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Performance Evaluation of Routing Protocols in VANET System for Congestion Detection

A Research Submitted in Partial fulfillment for the Requirements of the Degree of B.Sc. (Honors) in Electronics Engineering

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قال تعالى :

" يرفع الله الذين آمنوا منكم و الذين أوتوا العلم درجات "

صدق الله العظيم

To Our beloved Mothers

ACKNOWLEDGMENT

First and Foremost, we have to thank our research supervisor **Mayada Abd-Algadir Mohammed**. Without her assistance and dedicated involvement in every step throughout the process, this research would have never been accomplished. We would like to thank you very much for your support and understanding over these past three years.

ABSTRACT

VANETs (Vehicular Ad-hoc Networks) are an emerging new technology which integrates the capabilities of new generation wireless networks to vehicles. It includes a variety of applications such as safety application, Mobility, Convenience and Internet Access Applications. Because of the high nodes mobility and unreliable channel conditions, VANETs have unique characteristics which pose many challenging research issues.

This work is mainly focused on routing protocol for VANETs. The main requirement of routing protocols is to achieve minimal communication time with minimum consumption of network resources. Many routing protocols have been developed for VANETs (Vehicular Ad-hoc Networks), such as AODV (Ad-hoc On demand Distance Vector) and DSDV (Destination Sequence Distance Vector). The main aim of this work is to evaluate two different routing protocols (AODV and DSDV) in terms of Packet Delivery Ratio (PDR), average Delay and throughput by using MOVE and SUMO to generate mobility model and NS-2 to evaluate these protocols. Simulation results showed that AODV is better for VANET system because in AODV there is no need to maintain route table, which results in less bandwidth consumption.

المستخلص

شبكات النمط الخاص للسيارات هي عبارة عن تقنية جديدة ناشئة تقوم بدمج قدرات الشبكات اللاسلكية للمركبات من الجيل الحديث. وهو يتضمن مجموعة متنوعة من التطبيقات مثل تطبيق السلامة والتنقل،تطبيقات الوصول إلى الإنترنت. شبكات النمط الخاص للسيارات لها خصائص فريدة من نوعها والتي حازت على اهتمام العلماء في الاونة الاخيرة.

ويركز هذا العمل أساسا على بروتوكولات التوجيه المستخدمة في شبكات النمط الخاص للسيارات. الغرض الرئيسي من بروتوكولات التوجيه هو تقليل الوقت المستهلك للتواصل و كذلك تقليل استهلاك موارد الشبكات. وقد وضعت العديد من بروتوكولات التوجيه لشبكات النمط الخاص للسيارات ، مثل بروتوكول متجه المسافة عند الطلب و برتوكول متجه المسافة حسب الوجهة. الهدف الرئيسي من هذا العمل هو تقييم اثنين من بروتوكولات التوجيه المختلفة (بروتوكول متجه المسافة عند الطلب و برتوكول متجه المسافة حسب الوجهة) من حيث نسبة تسليم الحزم، متوسط التأخير وكمية البيانات المرسلة باستخدام MOVE وSUMO لتوليد نموذج التنقل وNS-2 لتقييم هذه البروتوكولات. وأظهرت نتائج المحاكاة أن بروتوكول متجه المسافة عند الطلب هو الأفضل للنظام شبكات النمط الخاص للسيارات لأنه ليست هناك حاجة للحفاظ على جدول التوجيه، مما يؤدي إلى استهلاك أقل عرض النطاق الترددي.

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List of Abbreviations

ADAS	Advanced Driver Assistance Systems
ITS	Intelligent Transport System
VANETs	Vehicular Ad-hoc Networks
RSUs	Road Side Units
ECODE	Efficient COngestion DEtection
PDR	Packet Delivery Ratio
ADV	Advertisement Beacon Message
NT	Neighboring Table
V2V	Vehicle-to-Vehicle
V2I	Vehicle to Infrastructure
OBUs	On-Board Units
V2B	Vehicle to Base-Station Communication
QoS	Quality of Service
CSMA	Carrier Sense Multiple Access
CCC	Common Control Channel
DSRC	Dedicated Short Range Communication
ISM	Industrial-Scientific-Medical
WLAN	Wireless Local Area Network
CCK	Complementary Code Keying
MOVE	MObility model generator for VEhicular networks
GUI	Graphical User Interface
SUMO	Simulation of Urban Mobility
NS-2	Network Simulator 2
MAC	Medium Access Control
DCF	Distributed Coordination Function
SD	Saturated traffic Density
TD	Traffic Density
MAS	Maximum Allowable Speed
TS	Traffic Speed
V	Vehicle
Ttraff	Local Traffic Table

ET	Estimated traveling Time
Tid	Cluster Identifier
TTD	Cluster Traffic Density
TTS	Cluster Traffic Speed
TET	Cluster Estimated Time
TErep	Traffic Evaluation Report
TMR	Traffic Monitoring evaluation Report
DSDV	Destination Sequenced Distance Vector
AODV	Ad-Hoc on Demand Distance Vector
ZOR	Zone of Relevance
RREQ	Route REQuest message
RREP	Route REPly message
NAM	Network AniMator
TCL	Tool Command Language

Chapter One

Introduction

1.1 Introduction

Nowadays, the integration of cooperative functions is the main focus of advanced driver assistance systems (ADAS). Following the European policy for Intelligent Transport System (ITS), these cooperative functions aims to improve road safety, optimize the traffic and reduce the impact of transports on the environment. A key potential is the combination of local environment data (exchanged between neighbor vehicles or between vehicles and Road Side Units) and regional traffic data broadcast. In other words, the drivers can get detailed information from immediate surroundings and longer-term forecasts and alerts controlled from a central infrastructure [1,2]. Thus, Vehicular Ad-hoc Networks (VANETs) as part of ITS has become an attracted attention research area in order to achieve those main goals in Japan, EU and US. Recently, ITS have emerged as an efficient way to improve the performance of the flow of vehicles in the roads. The goals of ITS are road safety, comfortable driving and distribution of updated information about the roads [3]. Growing traffic on roads leads to unwarranted and unscheduled delays that have implications leading to loss of revenue and sometimes even loss of life. This consideration has led engineers putting in work in the recent past to detect traffic congestion and offer solutions that aim to reduce unwanted effects [4].

Automobile traffic and congestion detection are one of the major problems in modern societies especially in urban area. Millions of hours and gallons of fuel are wasted everyday by vehicles stuck in traffic as well as time. According to the Texas Traffic Institute, drivers in the US wasted around 6.9 billion hours of time, 3.1 billion gallons of fuel, and a total cost of 28 billion dollars in 2014 due to traffic delays [5]. Indeed, congestion detection is only one of many applications of VANETs and it is not designed to be used as means for automated driving but rather as a tool to deliver information to the driver that will help him/her make decisions to avoid heavy traffic. Developing a traffic congestion detection system will have tremendous impact on the economy, the environment and society in general allowing us to spend less time stuck in traffic and more time doing more productive and enjoyable activities. Vehicular Ad-hoc Network (VANET) has emerged as a possible solution to design a network system that can solve the problem of traffic congestion detection. Different protocols are proposed to assist drivers and passengers during their trips. Each traveling vehicles in VANET has a set of Road Side Units (RSUs) which installed over road networks to assist and communicate between different vehicles with addition of transceiver device [3,6]. Transceiver equipment's enable the communications between traveling vehicles (V2V), as well as the connecting between traveling vehicles and located RSUs (V2I) as shown in figure 1-1 [6].

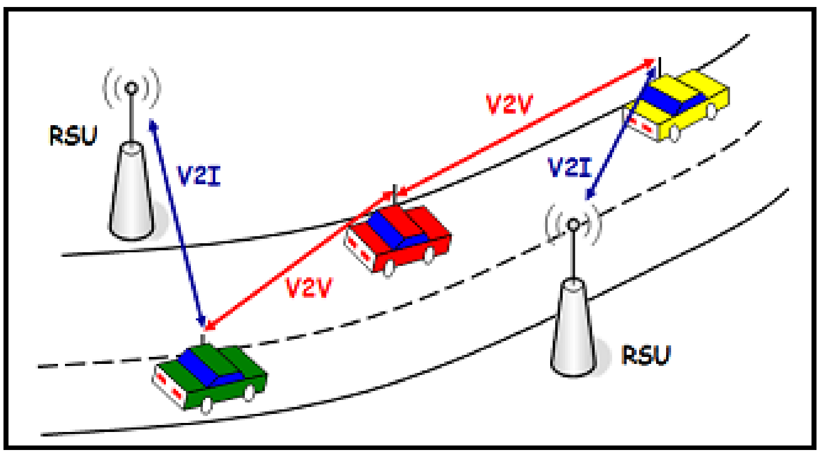


Figure 1-1: V2V and V2I Modes of Communications.

Indeed, mobility of VANET is very high as compared to other traditional ad-hoc networks. The node movement characteristics differentiate VANETs from other kinds of ad hoc networks. Therefore, the evaluation of an efficient routing protocol for VANETs is very crucial. The bandwidth resources are limited in VANETs and the topology of the network changes frequently. Hence, it is not necessary to maintain routes to each node. The dynamic change in topology shortens the effective time of routing. In addition, it reduces utilization rate of routing information [7]. Mobility models, or the movement patterns of nodes communicating wirelessly, play a vital role in the simulation-based evaluation of VANETs. Mobility models determine the location of nodes in the topology at any given instant, which strongly affects network connectivity and throughput.

1.2 Problem Statement

Vehicular Ad-hoc Networks (VANET) is one of the most challenging research area in automotive companies and ITS designers. The presence of such these networks opens the way for a wide range of applications such as safety applications, mobility and connectivity to exploit the transport systems in an efficiently and safer way. However, VANET system has dynamic and unexpected network topology due to the high speed of vehicles nodes and in addition frequent disconnections status. For safety applications such as congestion detection, which is a critical section from VANET, the best routing protocol must be selected. It is important to test and evaluate different routing protocols before apply them in the real environment which can be done via VANET simulation tools.

1.3 Proposed Solution

A realistic mobility and traffic network models have been proposed to evaluate the performance of different routing protocols for VANET using different road scenarios. Mobility models, or the movement patterns of nodes communicating wirelessly, play a vital role in the simulation-based evaluation of VANETs.

Mobility models determine the location of nodes in the topology at any given instant, which strongly affects network connectivity and throughput.

1.4 Aim and Objectives

This research aims to study and evaluate different routing protocols for VANET system in order to enhance traffic efficiency applications.

The three main objectives of this research are:

1. To study and compare between different routing protocols that are used in VANET systems.
2. To model mobility and traffic network models for VANET system using simulators tools (MOVE, SUMO and NS-2).
3. To evaluate the performance of different routing protocols for VANET system using different road scenarios.

1.5 Methodology

This research evaluates the performance of routing protocols in VANET system. In this work, urban mobility and network traffic models are simulated by using Simulation of Urban Mobility (SUMO) and MObility model generator for VEhicular networks (MOVE) as a VANET's mobility simulators with Network Simulator 2 (NS-2) software to introduce the network model. The system performance of simulation area is evaluated in terms of PDR, average throughput and delay. MOVE is implemented in Java and runs on top of an open-source micro-traffic simulator SUMO. As introduced in figure 1-2, MOVE consists of two main components Map Editor and Vehicle Movement Editor. The Map Editor is used to create the road topology manually, The Vehicle Movement Editor used to specify the trips of vehicles and the route that each vehicle will take for one particular trip manually. The information that used in Map Editor and the Vehicle Movement Editor fed into SUMO to generate mobility trace that can be immediately used by NS-2 version 2.35 to simulate real world vehicle movements. NS-2 used to evaluate the impact of mobility models generated by MOVE on VANET routing protocols (AODV and DSDV) in terms of PDR, average delay and throughput.

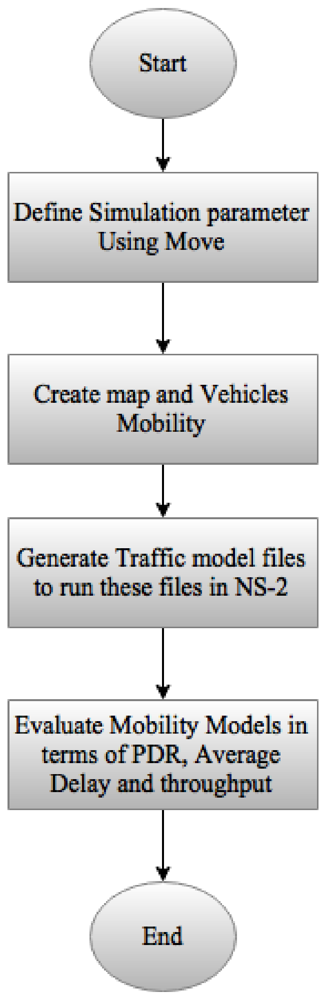


Figure 1-2: Simulation steps flow chart.

1.6 Thesis Outlines

The research consists of five chapters. Chapter 2 introduces the concept of VANET and applications of VANET, protocols and standards in VANETs, simulation of VANET. Chapter 3 summarizes the different routing protocols available in ad hoc networks emphasizing in AODV and DSDV, the used routing protocols in this research. Chapter 4 includes an overview of the simulation tools used in the research and the simulation process. In addition, it summarizes the results obtained after a whole simulation process. Chapter 5 outlines the main conclusions and gives recommendations for future work.

Chapter Two

Introduction to VANET Systems and Congestion Detection Application

2.1 Introduction

During the last decades, Intelligent Transportation System (ITS) has progressed at a rapid rate, which aims to improve transportation activities in terms of safety and efficiency as shown in figure 2-1. Car to Car or Vehicle-to-Vehicle (V2V) communications and Car/Vehicle-to Infrastructure (I2V or V2I) communications are important components of the ITS architecture. Communication between cars is often referred to Vehicular Ad-Hoc Networks (VANET) and it has many advantages such as reducing cars accidents, minimizing the traffic jam and reducing fuel consumption. VANET is one of the promising technology that uses moving cars as nodes in a network to transfer information between close cars and between cars and roadside units (RSU). The main goal for VANETs is providing comfort and safety for both passengers and drivers. VANETs turn every participating car into a wireless router, allowing cars to connect to each other and create a network with a wide range [8].

Indeed, VANET has emerged as a possible solution to design a network system that can solve the problem of traffic congestion detection. Several useful application protocols are be proposed to assist drivers and passengers during their trips. Each traveling vehicles in VANET has a set of Road Side Units (RSUs) which installed over road networks to assist and communicate between different vehicles with addition of transceiver device [1, 9]. Transceiver equipment's enable the communications between traveling vehicles (V2V), as well as the connecting between traveling vehicles and located RSUs (V2I).

