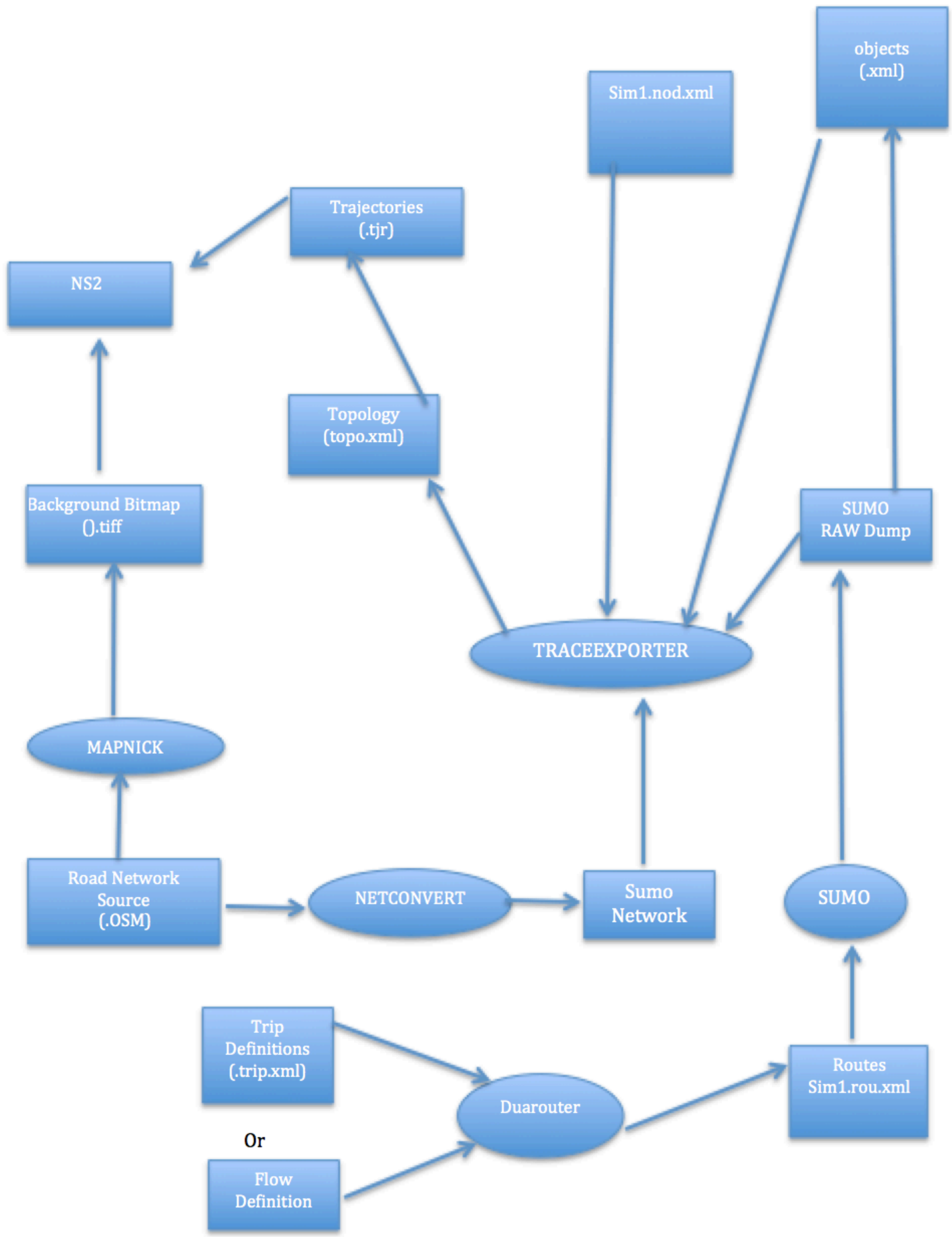

Figure 5. Process to generate vehicular mobility with SUMO.

Chapter 4

Results

4.1 Implementing VANET Scenarios

This chapter will evaluate and analyze the performance of the routing protocols AODV, DSR and DSDV with respect to different parameters, for example, the packet delivery ratio, throughput, end-to-end delay, loss packet ratio, and jitter for distinctive number of vehicles. The implementation of the mentioned protocols has been simulated using SUMO and NS-2.

The simulation in NS-2 can be done as mentioned in figure 5. This simulator has been acutely examined and it is known to provide an accurate test for wireless networks like VANET. Every plotted result is an average of 32 distinct executions, each with different seeds for random numbers and unique mobility behavior. Confidence intervals were calculated and plotted at a confidence level of 95% [32].

Two kinds of distributions were needed, even and uneven distribution. Therefore, the simulation was started by creating the scenario in SUMO. Xml files were created as shown in the following figures from 6 to 11 to input into SUMO. I have to use the files with nod.xml and edg.xml extensions which contain the network information as input files in SUMO, which is converted to node and link in SUMO. The file called rou.xml has the traffic route info. After creating the route files, I used “Dauraouter”, which is a Sumo command. Dauraouter create net file. After that the net file can be used an input for Sumo to create the network as shown in the figure 12.

```
<nodes>
   <node id="92" x="-100.0" y="0.0" />
   <node id="93" x="300.0" y="0.0" />
   <node id="94" x="+300.0" y="+100.0" />
   <node id="911" x="-50.0" y="+100.0" />
   <node id="912" x="-50.0" y="0.0" />
   <node id="913" x="+250.0" y="0.0" />
   <node id="914" x="250.0" y="+100.0" />
[redacted]
```

Figure 6. Node file: network layout for origins, destinations and intersections.

```
<edges>

    <edge id="D3" from="912" to="92" type="a"/>
    <edge id="D4" from="92" to="912" type="b"/>
    <edge id="D5" from="913" to="93" type="a"/>
    <edge id="D6" from="93" to="913" type="b"/>
    <edge id="D7" from="914" to="94" type="a"/>
    <edge id="D8" from="94" to="914" type="b"/>
    <edge id="L1" from="1" to="911" type="a"/>
    <edge id="L2" from="911" to="1" type="b"/>
    <edge id="L3" from="2" to="912" type="a"/>
    <edge id="L4" from="912" to="2" type="b"/>
    <edge id="L5" from="4" to="913" type="a"/>
    <edge id="L6" from="913" to="4" type="b"/>
    <edge id="L7" from="5" to="914" type="a"/>
    <edge id="L8" from="914" to="5" type="b"/>
    <edge id="L9" from="5" to="6" type="a"/>
    <edge id="L10" from="6" to="5" type="a"/>
    <edge id="L11" from="6" to="1" type="a"/>
    <edge id="L12" from="1" to="6" type="a"/>
    <edge id="L13" from="3" to="2" type="a"/>
    <edge id="L14" from="2" to="3" type="a"/>
    <edge id="L15" from="6" to="3" type="c"/>
    <edge id="L16" from="3" to="6" type="c"/>
    <edge id="L17" from="4" to="3" type="a"/>
    <edge id="L18" from="3" to="4" type="a"/>
</edges>
```

Figure 7. Edges file: The sequence of the names of the links, composing a defined route.

```xml
<?xml version="1.0" encoding="UTF-8"?>
<types>
   <type id="a" priority="3" numLanes="3" speed="13.889"/>
   <type id="b" priority="3" numLanes="2" speed="13.889"/>
   <type id="c" priority="2" numLanes="3" speed="13.889"/>
</types>
```

Figure 8. Type file.

```xml
<?xml version="1.0" encoding="UTF-8"?>
<connections xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
 xsi:noNamespaceSchemaLocation="http://sumo.sf.net/xsd/connections_file.xsd">
    <connection from="L2" to="L12" fromLane="0" toLane="0"/>
    <connection from="L2" to="L12" fromLane="0" toLane="1"/>
    <connection from="L2" to="L12" fromLane="1" toLane="2"/>
    <connection from="L4" to="L14" fromLane="0" toLane="0"/>
    <connection from="L4" to="L14" fromLane="1" toLane="1"/>
    <connection from="L4" to="L14" fromLane="1" toLane="2"/>
    <connection from="L9" to="L11" fromLane="0" toLane="0"/>
    <connection from="L9" to="L11" fromLane="1" toLane="1"/>
    <connection from="L9" to="L11" fromLane="1" toLane="2"/>
    <connection from="L9" to="L15" fromLane="1" toLane="1"/>
    <connection from="L9" to="L15" fromLane="2" toLane="2"/>
    <connection from="L16" to="L10" fromLane="0" toLane="0"/>
    <connection from="L16" to="L10" fromLane="1" toLane="1"/>
    <connection from="L16" to="L10" fromLane="1" toLane="2"/>
    <connection from="L16" to="L11" fromLane="2" toLane="2"/>
    <connection from="L12" to="L15" fromLane="0" toLane="0"/>
    <connection from="L12" to="L15" fromLane="1" toLane="1"/>
    <connection from="L12" to="L10" fromLane="1" toLane="0"/>
    <connection from="L12" to="L10" fromLane="1" toLane="1"/>
    <connection from="L12" to="L10" fromLane="2" toLane="2"/>
    <connection from="L14" to="L16" fromLane="1" toLane="1"/>
    <connection from="L14" to="L16" fromLane="1" toLane="0"/>
    <connection from="L14" to="L16" fromLane="2" toLane="2"/>
    <connection from="L14" to="L18" fromLane="0" toLane="0"/>
    <connection from="L14" to="L18" fromLane="1" toLane="1"/>
    <connection from="L14" to="L18" fromLane="1" toLane="2"/>
    <connection from="L17" to="L16" fromLane="0" toLane="0"/>
    <connection from="L17" to="L16" fromLane="1" toLane="1"/>
    <connection from="L17" to="L16" fromLane="1" toLane="2"/>
    <connection from="L17" to="L13" fromLane="1" toLane="0"/>
    <connection from="L17" to="L13" fromLane="1" toLane="1"/>
    <connection from="L17" to="L13" fromLane="2" toLane="2"/>
</connections>
```

Figure 9. Connections file: To specify traffic movements and lane connection.

```xml
<?xml version="1.0" encoding="UTF-8"?>
<routes>
  <vType accel="3.0" decel="6.0" id="CarA" length="5.0" minGap="2.5" maxSpeed="50.0" sigma="0.5" />
  <vType accel="2.0" decel="6.0" id="CarB" length="7.5" minGap="2.5" maxSpeed="50.0" sigma="0.5" />
  <vType accel="1.0" decel="5.0" id="CarC" length="5.0" minGap="2.5" maxSpeed="40.0" sigma="0.5" />
  <vType accel="1.0" decel="5.0" id="CarD" length="7.5" minGap="2.5" maxSpeed="30.0" sigma="0.5" />
  <route id="route01" edges="D2 L2 L12 L10 L7 D7"/>
  <route id="route02" edges="D2 L2 L12 L15 L18 L5 D5"/>
  <route id="route03" edges="D2 L2 L12 L15 L13 L3 D3"/>
  <route id="route04" edges="D4 L4 L14 L18 L5 D5"/>
  <route id="route05" edges="D4 L4 L14 L16 L10 L7 D7"/>
  <route id="route06" edges="D4 L4 L14 L16 L11 L1 D1"/>
  <route id="route07" edges="D6 L6 L17 L13 L3 D3"/>
  <route id="route08" edges="D6 L6 L17 L16 L11 L1 D1"/>
  <route id="route09" edges="D6 L6 L17 L16 L10 L7 D7"/>
  <route id="route10" edges="D8 L8 L9 L11 L1 D1"/>
  <route id="route11" edges="D8 L8 L9 L15 L13 L3 D3"/>
  <route id="route12" edges="D8 L8 L9 L15 L18 L5 D5"/>
  <vehicle depart="54000" id="veh0" route="route01" type="CarA" color="1,0,0" />
  <vehicle depart="54000" id="veh1" route="route02" type="CarA" />
  <vehicle depart="54000" id="veh2" route="route03" type="CarA" />
  <vehicle depart="54000" id="veh3" route="route04" type="CarA" />
  <vehicle depart="54000" id="veh4" route="route05" type="CarA" />
  <vehicle depart="54000" id="veh5" route="route06" type="CarA" />
  <vehicle depart="54000" id="veh6" route="route07" type="CarA" />
  <vehicle depart="54000" id="veh7" route="route08" type="CarA" />
  <vehicle depart="54000" id="veh8" route="route09" type="CarA" />
  <vehicle depart="54000" id="veh9" route="route10" type="CarA" />
  <vehicle depart="54000" id="veh10" route="route11" type="CarA" />
  <vehicle depart="54000" id="veh11" route="route12" type="CarA" />
  <vehicle depart="54000" id="veh12" route="route01" type="CarB" color="1,0,0" />
  <vehicle depart="54000" id="veh13" route="route02" type="CarB" />
  <vehicle depart="54000" id="veh14" route="route03" type="CarB" />
  <vehicle depart="54000" id="veh15" route="route04" type="CarB" />
  <vehicle depart="54000" id="veh16" route="route05" type="CarB" />
  <vehicle depart="54000" id="veh17" route="route06" type="CarB" />
  <vehicle depart="54000" id="veh18" route="route07" type="CarB" />
...
</routes>
```

Figure 10. Routes file: Traffic demand and route data.

```xml
<configuration>
    <input>
        <edge-files value="quickstart.edg.xml"/>
        <node-files value="quickstart.nod.xml"/>
        <type-files value="sim1.typ.xml"/>
        <connection-files value="sim1.con.xml"/>
    </input>
    <output>
        <output-file value="sim1.net.xml"/>
    </output>
    <processing>
        <no-turnarounds value="true"/>
    </processing>
</configuration>
```

Figure 11. Configuration file: includes the names of input and output files.

