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**SURVEY STUDY FOR VEHICULAR AD HOC NETWORKS PERFORMANCE
IN CITY AND URBAN RESIDENTIAL AREAS**

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ABBREVIATIONS

A-STAR	Anchor-Based Street and Traffic Aware Routing
ABR	Associativity-Based Routing
ACK	Acknowledgment
AGF	Advanced Greedy Forwarding
AMAR	Adaptive Movement Aware Routing
AODV	Ad Hoc on Demand Distance Vector
ARP	Address Resolution Protocol
B-MFR	Border-Node Based Most Forward within Radius
CAR	Connectivity Aware Routing Protocol
CBDRP	Cluster-Based Directional Routing Protocol
CBR	Constant Bit Rate
CFM	Car Following Models
CGSR	Cluster-head Gateway Switch Routing
CTS	Clear to Send frame
DAG	Directed Acyclic Graph
DIR	Diagonal-Intersection-based Routing Protocol
DRG	Distributed Robust Geocast
DSDV	Destination-Sequenced Distance-Vector Routing
DSR	Dynamic Source Routing
DSRC	Dedicated Short-Range Communication
DTN	Delay Tolerant Network
DTSG	Dynamic Time-Stable Geocast Routing
EBGR	Edge Node Based Greedy Routing Protocol
EDR	Event Data Recorder
FIFO	First in First Out
FSR	Fisheye State Routing
GDF	Geographical Data File
GPCR	Greedy Perimeter Coordinator Routing
GPS	Global Positioning System
GPSR	Greedy Perimeter Stateless Routing
GRANT	Greedy Routing with Abstract Neighbor
GSR	Geographic Source Routing
GUI	Graphical User Interface
GyTAR	Greedy Traffic Aware Routing Protocol
HARP	Hybrid Ad Hoc Routing Protocol
IARP	Intra-Zone Routing Protocol
IDM	Intelligent Driver Model
IEEE	Institute of Electrical and Electronics Engineers
IERP	Inter-Zone Routing Protocol
IP	Internet Protocol
IPv6	Internet Protocol version 6
ISI	Inter Symbol Interference
IVG	Inter-Vehicle Geocast
LORA-CBF	Location Routing Algorithm with Cluster-Based Flooding
LOS	Line of Sight

MANET	Mobile Ad-Hoc Network
MOVE	Mobility Model Generator for Vehicular Networks
MPR	Multipoint Relays
NCTUns	National Chiao Tung University Network Simulator
ns-2	network simulator 2
OFDM	Orthogonal Frequency Division Multiplexing
OLSR	Optimized Link State Routing Protocol
OSR	Open Street Map
pdf	probability density function
PGB	Preferred Group Broadcasting
ROMSGP	Receive on Most Stable Group-Path
ROVER	Robust Vehicular Routing
RPGM	Point Group Mobility Model
RSU	Rode Side Unit
RTS	Request to Send frame
RWP	Random Way Point
TBRPF	Topology Dissemination Based on Reverse-Path Forwarding
TCP	Transmission Control Protocol
TIGER	Topologically Integrated Geographic Encoding and Referencing
TORA	Temporally Ordered Routing Algorithm
TraNS	Traffic and Network Simulation Environment
STBR	Street Topology Based Routing
STRAW	Street Random Waypoint
SUMO	Simulation of Urban Mobility
UDP	User Datagram Protocol
UMB	Urban Multi-hop Broadcast Protocol
UMTS	Universal Mobile Telecommunications System
V-TRADE	Vector Based Tracing Detection
V2I	Vehicle to Infrastructure
V2V	Vehicle to Vehicle
VADD	Vehicle-Assisted Data Delivery Routing Protocol
VANET	Vehicular Ad Hoc Network
VGPR	Vertex-Based Predictive Greedy Routing
WAVE	Wireless Access for Vehicular Environment
WLAN	Wireless Local Area Network
WRP	Wireless Routing Protocol
XML	Extensible Markup Language
ZOF	Zone of Forwarding
ZOR	Zone of Relevance
ZRP	Zone Routing Protocol

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ABSTRACT:

The number of vehicles on roads is increasing annually. Due to the higher amount of traffic, there are more accidents associated with road traffic complexity. According to the Association for Safe International Road Travel (ASIRT) nearly 1,3 million people die in road crashes every year. Vehicular Ad-hoc Networks (VANET) can be used to detect dangerous situations which are forwarded to the driver assistant system by monitoring the traffic status. VANET provides essential safety controls for drivers such as switching lanes warnings, nearby cars vision in blind spot. It is an intelligent form of AD hoc networks that accompanied by rapid mobility. VANET integrates numerous ad hoc networking technologies as WiMax, WiFi, Bluetooth and ZigBee to provide the essential high quality communication link between vehicles in such high level of mobility. Regardless of the benefits, VANET is considered as an expensive and complex technology due to the costly establishment of network control nodes on sides of roads and the mobile network nodes, i.e. vehicles. This research work is a survey on the best optimized VANET simulation to comply with Urban and city conditions providing maximum QoS and network performance.

KEYWORDS: VANET, wireless communications, mobility modelling, traffic safety.

1. INTRODUCTION

Vehicular ad hoc networks are developed for assuring safety, traffic regulation and commercial purposes. It is a subdirectory from the broader topic of mobile ad hoc networks MANET. Having vehicles as network nodes, these nodes are characterized by the high mobility and high ability to communicate to each other at high velocities. Vehicle to vehicle and vehicle to infrastructure are the two major types of communication between all existed network nodes in the network. (Boban & Vinhoza 2011)

First approach for VANET was back in 1970s when the United States introduced an Electronic Route-Guidance System to regulate vehicle movement on roads. The vehicle had to send a unique codeword to the roadside every predefined checkpoint then wait to receive the next instruction to safely arrive its destination. After the release of that prototype, Japan introduced the Comprehensive Automobile Traffic Control System in 1973 to limit the accidental car crashes. In 1986, Europe developed the PROMETHEUS program having the vehicle to vehicle communication V2V term for the first time in addition to the vehicle to infrastructure V2I. Several major attempts followed by the US, Japan and Europe until in 1999, a 75 MHz band was allocated to Short-Range Communication DSRC. In 2004, the IEEE institute initiated the 802.11p standard. One year after in 2005, the first practical implementation for VANET applications such as vehicles locations and traffic signal indications are carried out by the US department of transportation. (Boban & Vinhoza 2011)

VANET technology is facing many obstacles and challenges making it a complex technology and expensive. Some of these challenges are:

1. High Velocity while transmitting: This factor has a direct impact on varying network topology with higher probability for frequent disconnections. Nodes are moving deterministically or randomly generating more than one route for signaling from source to destination nodes, yielding a tough decision making to be made by the network for routing data packets besides the complex topology. (Ali 2013)

2. Security: VANET is a type of wireless communication networks which in fact possess security vulnerability and channel impairments. (Ali 2013)
3. Standardization: When it comes to vehicles, there is a broad market of vehicles manufacturers and various types such as: cars, motorcycles and trucks whereas each one has his own differentiation however it is essential to propose a unified standard for VANET communication between all the brands. (Ali 2013)
4. Implementation: Road Side Units RSUs establishment, embedding public and private transportations with VANET modules are factors affecting the cost of VANET implementation. This is the main reason that VANET still an under-research topic which is only implemented through simulators and not yet in reality. (Ali 2013)

Almost all VANET research works are based on simulations because of the costly testing requirements. Modern VANET simulators are differing from the classic ones; they are employing a realistic simulation environment instead of the unrealistic assumptions such as random waypoint mobility and interference-free conditions. Indeed, it is not yet up to perfection but researchers are exerting more efforts to enhance VANET simulators to be able to yield more realistic results. (Boban & Vinhoza 2011)

To conduct a VANET simulation, there are three main models:

- Mobility models
- Networking models
- Signal propagation models

Mobility models are the theoretical demonstration of all sorts of vehicular movements such as obeying the traffic regulations, behavior to neighboring vehicles and sticking to the aligned roadway. Networking models are the models which concerned to the medium access control layer (MAC) protocols for easiness to correspondence between network nodes, these models share in the responsibility for realizing the simulation. Signal

propagation models describes the complex channel impairments associated to the wireless communication links between vehicles-to-vehicles and vehicles-to-units including the static blockages such as buildings and natural obstacles as well as mobile objects such as vehicles. (Boban & Vinhoza 2011)

The work introduced in this thesis is an approach to combat the drawbacks of wireless network problems in addition to solve some of VANET challenges that are preventing the reality to benefit from this technology.

It consists of seven chapters.

- Chapter 1 introduces the Vehicular Ad-hoc network as modern technology, stating its challenges and characteristics.
- Chapter 2 shows the analysis of mobility models mathematically and analytically.
- Chapter 3 speaks about the wireless channel, its impairments and the free space medium path losses and how to combat them.
- Chapter 4 elaborates about the essential VANET routing protocols discussed by researchers.
- Chapter 5 defines some of VANET well known simulators and introduces the designed simulation environment which is the main objective of this thesis.
- Chapter 6 exhibits three simulation attempts from three carried out experiments from textbooks and showing its results, strengths and further development.
- Finally, Chapter 7, at the conclusion section, notes concerning the output are stated.

2. MOBILITY MODELS

Mobility models are the study of the mobile patterns of network nodes i.e. vehicles. Knowing the closest model to reality depends on the accuracy of data acquired and the proper solution to each of the impairments found that is why these models are essential in realizing VANET practically. Thus, the rest dependent modelling layers are all affected by stating the mobility model in the first place. Routing protocols functions such as resolving routes and creating new routes are directly proportional to the mobile nature of vehicles because any slight change in topology equals change in network decision.

2.1. Factors affecting mobility modelling

1. Street layout: street borders act as guidelines in which vehicles have to follow, besides the number of lanes per road and one-way or two-ways road are both factors that determine the area in which network nodes are allowed to move. (Mahajan, Potnis, Gopalan & Wang 2006)
2. Block size: The bordering small-sized area surrounds each street is considered as the city block area which determines the number of intersections hence regulate number of car stops. Larger block size increases the effect of clustering. (Ali 2013)
3. Traffic control mechanisms: Traffic law enforcements are a direct affecting factor for vehicle clustering. At intersections, road stop signs and traffic congestions vehicles have to operate at slower speeds or attempt full stops which in turn format car queues. Slower speed is a positive factor from topology point of view but negative from network performance perspective. (Ali 2013)
4. Interdependent vehicular motion: Movement interaction between vehicles on same roadway is affected by the pattern of every nearby vehicle such as maintaining suitable safe distance between each other, changing lanes and so forth. (Mahajan, Potnis, Gopalan & Wang 2006)
5. Average speed: Network topology varies with vehicular speed variations since vehicle position changes directly with changing speed. Road speed limitations are a contributing factor as well, it helps in stating vehicle routes and reroutes

whenever certain route is broken. In case of fewer intersection point within a map, the probability of getting more accelerated vehicles increases.

(Mahajan, Potnis, Gopalan & Wang 2006)

6. Weather conditions: Foggy, snowy and rainy days affect drivers' visibility to roads as well as his\her control of the vehicle. Sometimes the bad weather condition may shut off entire routes in case of major situations like landslides, bridge falls or hurricanes. (Ali 2013)

2.2. Classification of mobility models:

2.2.1. Random mobility model

In the earliest VANET simulations, primarily the RWP Random Way Point mobility model was used. It assumed a totally free random movement of network nodes regardless of the constraints that are applied to vehicles on roadway and the presence of obstacles. The RWP employed mathematical stochastic processes to randomly sample mobility parameters such as speed, direction and destination. Unlike MANETs models, vehicles are characterized by unpredictable state of motion i.e. acceleration, deceleration, and full stops in traffic thus the RWP models is not considered as a realistic model that can be realized in practice, researches are still underway for more real models. (Ali 2013)

2.2.2. Flow mobility models

Flow of vehicles is the movement of vehicles in same direction at same unit of time for one unit of distance. Vehicular flow modelling is the process of understanding vehicular attitude to each other on roads. These models study all sorts of vehicular flow interactions within routes. Depending on the amount of data acquired, flow models can be divided to microscopic, mesoscopic and macroscopic models. (Ali 2013)

Both Human behavior and external conditions act as the realistic behavior of the model hence a deep study is required for a close-to-reality simulation. Flow modelling is essential in determining the critical aspect of vehicular motion, as surveyed. Models were developed to explain the behavior of human drivers and his\her reactions while relative

position between vehicles changes. Drivers' reactions to relative positions of vehicle in front are described by various models yet the basic idea of such models is assigning certain safe distance between each vehicle, usually it is greater than or equals the size of extra vehicle in between. (Vaity & Thombre 2012)

Figure 1 shows the movement of vehicles as directional.

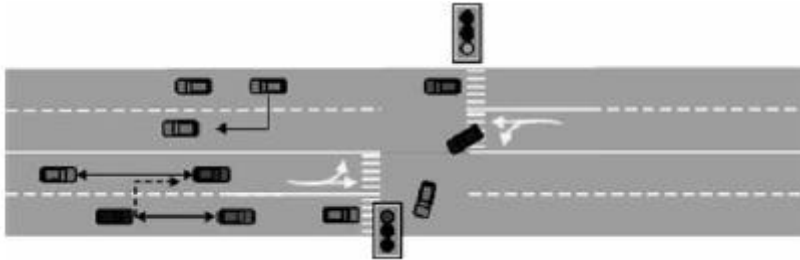


Figure 1. Movement of vehicles as directional flow (Ali 2013)

(Vaity & Thombre 2012) describes the main factors that are taken into consideration while designing which directly affect flow mobility models:

- Flow of vehicles
- Blockage size
- Traffic regulation
- Average speed and street layout

Factors affecting mobility design are illustrated in Figure 2.