The basic concept of the VANET is straight and simple; create a wide and cheap wireless technology to connect vehicles to each other and to RSU for sending and receiving the information. The nodes (Vehicles and RSU) in VANET system can move very fast, and the considered network has a highly dynamic topology. In which, this topology of the network is continuously changing with changing the position of the nodes and density. In summary, VANET is one of the wireless technology to communicate between different vehicles and in addition with Road Side Units (RSUs) [8].

Though VANETs could be treated as a subgroup of MANETs and a component of ITS systems, it is still necessary to consider VANETs as a distinct research field, especially in the light of security provisioning. VANET system introduces some unique characteristics as the following:

1. **High Mobility:** The nodes (vehicle) in VANETs usually are moving at high speed. The node motion is constrained by the road topology and layout.
2. **Rapidly Changing Network Topology:** Due to high node mobility, the network topology in VANETs tends to change frequently.
3. **Unbounded Network Size:** VANETs could involve the vehicles in one city, several cities, or even a country. Therefore, the VANETs network should not be dependent on the number of the nodes [1].
4. **Low Communication Latency:** Latency is very critical for the broadcasted messages especially in an emergency case [8].
5. **Power Saving:** The battery life is not a problem in OBU since they are normally powered by the vehicle battery and their power consumption is significantly lower than the vehicle own equipment. Therefore, there is no substantial design challenge when it comes to power consumption [8].

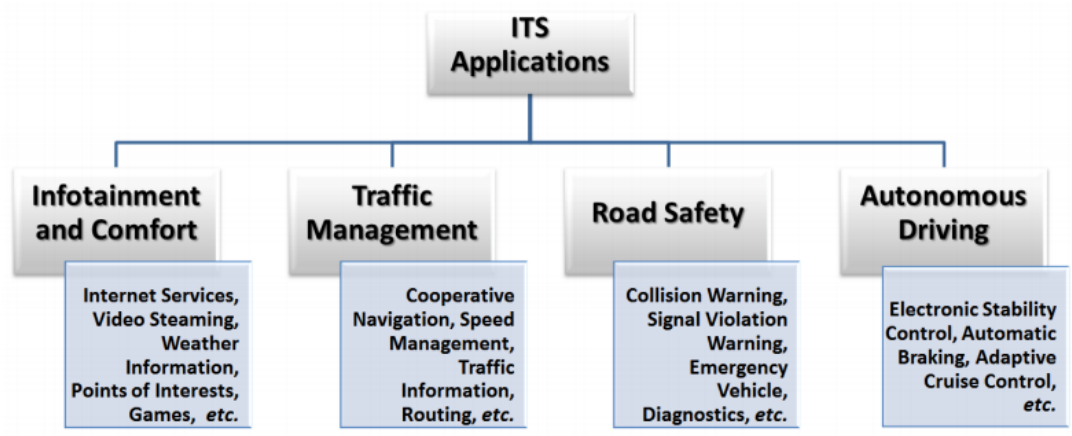


Figure 2-1: Classifications of ITS Applications.

2.2 Applications of VANETs

The Road Side Unit (RSU) can be treated as an access point or router or even a buffer point which can store data and provide data when needed. All data on the RSUs are uploaded or downloaded by vehicles for various applications. The classifications of applications are introduced in figure 2-2 is also done as Car to Car Traffic applications, Car to Infrastructure applications, Car to Home applications and Routing based applications. Applications are divided different groups starting from Soft and Hard Safety applications, Internet Access, Convenience applications and Mobility [10].

2.2.1 Hard Safety Applications

Hard safety applications aim to avoid imminent crashes and minimize the damage when these crashes become unavoidable. These applications impose the most stringent requirements on the communication system to reduce communication latency in order to offer the driver sufficient time to take action. The communication system must provide high levels of reliability such as high message reception probabilities [10].

2.2.2 Soft Safety Applications

Soft safety applications are less time-critical. These applications increase driver safety but do not require immediate driver reaction, because the hazards are not imminent. Examples include warning the driver of weather, road, traffic, icy roads, construction zones, reduced visibility, pot holes, and traffic jams. Typical actions in response to soft safety application alerts would be to proceed with caution or take alternate routes to avoid the dangerous conditions ahead [10].

2.2.3 Mobility, Convenience and Internet Access Applications

Mobility applications focus on improving traffic flow. Examples include navigation, road guidance, traffic information services, traffic assistance, and traffic coordination. Convenience and Internet Access Applications focus on making driving more enjoyable, providing greater convenience to the driver and passengers and different internet services. These applications include point-of-interest notification, email, social networking, media download, and applications update.

Mobility and Convenience applications can be delivered to drivers and passengers through consumer electronic devices such as smart phones and other portable electronic devices, which drivers and passengers routinely bring into their vehicles. Also these applications can tolerate even longer communication delays than soft safety application. However, some mobility and convenience applications that download large files to vehicles will demand high communication bandwidths [10].

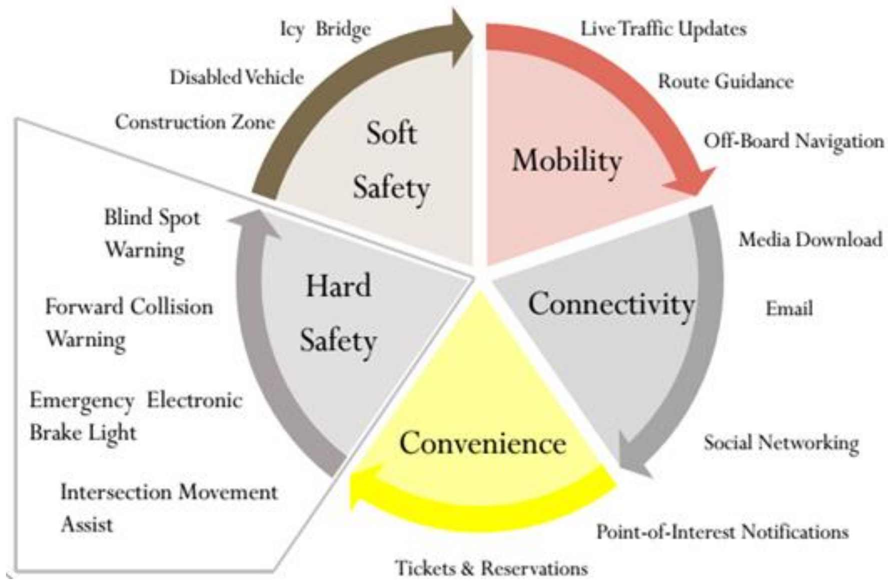


Figure 2-2: VANET Applications.

2.3 VANETs Communication Techniques

As shown in Figure 2-3 VANET communication technique can be classified into Vehicle-to-Vehicle communication (V2V), Vehicle-to-Infrastructure Communication (V2I) and Vehicle to Base-Station Communication (V2B). Firstly, the V2V communication configuration uses multi-hop multicast/broadcast to transmit traffic related information over multiple hops to a group of receivers.V2V communications have the following advantages:

1. Allow short and medium range communications.
2. Support short messages delivery.
3. Minimize latency in the communication link [11].

On the other hand, the V2I communication configuration represents a single hop broadcast where the roadside unit sends a broadcast message to all equipped vehicles in the vicinity .V2I communication configuration provides a high bandwidth link between vehicles and roadside units. The Infrastructure may be placed every kilometer or less, enabling high data rates to be maintained in heavy traffic [11].

Finally, Infrastructure-to-infrastructure communication is the wireless exchange of data between the two base stations. The base station will collect data from vehicle and processing will be done [12].

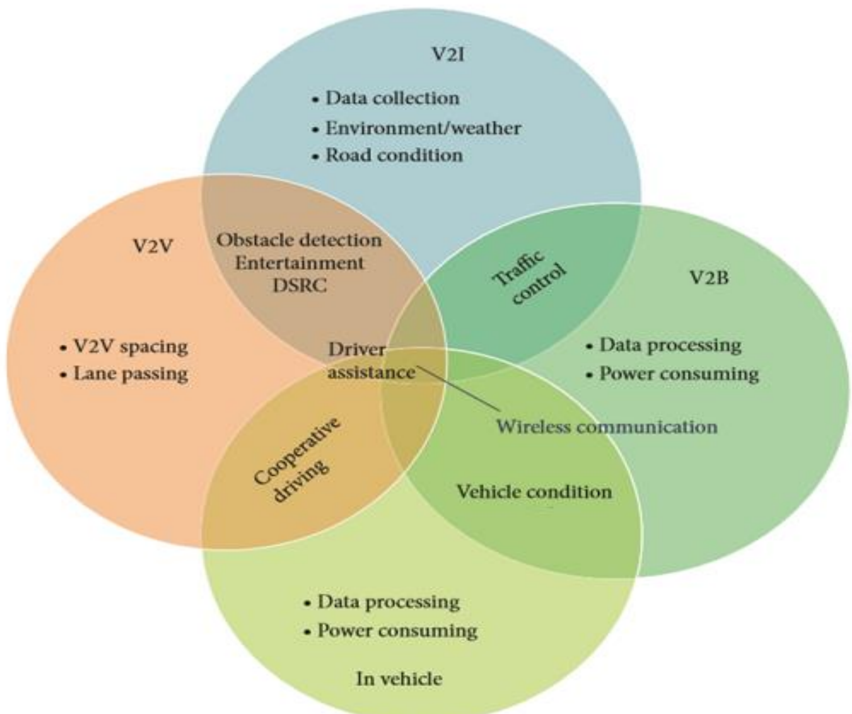


Figure 2-3: Key Functions of each Communication Type.

2.4 VANET Challenges

VANET has been one of the active field of research and development for many years but it is fair to say that, with the recent dramatic improvements in communication and computing technologies. It is only in the last decade that this field has really gained a lot of momentum. In fact, VANET research has attracted a lot of attention from researchers working in various fields including electronics, networking, security, software engineering, automotive, transportation, and so on. Recent results covering VANET-related issues include areas such as routing, Quality Service (QoS), broadcasting, security attacks and threats, capacity, collision and interference, the effects of transmission power on protocol performance and power control algorithms, congestion control, and service discovery [13].

2.4.1 Mobility and Dynamic Network Topology

High mobility (for instance, 100 to 200 km/h) of vehicles makes the topology of VANETs very dynamic resulting in very short lived vehicular communication links. Additionally, vehicular density keeps varying from sparse to dense, and high mobility in sparse areas may cause fragmentation problem for VANET, which, in turn, will result in network unreachability for some nodes. Further, high speeds can deteriorate signal due to Doppler and fast fading. These factors can degrade the performance of applications that have Quality Of Service (QoS) requirements in terms of high reliability, low latency, etc [13].

2.4.2 Distributed Ad-hoc Coordination and One-channel vs. Multiple-channel Paradigm

In V2I communications, the fixed roadside units can serve as coordinators. However, V2V communications are expected to be self-organizing and to function with or without roadside assisting units. Argument of one-channel paradigm, with a single shared control channel, is a good solution for V2V communications in the absence of central coordination, considering that various applications will be broadcasting messages to many neighboring vehicles. However, one channel paradigm comes with the problem of hidden terminal and poses difficult requirements on the design of MAC protocol for V2V communications. Though IEEE 802.11 carrier sense multiple access (CSMA)-based MAC is good for V2V communications, its performance degrades in the presence of high number of users [13].

Moreover, in case of a larger number of vehicles, the dissemination protocols could lead to a larger overhead. Additionally, a high data traffic density may lead to channel congestion, e.g., in case of an accident and consequent outburst of messages. Multiple-channel paradigm can be a potential solution for such scenarios where instant sharing of message is required between vehicles and thereby reducing congestion on Common Control Channels (CCC). Currently, the approach that is in use is to let all vehicles synchronize to a global time reference and alternate between a common control channel and separate service channels every 100 ms. However, this approach is not efficient [13].

2.4.3 Routing Issues

Conventional routing protocols are not suitable for VANETs due to their specific network characteristics, e.g., varying network topology and frequent disconnections. Some of the VANETs' routing algorithms can be categorized as opportunistic forwarding, trajectory-based forwarding, and geographic forwarding. Opportunistic forwarding algorithms (carrying and forwarding a message whenever given the opportunity) are useful in scenarios with frequent disconnections and can be combined with other approaches that use trajectory-based or geographic forwarding. Geographic forwarding algorithms forward packets towards the destination as a function of its geographical location. This routing approach is scalable but not efficient for handling dead ends and voids. Trajectory routing can be the most suitable message forwarding algorithm for

VANETs as it considers the road infrastructure as an overlay directed graph, with intersections as graph nodes and roads as graph edges allowing messages to move in predefined trajectories. Moreover, some recent opportunistic approaches for delay-tolerant applications exploit social networking analyses to forward packets. The idea with social-based forwarding is to forward a packet to a node which has a high chance of meeting the destination node in near future [13].

2.4.4 Privacy, Security and Safety

Privacy and security issues are highly important in VANETs due to potential threats to traffic flow and human lives by any malicious attempt, for example, fake messages leading to traffic disruption and fatal accidents. Security protocols for vehicular networks should take into account their specific characteristics such as high mobility and requirements such as trust (vehicles should be able to trust the received messages), resiliency (for interference), and efficiency (e.g., ability to authenticate message in real time). In addition, privacy concerns include preserving anonymity to prevent tracking or identification of vehicle for non-trusted parties based on vehicular communication. Nevertheless, such security mechanisms generally come at the cost of degraded communication performance [13].

2.5 VANET Standards

As it is known, VANETs use broadcasting for communication. This means that, each vehicle will transmit several messages and these messages can be received by several neighbors' vehicles, and in addition neighbors RSUs. There is no communication coordinator in the VANET architecture and this is the main challenge of VANET. In the VANET one control channel (shared) is needed even if several channel would be available using several transmitter and receiver. Requirement for distributed control channel and mentioned One-Channel are the key challenge of designs for VANETS. The design for MAC is the main and most important issue in the VANET as shown in table 2-1[14].

2.5.1 Dedicated Short Range Communication (DSRC)

DSRC is the recent technological trends to provide real time traffic information for effective implementation of ITS. Thus, in the following subsection the new technologies of DSRC for vehicular networks are introduced**.** DSRC is a short to medium range wireless protocol specifically designed for automotive use. It supports both public safety and private operations for V2V and V2I communication environments. DSRC is a complement to cellular communications by providing very high data transfer rates in circumstances where minimizing latency in the communication link and isolating relatively small Dedicated Short Range Communications DSRC is a short to medium range wireless protocol specifically designed for automotive use. It supports both public safety and private operations for V2V and V2I communication environments. DSRC is a complement to cellular communications by providing very high data transfer rates in circumstances where minimizing latency in the communication link and isolating relatively small communication zones are important. This technology for ITS applications is working in the 5.9 GHz band (the U.S.) or 5.8 GHz band in Japan and Europe [14].