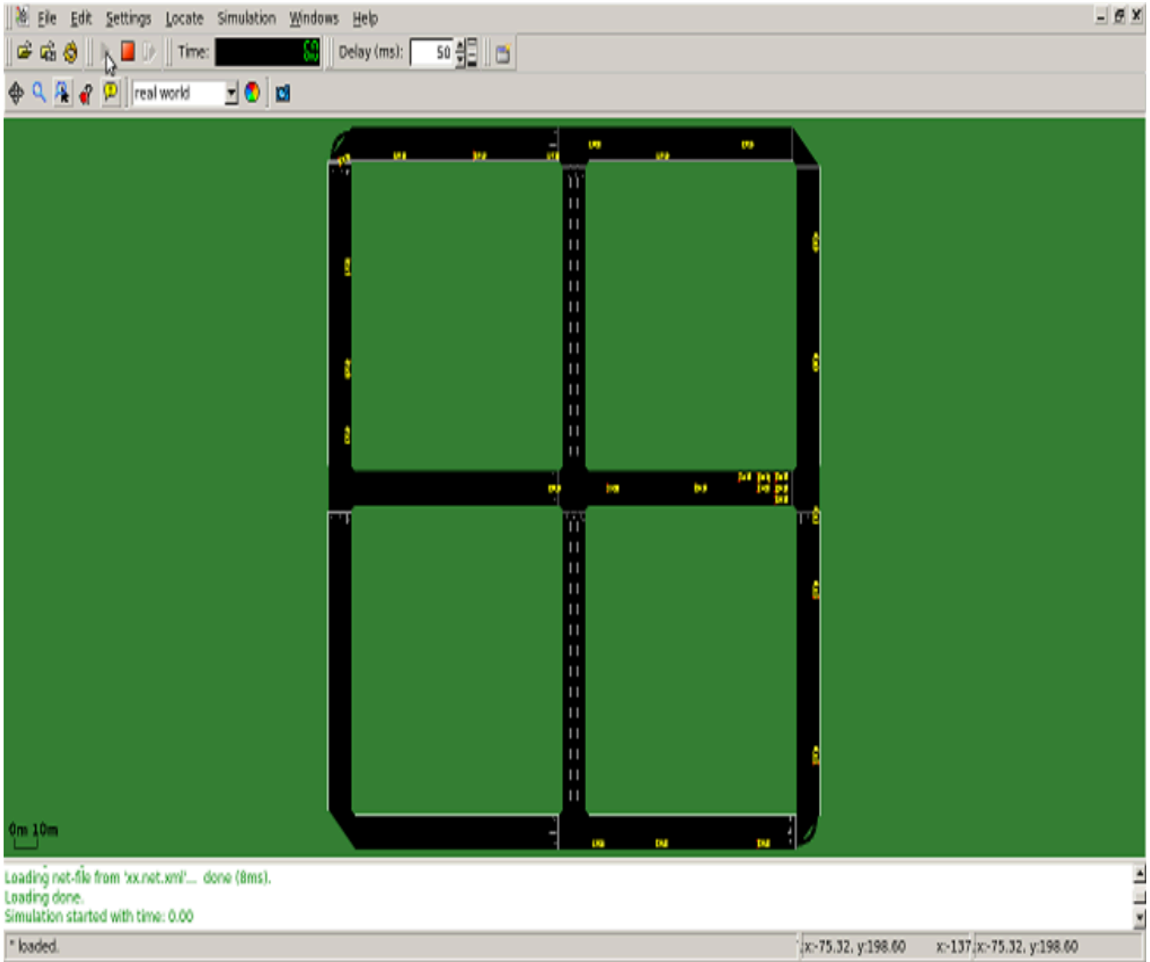

Figure 12. Example of a network in SUMO-GUI.

Trace files are a significant step in creating a network scenario for the network simulator NS- 2. To create these trace files, I used SUMO trace exporter. SUMO has a built feature to generate trace files. To use this feature I used the Python Script command. Which left trace files that can be used for the NS-2.

NS-2 is a simulator-using TCL programming which allows the TCL files to be executed. It is complex to create scripts in NS-2 because it needs full comprehension. In my thesis I needed to design three different scenarios for DSDV, AODV and DSR protocols in VANET network and compare the outputs. I have created codes for these scenarios as shown in figures 13, 14 and 15.

```
set val(chan)  Channel/WirelessChannel;# channel type
set val(prop)  Propagation/TwoRayGround ;# radio-propagation model
set val(netif) Phy/WirelessPhy ;# network interface type

set val(mac) Mac/802_11 ;# MAC type
set val(ifq) Queue/DropTail/PriQueue ;# interface queue type
set val(ll) LL ;# link layer type
set val(ant)            Antenna/OmniAntenna        ;# antenna model
set val(ifqlen)         50                         ;# max packet in ifq
set val(nn)             100                        ;# number of mobilenodes
set val(rp)             AODV                       ;# routing protocol
set val(x)              500                        ;# X dimension of topography
set val(y)              400                        ;# Y dimension of topography
set val(stop)           150                        ;# time of simulation end

set ns            [new Simulator]
set tracefd       [open testAODV.tr w]
set windowVsTime2 [open win.tr w]
set namtrace      [open testAODV.nam w]

$ns trace-all $tracefd
$ns namtrace-all-wireless $namtrace $val(x) $val(y)
set topo       [new Topography]
$topo load_flatgrid $val(x) $val(y)
create-god $val(nn)
        $ns node-config -adhocRouting $val(rp) \
             -llType $val(ll) \
             -macType $val(mac) \
             -ifqType $val(ifq) \
             -ifqLen $val(ifqlen) \
             -antType $val(ant) \
             -propType $val(prop) \
             -phyType $val(netif) \
             -channelType $val(chan) \
             -topoInstance $topo \
             -agentTrace ON \
             -routerTrace ON \
             -macTrace OFF \
             -movementTrace ON
```

Figure 13 . AODV.tcl

```
Agent/DSDV set sport_ 0
Agent/DSDV set dport_ 0
Agent/DSDV set wst0_ 6 ;# As specified by Pravin
Agent/DSDV set perup_ 15 ;# As given in the paper (update period)
Agent/DSDV set use_mac_ 0 ;# Performance suffers with this on
Agent/DSDV set be_random_ 1 ;# Flavor the performance numbers :)
Agent/DSDV set alpha_ 0.875 ;# 7/8, as in RIP(?)
Agent/DSDV set min_update_periods_ 3 ;# Missing perups before linkbreak
Agent/DSDV set verbose_ 0 ;#
Agent/DSDV set trace_wst_ 0 ;#
set opt(ragent) Agent/DSDV
set opt(pos) NONE ;# Box or NONE
if { $opt(pos) == "Box" } {
puts "*** DSDV using Box configuration..."
}

Agent instproc init args {
eval $self next $args
}

Agent/DSDV instproc init args {
eval $self next $args
}

proc create-dsdv-routing-agent { node id } {
global ns_ ragent_ tracefd opt

set ragent_($id) [new $opt(ragent)]
set ragent $ragent_($id)

set addr [$node node-addr]
$ragent addr $addr
$ragent node $node
if [Simulator set mobile_ip_] {
$ragent port-dmux [$node set dmux_]
}
$node addr $addr
$node set ragent_ $ragent
$node attach $ragent [Node set rtagent_port_]
```

Figure 14. DSDV.tcl

```
set val(chan) Channel/WirelessChannel ;# channel type
set val(prop) Propagation/TwoRayGround ;# radio-propagation model
set val(netif) Phy/WirelessPhy ;# network interface type
set val(mac) Mac/802_11 ;# MAC type
#set val(ifq) Queue/DropTail/PriQueue ;# interface queue type
set val(ll) LL ;# link layer type
set val(ant) Antenna/OmniAntenna ;# antenna model
set val(ifqlen) 1000 ;# max packet in ifq
set val(rp) DSR ;# routing protocol
set val(seed) 1.0 ;#

if { $val(rp) == "DSR" } {
    set val(ifq) CMUPriQueue
} else {
    set val(ifq) Queue/DropTail/PriQueue
}

set val(nn) 50 ;# number of mobilenodes
set val(x) 1000 ;# X dimension of the topography
set val(y) 1000 ;# Y dimension of the topography
set val(stop) 900.0 ;# simulation time
set val(path) /home/acharya/ns-allinone-2.35/ns-2.35
set val(cp)
set val(sc)

Agent/Null set sport_ 0
Agent/Null set dport_ 0
Agent/CBR set sport_ 0
Agent/CBR set dport_ 0

Antenna/OmniAntenna set X_ 0
Antenna/OmniAntenna set Y_ 0
Antenna/OmniAntenna set Z_ 1.5
Antenna/OmniAntenna set Gt_ 1.0
Antenna/OmniAntenna set Gr_ 1.0

set nominal_range 250.0
set configured_range -1.0
set configured_raw_bitrate -1.0
set ns_ [new Simulator]
set tracefd [open conf-out-tdsr.tr w]

$ns_ trace-all $tracefd
```

Figure 15. DSR.tcl

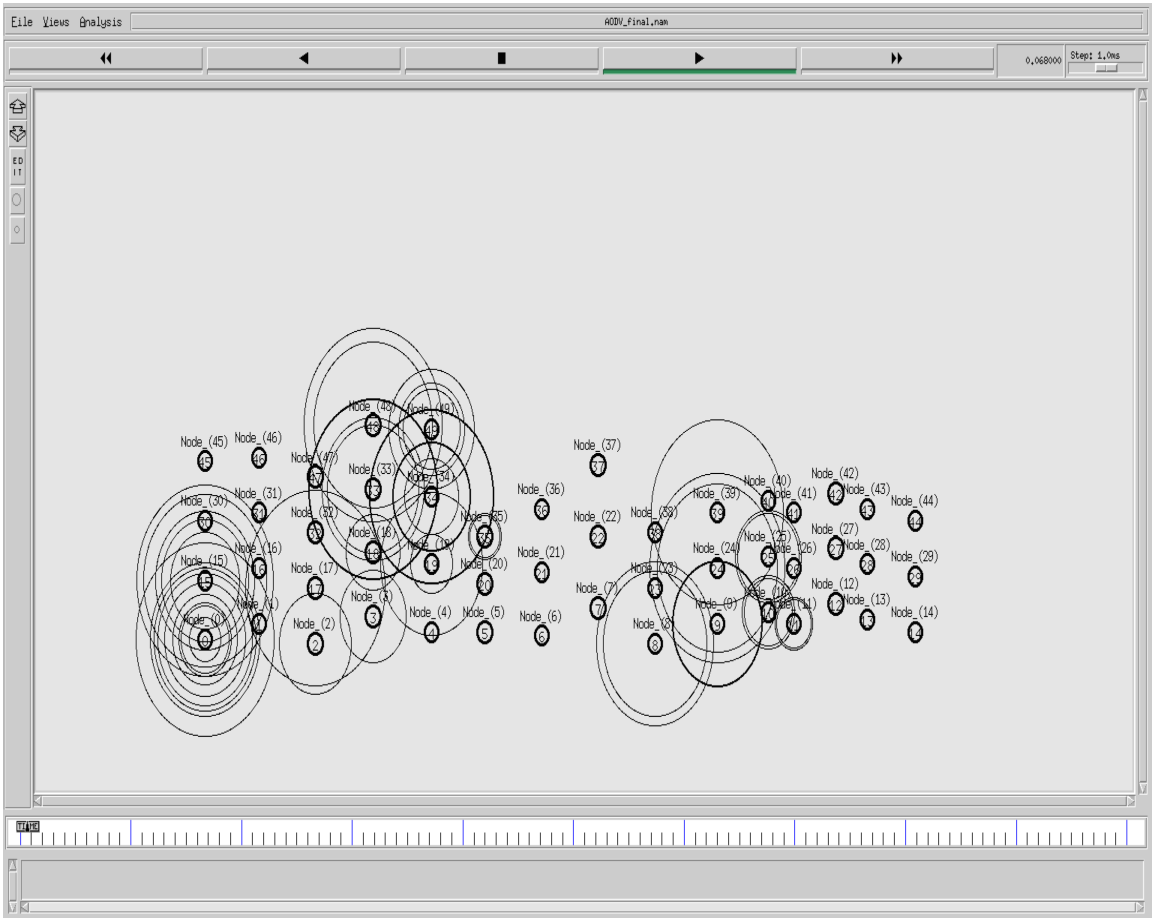

Figure 16. Sample VANET in NS-2.