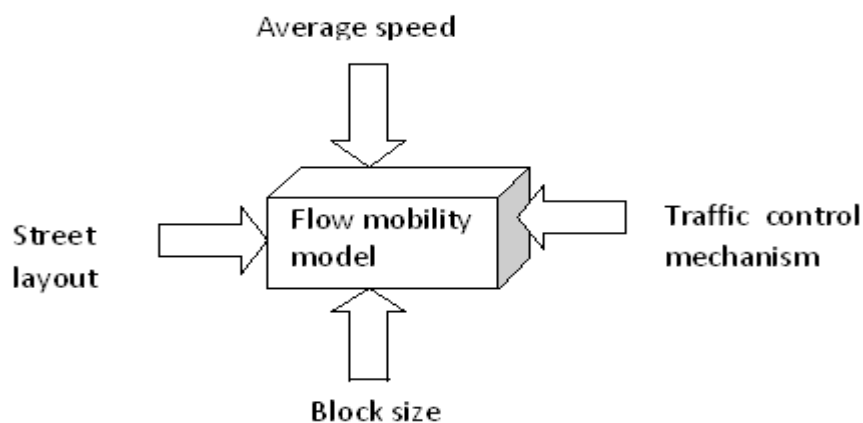


Figure 2. Factors affecting flow mobility models.

V2V and V2I Correspondences are done through network routing protocols. They are based on distance vector or link state algorithms. These protocols are used to ease routing of messages through the entire network nodes avoiding crowded paths and generating new routes to maximize the overall QoS of communication links.

2.2.3. Flow modelling representation

The flow can be represented by three different ways:

- Microscopic flow modelling
- Macroscopic flow modelling
- Mesoscopic flow modeling

2.2.3.1. Microscopic flow modelling

Studying the mobility modelling and flow of vehicles in detailed view, meaning that all vehicles' parameters are taken into account such as acceleration, deceleration, driver behavior and vehicle speed. Although its complexity, these models are essential in finding the accident free environments. (Ali 2013)

Types of Microscopic flow modelling are shown in Figure 3.

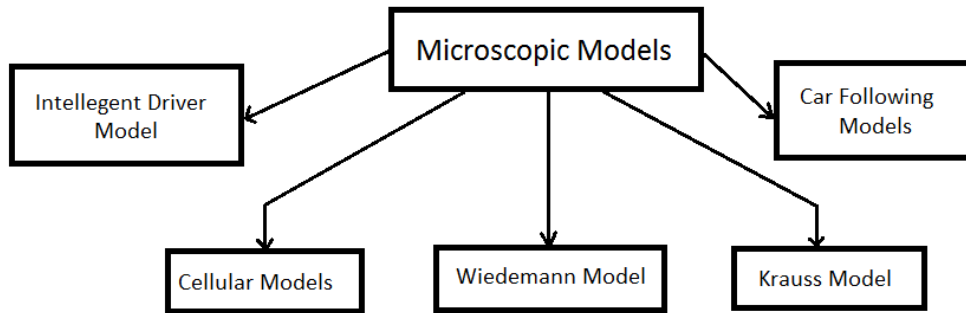


Figure 3. Microscopic Mobility Models (Ali 2013)

1. Car Following Model (CFM)

In this model, microscopic information as time, velocity and car position are represented. Mobility patterns are generated upon condition of avoiding any physical contact with the leading vehicle, this distance is called distance headway.

Pipe rule equation used in this case as in equation 1.

$$\Delta x^{safe}(v_i) = L + Tv_i + \mu \cdot v_i^2 \quad (1)$$

Where L is Length of vehicle, V_i is the velocity of vehicle, T is the safe time headway and μ is the adjusting parameter for deceleration. (Vaity & Thombre 2012)

2. Intelligent Driver Model (IDM)

This model is the enhancement of CFM; it counts in the vehicle's instantaneous acceleration which is based on stimulus response approach. The safe distance is replaced by free acceleration calculation equation, as shown in equation 2.

$$a^{free} = a[1 - (\frac{v_i}{v_i^{des}})^4] \quad (2)$$

To state specific speed, Interaction deceleration to contact leading vehicle is calculated as in equation 3.

$$a^{int} = -a(\frac{\delta}{\Delta x_i(t)})^2 \quad (3)$$

Whereas δ is the desired gap between follower and leader vehicle. In 2009, This model is introduced in traffic simulator VanetMobiSim. (Vaity & Thombre 2012)

3. Krauss Mobility Model

Unlike IDM, this model maps the acceleration as discrete in time domain also it is based on stimulus response approach. IDM states the maximum acceleration and maximum velocity but Krauss model states the μ : adjusting parameter for acceleration/deceleration to control maximum velocity. Simply it is the change in current speed for a unit step time Δt . this assures driver's commitment to the model and regular increase in speed.

In 2009, this model was introduced in traffic simulator SUMO.

(Vaity & Thombre 2012)

4. Wiedemann Mobility Model

It is considered as a psycho- physical model i.e. driver's mentality is taken into consideration to predict multiple responses for the same input stimulus.

The driver probably should be one profile out of the following four probabilities as follows:

- In case of no leading vehicle, the driver accelerates without restrictions.
- Approaching mode: While approaching a leading vehicle, the driver decelerates till assigning a suitable safe distance in between.
- Following mode: The same core idea of Car Following mode adding the smooth acceleration and deceleration.
- Breaking mode: Crash avoidance away from leading vehicle using deep sudden deceleration. (Ali 2013)

The driver's driving is influenced differently by nearby vehicles as long as the following equation is true.

Driver's response = stimulus * sensitivity

In 2008, this model was introduced in traffic simulator VISSIM.

(Vaity & Thombre 2012)

5. Cellular Automata Model (CAM)

Computational complexity is reduced thanks to the discrete nature of both time and space in this model. Road lanes are represented as frame of identical cells lattice. It employs same driver mentality probabilities as the Wiedemann model. The vehicle movement is implemented by switching between cells noting the speed as the number of cells per unit time. Acceleration, braking and randomization are applied in terms of distance and velocity.

In 2009, this model was introduced in traffic simulator TRANSIMS.

(Vaity & Thombre 2012).

2.2.3.2. Macroscopic flow modelling

Focusing on the overall flow of the group of vehicles from a global perspective. These models are able to state mass, density and flow of vehicles if time and location are constant. (Ali 2013)

Macroscopic flow models can be described by three equations. Given that the road is segmented into x road segments therefore the flow is stated as $m(x.t)$ the expected number of vehicles passing by x for interval $(x\Delta t)$ and density $\rho(x.t)$. (Vaity & Thombre 2012)

The velocity $v(x.t)$ which is the speed of vehicles in road segment x is calculated from equation 4, by knowing density and flow.

$$v(x.t) = m(x.t) / \rho(x.t) \quad (4)$$

The second equation describes the variation in density of vehicles with respect to the flow in or out of specific position on road segment x , as in equation 5.

$$\frac{\partial \rho(x.t)}{\partial t} + \frac{\partial m(x.t)}{\partial x} = 0 \quad (5)$$

Third equation is formulated from the well-known Lighthill-Whitham-Richard (LWR) macroscopic model whereas the speed is described in terms of density, as illustrated in equation 6.

$$\frac{\partial \rho(x.t)}{\partial t} + \frac{\partial \rho(x.t) * v(\rho(x.t))}{\partial \rho} + \frac{\partial \rho(x.t)}{\partial x} = 0 \quad (6)$$

Studying on the macroscopic perspective is useful in case of large scale flow modelling. Although it is beneficial to simplify the computational complexity, fewer details are present in this model unlike studying microscopic one which considers each and every piece of information. (Ali 2013)

2.2.3.3. Mesoscopic flow modelling

Mesoscopic modelling is considered as an intermediate modelling technique between the microscopic and macroscopic one. In Mesoscopic modelling, traffic flow is represented as probability density function depending on clustering effect and the individual interaction of vehicles. One example is the queue model, the queue is the waiting mandatory path in which vehicles have to pass by to flow, that is why road segments are divided in queues operating with FIFO principle (first in first out). The capacity and maximum ongoing capacity of each queue is limited to certain value, the dynamic behavior of vehicles and macroscopic properties such as density and velocity of large number of vehicles are also determined and taken into consideration. In switching queues situation, a certain vehicle cannot switch its current queue as long as the target queue does not have a free space to accept it, as in Figure 4. (Ali 2013)

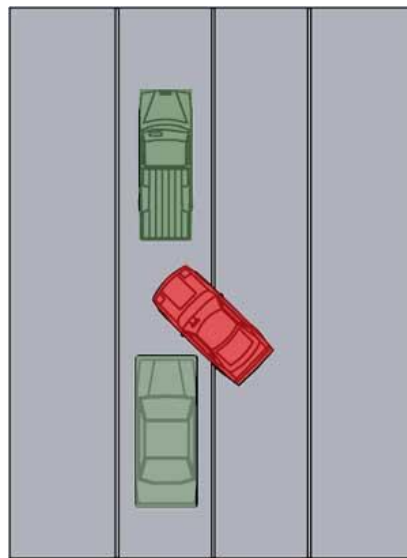


Figure 4. Wrong switching queues in Mesoscopic modelling (Larson 2016)

2.2.4. Traffic simulator-based models

Researchers developed this type of models to make the best use of the regular gathered information about the traffic status. This model has the capability for modelling the characteristics of the trip path such as fuel consumption needed, fluency of traffic and even modelling noise and pollution found within the road. For instance, if the user seeks

moving from the origin point (O) to the destination point (D) then the model calculates the shortest, less crowded path depending on obtaining the location of turns, traffic stops, and analyzing signs at intersections. (Harri, Filali & Bonnet 2006)

Two types of planning were introduced in that model. (Ali 2013)

1- Trip Planning

Using stochastic process to set the next new direction after performing a turn and the OD points are left for the vehicles to decide.

2- Path Planning

The OD points are set firstly, following by obtaining the best choice of paths based on lower latency, shorter and less populated paths. The measured paths are subject to a change regularly due to the dynamic nature of these parameters.

The model was primarily set to comply with urban traffic simulators as VISSIM or PARAMICS. Consequently, there is a difficulty adapting these simulators with network ones due to the absence of valid network interfacing between simulators. In addition to the large number of parameters those are used to be calibrated making it a time-consuming process. (Harri, Filali & Bonnet 2006)

2.2.5. Behavioral models

Nothing is certain while human driving behavior is studied as it is one of the most complex modelling issue. That's due to the vast number of influencing factors that affect human behavior as: the driver's physical condition, driver's habits (depends on territory), visual acquisition of traffic, obstacles, weather conditions and timing. Behavioral models assumption is the key to develop an artificial intelligence system that can - in the future - mimic human reactions for every slight change in model parameters. Second best option is developing a collection set of certain common habits and strategies called "Driver Agents" then distribute it over a certain number of cars to finally gain a percentage of cars from the total number which represents the associated Driver Agent. (Ali 2013)

2.2.6. Trace-based models

Unlike the synthetic models which employ complex data to evaluate, the Trace-based model approach avoids the previous drawbacks by concluding direct mobility patterns from the traces of vehicles instead of conducting complex mobility model then study. This approach was endorsed by numerous projects to carry out measurement campaigns such as UMASSDieselNet and CawDaD. (Harri, Filali & Bonnet 2006)

Though, some measurements' limitations are present in each campaign. For example, when tracing heavy-freight vehicles from traffic perspective is not as tracing privately owned cars. In addition, the unavailability of free vehicular tracing testbeds available for public which make the research process time and budget costly.

(Harri, Filali & Bonnet 2006)

2.2.7. Survey-based models

Surveying car mobility patterns in cities in real time is found to be more efficient than assuming editable synthetic models and reevaluate redundantly. The United States department of labor produces most of the large-scale surveys that researchers rely on. The acquired statistics are thorough enough to record the daily behavior of labors such as arriving time, break durations and traveled distances. These data when embedded to a certain mobility model, the result will be more likely to be generic and realistic. (Harri, Filali & Bonnet 2006)

3. WIRELESS CHANNELS

Varieties of road types are present all over the Earth. At one hand, some roads can be across Desert, Mountains, Forests, Rivers and plain grounds, they can be atop mountain or hills or even below sea level. Every geographical place has a different situation with respect to communication link quality of service than others. On the other hand, city topography is usually crowded with small and large buildings and sometimes skyscrapers. These aspects are all taken into consideration while studying the wireless channel that operates all over VANET nodes as they directly affect the quality of transmission and the controlling of losses.

Channel impairments can be divided into small scale fading and large scale fading.

3.1. Large scale fading

It is the channel effect towards the propagated signal from transmitter to receiver after covering long distances. Signal gets attenuated i.e. suffers from power losses due to the medium path loss factor that differs from medium to another.

This effect can be formulated mathematically as in equation 7.

$$\Gamma_{dB} = 10v \times \log\left(\frac{d}{d_0}\right) + c \quad (7)$$

where Γ_{dB} is the Decibel path loss, d is the kilometer distance between transmitter and receiver, v is the exponent path loss, c is a constant, and d_0 is the kilometer distance to the reference point. The 'C' constant is a transmitter specific i.e. depends on the height of antenna and the wavelength. (Ali 2013)

Practically, it is found that path loss does not only depend on the distance between transmitter and receiver but also the type of obstruction hence there is another term that has to be implemented in the previous equation whereas its effect is modeled as random variable. The equation is modified to be as represented in equation 8.

$$\Gamma_{dB} = 10v \times \log\left(\frac{d}{d_0}\right) + S + c \quad (8)$$

Whereas S is the shadow loss random variable.

After conducting several measurements, it was found that the decibel form of 'S' can be expressed as a Gaussian zero-mean random variable having a decibel standard deviation. (Liu, Sadek, Su & Kwasinski 2009)

3.2. Small scale fading

It is the channel effect towards propagated signal between the transmitter-end and receiver -end for smaller distances. The main causes of small scale fading are the existence of obstruction between transmitters and receivers like buildings, vehicles, trees and lamp posts which block LOS (Line of Sight). The particle nature associated with transmitted electromagnetic waves cause the signal to reflect, diffract and scatter depending on the type and the size of the obstacle. A signal suffers from successive distortions due to

3.2.1. Reflection

The signal encounters reflection whenever it hits smooth and relatively larger sized-obstacles compared to the signal wavelength. (Koivo and Elmusrati 2009)

3.2.2. Refraction

The signal encounters refraction whenever it propagates through large dense obstacle resulting in formation of secondary waves that are refracted from its original version at the surface of that body. (Ali 2013)

3.2.3. Scattering

Rough obstacles having smaller or equal dimension compared to the signal wavelength such as lamp posts or traffic signs cause signal scattering phenomenon. Scattering will be in all directions. (Ali 2013)

Figure 5 illustrates small scale fading effects as showing in the next page.