2.5.2 Bluetooth

Bluetooth is a wireless network commonly deployed in automobiles. It is a relatively low-power, short range wireless network that operates in the (2.40 – 2.48) GHz Industrial-Scientific-Medical (ISM) band. This is the same unregulated frequency band occupied by WiFi networks, microwave ovens, and a variety of other ISM devices. To minimize interference, Bluetooth networks divide the band into 791-MHz channels and Bluetooth communication hops between channels. In this way narrow band interference that blocks only a few channels does not have a significant overall impact on communications. Of course, broadband or even out-of-band noise can disrupt Bluetooth networks if the power levels are sufficient. Automobiles must also co-exist with other wireless transmitters and receivers such as cell phones, WiMax devices, satellite communications devices and Dedicated Short Range Communications (DSRC) equipment. Unfortunately, current international EMC test standards do not adequately address potential interference problems with these devices. The technology has advanced faster than the standards organizations can react. Some manufacturers have developed their own tests and others test the vehicle by simply installing representative equipment and driving around. Fortunately, the transmitted power levels from most of these devices are relatively low. In addition, the electromagnetic immunity is enhanced by the fact that the newer wireless communication technologies tend to be either spread spectrum or very narrow-band. Spread spectrum communication networks (like Bluetooth) shift in both time and frequency making them relatively immune to narrow-band interference, while narrow-band communication is relatively insensitive to interference occurring at frequencies other than the operating frequency. Nevertheless, as the number of interference sources in an automobile rises, the signal-to-noise ratio (and the range) of spread spectrum devices degrades and the probability of interfering with a narrow band transmission increases. New test procedures and design practices will be required to insure that future automobiles are electromagnetically compatible with an increasingly wide variety of wireless devices [14].

2.5.3 Wi-Fi

IEEE 802.11 (Wi-Fi is in current usage) is a set of standards for wireless local area network (WLAN) computer communication, developed by the IEEE LAN/MAN Standards Committee (IEEE 802) in the 2.4 GHz, 5 GHz and public spectrum bands. It includes IEEE 802.11b/g standards in the 2.4 GHz band and IEEE 802.11a in the 5 GHz band. IEEE 802.11b is a based on the direct-sequence spread spectrum modulation technique. Technically, IEEE 802.11b applies Complementary code keying (CCK) as its modulation technique. As it uses the CSMA/CA media access method, the maximum IEEE 802.11b throughput that an application can achieve is about 5.9 Mbit/s using TCP (7.1 Mbit/s using UDP). Then, the IEEE 802.11g was the third modulation standard for Wireless LAN. The modulation scheme used in 802.11g is OFDM. Like IEEE 802.11b it works in the 2.4 GHz band but operates at a maximum raw data rate of 54 Mbit/s (19 Mbit/s net throughputs). 802.11g hardware is fully backwards compatible 802.11b hardware. For the two standards, two network topologies are available namely ad-hoc or infrastructure. A wireless ad hoc network is a decentralized wireless network where each node is willing to forward data for other nodes, and so the determination of which nodes forward data is made dynamically based on the network connectivity. On the other hand, in the infrastructure. network, a wireless access point connects wireless communication devices together to form a wireless network .Data rate measurements have been carried out between two ECU/modems according to the engine and equipment’s states using the infrastructure configuration. As for Bluetooth, IEEE 802.11 b/g can be proposed as a potential wireless solution. However, there are not a lot of experimentations of 802.11 b/g in vehicles. Besides, IEEE 802.11 b/g devices suffer interference from other products operating in the 2.4 GHz. When 802.11b/g is used in a point-tomultipoint configuration, the overall bandwidth is dynamically demand shared across all the users on a channel. Thus, real time is no more guaranteed [14].

Table 2-1: VANET Protocols and Standards [14].

	DSRC	Bluetooth	WIFI
Standard/ Technology	A short to medium range communications	First launched (1998)	New Wi-Fi technology with MIMO standard in2009,802.11n standard in 2009
Coverage	1000m	1meter, 10meters, 100 meters	500m
Bit Rate	6 to 27 Mbps	3 Mbit/s (Version 2.0 +EDR) 53-480 Mbps (WI Media Alliance)	600 Mbps using MIMO

2.6 VANET Simulators

Simulation of VANETs networks are divided into two different parts. Firstly, the issues which are should be considered about the vehicles communication. For this part, the network simulators are used and these network simulators are consider network protocols and focused on communication parts. Another aspect, which should be considered, is the pattern for movement of vehicles in the VANETs that is very important and essential. For this part, traffic simulators are mostly used to provide realistic traffic pattern and vehicles movement [8].

Traffic models are categorized into Macroscopic, Microscopic, The basic entity in the macroscopic model is the traffic flow and it is just modeled the traffic flow.

The movement of every single cars in the roads are simulated in the Microscopic models. This model mainly assume that the behavior of each cars are depend on the physical ability of vehicles and also controlling behavior of drivers [8].

2.6.1 Mobility Model Generator for Vehicular Networks (MOVE)

MOVE rapidly generates realistic mobility models for VANET simulations. MOVE is built on top of SUMO. The output of MOVE is a mobility trace file that contains information of realistic vehicle movements which can be immediately used by popular network simulation tools such as ns-2 or Qualnet. In addition, MOVE provides a Graphical User Interface (GUI) that allows the user to quickly generate realistic simulation scenarios without the hassle of writing simulation scripts as well as learning about the internal details of the simulator[15].

2.6.2 Simulation of Urban Mobility (SUMO)

SUMO is an open source, highly portable, microscopic road traffic simulation package designed to handle large road networks. Its main features include collision free vehicle movement, different vehicle types, single-vehicle routing, multi-lane streets with lane changing, junction-based right-of-way rules, hierarchy of junction types, an openGL graphical user interface (GUI), and dynamic routing. SUMO can manage large environments, i.e., 10 000 streets, and it can import many network formats such as Visum, Vissim, ArcView, or XMLDescriptions. Thus, by combining SUMO and openstreetmap.org, traffic in different locations of the globe is simulated [15].

2.6.3 Network Simulator (NS-2)

NS-2 is a discrete event simulator developed by the VINT project research group at the University of California at Berkeley. The Monarch research group at Carnegie Mellon University to include extended the simulator:

1. Node mobility.
2. A realistic physical layer with a radio propagation model.
3. Radio network interfaces.
4. The IEEE 802.11 Medium Access Control (MAC) protocol using the distributed coordination function (DCF).

However, the ns-2 distribution code had some significant shortcomings both in the overall architecture and in the modeling details of the IEEE 802.11 MAC and PHY modules [15].

2.7 Traffic Congestion Detection Application

Traffic congestion has been studied extensively in traffic flow theory for various reasons such as road capacity planning, estimating average commute times etc. Congestion information can be useful for many VANET applications also, such as for route planning or traffic advisories. Typically, congestion information is collected as the number of vehicles passing a point per unit time by some roadside equipment, and transmitted to other places for broadcasting to vehicles. However, in the absence of such roadside infrastructure, congestion information is not available. Moreover, the congestion information is usually available only at a single macroscopic level for all vehicles, and is not customized for the requirements of each vehicle [16].

2.8 Measures of Congestion

Two types of congestion around a vehicle that are of primary relevance to VANET applications are identified as the following [16].

2.8.1 Instantaneous Congestion

This gives the instantaneous picture of the traffic in the vicinity of a vehicle at any instant, measured as the set of vehicles in the communication range of at that instant [16].

2.8.2 Stabilized Local Congestion

This is measured as the set of neighboring vehicles of a vehicle *u*, which have been stable members of the instantaneous congestion for a certain amount of time. The two congestion measures are relevant in different applications. Short-term applications, such as information broadcasting may employ instantaneous congestion [16].

2.9 Need for Congestion Control

Traffic congestion is one of the crucial and critical problem for urban areas. Figure 2-4 gives an idea about traffic jam. Situations are worse than shown in the figure 2-4. It starts due to several reasons such as driver's misbehavior, accident on the road, obstacle on the road, weather conditions etc. Above scene shows congestion occurred due to accident. Result of this is, vehicles are either standstill or moving with very low speed resulting in time lapse and also wasting large amount of fuel. Traffic jam can get resolved within several hour or in critical condition it may take few days to get resolved. Thus, congestion affects economy as well as it gives bad affect the environment. Due to this, many Automobile industries are taking initiative to find efficient solution for congestion control [17].

Figure 2-4: Traffic Congestion in Khartoum City in SUDAN.

2.10 Estimating Congestion Using Beacon Relevance

For congestion detection application, each vehicle sends a beacon containing its position and velocity periodically. A receiving vehicle first assigns a relevance value to each beacon, and then estimates its congestion based on the beacons received. A beacon received at a vehicle may convey different types of information with respect to congestion around the vehicle: beacons from nearby vehicles convey more information with regards to vehicular congestion, a continuous stream of beacons from the same sender signifies close proximity of the sender, beacons from a vehicle with a lower relative velocity indicates it is expected to stay close for a longer duration of time [16].

2.11 Efficient COngestion DEtection Protocol (ECODE)

ECODE protocol aims at evaluating the real-time traffic characteristics of each road segment (i.e., the road section connecting between any two adjacent intersections). Moreover, ECODE efficiently and reliably detects road segments with high traffic congestion in any urban grid-layout area. The traffic situation and the traffic congestion level of each road segment change from time to time [18].

ECODE first evaluates traffic characteristics in terms of traffic speed, traffic density and estimated travel time of each road segment separately. The consideration of three different characteristics enhances the accuracy of the traffic evaluation at any road segment. In the case of inaccurate information derived from investigating any of these characteristics due to voluntarily slow-moving vehicles or inaccurate traffic density evaluations, other characteristics can help estimate the traffic situation accurately. Moreover, when ECODE evaluates these characteristics, it considers the direction of traffic flow in each road segment. It is common to see high traffic congestion in one side of any road segment, while the other side experiences very low traffic density; ECODE is able to detect these scenarios efficiently. The consideration of traffic direction is new in this field of research, and it is essential for accurate path recommendations and for efficient traffic light controlling applications. Finally, when considering location-based cluster mechanisms in our work, it is important to note that the level of accuracy and the efficiency level of the protocol are both enhanced when the configured clusters do not overlap with each other. In order to evaluate traffic in a certain road segment, every road segment is divided into sub-segments or ‘clusters’ were the cluster length should be smaller than the transmission range of the cars. Every car should be able to its current cluster, speed and direction. Vehicles within the same cluster (i) broadcast an advertisement beacon message (ADV) periodically, ADV message declares the location, speed and travel direction of the sender vehicle on each road segment. Whenever any vehicle receives an ADV message from the surrounding vehicles, it adds the basic traffic data of the sender vehicle to its Neighboring Table (NT) as shown in figure 2-5 [18].

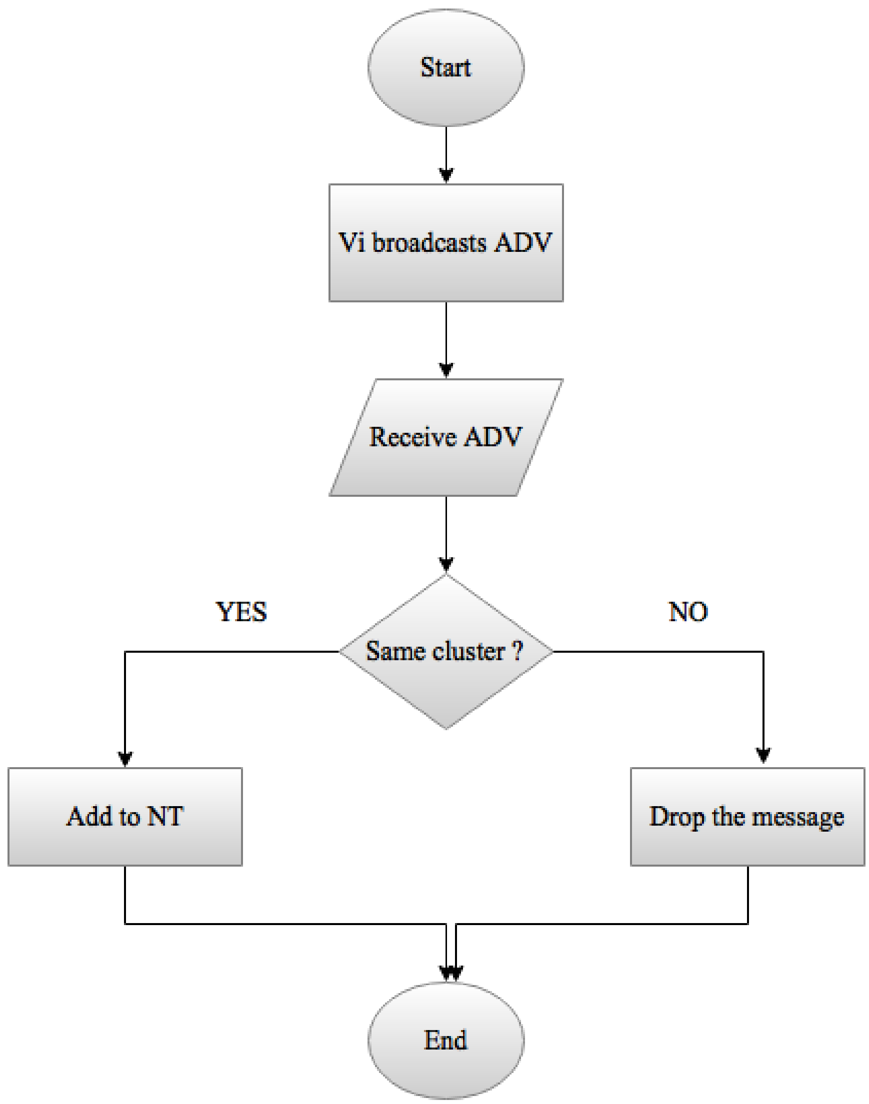


Figure 2-5: Basic Traffic Data Gathering.