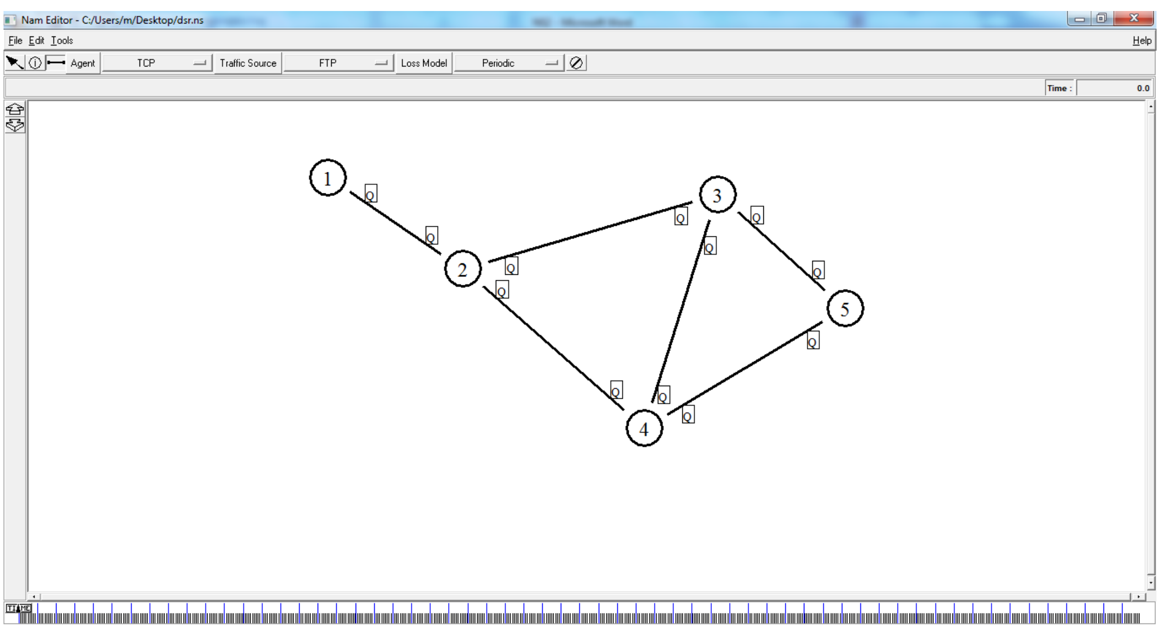

Figure 17. Example of even Distribution.

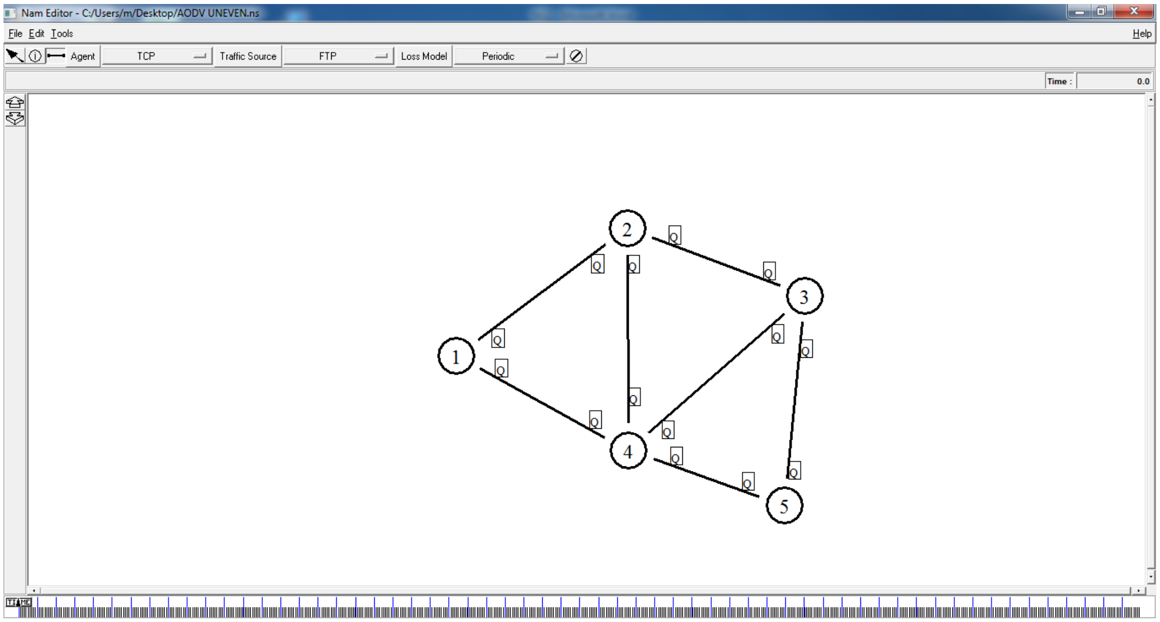

Figure 18. Example of uneven Distribution

4.2 Impact Of Traffic Loads

In order to evaluate performance metrics for each event, singular simulations are needed and next the average value is used for graphs. This section will implement Scenario one as discussed in chapter three; I will compare the traffic loads with different number of nodes. The first graph, figure 20, is plotted for packet delivery ratio vs. number of vehicles. This graph shows that the data packets were sent and effectively delivered at destinations by the number of data packets that were showed by sources for the three different routing protocols being used. The graph indicates that AODV outperform the other protocols in terms of the Packet delivery ratio.

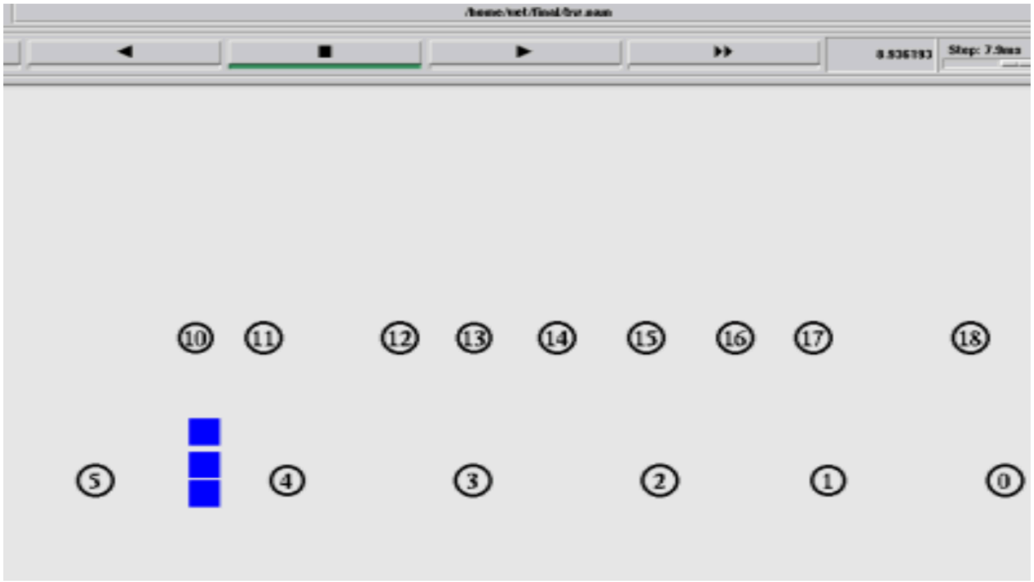

Figure 19. AODV using NS-2 Showing Packet Loss.

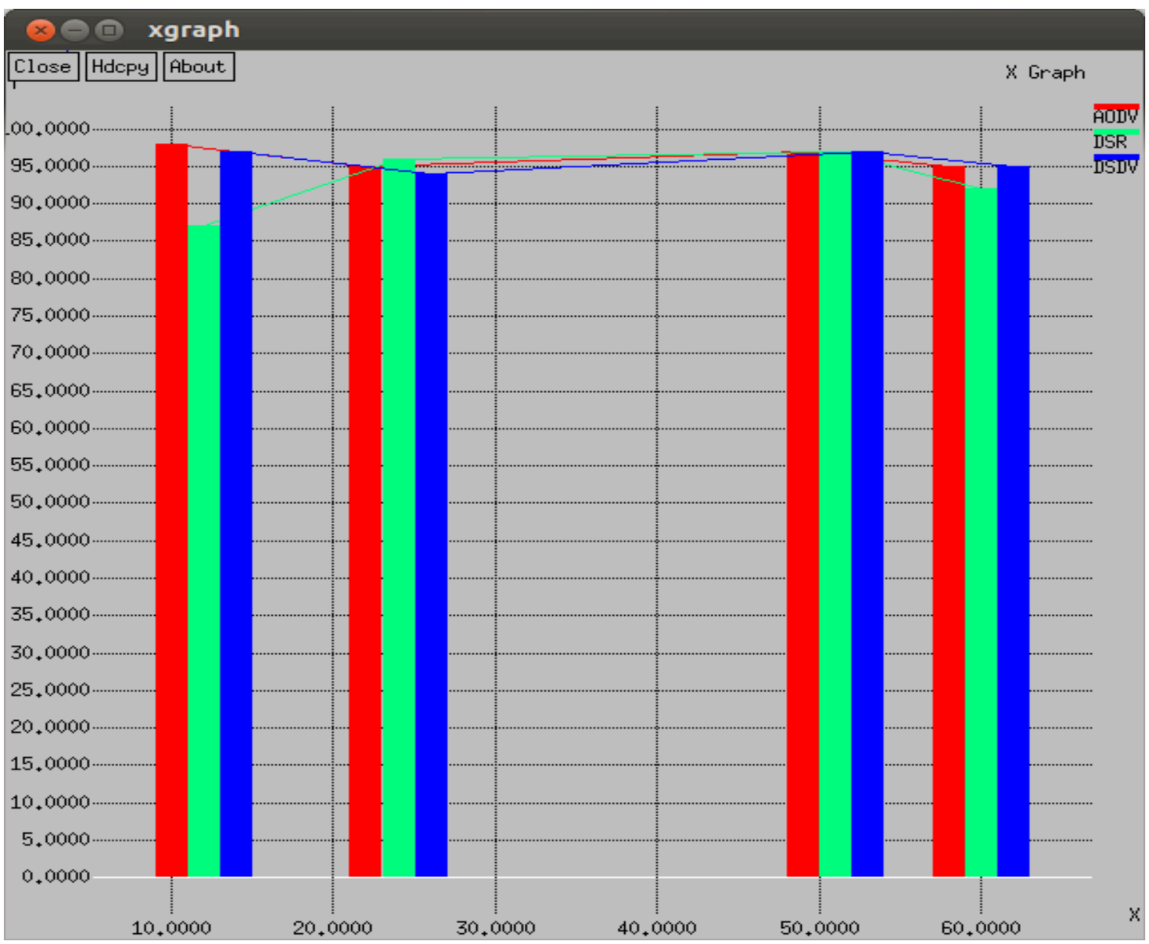

Figure 20. Packet delivery ratio vs. Number Of Nodes.

Regarding the throughput for three protocols, the graphs shows that AODV works well in low density, and it decrease the nodes number increase. On the other hand, DSDV was constant among the various numbers of nodes. But DSR throughput increased the nodes increase, which is opposite from the AODV.

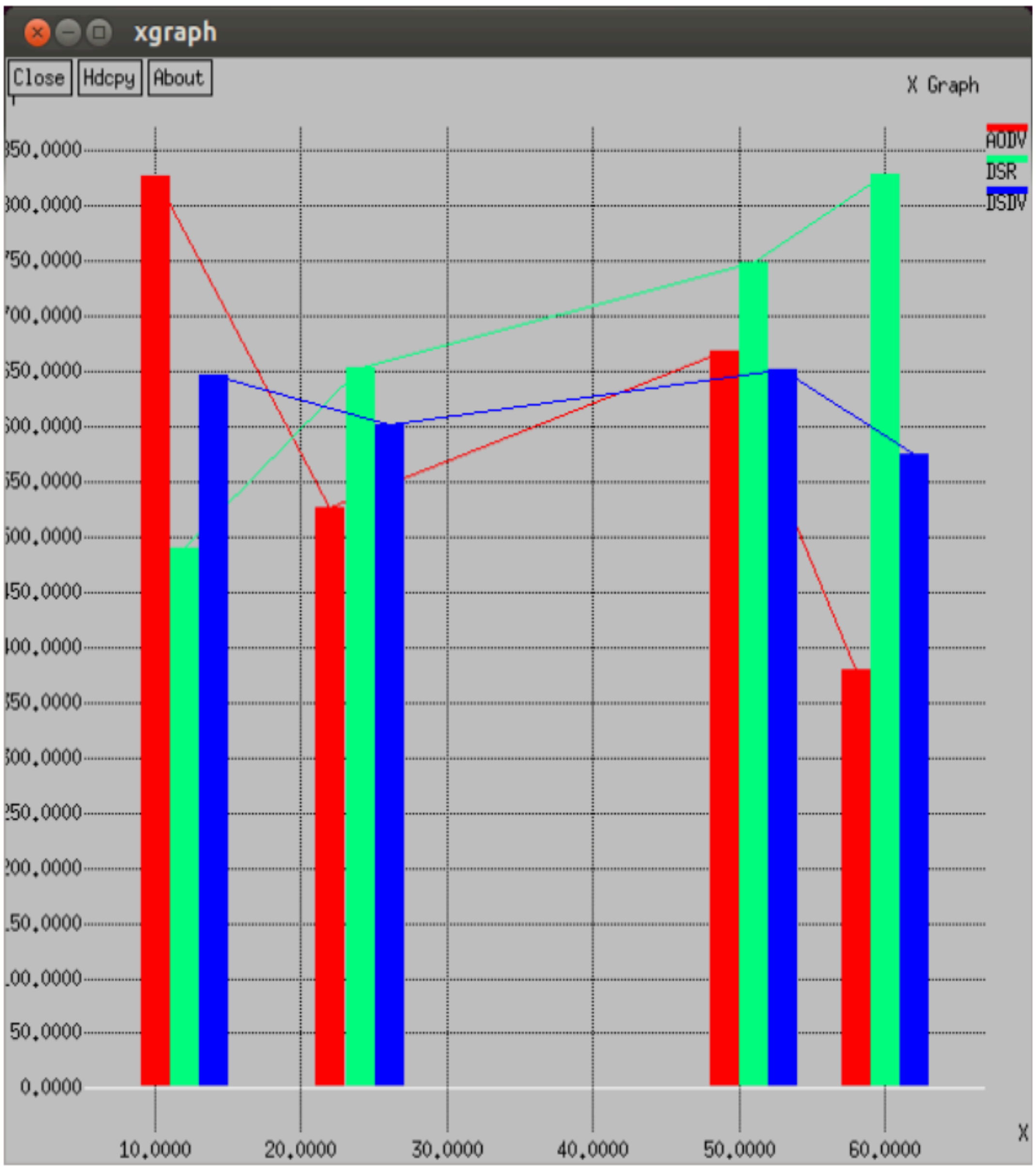

Figure 21. Throughput Vs Number of Nodes.