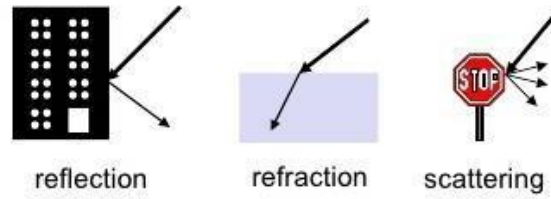


Figure 5. Reflection, Scattering and diffraction phenomena illustration

Assuming channel linearity i.e. no change by time passage, the received signal can be described as in equation 9.

$$y(t) = \sum_{i=0}^L h_i x(t - \tau_i) \quad (9)$$

Whereas h_i is the path attenuation and τ_i is the time delay which correspond to the i th path. (Liu, Sadek, Su & Kwasinski 2009)

Due to channel impairments described above, multiple replicas of the original signal arrive at the same time causing losses in amplitude and phase of the signal. Having different delays and directions, these replicas are called Multipath signals. (Ali 2013)

3.3. Essential Wireless Channels Parameters

Fading can be fast fading or slow fading, frequency flat fading or frequency selective fading depending on the transmitted signal and its properties and the medium channel that propagates through. The following characteristics define this effect

3.3.1. Channel's Delay spread

It is the time spent since receiving the first path till receiving the last measured path. Intersymbol interference (ISI) occurs when the time spent by the transmitted symbol is larger than the delay spread resulting in a mixture of redundant versions coming from multipath with the original signal causing ISI. This effect can be fixed by introducing Orthogonal Frequency Division Multiplexing (OFDM) modulation technique that employs frequency subcarriers to avoid ISI, showed in Figure 6 in the next page. (Ali 2013)

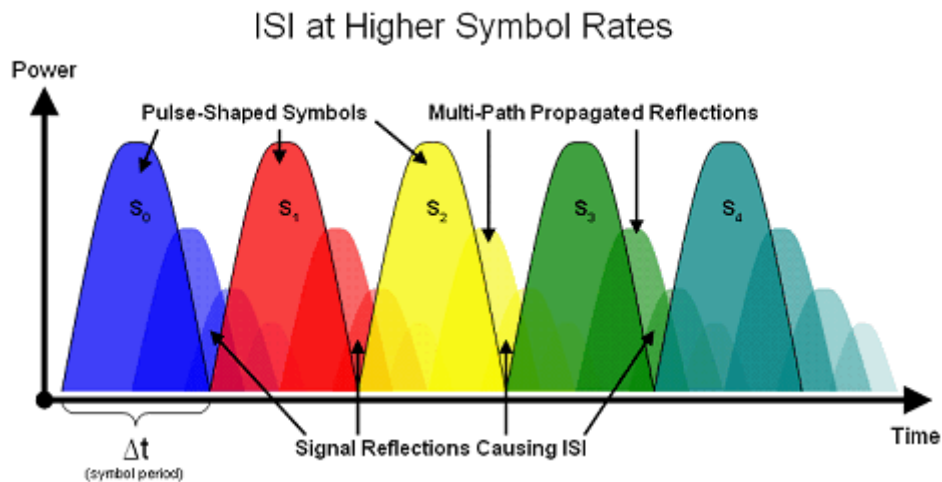


Figure 6. Intersymbol Interference (National Instruments 2014)

3.3.2. Channel's Coherence Bandwidth

It is the frequency band that propagates through the given channel and can be successfully received at the receiver end almost free from phase amplitude distortions.

3.3.2.1. Frequency selectivity channel

When the transmitted signal bandwidth exceeds the channel's coherence bandwidth, it is common that ISI (Intersymbol interference) occurs.

3.3.2.2. Frequency flat fading channels

Unlike frequency selectivity, this occurs when the transmitted signal bandwidth is much less than the coherence bandwidth of the channel. This channel effect does not distort the signal severely that is why researchers made the best use of flat fading channels in Orthogonal Frequency Division Multiplexing (known as OFDM) technique by converting the selective channel to several flat channels using subcarriers, described in Figure 7 in the next page.

Reduced ISI with Low Symbol Rate (OFDM)

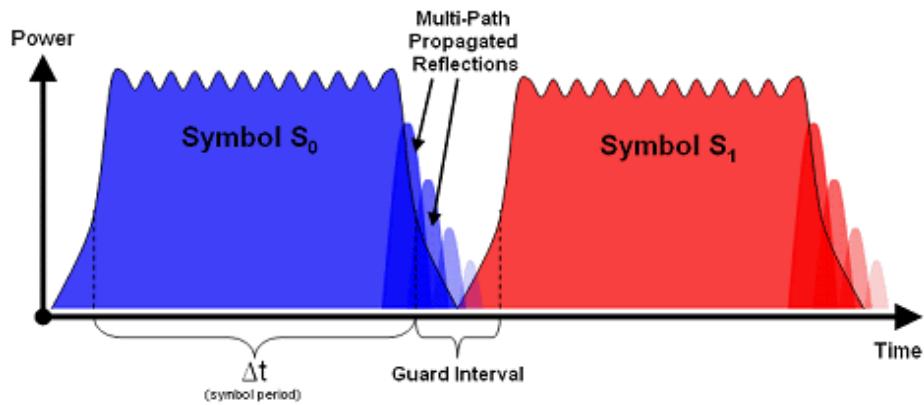


Figure 7. ISI mitigation using OFDM (National Instruments 2014)

3.3.3. Doppler Phenomenon

When either of the Sender or the Receiver is in a rapid mobility movement, the Doppler physical phenomenon is inevitable. The signal frequency is shifted by f_d known as (Doppler Shift), mathematically represented in equation 10.

$$f_d = \frac{v}{\lambda} \cos \theta \quad (10)$$

Whereas θ is the arrival angle, v is equal to the velocity difference between the transmitter and the receiver. The frequency increases when the transmitter approaches the receiver and vice versa i.e. like the ambulance model in Figure 8 as showed (Rappaport & Theodore 2002)

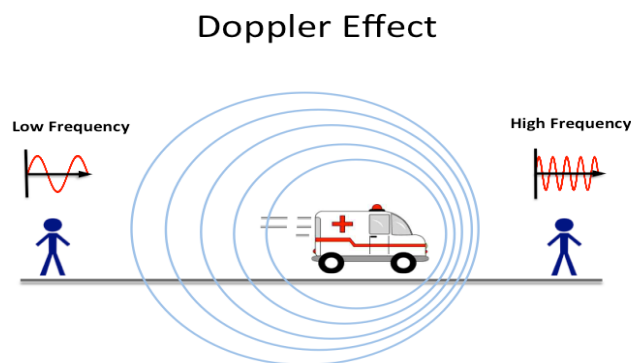


Figure 8. Doppler Effect (Think Link 2016)

3.4. Conducting a realistic VANET modelling

Three categories of Path loss models are considered for realizing a VANET simulation scenario to the nearest realistic scenario, they are as follows:

Deterministic Models: The result of Theories and Mathematical equations results which study the essential parameters as the size of obstacles and objects. These models require one to many computational inputs. (Ali 2013)

Empirical Models: Not always accurate because they are based on approximations (curve fitting) of statistical information determined from real site measurements. These models are not complex, straightforward and site specific hence they are inaccurate if used in wrong situations. (Ali 2013)

Semi-Deterministic Models: Based on empirical methods but with employing other deterministic inputs. (Ali 2013)

3.5. Path-Loss models for VANET

Some of Vehicular Ad Hoc Networks propagation models are described as follows

3.5.1. Free space Radio Propagation

Assuming LOS with no obstruction in between the transmitter and the receiver, early researchers for MANETs proposed that if and only if LOS is available hence communications is valid otherwise no communication is possible. This model is stated to establish a LOS between the two ends. Received power depends on the transmitted power, mathematically as in equation 11.

$$P_r = \frac{P_t G_t G_r \lambda^2}{(4\pi)^2 d^2 L} \quad (11)$$

Whereas P_r is the power received in Watt, P_t the power transmitted in Watt, G_r the receiver antenna gain, G_t the transmitter antenna gain, d is the distance found from the transmitter to the receiver, L is the total losses in circuitry.

The free space model failed to practically realize VANET nodes communication due to the assumption of manipulating vehicles as if they were random moving points in free space regardless the existing blockage in between the nodes therefore it is not appropriate for usage in crowded places. (Ali 2013)

3.5.2. Two ray ground radio propagation

Although this model assumes that the transmitter and the receiver should be located in the same horizontal plane (identical heights from ground level) as well as the vehicles shall move within the same horizontal plane, this model is widely used in MANET researches as represented in Figure 9. It differs from the free space model in considering the connectivity of the ground as a dielectric material, as shown in equation 12. (Ali 2013)

$$P_r = \frac{P_t G_t G_r h_r^2 h_t^2}{d^4 L} \quad (12)$$

Whereas P_r is the power received in Watt, P_t the power transmitted in Watt, G_r the receiver antenna gain, G_t the transmitter antenna gain, d is the distance found from the transmitter to the receiver, h_t transmitter tower height, h_r receiver tower height, L is the total losses in circuitry.



Figure 9. Two ray model (Wikipedia 2017)

By increasing the transmitter-receiver distance, the effect of ground reflection grows better due to the direct proportionality with the distance travelled by an electromagnetic wave. (Singh & Lego 2011)

Eventually, this model found to be inappropriate practically due to discarding the existence of obstacles, in addition to inaccurate results for short distances due to the destructive interference from the two paths.

3.5.3. Ray tracing model

Ray tracing acquires the topographical data about buildings and objects in details that is why it simply can be used in crowded urban places for mobile cellular systems such as UMTS/IMT2000. Electrical characteristics (Conductivity and Permittivity), the exact fix and size of objects are acquired as well. For each ray transmitted from the antenna, the amplitude is A_n , time of arrival T_n and signal phase θ_n can be calculated using Snell's laws, the Uniform Geometrical Theory of Diffraction (UTD) and Maxwell's equations. The impulse response will be stated from equation 13 in the next page.

$$h(t) = \sum_{n=1}^N A_n \delta(t - T_n) \exp(-j\theta_n) \quad (13)$$

In case of high mobility and rapidly changing environment as in VANET, the Ray Tracing Model is not efficient due to the rapid change in surroundings hence equation parameters as well.

Figure 10 states Path Loss effects.

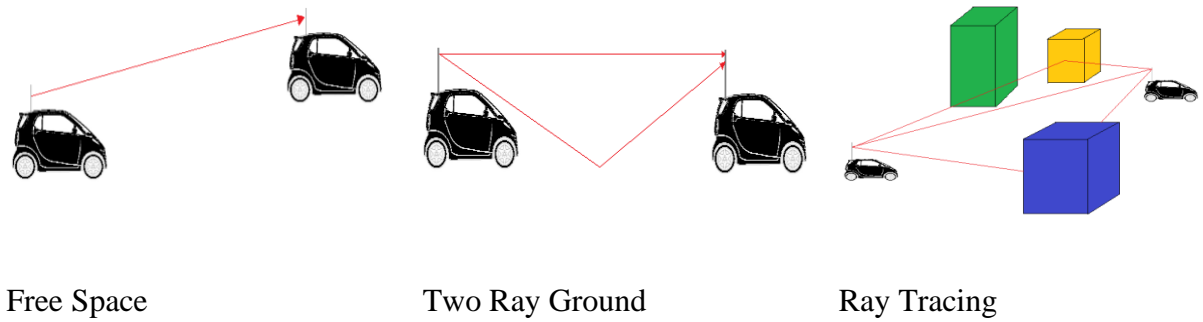


Figure 10. Path loss models for VANET illustration. (Ali 2013)

3.5.4. Log normal shadowing

In this model, received power at the receiver antenna end is assumed to be a random variable instead of being a deterministic function in an ideal case propagation in free space, practically this is not true. Because of multipath propagation effects, the shadowing model includes two models.

First is the path loss model for received average power calculations, as in equation 14.

$$\left[\frac{P_r(d)}{P_r(d_0)} \right]_{dB} = -10\beta \log\left(\frac{d}{d_0}\right) \quad (14)$$

Whereas d is the transmitter-receiver distance, $P_r(d_0)$ is the mean received power and β is the exponent path loss. (Singh & Lego 2011)

Second model accounts for the attenuation in received power due to multipath by representing it as a Gaussian zero-mean random variable X_{dB} to generalize the equation to become as in equation 15.

$$\left[\frac{P_r(d)}{P_r(d)_0} \right]_{dB} = -10\beta \log\left(\frac{d}{d_0}\right) + X_{dB} \quad (15)$$

By variation in β and σ_{dB} , many non-identical scenarios for the surroundings and blockage can be manipulated to apply more reality to the simulation. (Ali 2013)

Measured Path loss values are described in (Eenennaam , E.M. van 2009) as follows

Table 1. Typical Values for Path Loss β

Environment	Pathloss exponent β
Free space	2
Urban area, no blockage	2.7 to 5
Indoor, no blockage	1.6 to 1.8
Indoor, blockage	4 to 6

Table 2. Typical Values of Shadowing Deviation σdB in dB

Environment	Shadowing deviation σ dB
Outdoor	4 to 12
Office, hard partition	7
Office, soft partition	9.6
Factory, no blockage	3 to 6
Factory, blockage	6.8

3.5.5. Rician and Rayleigh models

They are used in case of existing numerous indirect paths which are containing a variation in signal characteristics such as phase, amplitude and power between the transmitter and the receiver. Rayleigh is a zero-mean random variable, on the contrary, Rician is a non-zero mean random variable. Another difference between these two models is that Rician model assumes at least one dominant component of LOS while

Rayleigh accounts only for the multipath signals. The probability density function of a signal received through Rician channel is given by equation 16.

$$f(x) = \frac{2x(k+1)}{P} \exp\left(-k - \frac{(k+1)x^2}{P}\right) I_0 \quad (16)$$

Whereas k is the LOS received power ratio, P is the average received power and I_0 is the zero-order Bessel function. (Rhattoy, A. & A. Zatni 2012)

Equation 17 states the zero order Bessel function evaluation.

$$I_0(x) = \frac{1}{2\pi} \int_0^{2\pi} \exp(-x \cos\theta) d\theta \quad (17)$$

If $k=0$ (i.e. no dominant path or Line of sight), equation reduced to be as in equation 18.

$$f(x) = \frac{2x}{P} \exp\left(-\frac{x^2}{P}\right) I_0 \quad (18)$$

Which is the same probability density function as the Rayleigh model.