This is done only if the sender vehicle is located on the same road segment. The direction of each traveling vehicle can be obtained from the ADV message. The

ADV message contains a special field that determines whether the vehicle is moving east, west, north or south. Each vehicle is equipped with a digital map that summarizes the physical characteristics (i.e, length, width, coordinates, maximum allowed speed, etc.) of the surrounding road segments. Each vehicle knows the length and coordinates of the road segment it is currently traveling through; therefore, each vehicle can configure the number of clusters and the boundaries of each cluster zone on that road segment. Each vehicle determines the cluster in which it is located; it also evaluates the traffic characteristics of that cluster zone based on its knowledge of the surrounding vehicles located within the same cluster. In the proposed protocol, the traffic speed represents the average speed of all vehicles, while the traffic density represents the number of located vehicles per square meter. In this work, a saturated traffic density (SDi) of each road segment (i) is defined. As long as the traffic density (TDi) of any road segment or cluster is less than the SDi, vehicles should be able to drive at the maximum allowable speed (MASi) of such a road segment. Otherwise, if TDi is more than SDi, vehicles will be forced to drive slower than MASi; this is due to the high level of traffic congestion over the road segment. The estimated travel time (ETi) is computed based on the length of each cluster zone and the traffic speed (TSi) of that zone. If the TDi of the cluster in the road segmentis less than SDi, ETi is computed based on the cluster length and the MASi of the road segment (i). The traffic speed (TS), traffic density (TD) and estimated traveling time (ET) are the main metrics that determine the local traffic situation in each cluster. Figure 2-6 illustrates systematically the steps that each vehicle (Vj) follows to evaluate the traffic condition in each cluster, where any vehicle (Vj) is located. The receiver vehicle stores the local traffic evaluation of the cluster where it is located, in a local traffic table (Ttraf). The local traffic table (Ttraf) contains the main characteristics of each cluster on the targeted road segment. The main fields of the Ttraf table include the cluster identifier (Tid), traffic speed (TTS), traffic density (TTD) and estimated travel time (TET) of each cluster [18].

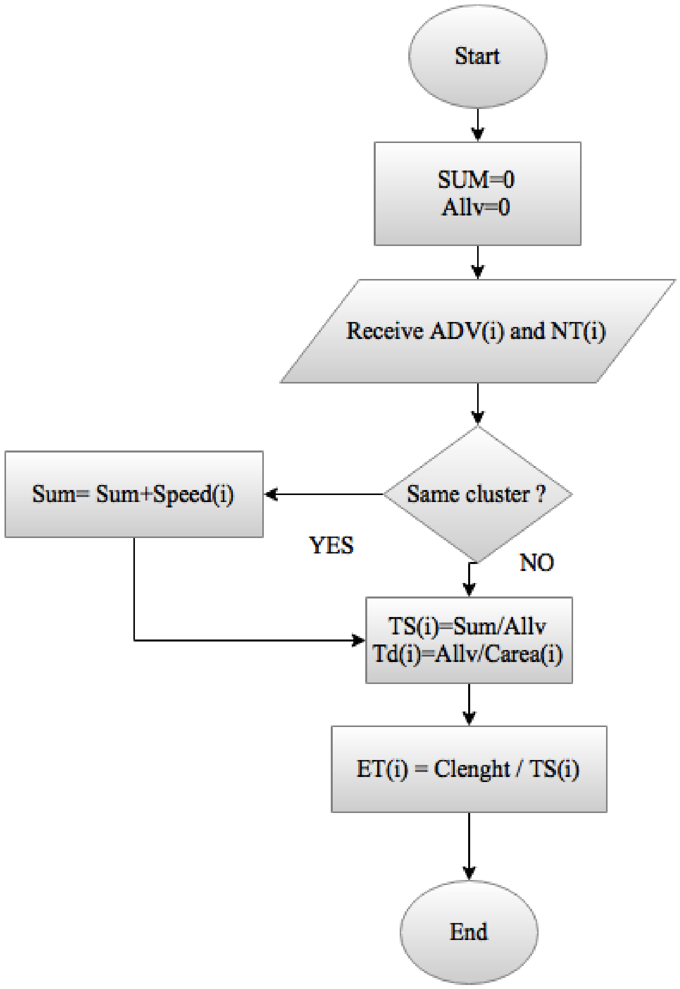


Figure 2-6: Local Traffic Evaluation Algorithm.

In order to expand the area evaluated to cover the entire road segment, each vehicle aggregates the traffic evaluation of all cluster areas in such a road segment. Adjacent clusters can communicate directly by transmitting traffic evaluation reports. Transmitting the traffic evaluation reports between adjacent clusters helps to obtain a more scalable traffic evaluation. This report tabulates the traffic evaluation of all clusters of which vehicles are informed [18].

Whenever any vehicle Vi receives the traffic evaluation report of any adjacent cluster, it inserts the traffic evaluation of this cluster as a new record into the internal Ttraf table. Selecting suitable relay vehicles to transmit the traffic evaluation report in each cluster helps reduce bandwidth consumption and the delay time needed to gather the traffic evaluation data. Figure 2-7 illustrates the process undertaken by any vehicle, after receiving traffic evaluation report (TErep) [18].

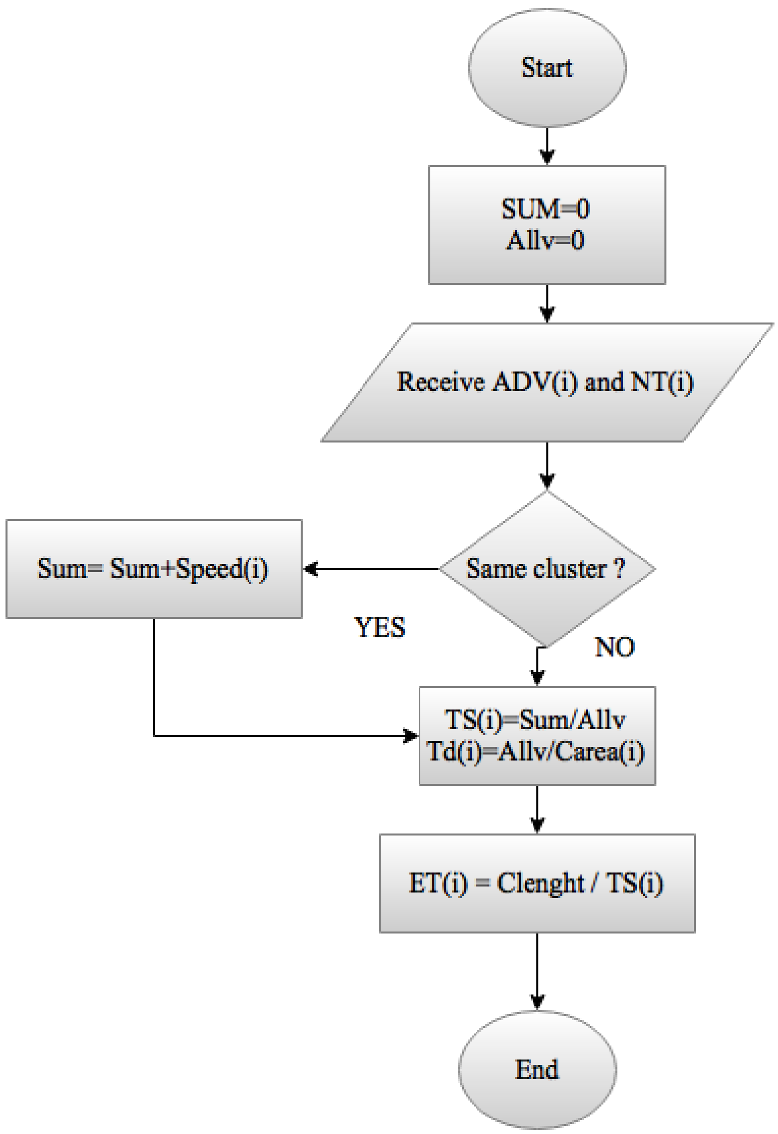


Figure 2-7: Expanding the Evaluated Area.

The traffic characteristics are first evaluated at each cluster separately based on the basic broadcast traffic data of each vehicle. In the case where a certain vehicle broadcasts its basic data while it is in Cluster A and then moves to Cluster B immediately, it will be only considered in the traffic evaluation of Cluster A. It must be considered that this vehicle (which is either in Cluster A or Cluster B), depends on its location when it broadcasts the basic data beacon. The process of continuously updating the Ttraf table with the surrounding clusters information, and the forwarding of the updated data TErep , is essential for evaluating the traffic characteristics of the road segment. It enables RSUs, installed at the end of such a road segment, to gather the traffic evaluation of all clusters in this road segment from nearby traveling vehicles. Real-time traffic monitoring evaluation reports (TMR) are generated by these RSUs, summarizing the traffic situation of each road segment in the applicable direction. The traffic evaluation reports of these RSUs feature the aggregated traffic evaluation of all adjacently considered clusters. These TMR reports should be available for any real-time traffic efficiency application that would require the traffic distribution data pertaining to its characteristics over the road network, including path recommendation and traffic lights control [18].

ECODE provides a highly accurate estimate about the congestion density and the traffic characteristics of each road segment. It uses three different metrics to evaluate the traffic of each road segment: traffic density, traffic speed and estimated travel time. Moreover, considering the direction of traffic while evaluating congestion levels enhances the accuracy of the traffic evaluations, particularly for a scenario in which there is a clear variation between the congestion level in opposite directions at the same road segment [18].

Chapter Three

Routing Protocols in VANETs

3.1 Introduction

Generally, routing protocols implemented for wired networks are not suitable for VANETs since they are based on periodic route updating mechanisms which increases overhead and cannot efficiently handle topology changes. Routing VANETs is complex since mobility causes frequent topology changes and requires more robust and flexible mechanism to search for routes and maintain them. When the network nodes move, the established paths may break and the routing protocols must dynamically search for other feasible routes. With a changing topology, even maintaining connectivity is very difficult. Therefore, routing protocols for VANETs must deal with the following premises [19]:

1. Distributed operation, since is the basis VANETs.
2. Signaling reduction, allowing conserving battery capacity and enhancing network efficiency.
3. Keeping the routes loop free, in order to avoid packets flowing indefinitely on the network and network congestion.
4. Reduced processing time, aiming to save node's resources.
5. Management of asymmetric links, caused by different power levels among mobile nodes and other factors such as terrain conditions.

3.2 Classifications of Routing Protocols

As shown in figure 3-1, the routing protocols in VANETs are classified into five main categories, Topology based routing protocol, Position based routing protocol, Cluster based routing protocol, Geo cast routing protocol and Broadcast routing protocol. These protocols are characterized based on area or application where they are most suitable [19, 20].

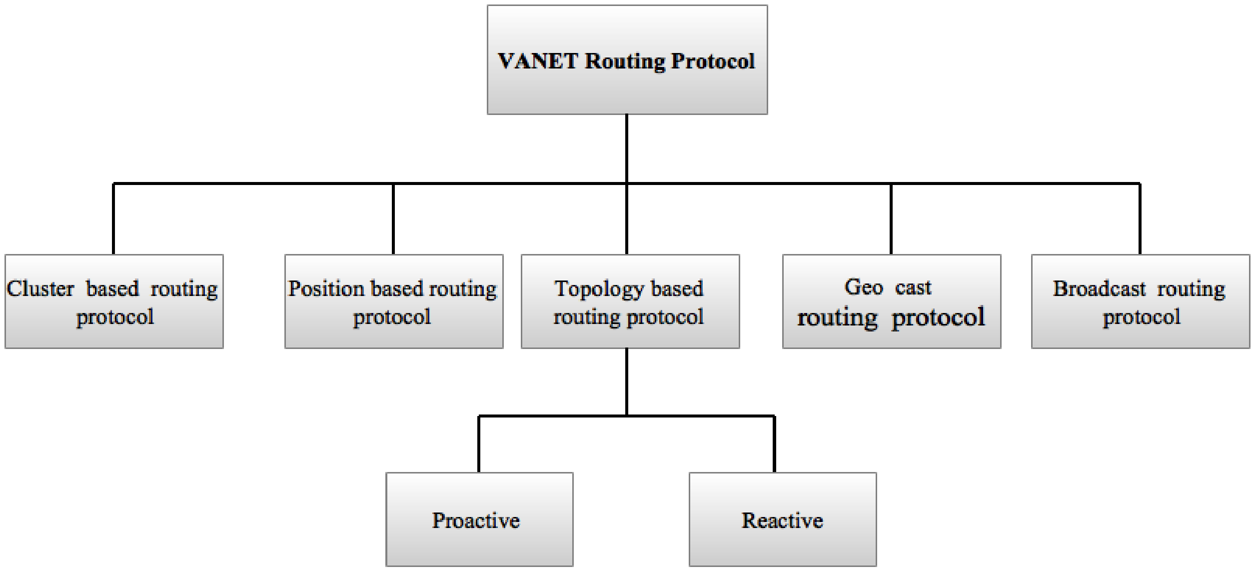


Figure 3-1: Classification of Routing Protocols for VANET Systems.

3.2.1 Topology Based Routing Protocols

These routing protocols use links information that exists in the network to perform packet forwarding. They are divided into Proactive and Reactive protocols as shown in table 3-1. The proactive routing protocols are called also Table Driven. In proactive protocols such as the Destination Sequenced Distance Vector (DSDV), each node only needs to know the next hop to the destination. And how many hops away the destination, this information stored in each node and it is arranged in a table, hence the term table driven routing [paper], while Reactive protocols such as Ad-Hoc on Demand Distance Vector (AODV), also called on-demand methods, are based on demand for data transmission. Routes between hosts are determinate only when they are explicitly needed to forward packets. They can significantly reduce routing overhead when traffic is lightweight and the topology changes decrease dramatically, since they do not need to update route information periodically and do not need to find and maintain routes on which there is no traffic (table 3-1 shows comparison between proactive and reactive topology based routing protocol). Hybrid methods combine proactive and reactive methods to find efficient routes, without much control overhead [19,21].

Table 3-1: Comparison of Proactive and Reactive Routing Protocols [20].

	Proactive Protocol (DSDV)	**Reactive Protocol (AODV)**
Network Organization	Flat/ Hierarchical	Flat
Topology Dissemination	Periodical	On-Demand
Route Latency	Always available	Available when needed
Mobility Handling	Periodical updates	Route maintenance
Commutation Overhead	High	Low

3.2.2 Position Based Routing Protocol

Position based routing consists of class of routing algorithm. They share the property of using geographic positioning information in order to select the next forwarding hops. The packet is send without any map knowledge to the one hop neighbor that is closest to destination. Position based routing is beneficial since no global route from source node to destination node need to be created and maintained [20].

3.2.3 Cluster Based Routing Protocol

Cluster based routing is preferred in clusters. A group of nodes identifies themselves to be a part of cluster and a node is designated as cluster head will broadcast the packet to cluster. Good scalability can be provided for large networks but network delays and overhead are incurred when forming clusters in highly mobile VANET. In cluster based routing virtual network infrastructure must be created through the clustering of nodes in order to provide scalability [20].