The graph of the average end-to-end delay shows that, AODV has stable average end-to-end delay regardless of the number of the node. However the DSDV fluctuates when nodes number increased. On the other hand DSR seems to increase as the number of nodes increase.

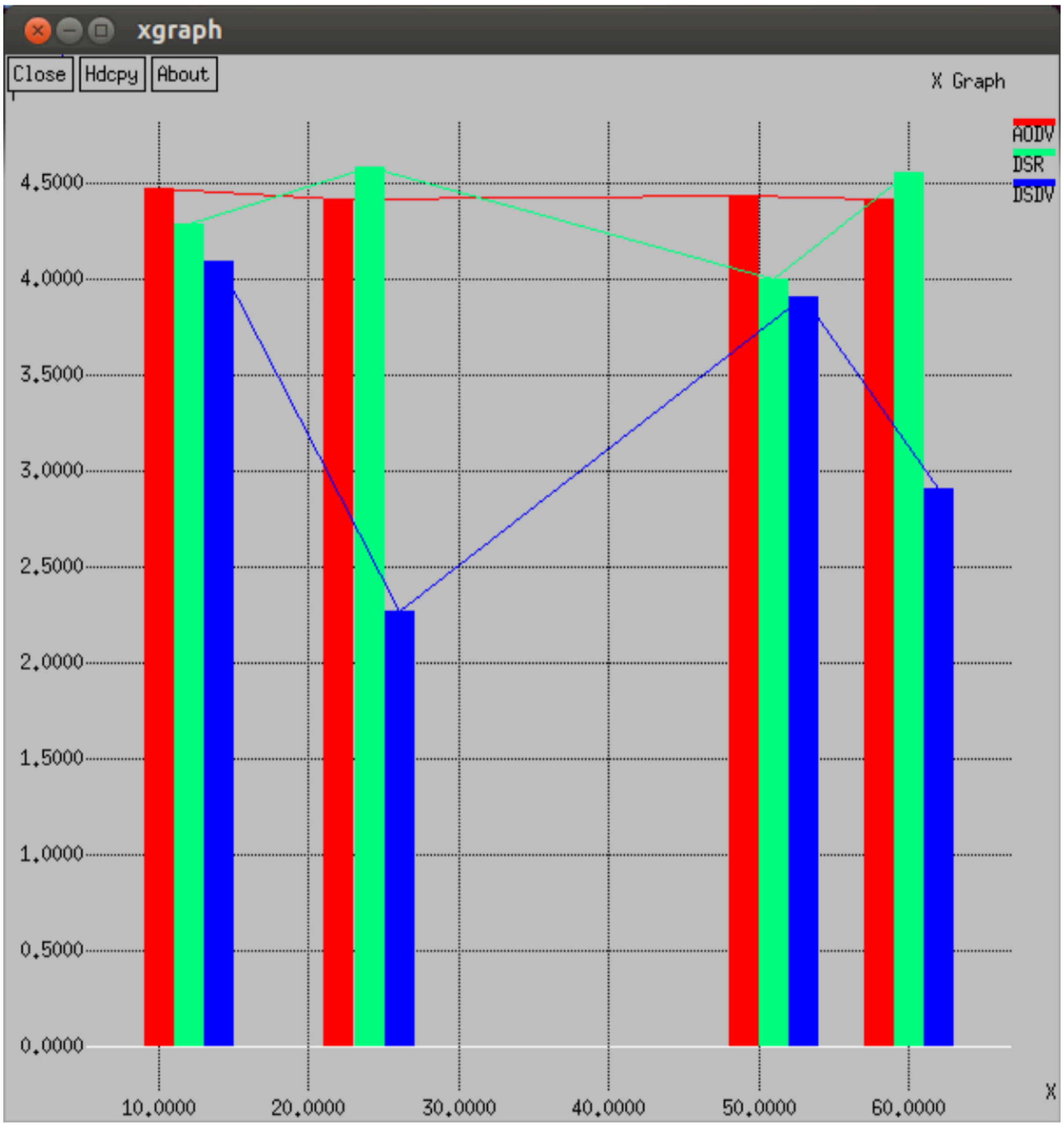

Figure 22. Average end-to-end delay Vs Number of Nodes.

The graph of the jitter shows that, AODV has stable amount of jitter regardless of the amount of nodes. Though the DSDV fluctuates when the amount of nodes increased. Instead DSR seems to increase as the amount of the nodes increase.

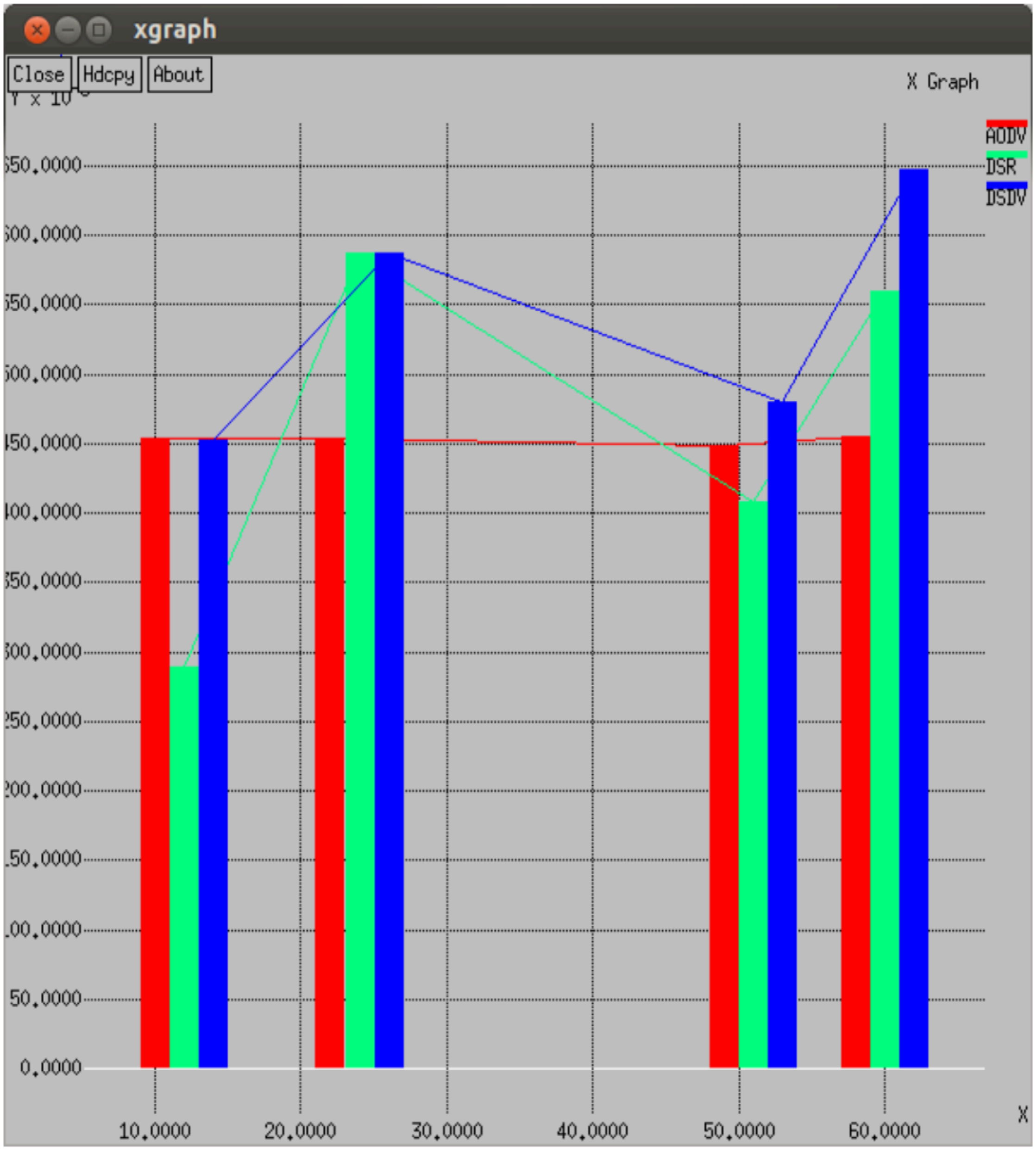

Figure 23. Jitter Vs Number of Nodes.

Looking at pause time as a parameter in a high dense network we can observe AODV as having stable delivery ratio which is considerably high, when I increased the pause time the delivery ratio started to fluctuates for AODV and DSDV. Overall Packet delivery ratio for AODV is high, DSDV is average, and DSR is low.

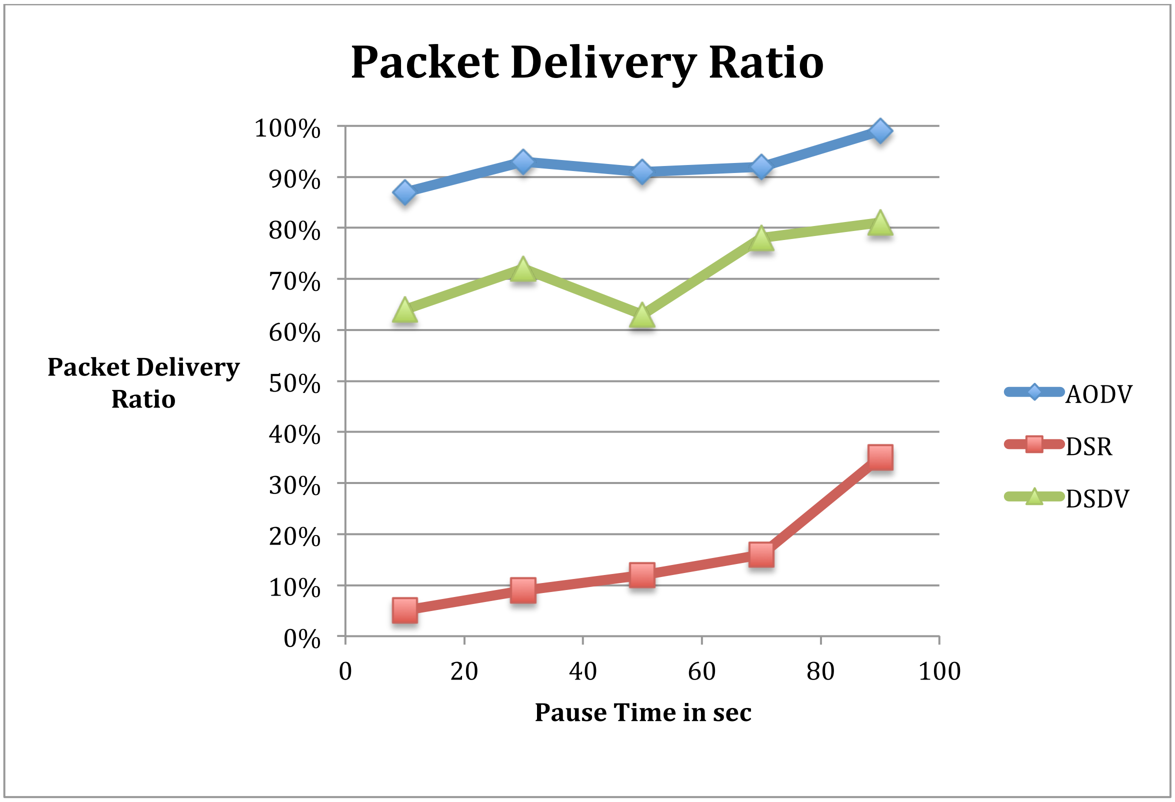

Figure 24. Packet Delivery Ratio Vs. Pause Time.

Looking at the Average End-to-End delay graph using varying pause time, it illustrates that AODV have average end-to-end delay, when the pause time is increased, the delivery ratio starts to fluctuate for AODV and DSR; however it was stable for DSDV all along. Overall average end-to-end delay for AODV and DSR is high, and DSDV has the lowest delay.

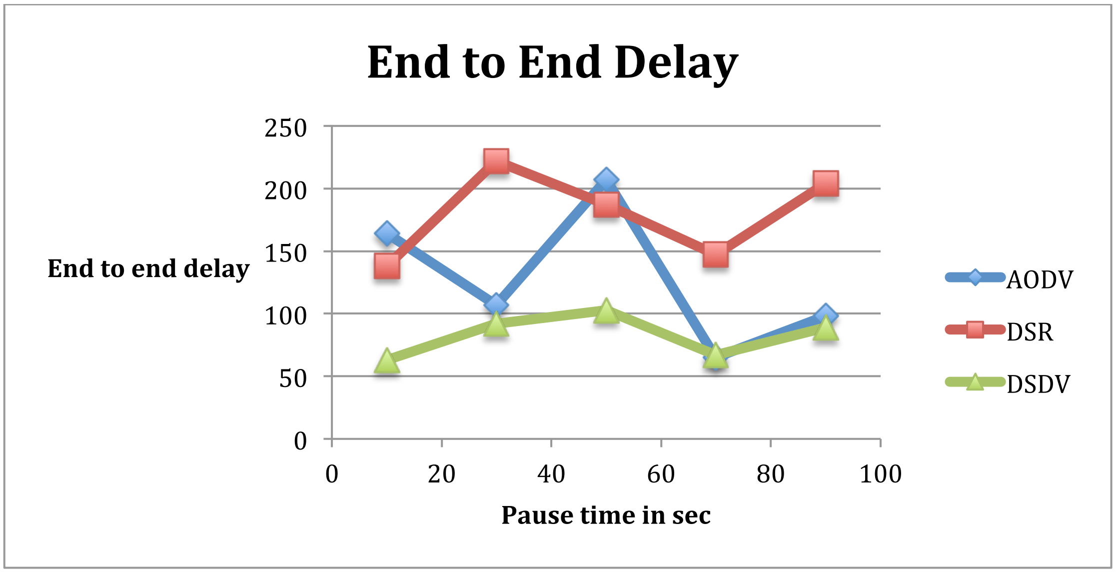

Figure 25. End-to-End Delay Vs. Pause Time.