3.5.6. Nakagami radio propagation model

The probability density function of Nakagami can be represented by equation 19.

$$f(x) = \frac{2m^m x^{2m-1}}{\Gamma(m) \sigma^{2m}} e^{-mx^2/\sigma^2} \quad m \geq 0.5 \quad (19)$$

Whereas m is the adjusting parameter for the Nakagami distribution, $\Gamma(m)$ is the Gamma function and σ is the standard deviation. A special case of Nakagami is the Rayleigh distribution if $m = 1$. Various scenarios starting with free space model till most faded channels can be implemented using Nakagami as it found to be the proper model for realizing VANET simulations. (Ali 2013)

4. ROUTING PROTOCOLS

Routing protocols are the organizing set of algorithms and rules that are responsible for adjusting transmission to the most optimized path from source to destination. The nature of VANETs network is highly dynamic which makes the routing process is challenging and complicated furthermore always exposed to sudden disconnections.

(Allal, Salim & Boudjit 2013)

Transmitting data wirelessly is either by unicast, forwarding to one certain node or multicast and broadcast; which involves a set of nodes. For an autonomous decentralized network, each node only has knowledge about its immediate neighbors, and all nodes are bounded by the same routing protocols. A packet keeps 'hopping' away from the source node, until it reaches the destination. Routing, the end to end determination of the path of a data packet from source to destination is done on the network layer level, and has to be governed by a set of rules, or routing protocols, which is implemented through algorithms. The target is to pick the optimal path, the one with the lowest cost. Factors which affect how good a routing protocol is include the end to end delay, power consumed, and the rate of delivery.

Routing protocols performance is depending on the power dissipated, the rate of delivered packets and/or beer to beer delay. Finding the most optimized and most beneficial design of routing protocols is a crucial approach which develops the overall quality of service between nodes in such dynamic vehicular networks. (Ali 2013)

When MANETs protocols were introduced to VANETs, the technical limitations found are as follows

- **Scalability** The number of nodes in MANETs was numerously low thus it was employing routing tables which are formed by storing all routes that lead to all other nodes. In VANET, the number of nodes within the network is considerably high hence storing all possible routes to other nodes is high costly.

(Spaho, Barolli, Mino, Xhafa & Kolicic 2011)

- **Mobility** in MANETs, the nodes movements were assumed to be random while in VANETs the nodes movements is limited by road segments and traffic regulations. (Spaho, Barolli, Mino, Xhafa & Kolicic 2011)
- **High usage of flooding** it means that every outgoing link should be flooded with every incoming datagram except the one it comes from. Until the destination is verified, flooding is used for route discovery purpose in reactive protocols. The size of bandwidth spent on such flow of data is increasing whenever flooding is used in larger networks i.e. larger number of nodes. (Ali 2013)
- **Localized Routing** All nodes participate in forming the routing tables in proactive routing protocols. On the other hand, in reactive routing protocols, all nodes have to take join the initial flooding to find all the possible routes that lead to destination. (Spaho, Barolli, Mino, Xhafa & Kolicic 2011)

It was found that deriving routing tables within VANET network is better done through clustering the network to smaller areas (clusters) though extra information is needed such as location which can be obtained through location services like GPS.

(Spaho, Barolli, Mino, Xhafa & Kolicic 2011)

For routing protocols in VANETs to be efficient and adapt to the rapidly changing network nodes positions, following criteria should be present

- **Low Latency** To be complying with the safety requirements.
(Spaho, Barolli, Mino, Xhafa & Kolicic 2011)
- **High Reliability** Achieved by minimizing packet collisions.
(Spaho, Barolli, Mino, Xhafa & Kolicic 2011)
- **Flexibility** It is the measure of providing best quality of service although maintaining correspondence through the vast density of vehicles as well as fast movement. (Spaho, Barolli, Mino, Xhafa & Kolicic 2011)
- **Driver Behavior** Network messages directly are affecting driver's reactions which in turn have a change in network topology again. This effect should be studied carefully and counted in. (Spaho, Barolli, Mino, Xhafa & Kolicic 2011)

- **Comfort Message** Urgent safety messages should be having higher priority than other types of message, and this should be considered when designing routing protocols for VANET. (Ali 2013)
- **Hierarchical Routing** Minimizing network unit of size into smaller units (Clusters) turned to be a minimizing factor for routing tables sizes as well which allows better quality of service, lower delay and smaller overhead. However Hierarchical routing practically enlarges network addressing fields. (Spaho, Barolli, Mino, Xhafa & Kolicic 2011)

Routing protocols in VANET can be divided to five main categories from application perspective as in Figure 11.

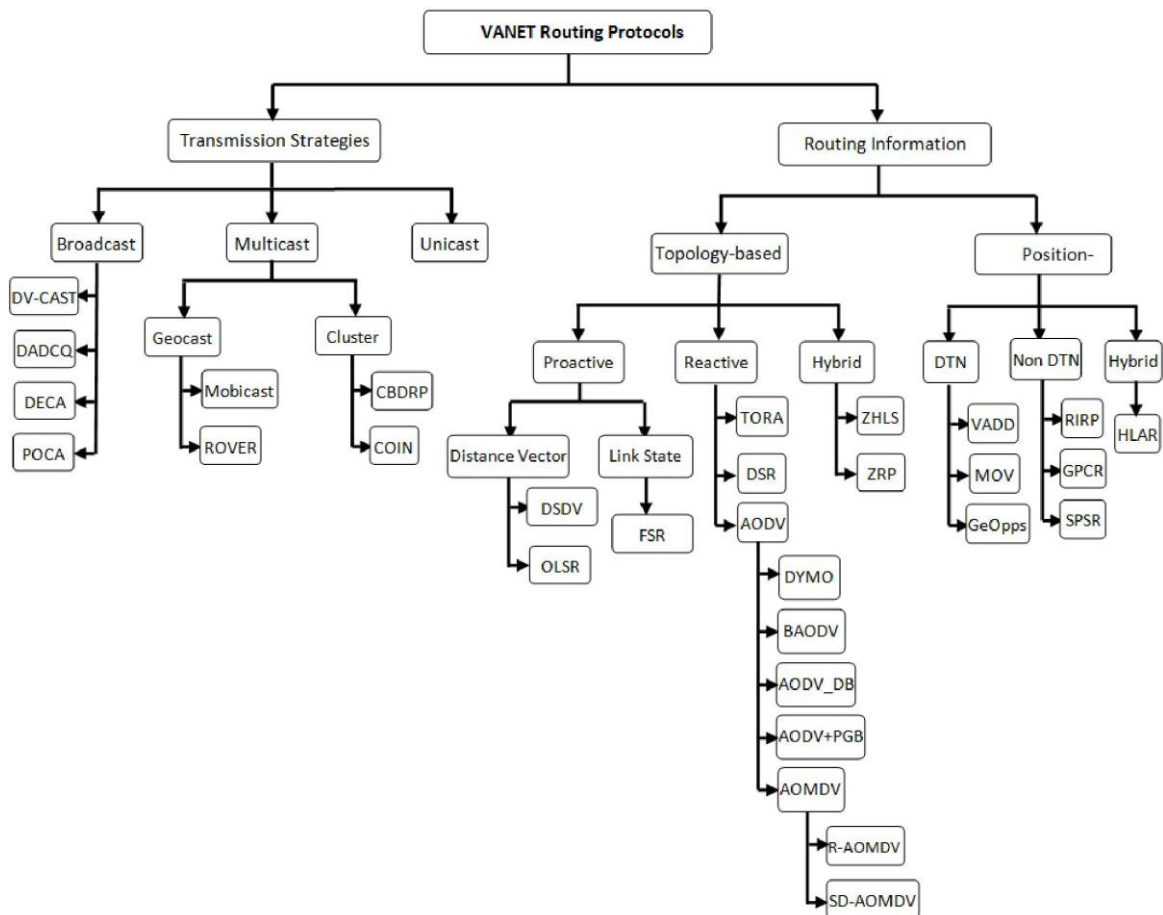


Figure 11. Classification of Routing Protocols (Altayeb & Mahgoub 2013)

4.1. Topology-based protocols

They are classified into proactive (table-driven), reactive (on-demand) and hybrid routing protocols. The main idea is based on utilizing the link information to send datagrams from source to destination. (Lee & Gerla 2009)

4.1.1. Proactive protocols

As mentioned, the proactive protocols enable the use of routing tables to save all possible paths to all nodes. In each table: current node, next hop and origin-destination nodes are described despite whether the routes will be used or not. The routing tables are regularly updated per any change in network topology or network nodes opting in or out then the new tables are broadcasted through the neighboring nodes. This routine reflects an excessive amount of information in case of dynamic mobility. For proactive protocols to choose shortest routes, besides algorithms calculations two strategies are employed: Link state and Distance vector. (Altayeb & Mahgoub 2013)

4.1.1.1. Destination Sequence Distance Vector Routing (DSDV)

To determine the shortest routes, the DSDV protocol employs Distance vector strategy in addition to shortest route algorithm (Bellman-Ford Algorithm) to search for the fastest path that lead to the assigned destination node from routing tables. The advantage of DSDV is to avoid the redundant traffic paths that contain delays whenever routing tables are refreshed and broadcasted hence reduce the overall size of tables. Furthermore, selecting the most optimized route that lead to every hoping node and decreasing the overhead of control signaling. On the contrary, bigger sizes of networks suffers from more overhead caused by DSDV due to the redundancy of refreshed routing tables that sometimes are a repeated version of the previous one. DSDV does not employ selecting more than one path that lead to destination node as well as failing to handle network congestion hence overall efficiency lowers. Due to these drawbacks, the Randomized DSDV (R-DSDV) protocol is used to handle network congestion along with DSDV by checking each node's decision either to pass or block certain packets of data. One disadvantage of R-DSDV is more overhead produced than what DSDV already produced. (Altayeb & Mahgoub 2013)

4.1.1.2. Optimized Link State Routing Protocol (OLSR)

Unlike DSDV, the OLSR protocols follow the Link state strategy and holds the possible paths generated in the routing table. Whenever new nodes register in the network or existing nodes opt out, each node send the changes in paths to selective nodes that in turns pass to the following selective ones but not to the unselected nodes. In higher mobile network, OLSR functions properly as it is designed to deal with varying network topology. The only found disadvantage of OLSR is the overhead caused by the continuous transmission of control signaling whenever network topology changes. Consequently, some developers endorsed the Hierarchical OLSR (H-OLSR) protocol to reduce this congestion in greater network sizes and identify each node with its hierarchical parent nodes. Others proposed the Quality of Service OLSR (Q-OLSR) as an enhancement to the quality of service of packet transmission by picking up the optimal path from bandwidth perspective. The enhancements to OLSR are valid and efficient in specific applications only and not generally. (Altayeb & Mahgoub 2013)

4.1.1.3. Fisheye State Routing (FSR)

Each node is responsible for sensing the changes in network topology that are provided from nearest nodes then update its own routing table accordingly. The new updated tables are sent to other nodes with distinguish frequencies depending on how far the required node from the broadcasting one; updates are sent to the nearest nodes via higher frequency than farther nodes that are sent via lower frequencies. The mentioned process assures reduction in network congestion in the range of smaller network size but in larger sizes it is not, and this is one disadvantage of FSR. (Altayeb & Mahgoub 2013)

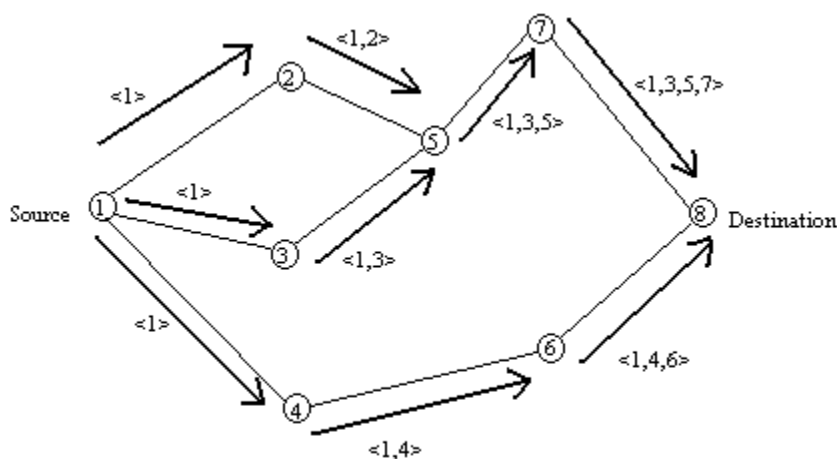
Proactive protocols are having best performance in smaller sized network topologies; as the routes are stored in routing tables and refreshed regularly with newer, optimized paths. This advantage does not exist in larger sized network topologies that have higher dynamic mobility as there will be a large surge of packet congestion throughout the network. Although the limited researches available in Proactive routing protocols development for VANET, some existed researches believe that OLSR protocol can achieve higher network throughput than Reactive protocols. (Altayeb & Mahgoub 2013)

4.1.2. Reactive Protocols

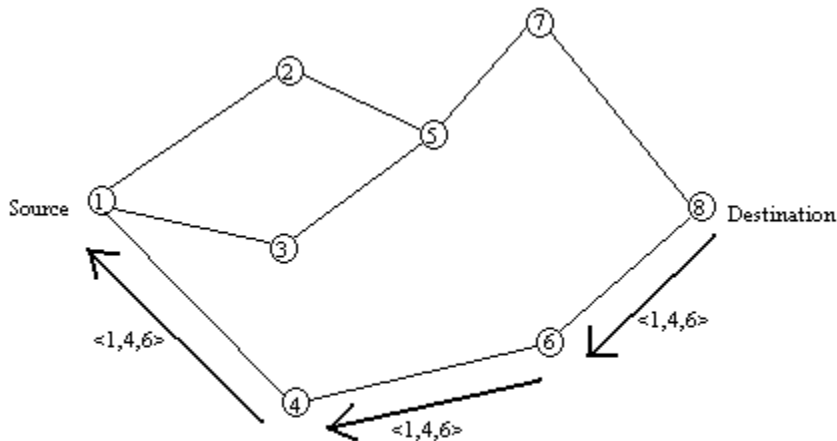
Reactive routing protocols are also known as on demand routing since routes are only used when they are required; the entire network is flooded with request messages, until it reaches the target node. RRP uses two main methods to discover and maintain routes: Incremental Search Method (ISM) and RRP uses Surroundings Repair Method (SRM). ISM is used rather than broadcast based method to discover new routes, and hence it is bandwidth-efficient. SRM detects repairs link breaks, as each node keeps track of its next hop neighbor's, and enters it in the routing table. (Lee & Gerla 2009)