3.2.4 Geo-cast Routing Protocol

Geo-cast routing is a location based multicast routing. Its objective is to deliver the packet from source node to all other nodes within a specified geographical region (Zone of Relevance ZOR). In Geo cast routing vehicles outside the ZOR are not alerted to avoid unnecessary hasty reaction. Geo cast is considered as a multicast service within a specific geographic region. It normally defines a forwarding zone where it directs the flooding of packets in order to reduce message overhead and network congestion caused by simply flooding packets everywhere. In the destination zone, unicast routing can be used to forward the packet. One pitfall of Geo cast is network partitioning and unfavorable neighbors, which may hinder the proper forwarding of messages [20].

3.2.5 Broadcast Routing Protocol

Broadcast routing is frequently used in VANET for sharing, traffic, weather and emergency, road conditions among vehicles and delivering advertisements and announcements [20].

3.3 Ad-Hoc on Demand Distance Vector (AODV)

Ad-Hoc on Demand Distance Vector (AODV) is a reactive routing protocol where the routes are formed only when needed. When the source has data to send to a destination, it broadcasts a Route Request message (RREQ) for that destination. When a RREQ is received to each intermediate node, a route to the source is created. If the intermediate node has not received this RREQ before, means that it is not the destination and does not have a route to the destination, so, it rebroadcasts the RREQ. If the receiving node is the destination or has a current route to the destination, it generates a Route Reply message (RREP). The RREP is unicast in a hop-by hop to the source. When the RREP propagates, each node creates a route record to the destination. When the source gets the RREP, it saves the route to the destination and then begins sending data. The route with the shortest hop count is selected when multiple RREPs are received to the source. As data flows from the source to the destination, each node along the route updates the timers associated with the routes to the source and destination, maintaining the routes in the routing table. If a route is not used for some period of time, a node cannot be sure whether the route is still valid; consequently, the node removes the route from its routing table. If data is flowing and a link break is detected, a Route Error (RERR) is sent to the source of the data in a hop-by hop fashion. As the RERR propagates towards the source, each intermediate node invalidates routes to any unreachable destinations. When the source of the data receives the RERR, it invalidates the route and reinitiates route discovery [21].

3.4 Destination Sequenced Distance Vector (DSDV)

DSDV is a proactive protocol that maintains route to all the destinations before requirement of the route. Each node maintains a routing table that contains next hop, cost metric towards each destination and a sequence number that is created by the destination itself. Each node to update route information exchanges this table. A node transmits routing table periodically or when significant new information is available about some route. Whenever a node wants to send packet, it uses the routing table stored locally. For each destination, a node knows which of its neighbor leads to the shortest path to the destination. DSDV generates a large volume of control traffic in a highly dynamic network like VANET. This excessive control traffic may take up a large part of available bandwidth. To avoid it two types of updates are used full dump and incremental dump. A full dump carries a complete routing table that is broadcasted infrequently. An incremental dump carries minor changes in the routing table. This information contains changes since the last full dump. When the size of an incremental dump becomes too large, a full dump is preferred. DSDV is an efficient protocol for route discovery. Whenever a route to a new destination is required, it already exists at the source. Hence, latency for route discovery is very low. DSDV also guarantees loop-free paths [22].

3.5 Methods of Routing Protocol in VANET

The methods of routing protocol divided into four methods unicast, multicast, geo cast and broadcast routing [22].

3.5.1 Unicast Routing

One to one communication takes place using multi hop scheme; where intermediate nodes are used to forward data. This is the widely used class in ad-hoc network. Most of the topology based routings are Unicast such as AODV [22].

3.5.2 Multicast Routing

One to many communication can take place. This can be further partitions into geo cast and cluster based. In cluster based routing, nodes automatically divided into clusters, one cluster head is selected, and all outgoing and incoming communication takes place through it [22].

3.5.3 Geocast Routing

Message delivery to other nodes lie within a specific geographic area, like area where accident takes place. Mobicast, ZOR (Zone of Relevance) are geo cast protocols [22].

3.5.4 Broadcast Routing

One to all communication takes place. Flooding is most frequently used routing protocol in VANET especially to communicate safety related message. Simplest of broadcast method is carried by flooding in which each node rebroadcast the message to other nodes. However, larger density of nodes, this causes exponential increase in bandwidth [22].

3.6 Related Works

In order to simulate a VANET applications, two different simulation modeled must be considered, Mobility model and traffic network model. Up to now, these two issues in VANET simulation are decoupled. Both traffic simulation and large-scale network simulation have their own high quality simulation and their own high-level modeling.

Veins [21] is one of the powerful framework for VANET simulation which is integrated network and traffic simulator together. SUMO has been selected to use as a the traffic simulator and while this time OMNeT++ has been selected to use as network simulator. Vehicles in Network Simulation or Veins is used these two simulator to generate the results. Veins make a TCP connection between SUMO and OMNET++ and it could simulate traffic and network. It works as follow, at first the traffic demand is generated by SUMO and veins send the traffic information to the OMNET++ a simulation is started. When any important event happened in the network simulator which should have effect in movement of vehicles, veins send the information to the SUMO, and the SUMO change the movement of vehicles.

Moreover, OPNET [8] is a sophisticated network simulator. The OPNET is include several implemented wireless communication technology (like satellite, Bluetooth, WiMAX, LAN, IEEE 802.11, etc.). It has a graphical and GUI package to present the results for simulated networks. In the OPNET simulation, random Drunken model is used for the mobility model. In this model, directions are selected randomly from four directions in each steps. Also for the better mobility model, there are three other modeling, Path-lossmatrix is that a model which the movements are defined with a matrix, Trace, is that a model which is used the location replacement and Random Waypoint Model which is a model based on “Stop-Think-GO”.

OMNeT++ (Objective Modular Network Tested in C++), [9], is a framework and simulation library developed based on C++ that is running on different operating systems such as Linux, Mac OS X, other Unix-like systems and Windows. Primarily, OMNET++ is developed for building network simulators. OMNET++ could be used for protocols modeling, hardware architectures validating, evaluating performance aspects of complex software systems, traffic modelling of communication network, modeling of queuing networks, etc.

Routing is one of a big issue in Vehicular ad hoc network. Mobility of VANET is very high as compared to other traditional networks. Thus, more attention towards routing protocols in such networks is provided.

Ahmad Shaheen, Awadh Gaamel, Abdulqader Bahaj in [21] studied the impact of AODV and DSR on VANET while using the well-known IEEE 802.11WIF by applied them over two different scenarios, dense and sparse traffic based on cars density on the road. Then both protocols are evaluated based on different performance metrics: Packet Delivery Ratio, End-to-End delay and throughput and total send-received packets. By The result of this simulation found that the AODV is better than DSR when dense mode scenario is simulated which means a large number of nodes, while the DSR protocol is better than AODV when the number of nodes is not that much.

According to Uma Nagaraj and Poonam P. Dhamal in [20] presented a comparative study of the ad hoc routing protocols (AODV, DSR, OLSR and DSDV) in realistic scenario of VANET by using three performance metrics packet delivery ratio, average end to end delay and routing overhead. The comparison has done by using simulation tool NS2 which is the main simulator, Network animator (NAM) and excel graph which is used for preparing the graphs from the trace files. the result present that the performance of AODV in terms of PDR is very good approximate 98% and DSDV is approximate 97%. OLSR has average performance as the PDR. The Average end to end delay of AODV is very high. The DSR performs well in both of the scenario in terms of Average end to end delay. OLSR is also having low end to end delay. Packet delivery Ratio (PDR) of AODV is better than other three protocols. Thus means, this protocol is applicable to carry sensitive information in VANET but it fails for the scenario where transmission time should be very less as it has highest end to end delay. For quick transmission, DSR performs well but not suitable to carry information, as packet loss is very high. The performance of OLSR is average.

In [23], Monika, Sanjay Batish and Amardeep Dhiman exploited the AODV, DSR and DSDV routing protocols by comparing their performances with respect to throughput and number of packets dropped during communication by using IEEE 802.11as a standard protocol for Vehicular Ad hoc Network with 5.9 GHz band. The results present that the routing protocol AODV is better. Throughput of AODV is highest. DSR also outperforms DSDV protocol. Number of packets dropped is high in case of AODV but it doesn't mean that most of the data packets are dropped. In case of AODV the control packets to establish route are maximum and most of these packets are dropped but data packets reach the destination successfully. It can be observed from results that the performance of the network is better in the presence of RSU as compared to the network without RSU.

Chapter Four

Simulation Results

4.1 Introduction

It is important and crucial to test and evaluate routing protocols in VANET systems before applying them to the real world. Thus, commonly simulations are still use as a first step to evaluate different routing protocols for VANET research environment. Several communication networking simulation tools are already exist to provide a platform to test and evaluate network protocols such NS-2, OPNET and Qualnet. One of the most important parameters in simulating ad-hoc networks is the node mobility. It is important to use a realistic mobility model in order to reflect a real view of performance parameters of those protocols. In this work, three popular software simulation tools are used to model both mobility and network traffic for VANET system. These tools are MOVE (MObility model generator for VEhicular networks), SUMO (Simulation of Urban Mobility) as mobility simulators and NS-2 as network simulator. Here, those three simulators were installed in Ubuntu 12.04 and all simulation steps are discussed in this chapter. MOVE was used to facilitate users to rapidly generate realistic mobility models for VANET simulations. It is built on top of an open source micro-traffic simulator SUMO. It is important to know that, the output of MOVE is a mobility trace file (*.tr) which contains the information of vehicle movement, which can be immediately fed into NS-2 or Qualnet.

4.2 VANET's Simulation

Simulation scenarios are carried out in this work for a VANET system that located in city of Khartoum. The simulation area (area of study) is around Sudan University of Science and Technology (Southern Campus) as shown in figure 4-1 and the assumed parameters are introduced in table 4-1. The road map is selected and created after connecting nodes via edges. The simulation steps are presented in figure 4-2.

The simulation steps are divided into two levels: mobility model using MOVE with addition of SUMO tool and networks traffic models via using NS-2. Indeed, MOVE consists of two main components as shown in figure 4-3, which are Mobility Model that used to generate road map topology and vehicle movement to add movement characteristics to simulation map.

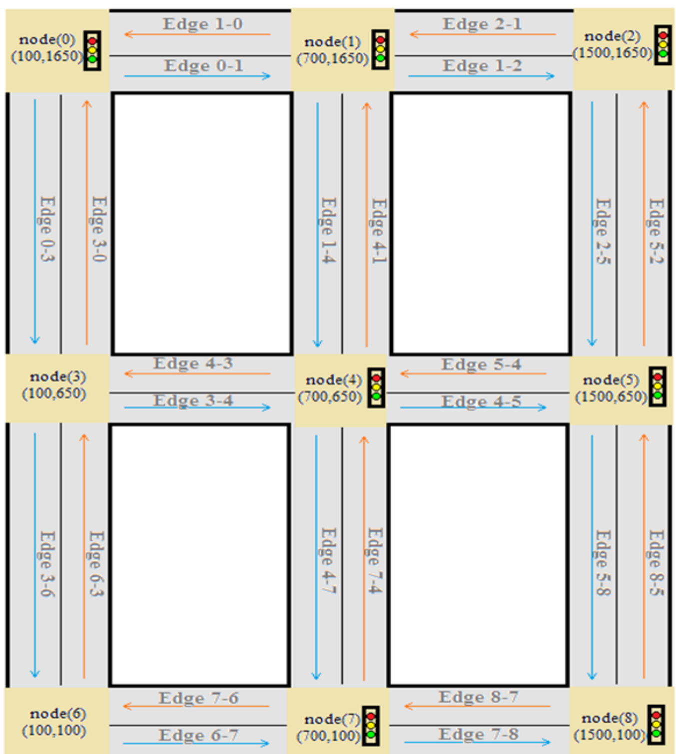


Figure 4-1: Simulated Road Map (Area of Study).

Table 4-1: The Simulation Parameters.

Channel Type	Channel/ wireless channel
Network Interface Type	Phy/Wireless Phy
Interface Queue Type	Queue / DropTail/PriQueue
Antenna model	Antenna/Omni Antenna
Ad-hoc Routing Protocol	AODV/ DSDV
Radio Propagation Model	Propagation / Two Ray Ground
MAC type	Mac/802_11
Max Packet in IFQ	50
Link Layer Type	LL
Lane Number	2
Maximum Speed	40
Roads Priority	75
Number of vehicles	25

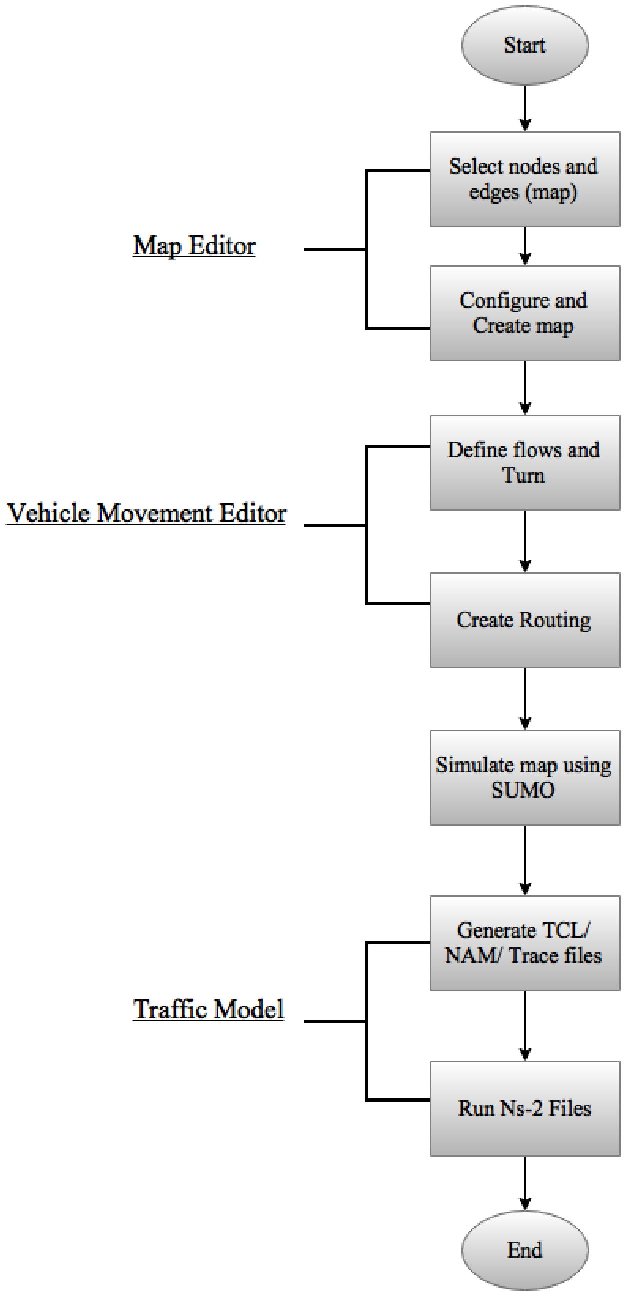


Figure 4-2: Simulation Steps.