The graph below indicates that DSDV has the lowest data packet loss with different pause timings. AODV has the highest data packet loss. While the DSR has an average data packet loss.

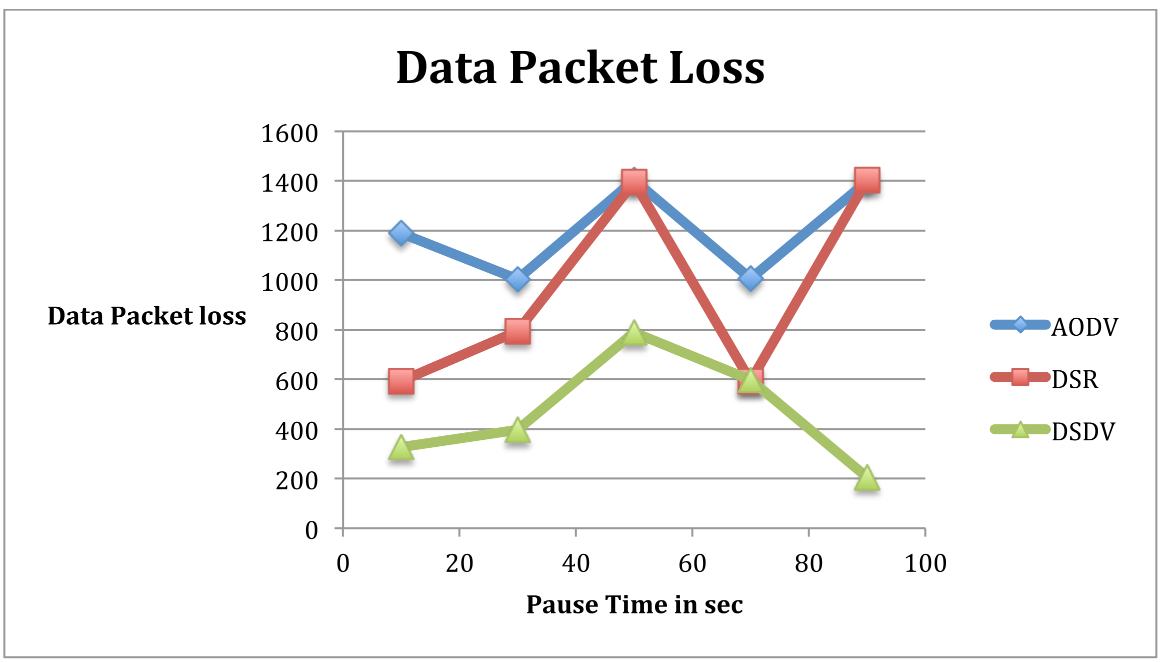

Figure 26. Data Packet Loss Vs. Pause Time.

From the pause time graphs, it indicates that DSDV could be the most suitable protocol in the case of a high amount of pauses. However, it was expected that AODV would outperform both DSR and DSDV. But it appears that AODV has the highest amount of data packet loss

4.3 Impact Of Mobility

In this section I will be generating scenario three as mentioned in chapter three. The implementation of AODV, DSR and DSDV has been studied with changing the speed time between 5 to 25 m/s for the different number of nodes 30, 90, and 150. So I examine the performance under different densities using TCP connection. I measured the packet delivery ratio, loss packet ratio and average end-to-end delay of AODV, DSDV and DSR and the simulated output has shown by using the following graphs.

Packet delivery ratio with 30 nodes graph indicates that AODV has higher delivery ratio than DSR as expected. Nonetheless when the speed increases the delivery ratio decreases but AODV still has a higher packet delivery ratio than DSR and DSDV, because when the speed increases, the DSR delivery significantly decreases.

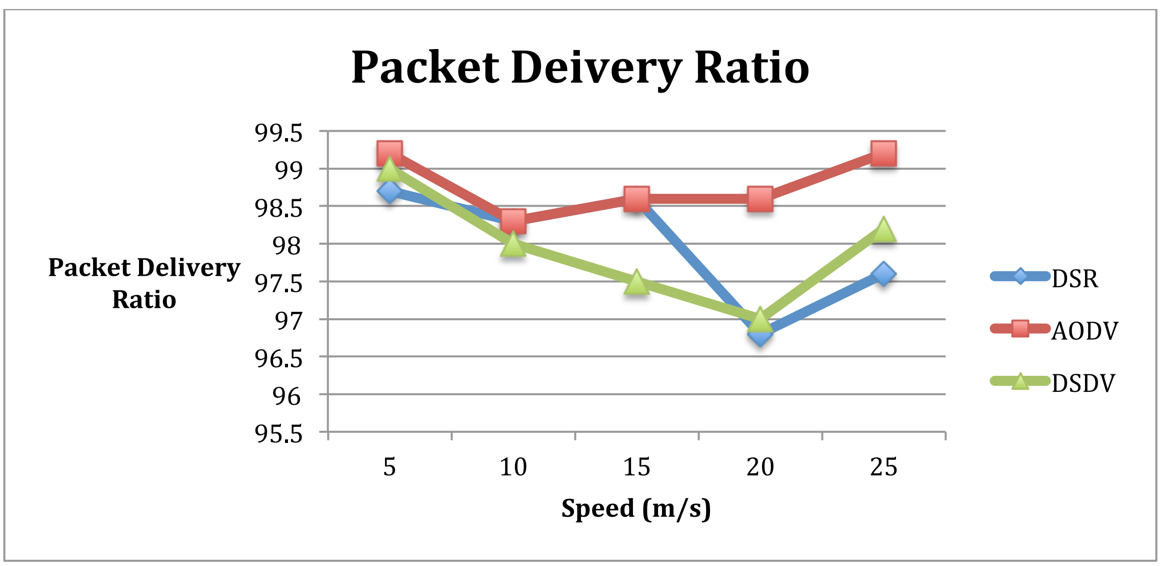

Figure 27. Packet Delivery Ratio With 30 Nodes.

Figure 28 Average End to End Delay with 30 nodes, graph indicates that AODV has lower average end-to-end delay with 30 nodes. Nonetheless when the speed increases the average end to end delay of the DSR and DSDV decreases but AODV still outperforms DSR and DSDV, since AODV still has lower average end to end delay.

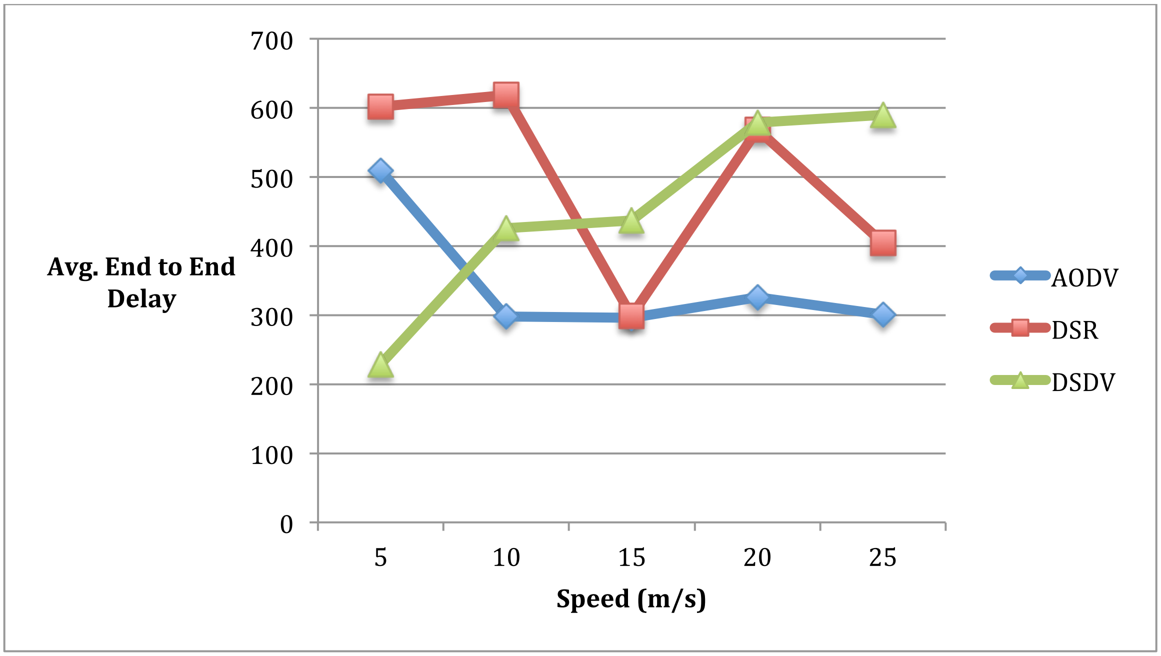

Figure 28. Average End To End Delay With 30 Nodes.

In Figure 29, the graph shows that the AODV has the highest loss packet ratio than DSR and DSDV. On the hand the DSR has a stable loss packet ratio as long as the speed increases. Therefore, DSR outperforms the AODV and DSDV in terms of Loss packet ratio.

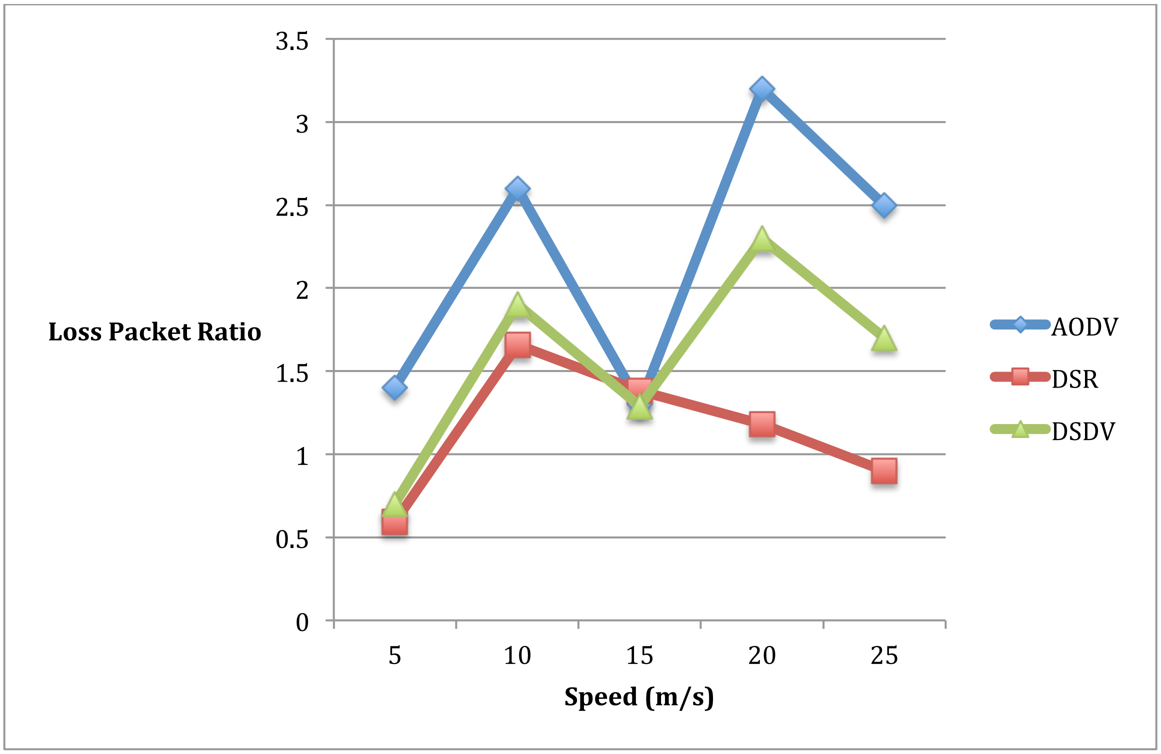

Figure 29. Loss Packet Ratio With 30 nodes.

The packet delivery ratio with 90 nodes graph indicates that DSR has the highest delivery ratio. However, when the speed increase the delivery ratio decreases, DSR still has the higher packet delivery ratio over AODV and DSDV, because when speed increases the AODV and DSDV delivery ratio significantly decreases. Therefore, DSR performs better than AODV and DSDV in a situation with a higher number of nodes. However, in the average end-to-end Delay with 90 nodes, AODV has less delay than AODV even with speed. On the other hand, regarding the loss packet ratio of the 90 nodes, the graph proves that AODV has less loss of packets than DSR. Though DSR outperforms AODV and DSDV in the packet ratio delivery AODV is better in an overall comparison.