4.1.2.1. Dynamic Source Routing (DSR)

DSR is a multi-hop protocol, where the search for a route begins when a route which supposedly exists is unreachable by the source. A packet intended for finding a route is sent, and checked whenever it arrives at a new node. That 'route request' packet has a unique identifier, plus the addresses of source and destination nodes. If the node receiving it cannot route it, it adds its own address to the route record of the packet, and passes it on to its neighbor's. Route request packets are only examined by nodes whose addresses are not stored which in the record, therefore reducing network overheads. When the destination address is found (directly, or by a node which knows it), the source node gets the response by tracing the sequence in the route record, stated in Figure 12 as showed in the next page. (Lee & Gerla 2009)



(a) Building Record Route during Route Discovery



(b) Propagation of Route Reply with the Route Record

Figure 12. Explains route discovery in DSR (Misra 2000)

4.1.2.2. Ad Hoc on Demand Distance Vector (AODV)

AODV is like a combination of DSDV and DSR protocols, with some contrast. Firstly, data packets only save the address of the target node, which makes it more efficient, particularly in sparse and rapidly changing networks. Besides, for AODV, reply packets keep the identifying number, along with the target node address, which is not the case with DSR as explained. However, this makes AODV slower, since it doesn't have the routes cached. (Rastogi, Ganu, Zhang, Trappe & Graff 2007)

DSR basically has an advantage in the opposite case; when a network is smaller networks and does not need constant updating. Moreover, it is possible for the destination node to send more than one route reply, unlike AODV.

4.1.2.3. AODV+ Preferred Group Broadcasting (PGB)

Regarding the selection of intermediate relay nodes, special care has to be taken because if distance between them is not too great, otherwise they would lose communication. On the other hand, if they are too close, they would need to hop more, which is expensive. Furthermore, very close nodes are in danger of interference, if they transmit at the same time (this is known as the hidden terminal problem). Thankfully, it is handled by blocking other in range nodes, until the first two are done. There is a possibility of the

new transmission colliding with the old ones. PGB solves this problem by reducing the possible intermediate nodes. Nodes are divided into three groups, depending on their proximity: Preferred groups (PG) have a moderate signal, the IN group has a stronger signal, while the OUT group has a weaker one. This is illustrated in Figure 13.

(Naumov, Baumann & Gross 2006)

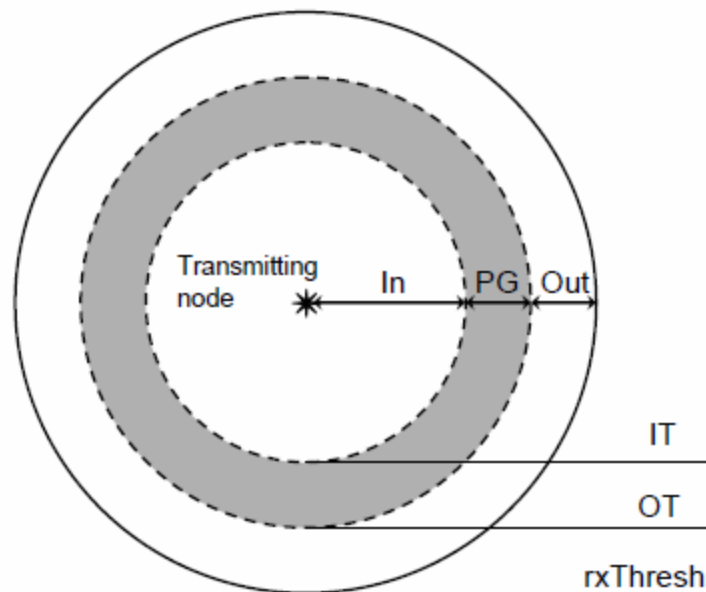


Figure 13. Node groups in PGB (Naumov, Baumann & Gross 2006)

To tell which category the node belongs to, the power of the signal it receives is compared to the Inner Threshold (IT) and Outer Threshold (OT) values. IN nodes will have a larger value than the IT, while OUT nodes will have one smaller than OT. Those with an in-between value of signal power are considered PG nodes.

(Naumov, Baumann & Gross 2006)

The relay choosing priority will go to the node with the smaller id value, hence PG nodes have an id of 1, and OUT nodes have the id 2, while IN nodes have the id 3.

(Naumov, Baumann & Gross 2006)

Hence, the issue regarding choosing the next best hop distance is resolved by PGB. Nevertheless, there are cases in sparse networks where it would be problematic, due to a non-continuous broadcast, and since discovering a route might take some time.

4.1.2.4. Temporally Ordered Routing Algorithm (TORA)

TORA looks for numerous paths between two nodes. When updates occur, nodes only keep track of information concerning their neighbors. TORA mainly creates, maintains, and erases the routes depending on what is necessary. (Hui & Datta 2012)

A route is created on basis on a parameter, called 'height', which is 0 for the target node, and initially unknown (null) for the rest. The sender node sends the destination id in a query packet. Nodes with a known height respond with an update packet, containing their height. When a node receives a packet, it will make its height equal to the sender's. Hence, a Directed Acyclic Graph (DAG) is created, which connects the sender to the receiver node. (Hui & Datta 2012)

Note: A node with a greater height is called an 'upstream node', while one with a lower height is called 'downstream'.

When a node becomes inaccessible; when there is not a single route which connects it to the source, this is when route maintenance is needed. In this procedure, each node sends a packet which works on reversing the links of that node's neighbors, if they do not have outgoing routes. This keeps going, by each neighbor forwarding to its own neighbors, until every single node has a minimum of one outgoing path. However, route maintenance possibly cause network congestion. (Hui & Datta 2012)

But if the source node is not reachable by those in the specified range, it resorts to route erasure, where the network is flooded with clear packets (CLR), which triggers nodes to set the links of their neighbours to null. This keeps going until all false routes to the unreachable node are removed. (Hui & Datta 2012)

An advantage TORA offers is that all nodes have a way of reaching each other, with the lowest overhead, but at the same time, maintaining those paths is quite expensive, particularly in VANETs' changing environment. (Hui & Datta 2012)

Although reactive routing protocols are superior to proactive routing protocols when it comes to saving bandwidth, delays are high. In addition, exaggerated route maintained, which uses flooding could possibly affect the communication between nodes.

(Hui & Datta 2012)

4.1.3. Hybrid Topology Based Routing Protocols

Hybrid routing protocols basically attempt to combine active and reactive routing protocols, to keep the packet size small and to speed up the detection of an initial path.

4.1.3.1. Zone Routing Protocol (ZRP)

In ZRP, the network is divided into regions, each which contains some nodes. If a node wants to communicate with another within its own zone, proactive intra-zone routing protocol (IARP) is used. However, if it is in another zone, reactive inter-zone routing protocol (IERP) will be used, to reach the other zone first, and then find the intended target node. (Nagaraj, Kharat & Dhamal 2011)

4.1.3.2. Hybrid Ad Hoc Routing Protocol (HARP)

HARP is similar to ZRP, however, zones in HARP do not overlap, since having a stable connection is crucial. (Nagaraj, Kharat & Dhamal 2011)

4.2. Position Based Routing

In position based, or geographical routing protocols, nodes rely on location services like GPS, in order to determine their position, plus the target node's. The main approach is periodic broadcasts of beacon messages (to bring attention to the location) with geographic coordinates. Therefore, there is no need to use routing tables neither to exchange link state information. Routing will depend on the target node and how the first hop neighbor's are positioned. Position based routing protocols are divided into three

classes, depending on how they deal with disconnections in the network, Delay Tolerant Networks (DTN), non-Delay Tolerant Networks (Non DTN), and hybrid.

(Lee & Gerla 2009)

4.2.1. Hybrid Position Based Routing

4.2.1.1. GeoDTN+Nav

It has three 'modes' for routing: greedy, perimeter and DTN mode. The protocol can tell how healthy a network connection is by counting the number of hops a packet needs to reach its destination, and delivery ratio of the neighbor, as well as the direction with respect to the destination. Data is made available by a piece of hardware like an Event Data Recorder (EDR) and navigation systems. Next, the routing mode is picked via a virtual navigation interface. (Lee & Gerla 2009)

Figure 14 shows Virtual navigation interference

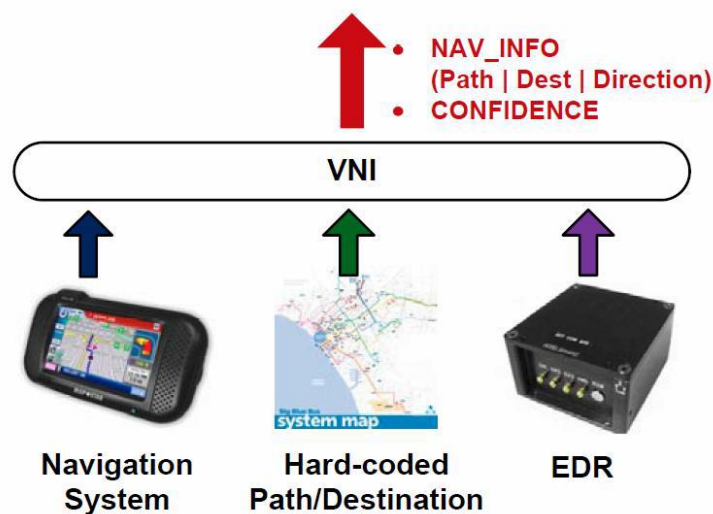


Figure 14. Illustration of Virtual Navigation Interface (Lee & Gerla 2009)

4.2.2. Delay Tolerant Network (DTN) Position Based Routing

VANETs, with nodes always in motion, have trouble with unstable connections. Hence, it is a good idea to get around the problem with delays by letting nodes save packets temporarily, until a clear route is available. (Lee & Gerla 2009)

4.2.2.1. Vehicle-Assisted Data Delivery Routing Protocol (VADD)

VADD compares every route at crossings, by a calculation which considers the average speed, density and segment length of cars, to eventually select the quickest route.

The next step is done depending on the type of VADD protocol

Direction First Probe (D-VADD) selects the node which is moving in the same direction as the path selection, without considering how distant it is.

However, Location First Probe (L-VADD) ignores the direction of movement, and works by picking the node which is in proximity to the forwarding path.

Multi-Path Direction First Probe (MD-VADD) saves time by choosing some nodes, which are heading to the picked path.

Hybrid Probe (H-VADD) is basically a combination of L-VADD and D-VADD. It attempts to solve the problems of both protocols, by, reducing D-VADD's delays and L-VADD's routing loops. H-VADD is said to give the best results in VADD.

(Lee & Gerla 2009)

4.2.2.2. Geographical Opportunistic Routing (GeOpps)

This protocol uses a car's navigation system to guess when a packet would be received, through an algorithm by which it calculates the shortest distance between the closest point on the path and the target node. (Lee & Gerla 2009)

However, security and privacy might be at stake, since the protocol's procedure involves accessing other nodes to get data.

Figure 15 illustrates how node A selects the node on route N1, because it is nearer to the destination than N2.

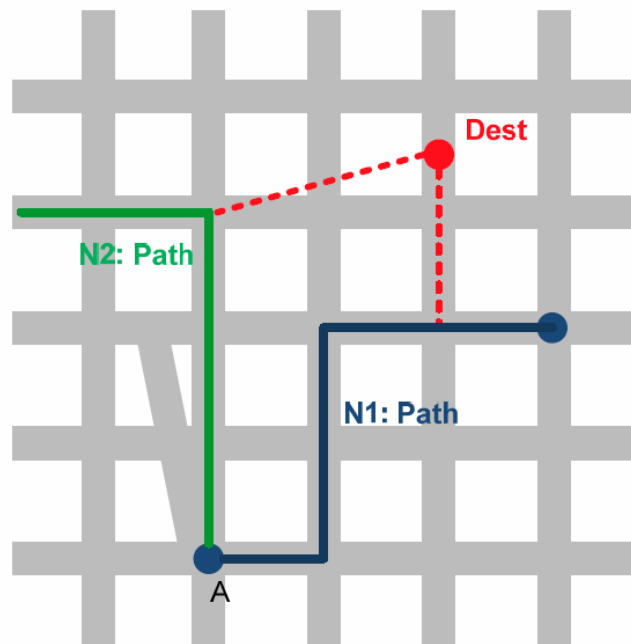


Figure 15. GeoOpps Nearest Point Calculations (Lee & Gerla 2009)

4.2.3. Non-Delay Tolerant Position Based Routing

Non-Delay Tolerant Network position based routing is either a beacon, not a beacon, or it could a hybrid of both.