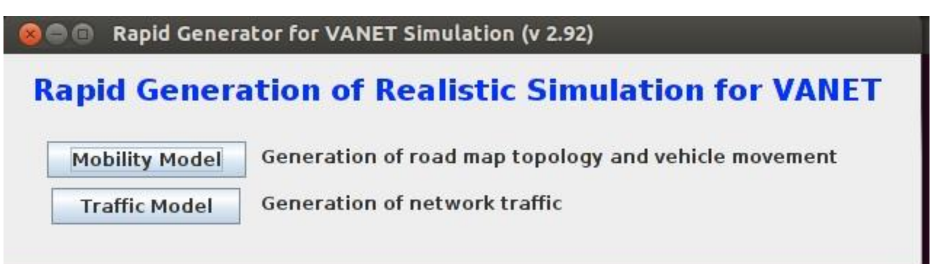


Figure 4-3: MOVE Architecture.

4.2.1 Mobility Model

Mobility Model consists of Map Editor and Vehicle Movement Editor, as shown in figure 4-4. The Map Editor is used to create the road topology. Basically implementation provides three different ways to create the road map. The map can be manually created, generated automatically and Imported from existing real world maps such as Google maps.

The Vehicle Movement Editor allows user to specify the trips of vehicles and the route that each vehicle will take for one particular trip. Three different methods to define the vehicle movements, the vehicle movement patterns can be manually created, Generated automatically and Specified based on a bus time table to simulate the movements of public transportations.

Figure 4-4: Mobility Component.

Generally in MOVE, the road map can be generated manually, automatically or imported from a real world map. Manual generated of the map requires inputs of two types of information, nodes and edges. A node is one particular point on the map which can be either a junction or the end of the roads. Furthermore, the junction nodes can be either normal road junctions or traffic lights. All nodes have specific location (x- and y-coordinate, that describe distance to the origin in meters) and also an id for future references. Thus our simple node file looks as shown in figure 4-5.

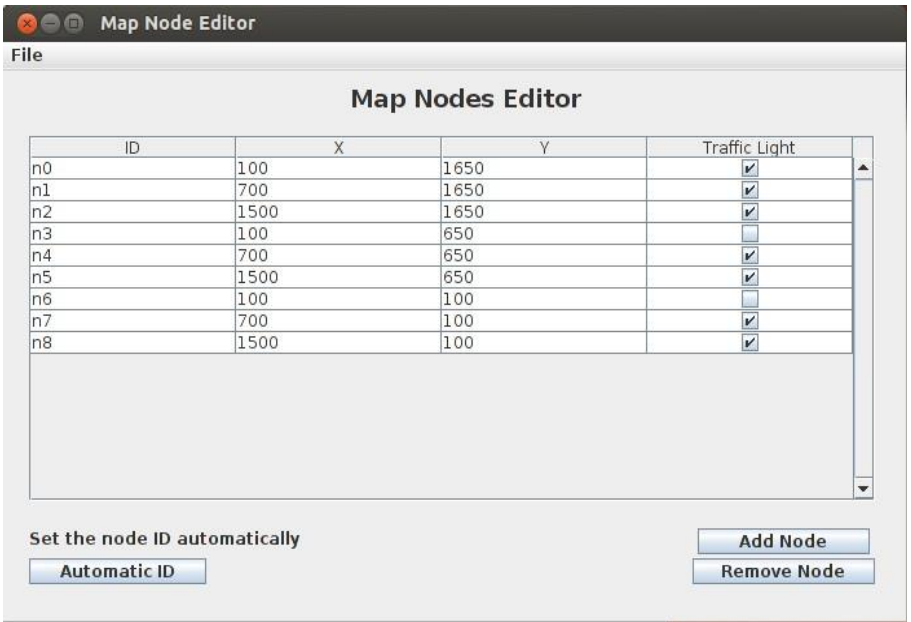


Figure 4-5: Map Node Editor

File can be edit with a text and save the instance as name.nod.xml where .nod.xml is a default suffix for Sumo node files.

The edge is the road that connects two nodes on a map. The attributes associated with an edge include speed limit, number of lanes, the road priority and the road length. Edges are directed, thus every vehicle that are travelling this edge will start at the node given in/from and end at the node given into. Save this data into a file called name.edg.xml. Figure 4-6 show the edges in this study.

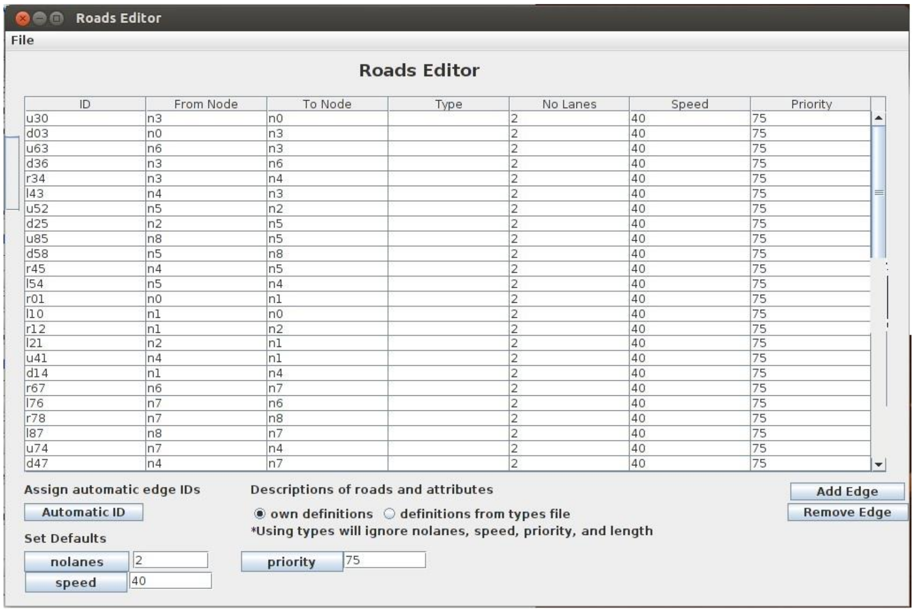


Figure 4-6: Roads Editor.

SUMO is used to create nodes and edges for road map. This will generate our network (as shown in figure 4-7) that is called name.net.xml as shown in figure 4-8.

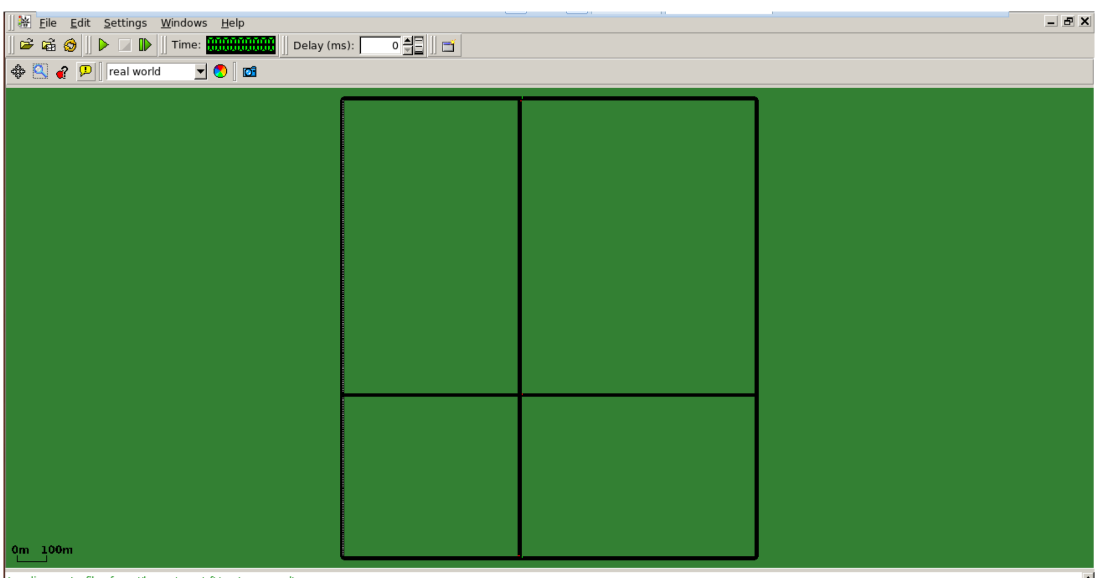


Figure 4-7: Figure show The Created Map via SUMO.

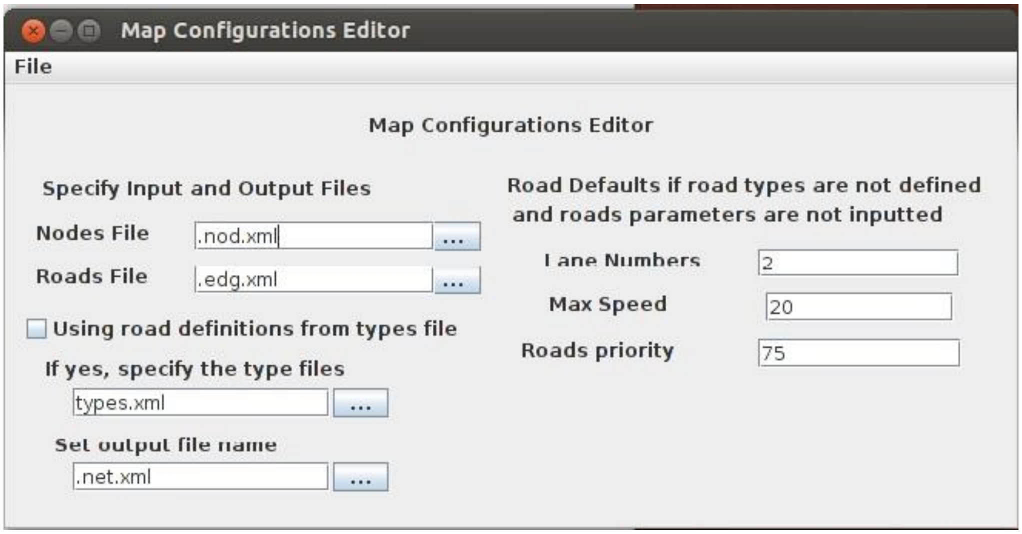


Figure 4-8: Map Configuration Editor.

The movements of vehicles can be generated automatically or manually using the Vehicle Movement Editor. The Vehicle Movement Editor allows users to specify several properties of vehicle routes including the number of vehicles in a particular route, vehicle departure time, origin and destination of the vehicle, duration of the trip, vehicle speed.

4.2.2 Traffic Model

The second section of MOVE is traffic modeling to generate network traffic. Traffic model consist of two network simulators NS-2 and Qualnet as shown in figure 4-9. Here in this work, NS-2 is used as network simulator tool for VANET. Ns-2 is simply an event-driven simulation tool that has proved useful in studying the dynamic nature of communication networks. Simulation of wired as well as wireless network functions and protocols (e.g., routing algorithms, TCP, UDP) can be done using NS-2. In general, NS-2 provides users with a way of specifying such network protocols and simulating their corresponding behaviors. It utilizes the federated approach, in which they both communicate via parser as shown in figure

4-10. The traces from the traffic simulators is sent to parser for the translation and then processed by network simulator as shown in figure 4-11. The updated file from network simulator is passed to traffic simulator through parser. The problem rose with this approach was the interaction between the two simulators was not held in timely manner.

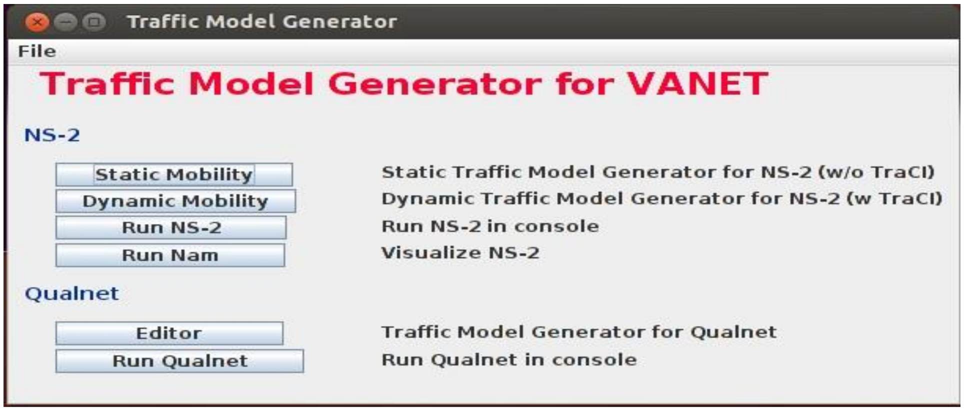


Figure 4-9: Traffic Model Generation for VANET.

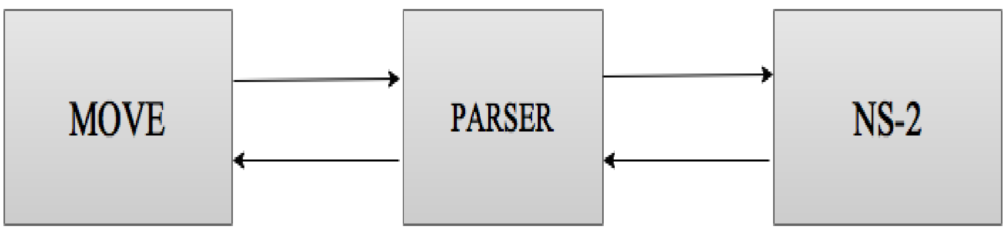


Figure 4-10: Interaction Between NS-2 and MOVE/SUMO.