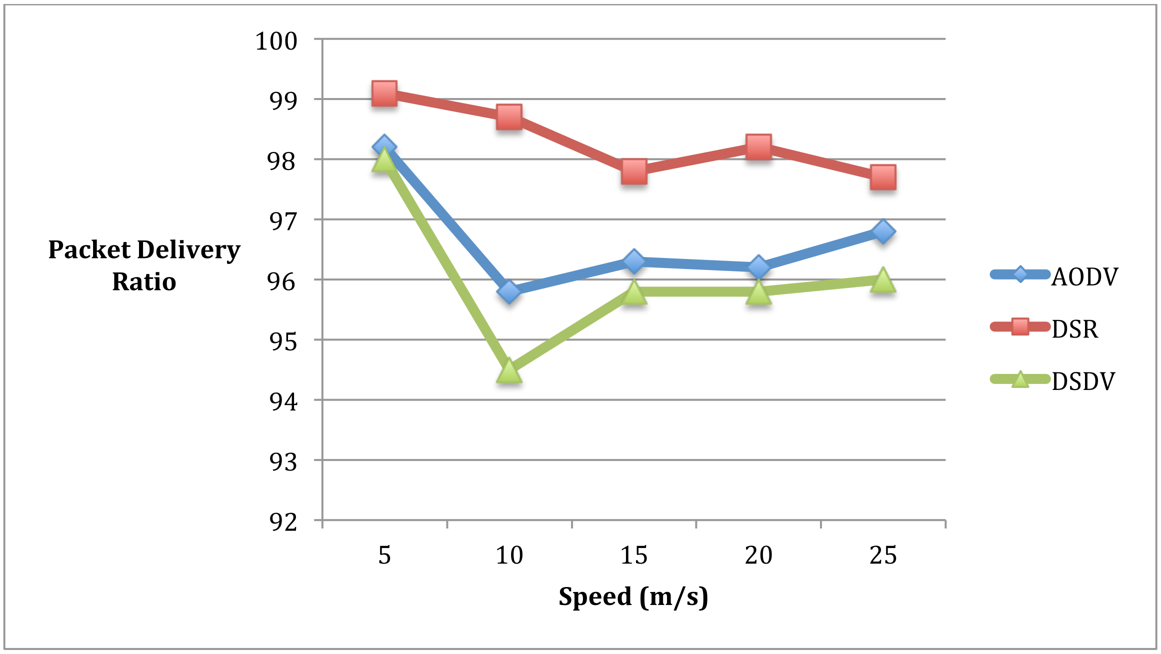

Figure 30. Packet Delivery Ratio With 90 Nodes.

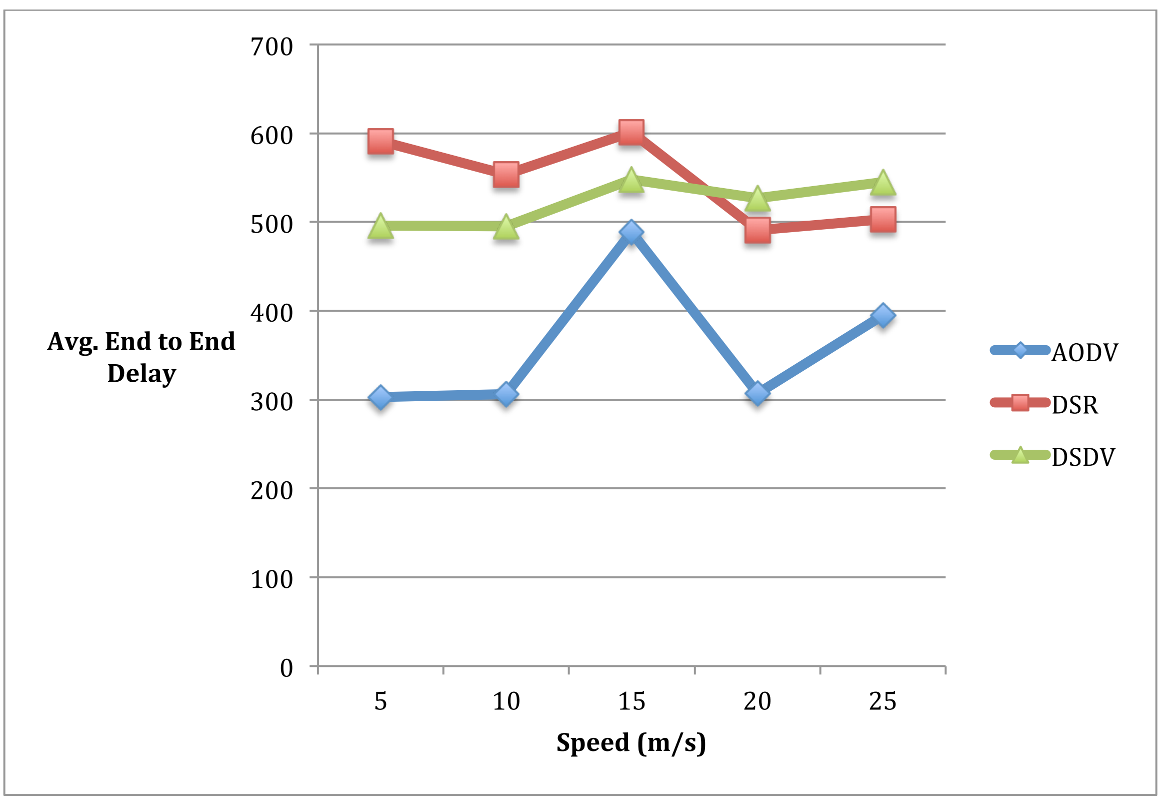

Figure 31. Average End To End Delay With 90 Nodes.

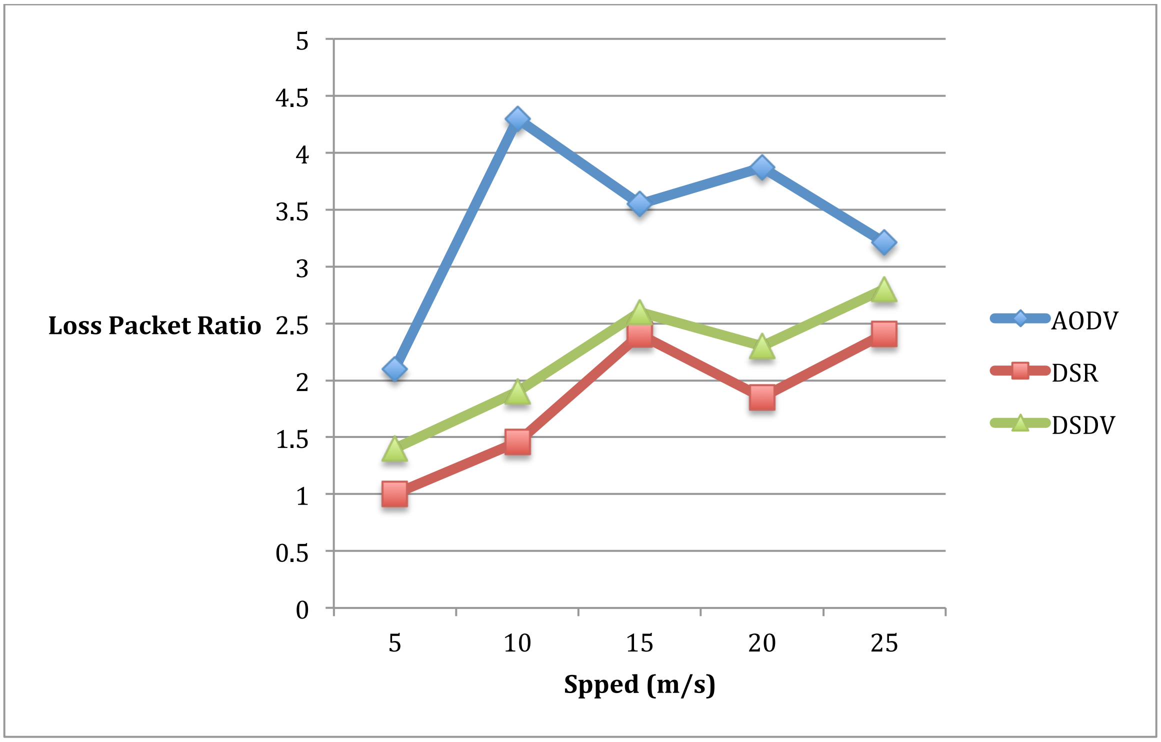

Figure 32. Loss Packet Ratio With 90 Nodes.

The packet delivery ratio with 150 nodes graph indicates that DSR has a higher delivery ratio than AODV and DSDV. However when the speed increases, the delivery ratio decreases, but DSR still has a higher packet delivery ratio than AODV and DSDV, because when speed increases the AODV, the DSDV delivery significantly decreases. Therefore, DSR perform better than AODV and DSDV in a situation with a higher number of nodes. However, looking at the average end-to-end Delay with 150 nodes, AODV has less delay than DSR even with various speeds. Regarding the loss packet ratio of the 150 nodes, the graph proves that DSR has less loss of packets than AODV and DSDV. Therefore, DSR outperforms AODV and DSDV in high density scenarios.

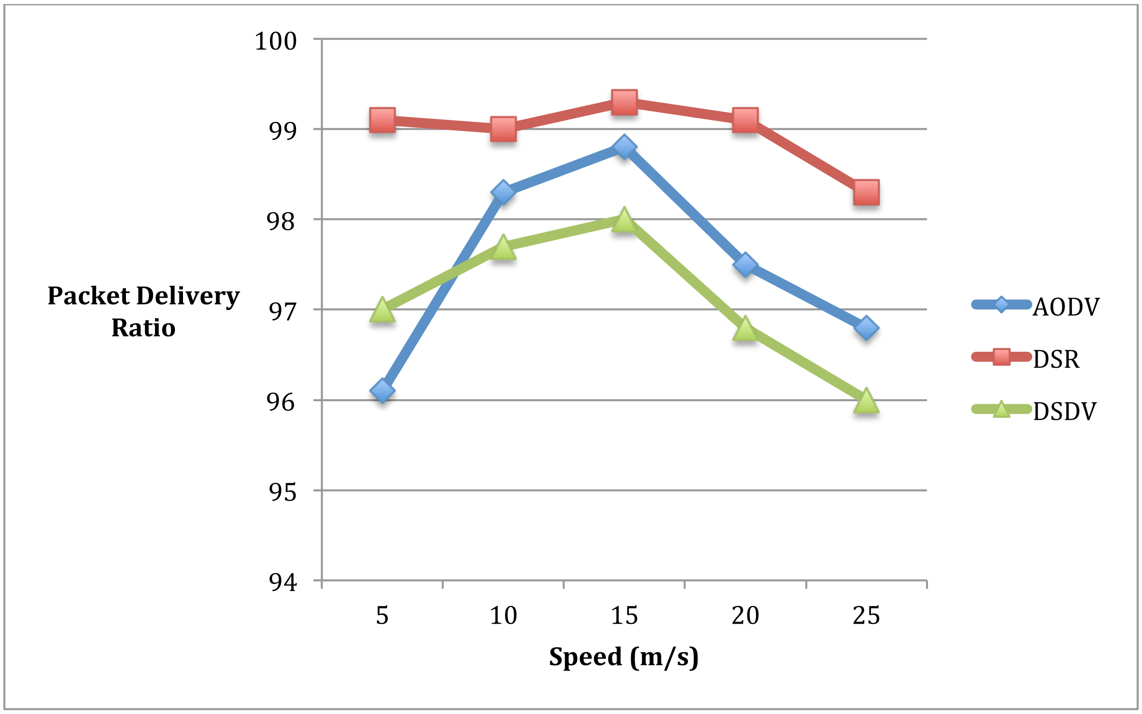

Figure 33. Packet Delivery Ratio With 150 Nodes.

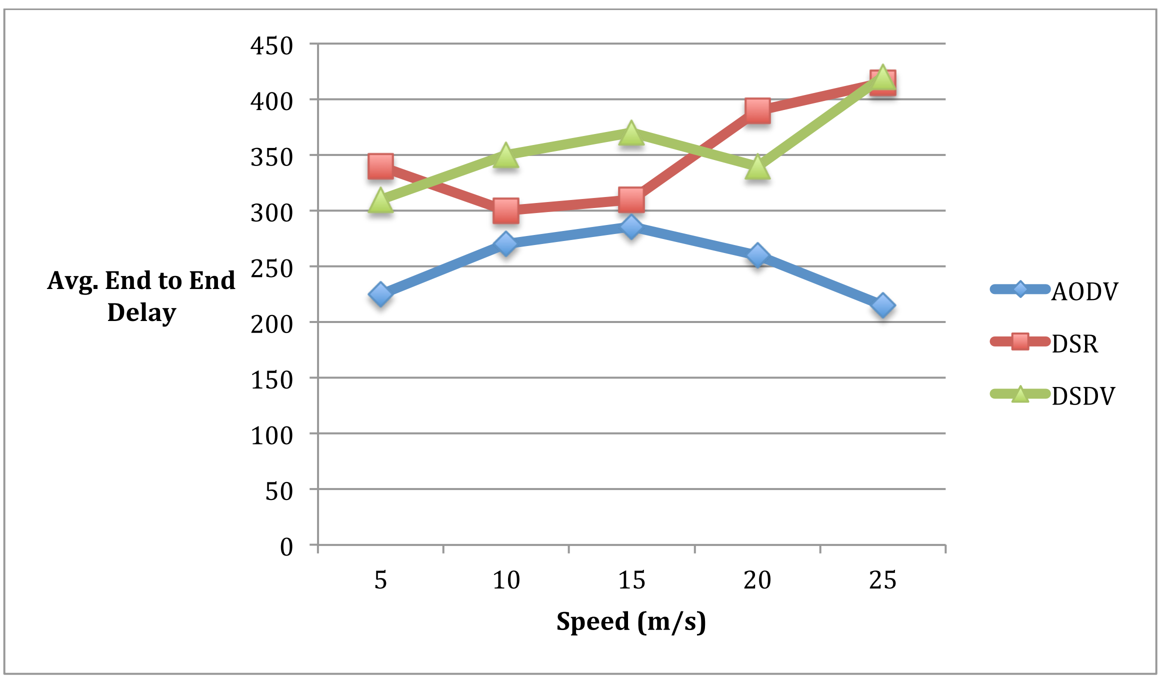

Figure 34. Average End-To-End Delay With 150 Nodes.