4.2.3.1. Non-Delay Tolerant Non-Beacon

Contention-Based Forwarding (CBF)

The sender node sends packets to every one of its neighbor's, and does not interfere with the next step. Next, the node with a shorter path forwards the packers, and inhibits the rests from sending it too; the calculation is done by compare the distance of the source and the node itself to the destination. Henceforth, CBF does not need beacon messages. (Lee & Gerla 2009)

4.2.3.2. Non-Delay Tolerant Hybrid

Topology-assist Geo-Opportunistic Routing (TO-GO)

Generally, the target node is in a different place, or 'street' than the sender node, therefore the packet does not directly reach it; it must go through some junctions first. TO-GO used the greedy algorithm, and is different from CBF, since packets are not forwarded to the destination, but a specific node. (Lee & Gerla 2009)

4.2.3.3. Non-Delay Tolerant Beacon

1- Receive on Most Stable Group-Path (ROMSGP)

Generally, when a node (vehicle) goes outside the transmission range of a neighboring node, the connection is lost. This protocol divides the vehicles into four groups, depending on their velocity vector. When two nodes are in the same group, routing is stable. As shown in Figure 16, there are two paths through which node A can send a packet to node E; either A, B, D, E or A, C, D, E. Here there is a possibility of node B getting out of range, so the second option is considered more stable, and is therefore selected. (Nagaraj, Kharat & Dhamal 2011)

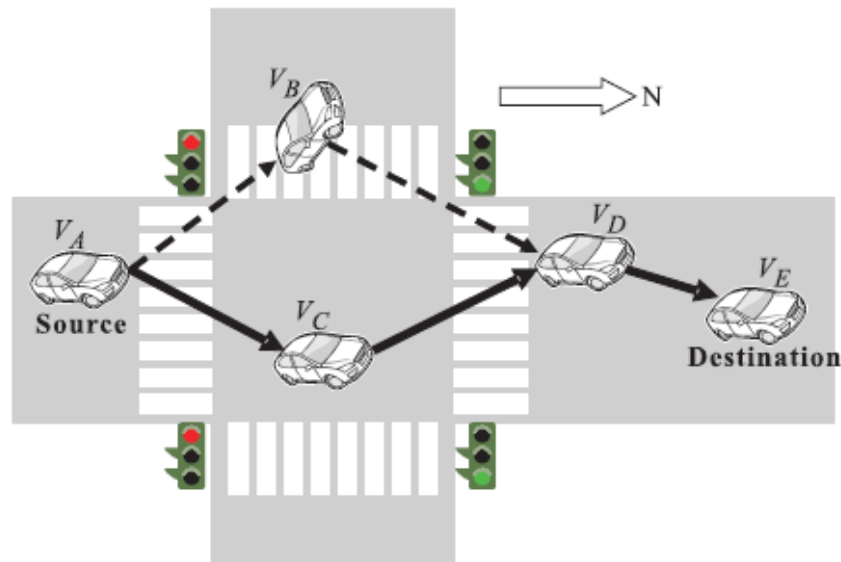


Figure 16. How ROMSGP selects a route (Lin, Chen & Lee 2010)

2- Adaptive Movement Aware Routing (AMAR)

Using data obtained from GPS, vehicles calculate their velocity vector, as well as their location. Next, neighbors are given weights, which take into account three factors: direction, position and speed, as shown in the equation 20.

$$W_i = \alpha P_m + \beta D_m + \gamma S_m \quad (20)$$

Note1: P_m , D_m and S_m have weights α , β and γ . They respectively represent position, direction and speed of a neighboring node.

Note 2: $\alpha + \beta + \gamma = 1$.

This protocol is very efficient in a dynamic network and works well in the event of pure greedy forwarding failure. (Raw & Das 2011)

3- Border-Node Based Most Forward within Radius Routing Protocol (B-MFR)

In B-MFR, the packet is forwarded to the most suitable node on the border, as the distance between the sending and receiving node is projected on a line from the source to destination. (Raw & Das 2011)

This aids in preventing useless packet retransmission if nodes are within range, as illustrated in Figure 17 in the next page.

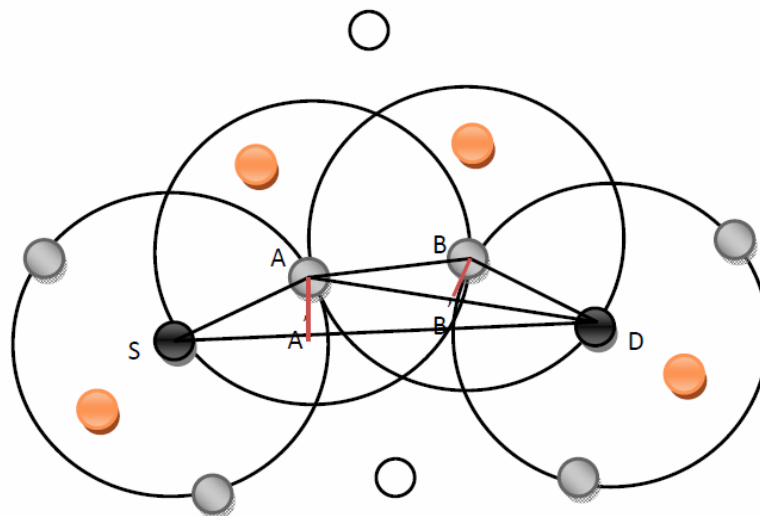


Figure 17. Forwarding Method in B-MFR (Raw & Das 2011)

4- Edge Node Based Greedy Routing Protocol (EBGR)

Three functions are required as packets are forwarded. Neighbor node selection function works by gathering data from all neighbor's within the range of transmission. Secondly, node direction identification function recognizes the velocity vector of other node's in with regard to the destination. Lastly edge node selection function picks the furthestmost node (in range) as next hop. EBGR is considered an efficient protocol since it results in the highest achievable network throughput, using the least number of hops.

(Raw & Das 2011)

5- The Associativity-Based Routing (ABR)

To select the shortest route, ABR is based on the associativity concept, whereby depends on how many beacons are given by neighbor's. A very mobile node will have a smaller number of beacons, while a less mobile node will have a larger number of beacons. (Taleb, Sakhaee, Jamalipour, Hashimoto, Kato & Nemoto 2007)

6- Vertex-Based Predictive Greedy Routing (VGPR)

This protocol uses the greedy algorithm to send packets, by looking for multi-hop routes from the source to a specific topology. Crossings are evaluated are chosen on basis of the position, trajectory and velocity of the vehicles. (Nagaraj, Kharat & Dhamal 2011)

7- Dynamic Time-Stable Geocast Routing (DTSG)

By accustoming itself to the situation by looking at the velocity and density of vehicles, this protocol works efficient in networks which are not very dense. It has two phases: pre-stable, to circulate packets locally, and stable, to store and forward packets.

(Nagaraj, Kharat & Dhamal 2011)

8- Greedy Perimeter Stateless Routing (GPSR)

GPSR protocol forwards packets in two ways: greedy and perimeter forwarding modes. In the default mode, greedy mode, packets advance by going to the neighbour who is nearest to the target node, right until it reaches it. This approach can go wrong if the packet gets to the local maximum, where there is no one close to the target, other than the

node itself! To resolve this issue, right hand rule is implemented when perimeter forwarding mode is used.

As shown in Figure 18, w and y are within the transmission area of node x . However, x itself is closer to D when compared to them, hence greedy mode does not work, and perimeter forwarding is used instead, by transmitting the packet around the void (the grey region). After that, right hand rule is used to find the next hop, node w , since it is the first one located anticlockwise to the path connecting x to D . Then, using the same rule, v is the next node anticlockwise to the route which joins x and x . The packet moves in the path $x \rightarrow w \rightarrow v \rightarrow D$, and reaching its intended target. (Karp & Kung 2000)

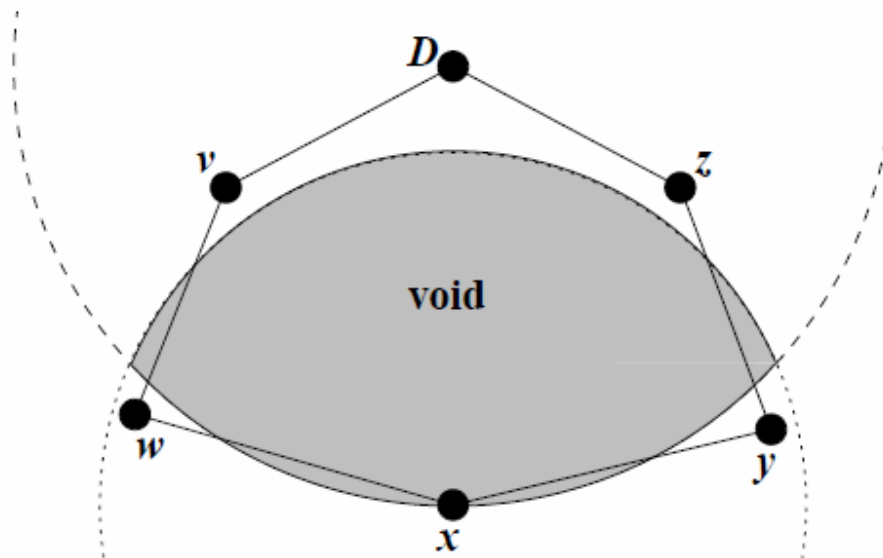


Figure 18. The void around node x , and its relation to the destination
(Karp & Kung 2000)

9- GPSR + Advanced Greedy Forwarding (AGF)

If GPSR is used in a very fast changing network like VANET, there are two main problems. Firstly, if updates are not quick enough, nodes might be working based on incorrect data. Furthermore, during the forwarding of a packet to its target node, there is no consideration to the fact that the destination itself is changing! Henceforth, AGF is used, since it adds the direction and velocity of the sender, plus the total travel time to beacon packets. By doing some computations, a node can expect which neighbor's will

be out of range when the packet is received, and therefore exclude them. Using the total time for the trip, the node which is forwarding the packet can expect the new location of the receiving node. (Lee & Gerla 2009)

10- Position-Based Routing with Distance Vector Recovery (PBR-DV)

When greedy mode does not work, the node at local maximum broadcasts its location, as well as the target node's in a request packet. If a node closer to the destination collects the packet, it will respond. If it is farther however, it will concatenate the address of the source to the request packet, and it will broadcast it once again. This process guarantees that when the node at the local maximum gets a response, it will have a clear path to another node, which can keep working in greedy mode until the target node is reached. (Lee & Gerla 2009)

11- Greedy Routing with Abstract Neighbor (GRANT)

In GRANT, a node is aware of the position of its neighbor at multiple hops. This enhances the routing, and helps prevent the situation where it would go to a local maximum. (Nagaraj, Kharat & Dhamal 2011)

These routing protocols work on a group of nodes, which are in critical locations, such as junctions, where packets go to a new division in the network.

12- Greedy Perimeter Coordinator Routing (GPCR)

GPCR is very efficient in a dynamic graph. Based on greedy forwarding, it utilizes junctions to pass on messages. A node knows its position via location services, and gets its neighbor's by beaconing. (Nagaraj, Kharat & Dhamal 2011)

Depending on the topology of intersections and the streets themselves, GPCR uses greedy forwarding method, and repairs the route when necessary.

(Lin, Chen & Lee 2010)

13- GpsrJ+

To decide which route packets are going to be sent on, nodes use two hop beacons. Packets are sent to the neighbor's who would send them across paths which would head out in another direction. In case of not finding this kind of node, packets are just sent to its farthest neighbor, to cut the time wasted at crossings. GpsrJ+ cuts the number of hops by about 200% in contrast to GPCR, in addition to increasing the ratio of packet delivery. (Lee & Gerla 2009)

Refer to Figure 19 for a comparison between the two as showed in the next page.

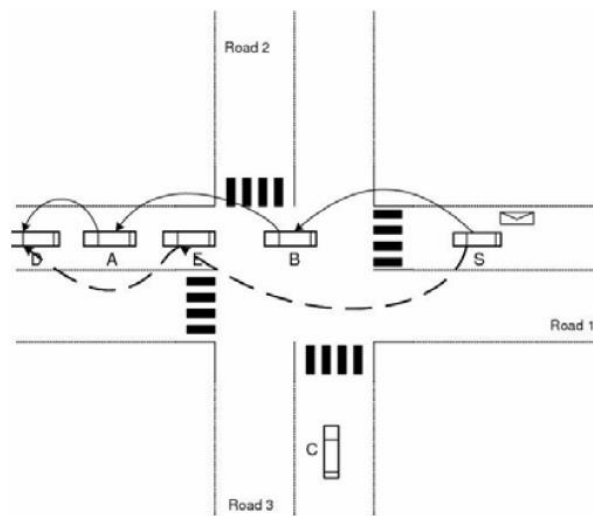


Figure 19. Comparison: Gpsr+ VS GPCR (Lee & Gerla 2009)

14- Connectivity Aware Routing Protocol (CAR)

This protocol is similar to AODV+PGB when it comes to finding a path, but it saves different data in the header of the packet. Right when it gets a packet for path discovery, a node at an intersection will regard itself to be an anchor point, if it is not aligned in the direction of the source node. If the destination gets more than one packet, it will only select the one with the lowest delay, and which connects better. The route reply is sent by AGF, over the anchor points, saved in the packet. (Lee & Gerla 2009)

15- Diagonal-Intersection-based Routing Protocol (DIR)

DIR is basically an enhanced version of CAR. By sending a packet through diagonal routes, by taking a hypotenuse-like path, instead of two perpendicular lines, until it reaches the target node. The algorithm is dynamic, and keeps selecting the shortest path, to ensure the packets arrives as early as possible. CAR is less efficient in comparison, since it works on more anchor points in comparison. (Lin, Chen & Lee 2010)

Figure 20 shows the difference between CAR and DIR in the next page.