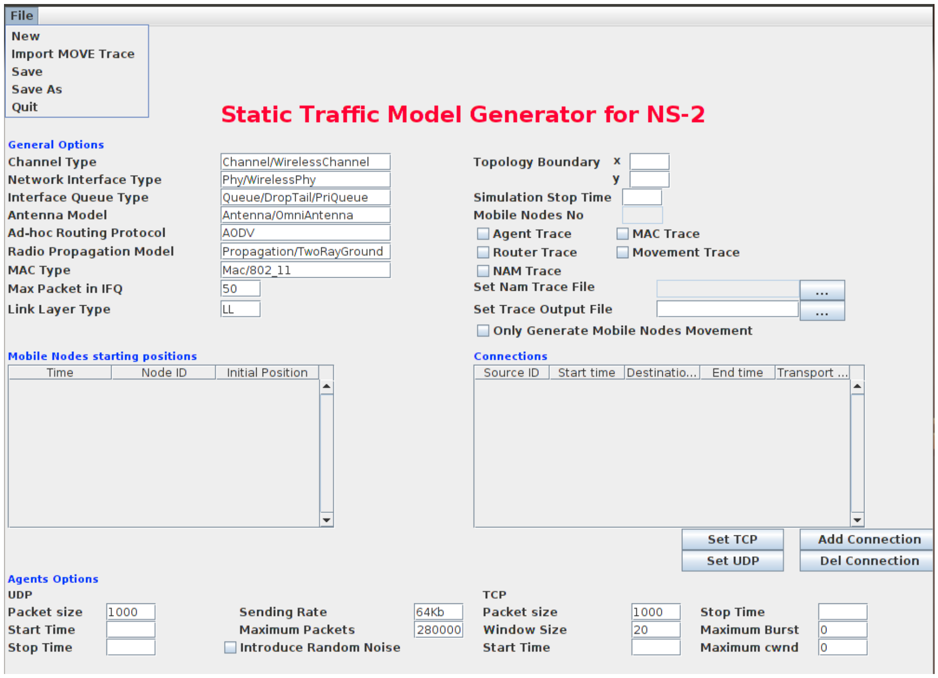


Figure 4-11: Static Traffic Model Generator for NS-2.

NS-2 used the translated move traces to generate the Tool Command Language (TCL) file, The Network AniMator (NAM) file to visualize the movement of nodes (as shown in figure 4-12) and the Trace File which is used for analyzing extracted data from network.

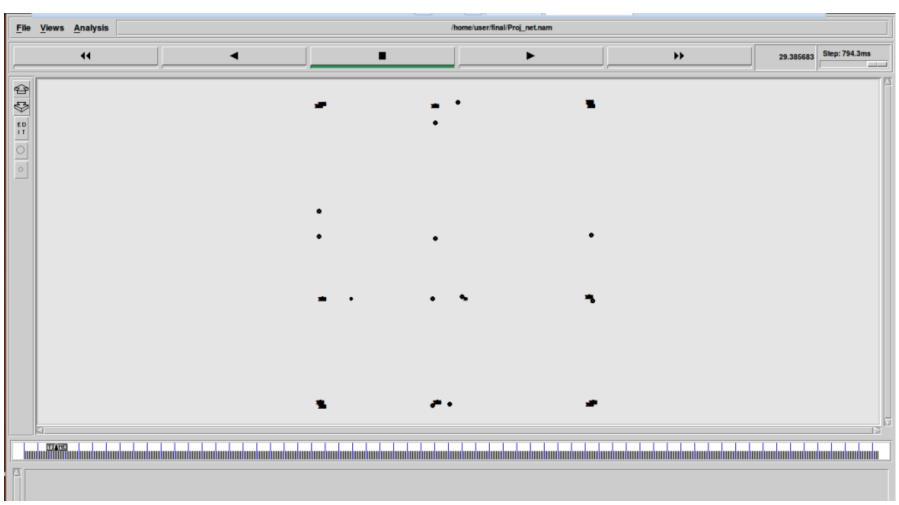
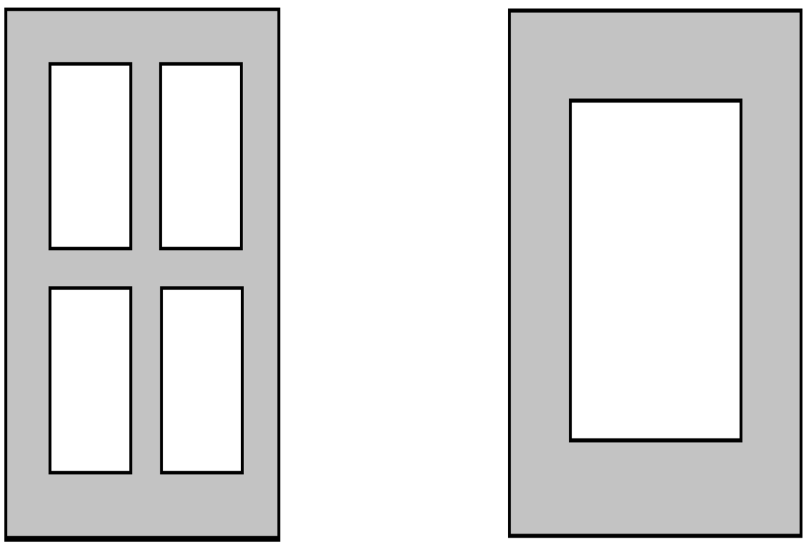


Figure 4-12: The Nam File.

4.3 Simulation Scenarios

In this section, different simulation scenarios are simulated via using three popular VANET's simulators. MOVE and SUMO as mobility simulator in addition with NS-2 as traffic simulator were installed in Ubuntu 12.04. Here, NS-2 was used to evaluate different mobility parameters including Packet delivery Ratio (PDR), Throughput and Average delay. Moreover, two routing protocols are simulated (AODV and DSDV) with different road scenarios (city and highway as shown in figure 4-13). The vehicles flows are shown in table 4-2.



(a) (b)

Figure 4-13: Simulation Scenarios. (a)City Scenario. (b)Highway Scenario.

Table 4-2 : Scenario Features Overview.

	City Scenario	Highway Scenario
Speed Km/hour	40	70
No of Vehicles	25	25
Routing Protocol	AODV/DSDV	AODV/DSDV
Vehicles Flows	Edge 6-3 to Edge 1-2 Edge 0-1 to Edge 5-8 Edge 2-5 to Edge 7-6 Edge 8-7 to Edge 3-0	Edge 6-7 to Edge 1-2 Edge 0-1 to Edge 7-8 Edge 0-3 to Edge 5-8 Edge 6-3 to Edge 5-2

4.4 Simulation Results

In this section, the simulation results are presented. AODV and DSDV are evaluated in terms of average delay, throughput and Packet Delivery Ratio (PDR). Firstly, all scenarios are evaluated studying the mobility and showing how the system performance is affected by configured number of vehicles. First scenario is simulated to compare routing protocols (AODV and DSDV). In order to analyze the performance of vehicular ad hoc networks, extracting some information from the simulations is required. An AWK programs must be implemented so that some metrics from traces files generated during simulation process can be studied. AWK scripts have been used to extract the PDR, throughput and average Delay.

4.4.1 Average Delay

The average delay can be defined as the time when the vehicle starts broadcasting the current situation message to when the traffic characteristics and the congestion level are computed and reported by the responsible RSU. As shown in figure 4-14 and figure 4-15, the average delay in city scenario is higher than the average delay in highway scenario because the congestion probabilities in city is greater than highway and AODV never takes much time to find route path in highway scenario. In addition, the average delay when using AODV as routing protocol is higher than when using DSDV because AODV takes much time to find another route if the previous one failed.

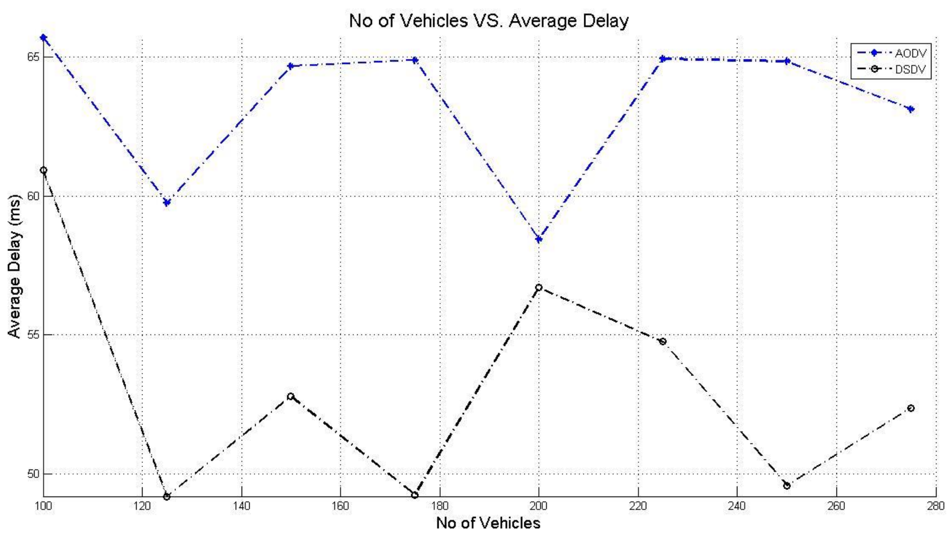


Figure 4-14: AODV Average Delay vs. DSDV in City Scenario as a Function of Number of Nodes.

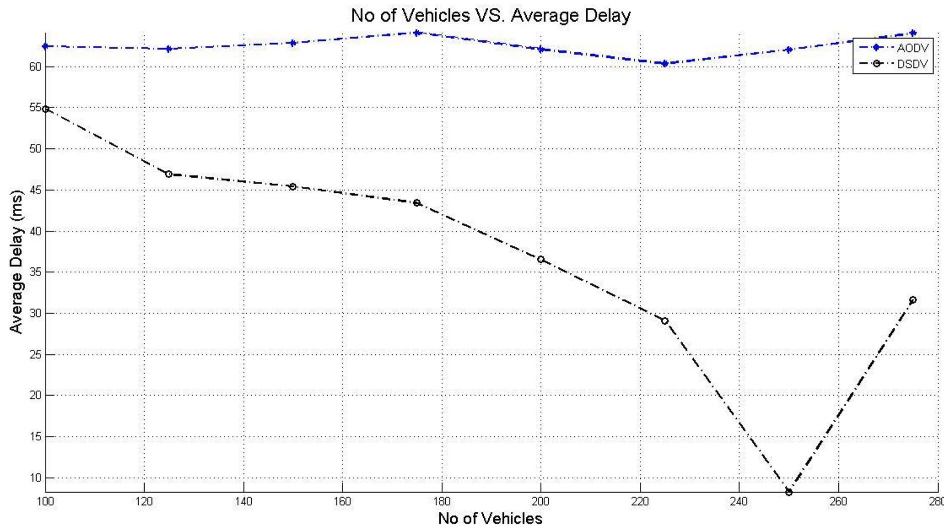


Figure 4-15: AODV Average Delay vs. DSDV Average Delay in Highway Scenario as a Function of Number of Nodes.

4.4.2 Throughput

According to figure 4-16 and figure 4-17, number of vehicles affects directly the throughput of VANET communication. Throughput refers to the rate of successful message delivery over a VANET communication channel. In addition, the average delay affect in throughput, increasing in average delay decrease the throughput. The throughput in highway scenario is higher than the throughput in City scenario. The congestion possibility in highway road is low, so the throughput increases with increasing in number of vehicles. Also, the throughput falling suddenly sometimes, that mean the congestion is occurred. The DSDV have much better throughput than AODV. Regardless of the interval between 0 to 1000 seconds where the simulation is not stable at this time because the route discovery processes in both AODV and DSDV.

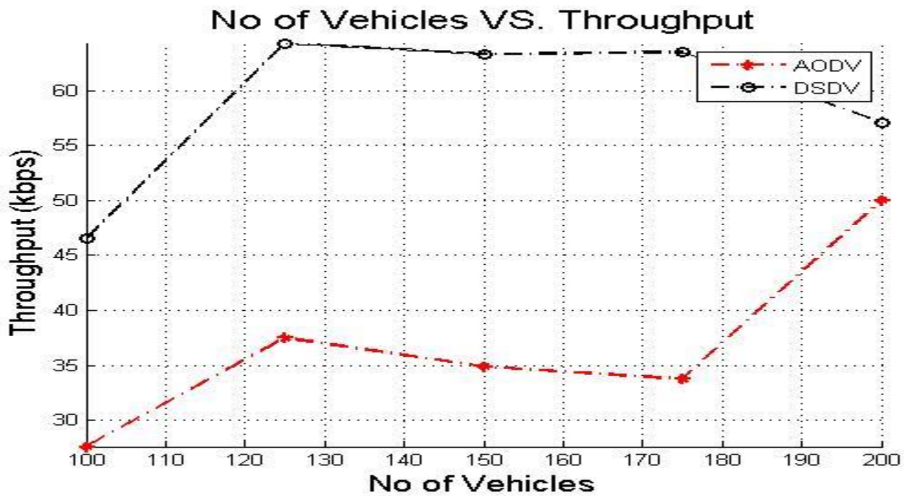


Figure 4-16: AODV Throughput vs. DSDV Throughput in City Scenario as a Function of Number of Nodes.

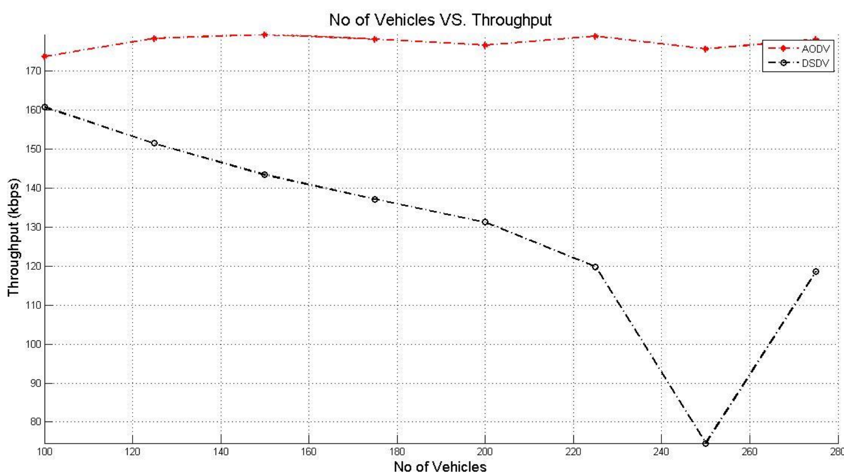


Figure 4-17: AODV Throughput vs. DSDV Throughput in Highway Scenario as a Function of Number of Nodes.

According to figure 4-18 and figure 4-19, the throughput increased proportionally with time in highway scenario and it is high because the congestion is low. DSDV protocol is better according to throughput because it is a table driven protocol.