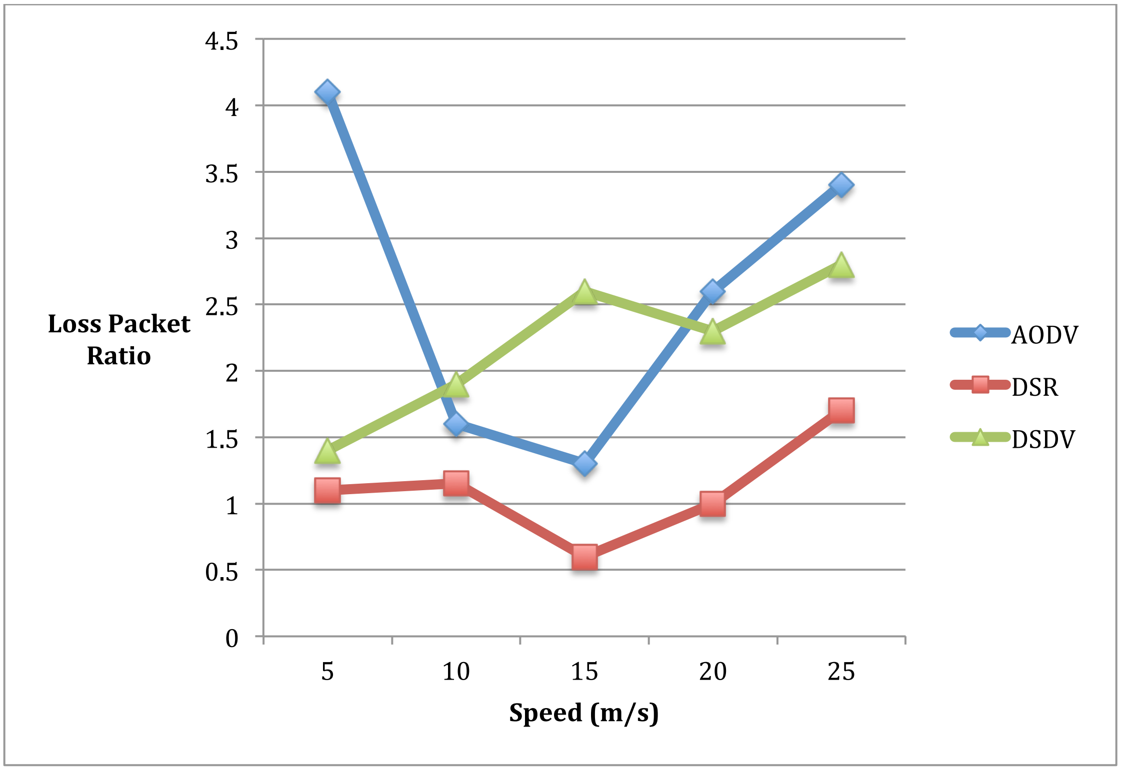

Figure 35. Loss Packet Ratio with 150 Nodes.

After studying and observing the simulation results, I concluded that when using the speed as my parameter in low mobility 30 nodes low speed, the packet delivery ratio for both protocols is high. In that scenario the average end to end delay is high, and the loss packet ratio is low for all protocols. While in low mobility and high speed, the packet delivery ratio for AODV is normal but high for DSR and DSDV. The end-to-end delay for all protocols is high. And the low packet ratio of AODV is average.

On the other hand, when using speed as a parameter in high mobility 150 nodes with low speed, packet delivery ratio of AODV is normal while it is high for DSR and DSDV. However, end-to-end delay for AODV, DSR is high. Low packet ratio is low for DSR but it is high for the AODV. Therefore, if the speed is high, AODV protocols implementation is normal while the DSR performs high. The end-to-end delay is high for both of the routing protocols. The low packet ratio of AODV is high but for DSR it is regular.

After analyzing the performance of three on routing protocols AODV, DSDV and DSR on the foundation of packet delivery ratio, average End-to-End delay and Loss packet ratio I can conclude that the performance of AODV outperforms DSR and DSDV.

4.4 Impact Of Node Distribution

The impact of node distribution is different from number of nodes. Meaning that both networks can have 200 nodes like in my simulation, but the distribution between the nodes will be different. There are two kinds of distributions (i) even distribution, where the distance between the nodes initial location is roughly equal and (ii) uneven distribution which means some nodes are very close to each other, and some are far apart. In VANET, it is important since an unevenly distributed network should have more link break.

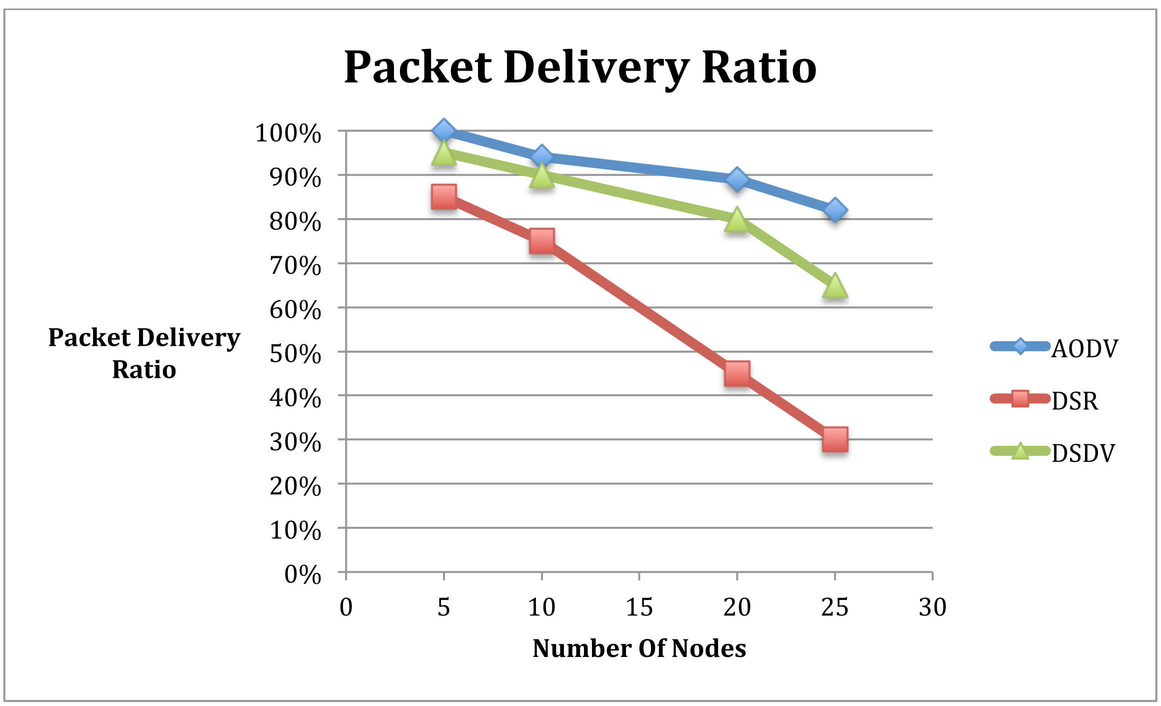

Figure 36. Even Distribution Packet Delivery Ratio.

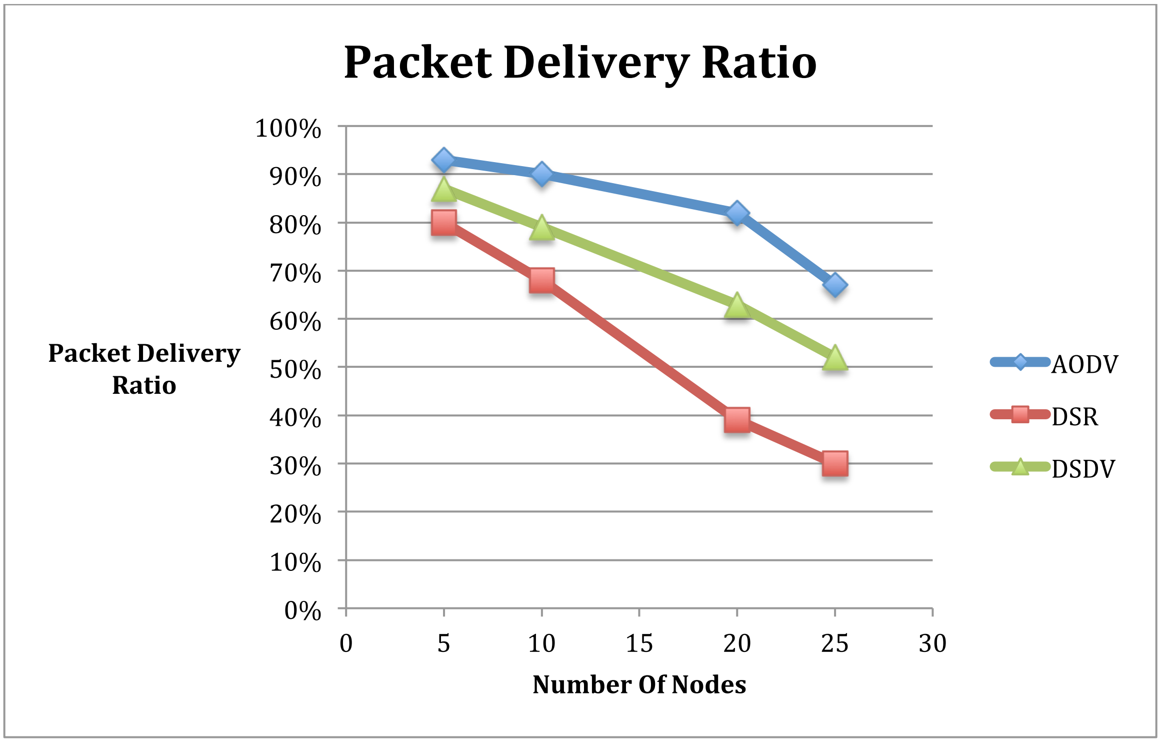

Figure 37. Uneven Distribution Packet Delivery Ratio.

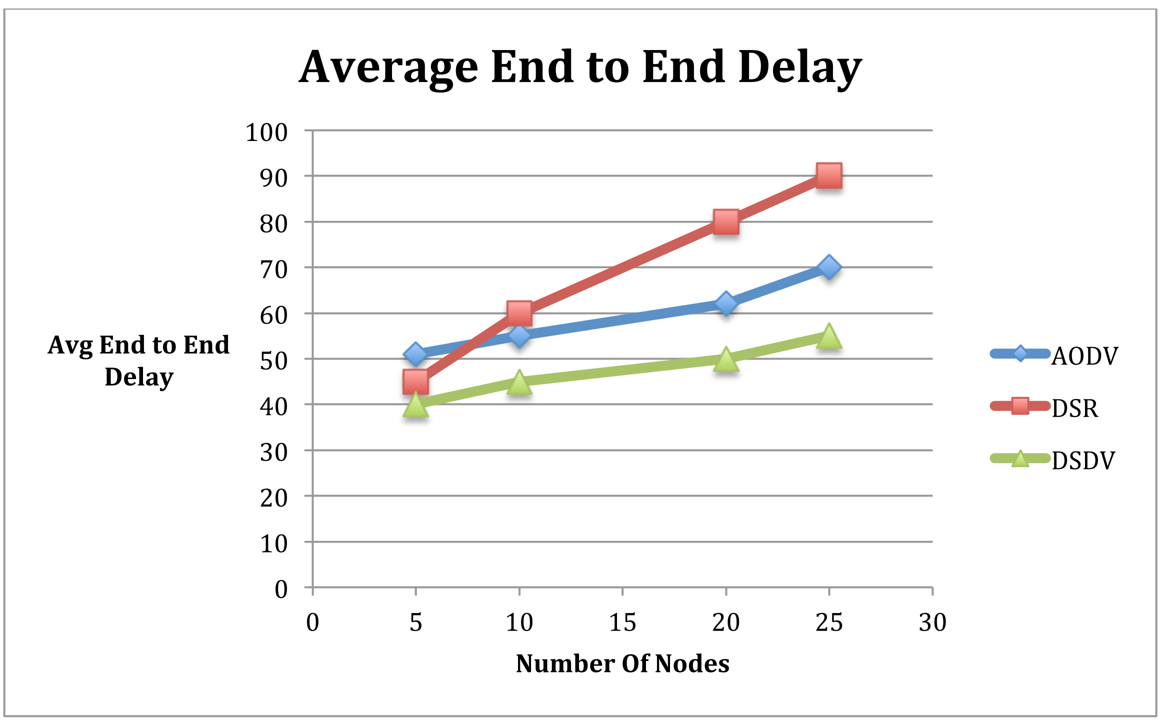

Figure 38. Even Distribution Average End To End Delay.