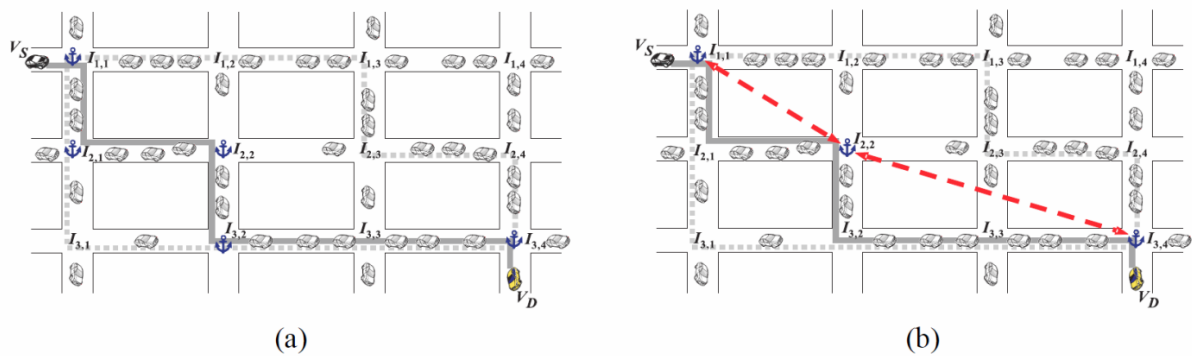


Figure 20. Contrast between DIR and CAR, regarding routing (Lin, Chen & Lee 2010)

16- Geographic Source Routing (GSR)

In contrast to CAR, GSR needs a map to calculate the shortest path using Dijkstra's algorithm; where a node is considered to be a vertex, which a street is an edge. A packet is sent over those vertices in greedy mode. (Nagaraj, Kharat & Dhamal 2011)

17- Anchor-Based Street and Traffic Aware Routing (A-STAR)

This protocol uses Dijkstra algorithm to send packets through intersection points, but unlike GSR, traffic is a crucial factor to pick the correct anchor point. It uses two types of maps, produced by roadside units. Maps which are statically rated have a balanced traffic, therefore the routes are linked. However, dynamically rated maps are more updated, since they are real time based. In case of a disassociated route, the packet will progress, and the node will look for another route, and will also alert the network that the route is unusable, to help avoid this scenario. (Lee & Gerla 2009)

18- Street Topology Based Routing (STBR)

In this protocol, supervisor, or 'master' nodes are chosen at every intersection. Their job is to check, and pass link state information to each other. Packets are sent to the target nodes, on basis of how close they are to the route where the target node is.

(Lee & Gerla 2009)

19- Greedy Traffic Aware Routing Protocol (GyTAR)

Nodes assess the crossings of their neighbors, depending on how far the distance is to the target node, as well as the of the density of the traffic. GyTAR implements greedy algorithm, and the resulting value is used in the next step, and this keeps going.

(Lee & Gerla 2009)

Instead of trading link state data, position based, or geographical routing uses location services to help with routing. Position based routing offers a strong, continuous and efficient connection, which could span a large area, in contrast to topology based routing. An unfortunate limitation of this system though is that it is dependent on location services like GPS, to provide updates locations at all instants of time; which is not quite possible since there are blind spots, particularly in distant places, or underground.

4.3. Cluster Based Routing Protocols

A network is grouped into 'clusters', with member nodes and one cluster head; whose job is to either send packets to its members (internally), or forward them to another cluster head, to be passed on their related member (externally). Henceforth, this makes a network more scalable, but less efficient as well as slower.

4.3.1. Cluster-Based Directional Routing Protocol (CBDRP)

CBDRP was mainly created for heavy roadways. It uses the processes: head selection and maintenance, which consider the critical factors of direction and velocity of the vehicles. Vehicles are grouped into clusters on basis of direction, and the node which wishes to send a packet will pass it to the cluster head. The packet is then forwarded to the correct

cluster head, which will pass it on to the destination node. Refer to Figure 21 and Figure 22 as showed in the next page for the routing process, head selection and maintenance. (Xia, Weiwei, Song & Shen 2010)

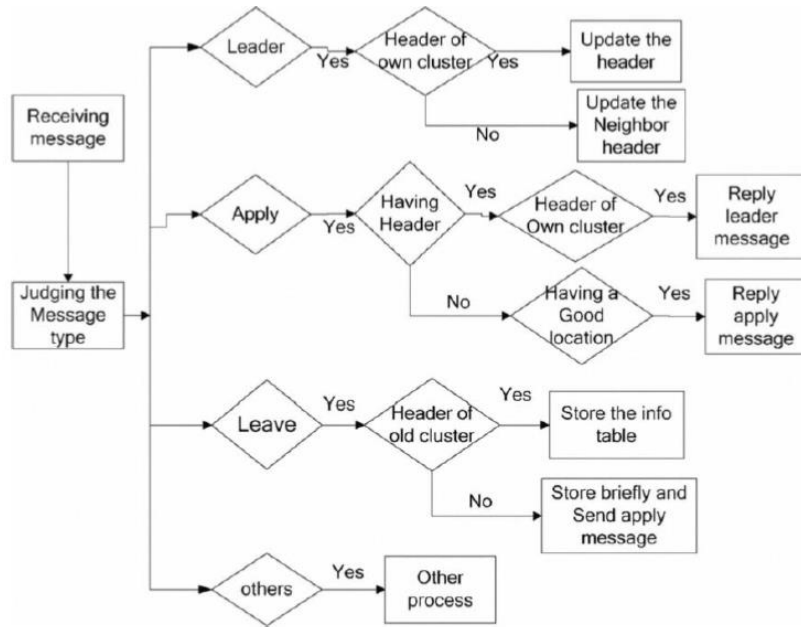


Figure 21. CBDRP head selection and maintenance (Xia, Weiwei, Song & Shen 2010)

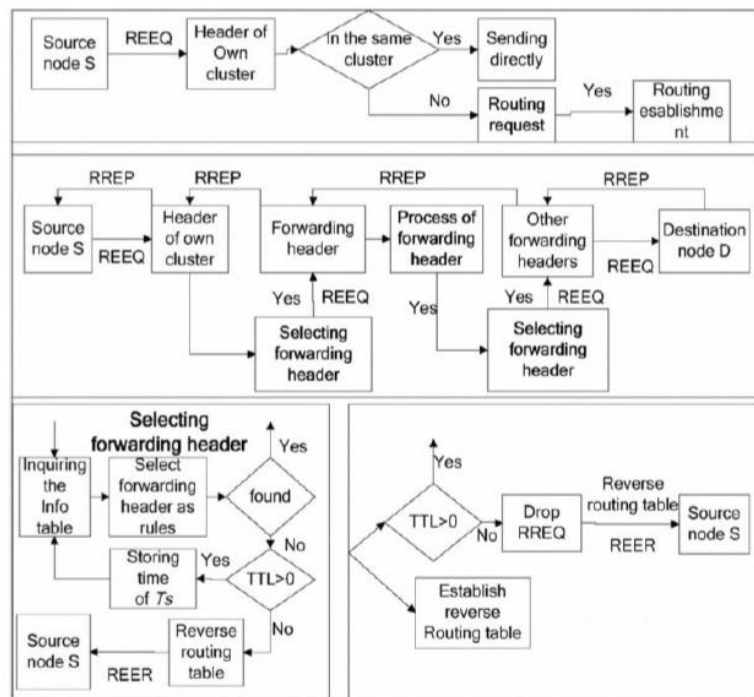


Figure 22. The CBDRP routing process. (Xia, Weiwei, Song & Shen 2010)

CBDRP is preferred to protocols like position based GPSR and topology based AODV, with regard to reaction time, delivery ratio for packets, as well as the connection itself, per the results of a simulation by (Xia, Weiwei, Song & Shen 2010)

4.3.2. Location Routing Algorithm with Cluster-Based Flooding (LORA-CBF)

In LORA-CBF, it is possible to have more than portal for communicating with other clusters externally. Each head node is aware of its members are portals ' gateway nodes ', and has this information saved in a table. When a sender node wants to forward a packet, there are two cases: it either sends it directly (if it is aware of the location), or it saves it in its buffer and sends out location request packets. These packets are kept on getting forwarded by heads and gateways in other clusters until they arrive at the cluster, which has the correct target node. Next, using geographical routing, a location reply packet is sent by the head to the source. (Santos, Álvarez & Edwards 2005)

4.3.3. Clustering for Open IVC Network (COIN)

This protocol selects the cluster head if it has the lowest mobility relative to the rest of the members, which helps guarantee long-lasting connections.

(Nagaraj, Kharat & Dhamal 2011)

4.4. Geo Cast Routing Protocols

Geo cast routing protocols use location based multicast routing and tries to distribute packets from the source node to all other nodes which exist within a defined geographical area called ZOR (Zone of Relevance). (Nagaraj, Kharat & Dhamal 2011)

4.4.1. Inter-Vehicle Geocast (IVG)

IVG is very valuable in collision avoidance applications. To discuss this protocol, let us first clarify what a risk zone is; it is an area which depends on the location of a damaged vehicle, and the streets which could be disturbed because of it. This vehicle broadcasts a

message to other cars in the risk zone, as a warning. Based on their direction with respect to the damaged vehicle, they would decide if they are at risk, and keep forwarding the warning message, by relaying to the furthestmost possible vehicle. (Allal & Boudjit 2012)

Figure 23 shows IVG relay selection process.

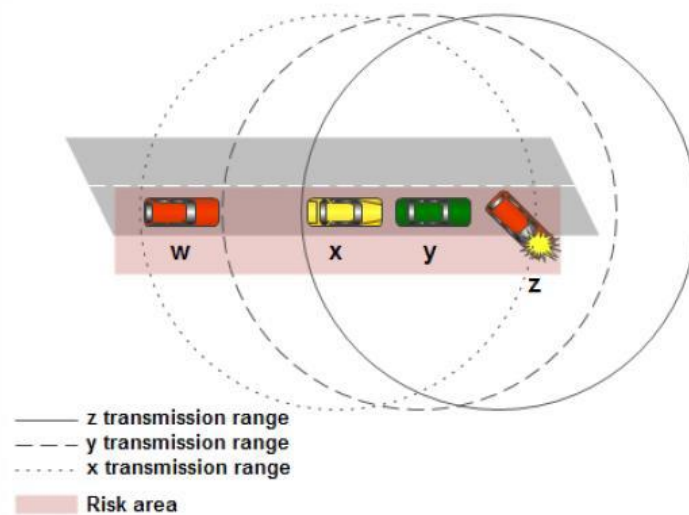


Figure 23. Relay selection in IVG (Allal & Boudjit 2012)

4.4.2. Direction-based GeoCast Routing Protocol for query dissemination in VANET (DGCASTOR)

DGCASTOR makes an attempt at foreseeing which neighbor's are expected to have the most stable connection, so that the source node can stay linked for if possible. Depending on the path and velocity of the source node and the neighbor's, a rendezvous region is assigned. (Allal & Boudjit 2012)

4.4.3. Distributed Robust Geocast (DRG)

We will introduce two definitions here: zone of relevance (ZOR); an area which depends on the topographical standards, and zone of forwarding (ZOF); the group of nodes which have the permission to pass on messages. When it comes to choosing a relay, the more distant the node, the better. After getting a message, a node checks its location, to decide

if it is applicable. As the name suggests, nodes within the ZOF forward messages, and ones within the ZOR receive messages. However, if a node belongs to neither zone, the message must be dropped. (Allal & Boudjit 2012)

4.4.4. Robust Vehicular Routing (ROVER)

In ROVER, packets from application are sent to nodes which are included in the ZOR; thereby packets which contain data are unicast, but control packets are broadcast. In this protocol, there is an assumption that each vehicle is connected to location services, and is identified by a specific value. It is also supposed that the ZOF consists of all ZOR nodes, plus the source node, and that the ZOR is shaped as a rectangle. (Allal & Boudjit 2012)

4.4.5. Dynamic Time-Stable Geocast Routing (DTSG)

DTSG principally alerts vehicles if there is an of significance, like road accidents.

The protocol supposes that cars move together, in groups going with the same speed. To communicate with a different group of vehicles, the message must be passed through helping vehicles; which are cars travelling in an opposite direction.

(Allal & Boudjit 2012)

4.5. Broadcast Based Routing Protocols

VANET applications use broadcast routing protocols to broadcast information of course. Popular examples are basically weather state and various types of announcements.

4.5.1. BROADCASTCOMM

In this protocol, a road is divided into cells, with vehicles classified into two ranked groups. The first group has nodes inside a cell, and the second has cell reflectors; nodes which are close to the cells' center. Cell reflectors act as cluster heads for specific periods, and pass messages of urgency from a cell member to a neighboring cell. This is analogous to routing protocols which are based on flooding for routing overhead and broadcasting. (Uma & Dhamal 2011)

4.5.2. Urban Multihop Broadcast Protocol (UMB)

This protocol solves issues for some issues common in multi-hop broadcasting; hidden node, broadcasting storm as well as unreliability. In the communication range of a sender, the path is divided into parts, and only the farthest node gets to forward messages, which increases the efficiency, and makes it need less information about the network. To improve reliability, the nodes acknowledges the message the moment it is received. Handshakes between nodes to request and clear broadcast help bypass the hidden node effect. At junctions, repeated help propagate messages in different directions.

(Lopez & Balderas 2010)

4.5.3. Vector Based Tracing Detection (V-TRADE):

Like ZRP, V-TRADE groups neighbouring nodes to unique groups to forward them, depending on their direction and position. Not all nodes can send messages; only a handful from each set get to do that. Although protocol is not very efficient when it comes to selecting the next hop node, it makes good use of the bandwidth.

(Uma & Dhamal 2011)

4.5.4. Distributed vehicular broadcast protocol (DV-CAST):

Depending on the quality of the connection, neighbors are grouped into three. If neighbors are well-connected, probability could be used to create a persistence scheme; this could be weighted, p-persistent or slotted 1.

If neighbors are sparsely connected, rebroadcasting to nodes going in the same direction is possible.

However, for neighbors who are completely disconnected, the vehicle will keep the packet on hold, and if after a particular time there is no new node in range, the packet will have to be discarded. (Uma & Dhamal 2011)

5. SURVEY ON VANET SIMULATORS

The high cost and the vast resources required for VANET implementation made it a tough task yet a simpler one for computer software simulators. Although that alternative is not a hundred percent accurate, it is found to be acceptable for system performance evaluation provided that diverse mobility scenarios are fed in. The nature of VANET simulation is based on simulating mobility patterns, network protocols and wireless channel impairments consequently the simulation process grows complex. Simulation is classified into three types of simulators which are VANET simulators, Network and mobility simulator. Firstly, a mobility generator is used to generate mobility traces to be passed to a network simulator. Commonly no programming skills are needed due to the presence of graphical user interface in some simulators. (Ali 2013)

Figure 24 shows the classification types of simulators.