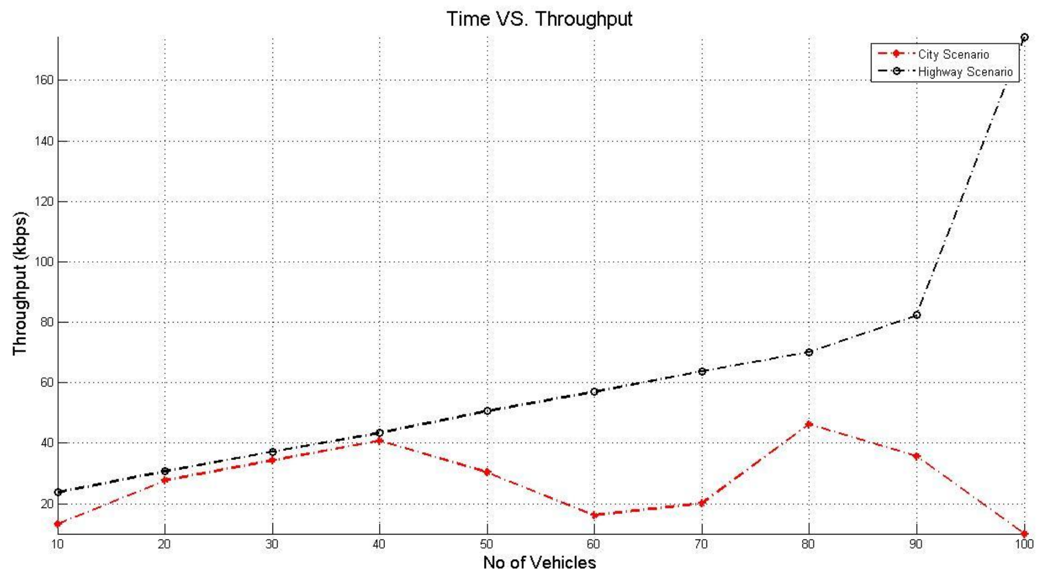


Figure 4-18: City Throughput vs. Highway Throughput Using AODV as a Function of Time.

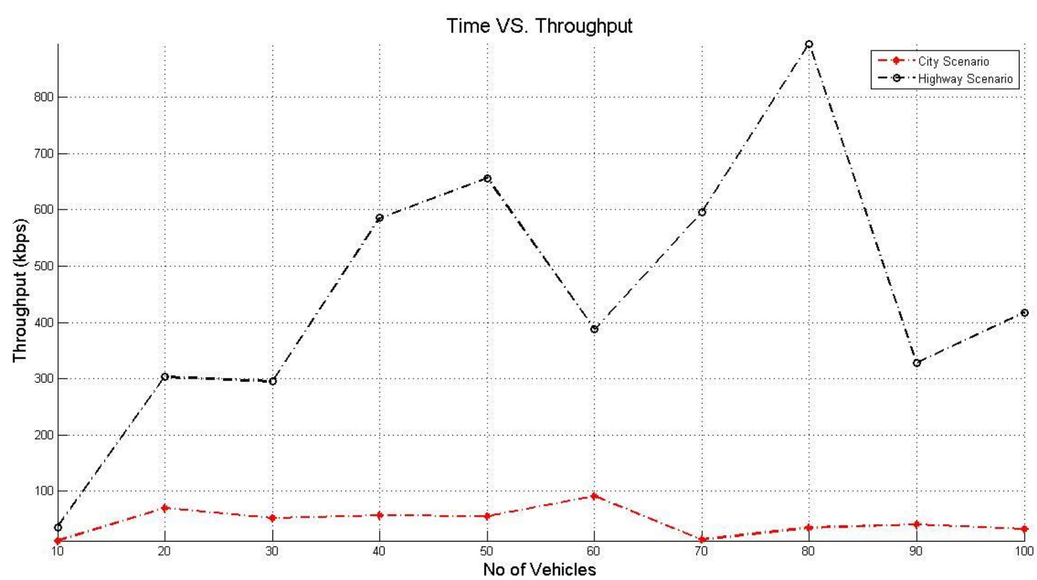


Figure 4-19: City Throughput vs. Highway Throughput Using DSDV as a Function of Time.

4.4.3 Packet Delivery Ratio (PDR)

Packet Delivery Ratio (PDR) is the ratio of received packets over sent packets in the network. As shown in figure 4-20 an figure 4-21, PDR when using AODV routing protocol is higher than PDR of DSDV routing protocol. Because AODV is on demand protocol and DSDV is table driven routing protocol.

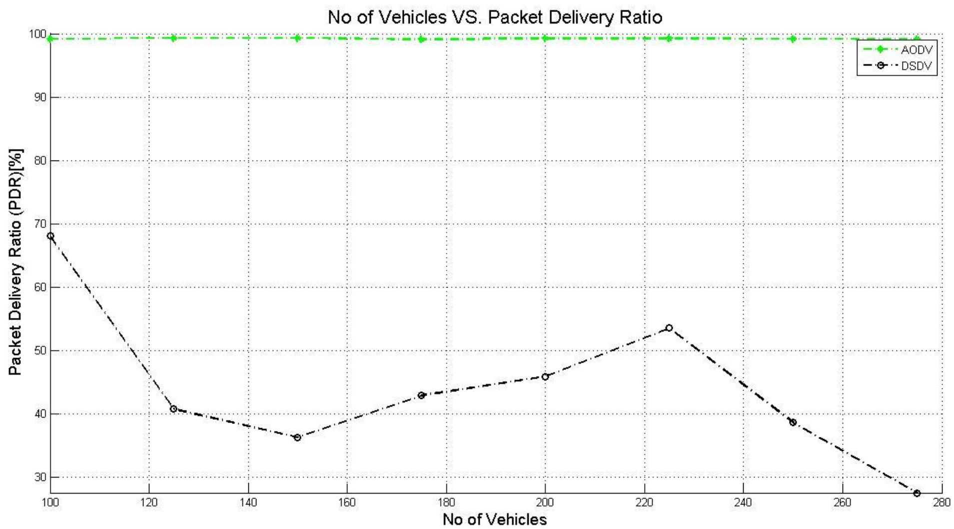


Figure 4-20: AODV PDR vs. DSDV PDR in City Scenario as a Function of Number of Nodes.

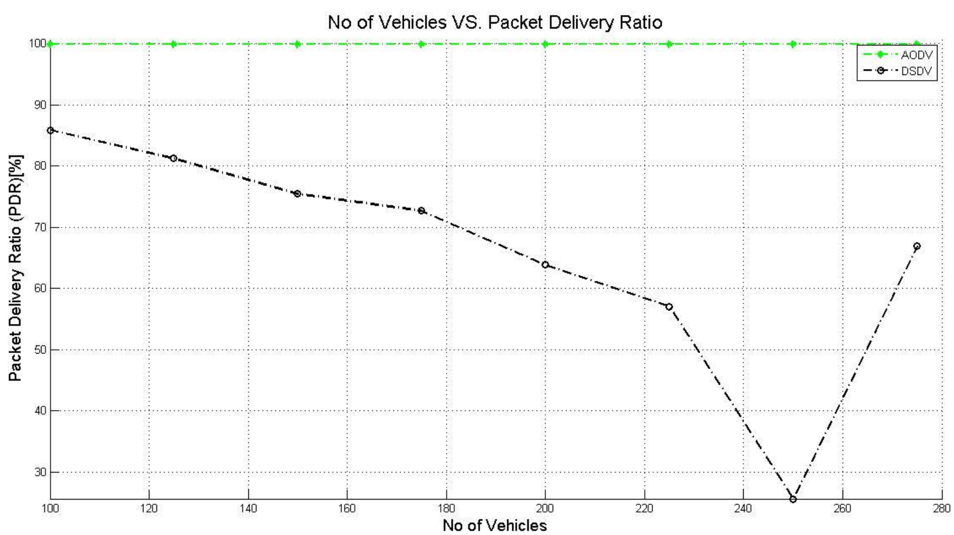


Figure 4-21: AODV PDR vs. DSDV PDR in Highway Scenario as a Function of Number of Nodes.

Chapter Five

Conclusion and Recommendations

5.1 Conclusion

Intelligent Transportation Systems (ITS) have progressed at a rapid rate, which aim to improve transportation activities in terms of safety and efficiency. Vehicle to Vehicle (V2V) communications and Vehicle to Infrastructure (V2I) communications are important components of the ITS architecture. Communication between cars often referred to Vehicular Ad-Hoc Networks (VANET) and it has many advantages such as reducing cars accidents, minimizing the traffic jam, reducing fuel consumption and emissions.

This work aims to test and evaluate two routing protocols (AODV and DSDV) in different mobility scenarios (Highway and city scenarios). The mobility model was created using MObility model generator for VEhicular networks (MOVE) tool in addition with Simulation of Urban Mobility (SUMO) simulator. Moreover, NS-2 was used to evaluate VANET system performance in terms of throughput, delay and PDR. As a result of this simulation AODV has a less throughput and higher average delay than DSDV, but it preferred in VANET system because the packet delivery ratio (PDR) of AODV is high (approximately 100%) and consumes less bandwidth. DSDV consumes more bandwidth because it periodically broadcast routing information, whereas in AODV there is no need to maintain route table, which results in less bandwidth consumption.

5.2 Recommendations

In this research, there are many recommendations that can be done as the following:

1. This research shows AODV, DSDV are not the best routing protocols for urban scenarios. A recommendation as a future work could be the evaluation of other newer existing proposals routing protocols with better performances on VANETs.

2. There are different simulation tools that can be used to simulate and evaluate mobility models. In this research MOVE, SUMO and NS-2 used to simulate and evaluate two different routing protocols. But these tools are complex so a recommendation as a future work is to use other simulation tools such as NCTUns, OMNET++ and OPNET.

3. Secure routing is one of the challenging areas. Due to the unsecure and ad hoc nature of VANET, there is prone to several security attacks that may lead to devastating consequences. Therefore, security attacks should be investigated with respect to different attacks in VANET.

4. Finally, other performance parameters including network statistics and energy consumption can be measured for QoS issues.

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APPENDEX

```
# Define options
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 opt(x)      1452      ;                         # x coordinate of topology
set opt(y)      1602;                               # y coordinate of topology
set stopTime      999.00
# Main Program
# Initialize Global Variables
set ns_ [new Simulator]
set tracefd [open /home/user/project/Pro_Trace_2.tr w]
$ns_ trace-all $tracefd
set namtrace [open /home/user/project/Pro_Nam_2.nam w]
$ns_ namtrace-all-wireless $namtrace $opt(x) $opt(y)
# Configure node
set chan_1_ [new $val(chan)]
```

```
$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) \
                  -topoInstance $topo \
                  -agentTrace ON \
                  -routerTrace ON \
                  -macTrace ON \
                  -movementTrace ON \
                  -channel $chan_1_

for {set i 0} {$i < $val(nn)} {incr i} {
 set node_($i) [$ns_ node]
 $node_($i) random-motion 0 ;# disable random motion
}

#predefine node in NAM
# ID of SUMO: F3_0
$node_(0) set X_ 10.05
$node_(0) set Y_ 1550.8500000000001
$node_(0) set Z_ 0.0
$node_(0) setdest 10.05 1550.8500000000001 1
# ID of SUMO: F1_0
```

$node_(1) **set** X_ 599.35

$node_(1) **set** Y_ 1569.95

$node_(1) **set** Z_ 0.0

$node_(1) setdest 599.35 1569.95 1

 # Now produce node movements

$ns_** at 0.0 "**$node_(0) setdest 10.05 1548.8700000000001 1.98"

$ns_** at 0.0 "**$node_(1) setdest 596.8100000000001 1569.95 2.54"

$ns_** at 0.0 "**$node_(2) setdest 30.86 10.05 1.71"

$ns_** at 0.0 "**$node_(3) setdest 19.95 30.630000000000003 1.48"

$ns_** at 1.0 "**$node_(0) setdest 10.05 1544.66 4.21"

$ns_** at 1.0 "**$node_(1) setdest 592.6500000000001 1569.95 4.15"

$ns_** at 1.0 "**$node_(2) setdest 35.05 10.05 4.19"

$ns_** at 1.0 "**$node_(3) setdest 19.95 33.94 3.31"

$ns_** at 2.0 "**$node_(0) setdest 10.05 1538.79 5.86"

$ns_** at 2.0 "**$node_(1) setdest 586.0600000000001 1569.95 6.59"

$ns_** at 2.0 "**$node_(2) setdest 40.81 10.05 5.76"

$ns_** at 2.0 "**$node_(3) setdest 19.95 39.08 5.13"

$ns_** at 3.0 "**$node_(1) setdest 577.76 1569.95 8.30"

$ns_** at 3.0 "**$node_(2) setdest 48.43 10.05 7.63"

$ns_** at 3.0 "**$node_(3) setdest 19.95 46.08 7.00"

$ns_** at 4.0 "**$node_(0) setdest 10.05 1521.3600000000001 9.49"

$ns_** at 4.0 "**$node_(1) setdest 567.5200000000001 1569.95 10.24"

$ns_** at 4.0 "**$node_(2) setdest 57.400000000000006 10.05 8.97"

 # Setup traffic flow between nodes

Agent/TCP **set** window_ 20

Agent/TCP **set** packetSize_ 1000

Agent/TCP **set** maxburst_ 0

```
Agent/TCP set maxcwnd_ 0
Agent/UDP set packetSize_ 1000
Application/Traffic/CBR set rate_ 64Kb
Application/Traffic/CBR set random_ NO
Application/Traffic/CBR set maxpkts_ 2280000
set tcp0 [new Agent/TCP]
$tcp0 set class_ 2
set sink0 [new Agent/TCPSink]
$ns_ attach-agent $node_(2) $tcp0
$ns_ attach-agent $node_(6) $sink0
$ns_ connect $tcp0 $sink0
set ftp0 [new Application/FTP]
$ftp0 attach-agent $tcp0
$ns_ at 0.0 "$ftp0 start"
$ns_ at 1000.0 "$ftp0 stop"
set tcp1 [new Agent/TCP]
$tcp1 set class_ 2
set sink1 [new Agent/TCPSink]
$ns_ attach-agent $node_(1) $tcp1
$ns_ attach-agent $node_(5) $sink1
$ns_ connect $tcp1 $sink1
set ftp1 [new Application/FTP]
$ftp1 attach-agent $tcp1
$ns_ at 0.0 "$ftp1 start"
$ns_ at 1000.0 "$ftp1 stop"
# Tell nodes when the simulation ends
for {set i 0} {$i < $val(nn) } {incr i} {
```

```
   $ns_ at $stopTime "$node_($i) reset";}
$ns_ at $stopTime "stop"
$ns_ at $stopTime "puts \"NS EXITING...\" ; $ns_ halt"
proc stop {} {
   global ns_ tracefd namtrace
   $ns_ flush-trace
   close $tracefd
   close $namtrace
}
puts "Starting Simulation..."
$ns_ run
```