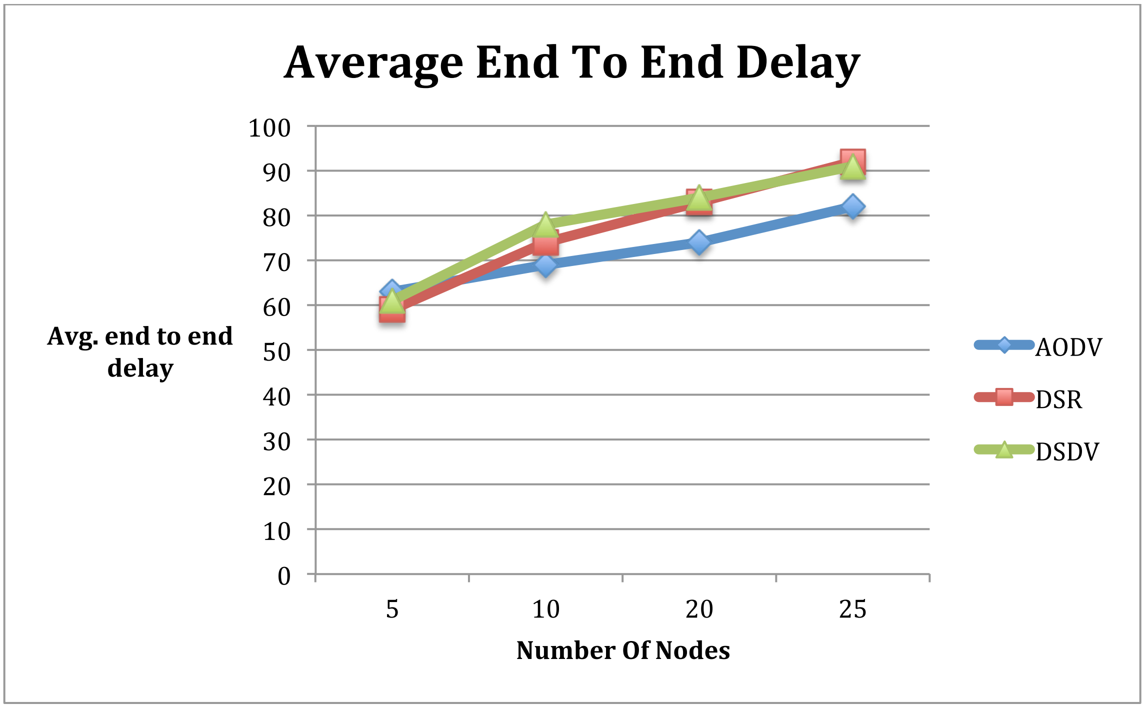

Figure 39. Uneven Distribution Average End To End Delay.

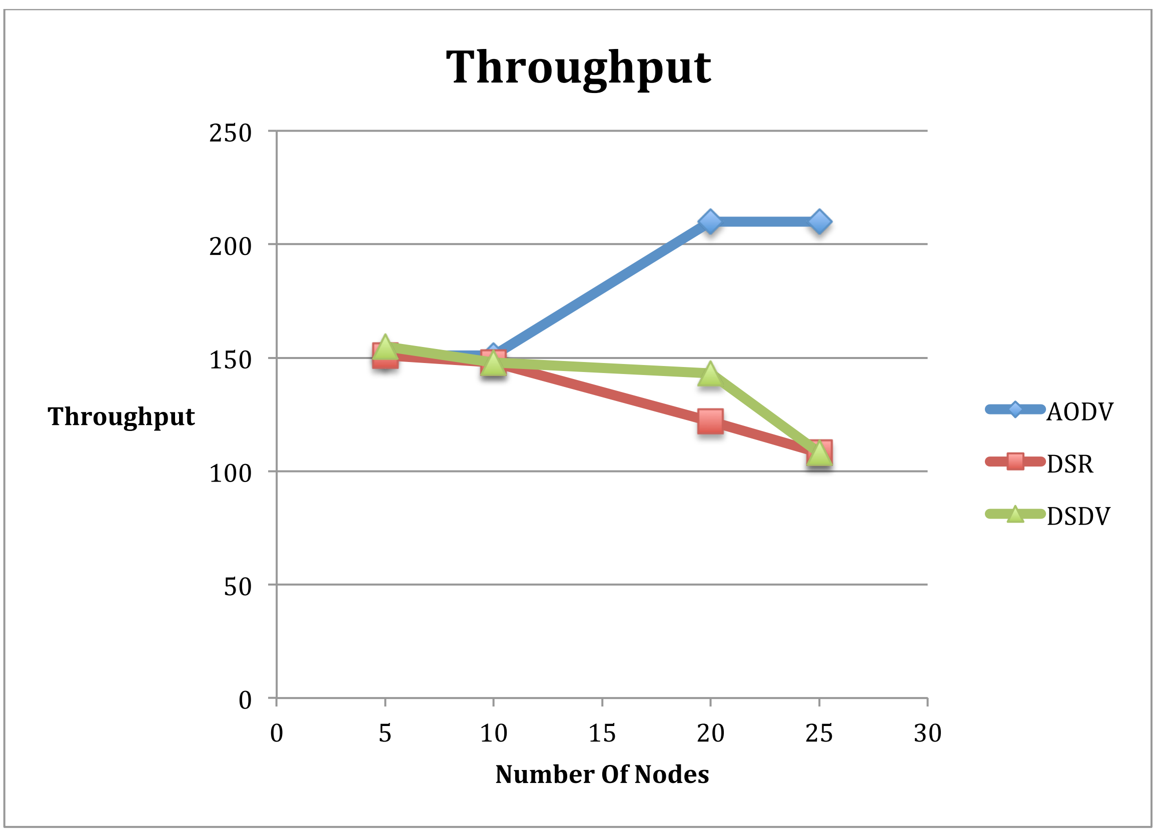

Figure 40. Even Distribution Throughput.

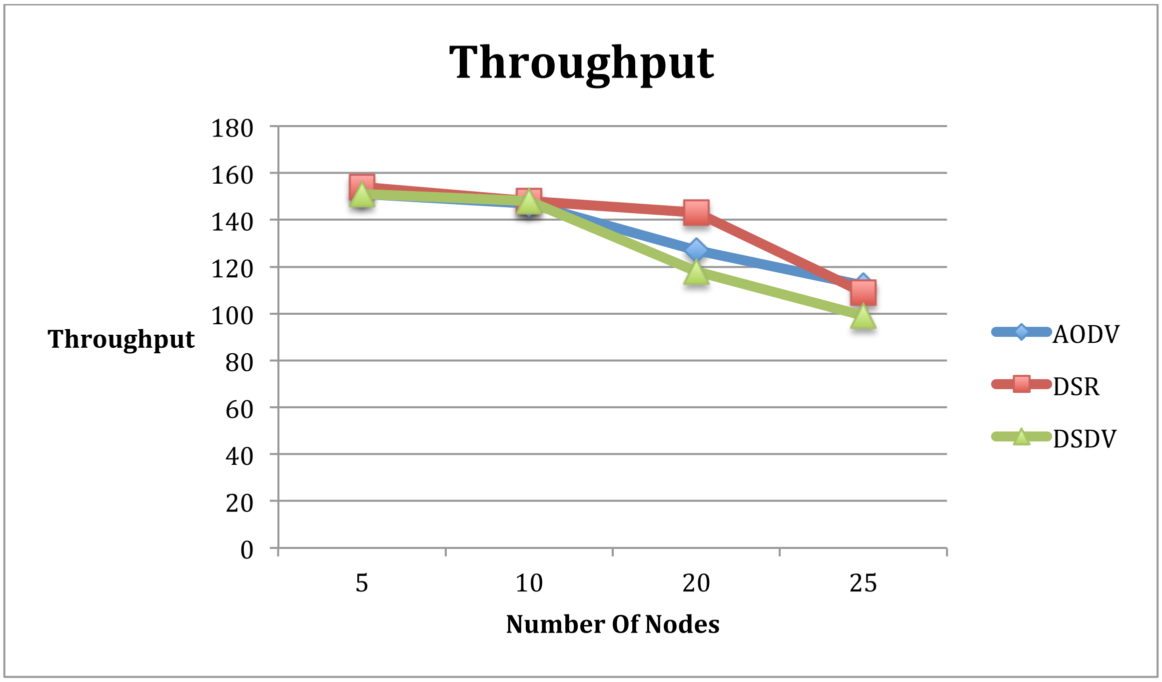

Figure 41. Uneven Distribution Throughput.

From graphs 36 -41, it is easy to observe that the protocols performance is much better in evenly distributed simulation, as anticipated. Looking at the AODV packet delivery ratio in evenly distributed simulation it is almost perfect but when it comes to the unevenly distribution the packet delivery ratio significantly decreased, while the same thing happened with the all the protocols and in different performance metrics. The reason I needed to simulate uneven distribution simulation is because in a realistic model, the nodes cannot be even; therefore uneven distribution was important.

In AODV packet loss always occurs because the link breakage or unavailable nodes. The error message will notify the source node about packet loss which may produce delay. While in DSDV, packet loss happens very rarely and when it happens; an error message is sent to all nodes in the network.

In DSDV, the throughput is less than the AODV due to higher mobility of the nodes and the nodes sometimes send their routing tables. On the other hand, the AODV doesn't need a routing path. Therefore, the throughput remains constant.

The main purpose of this simulation is to analyze the topology based routing protocols AODV, DSR, DSDV with different parameters in VANET. Since the nodes have a high mobility rate in VANET. The stability of the routes are unstable and sometimes break as well, and this depends on the road infrastructure. Therefore, realistic roads map are important so we can have realistic results as best as possible. I have used the MOVE and SUMO to create the network topology and then NS-2 to simulate AODV, DSR and DSDV routing protocols in real-time model. Comparing all the protocols under different parameters like speed and density, all lead to the same result where AODV outperforms both.

4.5 Discussion

The VANET system has been studied for its effectiveness, drawbacks and ways to overcome those drawbacks by various researchers. At the moment, there are still issues regarding the security of a transmission, the reliability of a link and the effectiveness thereof in transmitting data information. Currently, VANET systems can only be studied through simulation using software such as MOVE, since experimenting a VANET model in the physical world is costly and inefficient. Having said that, VANET remains attractive due to its minimal requirements, which can be implemented without the fuss of having to prepare dedicated infrastructures on the roadside to facilitate wireless communication.

Road safety and appropriate use is a concern in most parts of the globe. Several individuals lose their lives daily, monthly and annually in certain circumstances that can be avoided. The best way of avoided such deaths and injuries are ensuring the safety of road users and appropriate use of the roads. Designing and constructing reliable roads is an effective way of ensuring reduced accidents on roads. However, roads cannot be straight considering the nature of terrains across the globe. Curves and bends are some of the road features that have increased accidents in the recent past. Constructing such roads cannot be avoided. Drivers should be in a position to determine the characteristics of the road at different points to ensure that their safety and the safety of other users is protected. Empowering drivers with the ability to determine the characteristics of the road at different junctures is important in ensuring effective and appropriate use of roads. It also enhances safety and reduces the number of accident related deaths in the globe [22].

There are several individuals who speed unknowingly, leading to the loss of lives. Drivers require effective software that can notify them of their speed status and that of others on the road. It is easier colliding with a speeding driver than one who is taking a keen interest on his or her speed. Determination of other drivers' velocity and acceleration is also important in ensuring that respective drivers do not compromise the safety of other users on the road. Different steps have been taken to promoting road safety of all road users, but this has not been effective as the number of accidents is still high [35].

Communication with road users is also important. Through the establishment of an effective communication process with the users, it will be easy to determine the safety status. It will be easier as each driver will be in a position to communicate on their exact location and the status of safety in instances of accident or any road safety measure [9].

Nowadays, road accidents are a major problem globally. Road accidents are a result of poor communication between vehicles and understanding of the environment. VANET can effectively reduce road accidents by transforming communication between vehicles and making sure they are familiar with their surroundings. However, PASTA and a new MAC layer protocol that uses a conflict free TDMA can be implemented to get rid of path stability issues. Vehicles will be able to send packets continuously without path breaks, inconsistency and delays. Also, the solutions will reduce jitters and latency. Previously, the number of deaths on the road has been increasing because drivers are not in a position to determine several factors on the road. For instance, the characteristics of the road at different points, the acceleration and velocity of other vehicles on the road among others cannot be determined. This has led to increased accidents and collision on the road leading to increased accident related deaths.

CHAPTER 5

Conclusions and Future Work

5.1 Future Work

In future development, an individual can select an ideal path from source to the destination to minimize the risk of the accidents and also the communication time will be minimized. Moreover, continuing these studies towards the design of a VANET fit to the utilization of multimedia services with convincing requirements. The next step should be an analysis of the urban VANET and recognize challenges and offer solutions. However there is proposed VANET protocol PASTA (Path Stability protocol) from [32], which offers added advantage of working within the structure of MAC sub-layers. PASTA is a module in the MAC sub-layer protocol whose objective is to minimize the breaks in paths between the vehicles, which are within the cell. The results later showed that the PASTA protocol significantly reduces the latency of communication [32].

For the VANET system to function well, PASTA is used to broadcast inter-node communication. CTS or RTS are used to detect the next hop by transmitting packets from node to node [37]. The CTS or RTS mechanism is capable of forwarding the geographical messages without the tradition overhead required to keep track of the neighbor lists.

5.2 Conclusions

This thesis shows the evaluation study of routing protocols AODV, DSDV and DSR. In an overall evaluation of the three protocols AODV, DSR and DSDV, the simulation results proved that AODV outperform the performance of the DSR and DSDV using different speeds and different amount of nodes. Therefore, AODV is the most suitable for VANET.

Differences among reactive routing protocols themselves are definite due to the different approach of routing storage and preservation. Significant differences between DSDV routing protocol and other reactive routing protocol create this usual routing protocol highlighted. Large sums of packet loss in addition to a large number of fallen packets requires network to review on applying DSDV routing protocol on delay sensitive networks. Simulation of important major parameters Average End-to-End delay, Packet loss amount and Throughput for some reactive and proactive routing protocols in VANET results in some useful information. The simulation results proofs that though MANET routing protocols could be practical on VANET but the performance of both reactive and proactive routing protocols will decline and this makes using MANET routing protocols in vehicular ad hoc networks a major issue, which requires tangible improvements.

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