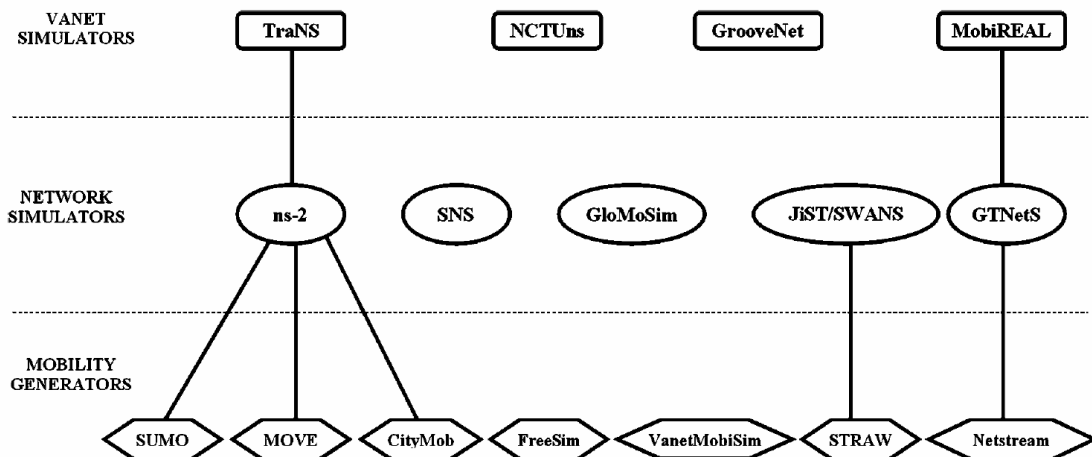


Figure 24. Classification of VANET Simulators
(Martinez, Toh, Cano, Calafate & Manzoni 2009)

NCTUns simulator is an integrated VANET simulator which possess a network and mobility simulators built in. This type of simulators can be more flexible and reliable as the refinement of parameters results appear instantly. (Ali 2013)

5.1. Mobility generators

5.1.1. Simulation of Urban Mobility (SUMO)

SUMO is an open source computer simulator which employs microscopic modelling i.e. vehicles are modelled individually following its own route. Continuous and time discrete vehicle movement is supported in SUMO as well as traffic regulations and switchable multi lane streets. It can be used to simulate up to 1000 streets and 100,000 vehicle update per second while a 1 GHz processor is used. Extra plugins and tools are available through SUMO website in order to assist in importing and/or processing results. Map files format as Shapefiles, OpenStreetMaps (OSM) and XML-Descriptions can be imported to SUMO. (Ali 2013)

For checking graphic user interface, refer to Figure 25.

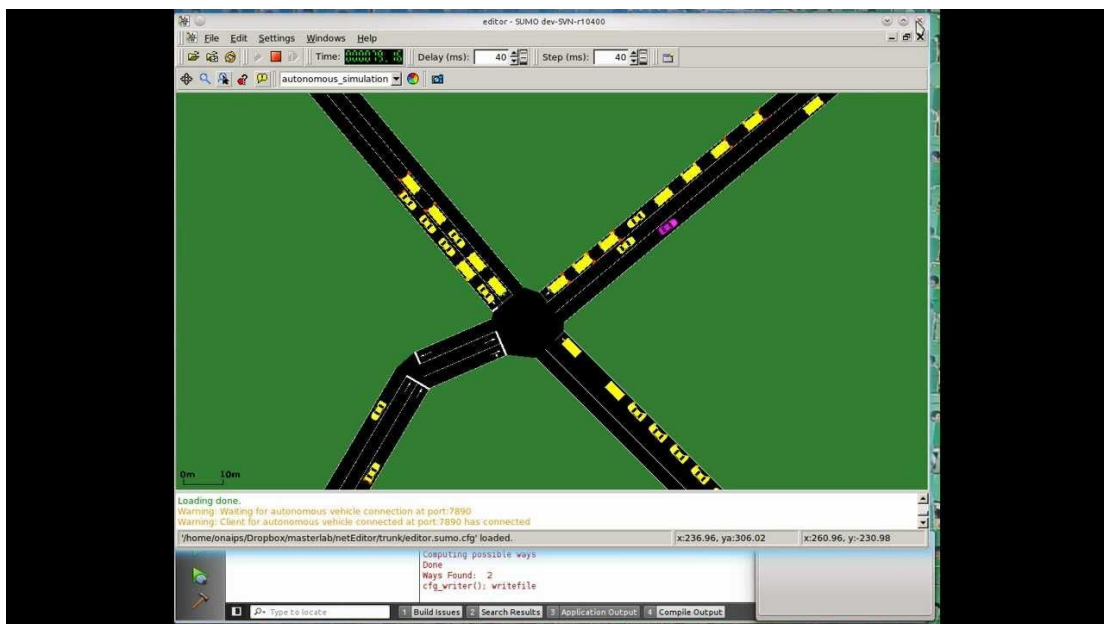


Figure 25. SUMO simulator graphic interface (Ali 2013)

5.1.2. Mobility Generator for Vehicular Networks (MOVE)

This simulator mainly employs SUMO simulator but with GUI interface instead of scripting. In MOVE, the user will be able to design roads or choose random map option or import from platforms like Google Maps or TIGER maps. Car movement is set by inserting values in the vehicle parameters fields such as acceleration, maximum velocity

and probability of turning during intersections. After setting all the required parameters, MOVE passes these data to SUMO compiler which in turns derives a tracing file. Consequently, the Traffic Generator for VANET can be used to run the simulation scenario in NS-2 and Qualnet. (Ali 2013)

Figures 26 and 27 illustrate the main windows for MOVE graphical interface and the traffic model generator.

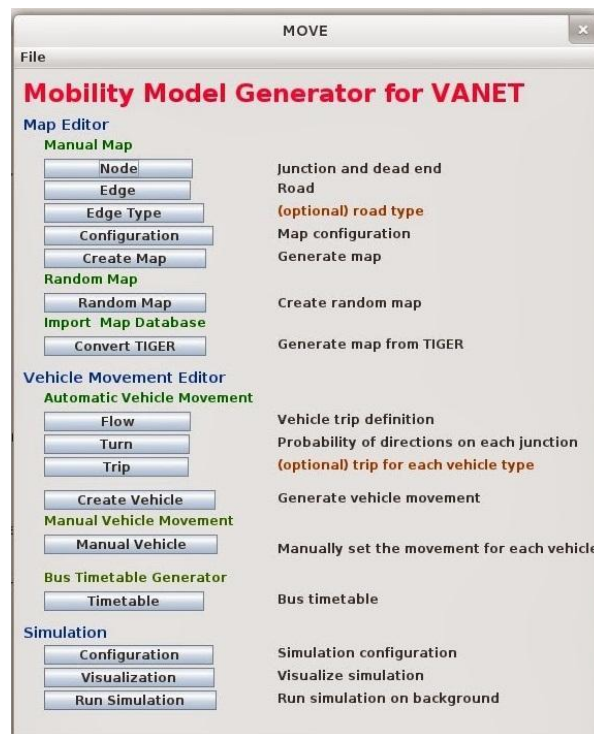


Figure 26. Mobility Generator for Vehicular Networks main GUI (Ali 2013)

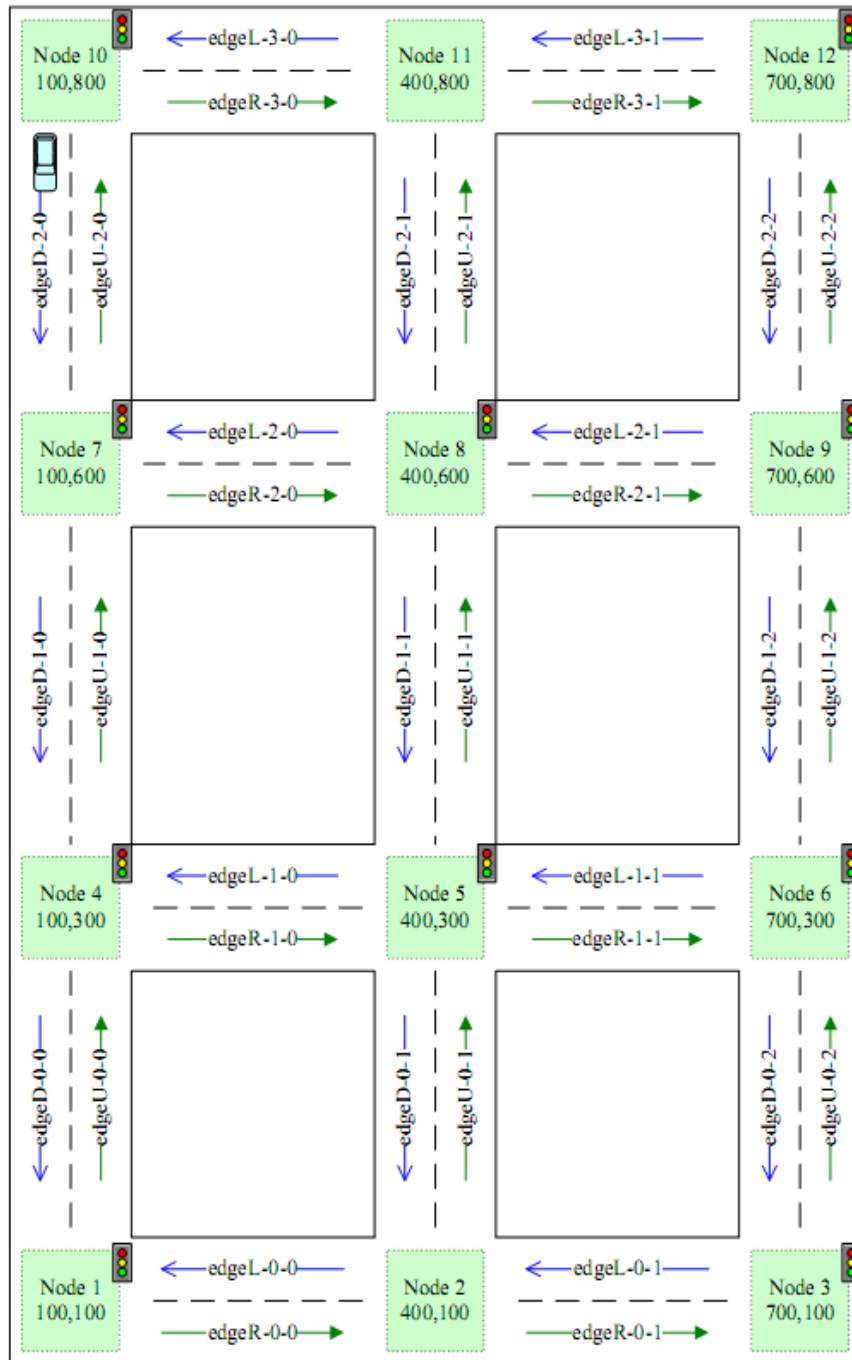


Figure 27. Screenshots of MOVE's Map Editor to create road topology (Khairnar & Pradhan 2010)

5.1.3. Vanet Mobi Sim

An open source mobility generator. Both Micro and Macro mobility models are supported in VanetMobiSim in addition to the interaction between vehicles on road.

(Ali 2013)

5.1.3.1. Macro features

The user can set each road topology through defining the coordinates of a certain topology object. Furthermore, topology can be loaded from GDF files or creating random objects. This simulator supports Clustering concept in which specific areas can be assigned a specific car density. In addition, it can vary the speed limits within the same road, multiple lanes and changing direction or full stops at intersections are supported. Trip path can be defined by two ways; generating random trip path by only defining the origin-destination points or selecting the fastest path using the algorithm developed by Dijkstra. (Ali 2013)

5.1.3.2. Micro features

It employs two models of type Intelligent Driver Model IDM; the first with managing the road intersections called IDM-Intersection Management, the second is supporting the management of Lane switching called IDM-Lane Changes. (Ali 2013)

5.1.4. Street Random Waypoint STRAW

This simulator offers a mobility model that relies on realistic measurements imported from traffic surveys in United States cities per STRAW's website. Each vehicular node movement is restricted to the previously defined maps that are controlled by traffic regulations and congestion. Although STRAW does not support TIGER format, the STRAW website published an installation link for a program to convert it to readable maps. (Ali 2013)

Figure 28 shows a mobility modelling project using STRAW in the next page.

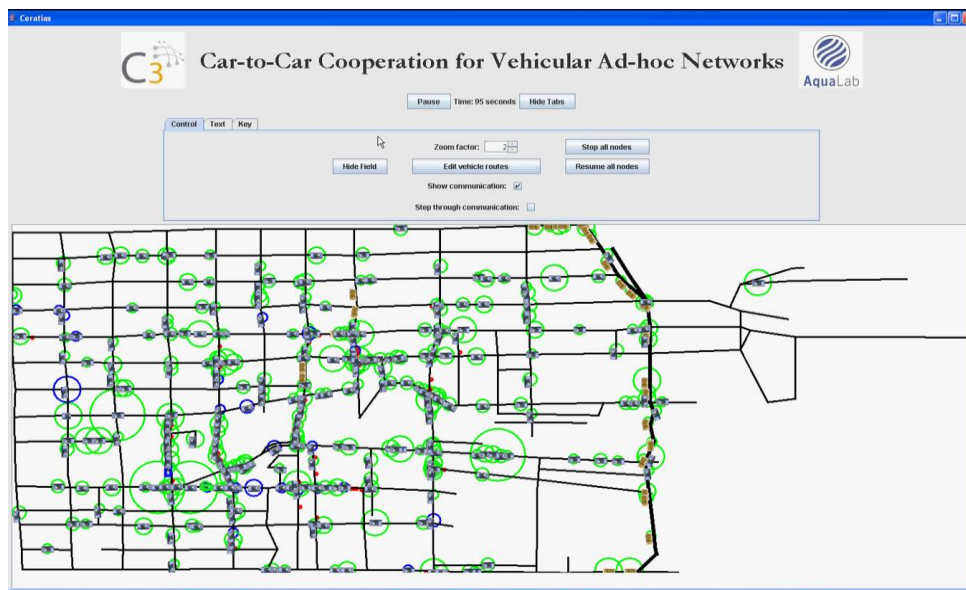


Figure 28. Screenshot for Mobility modelling simulation in Boston using STRAW (Otto & Choffnes 2016)

5.1.5. Free Sim

The FreeSim and FreeSim_Mobile simulation tools were founded by Prof. Jeffrey Miller of the University of Alaska. They should be running in association with other vehicles tracking devices to propose more accurate traffic maps to assist the VANET network in taking the proper decision. Future work is to embed these simulators in users' mobile phones. (Menard, Timothy & Miller 2010)

Figure 29 represents sample run using FreeSim.

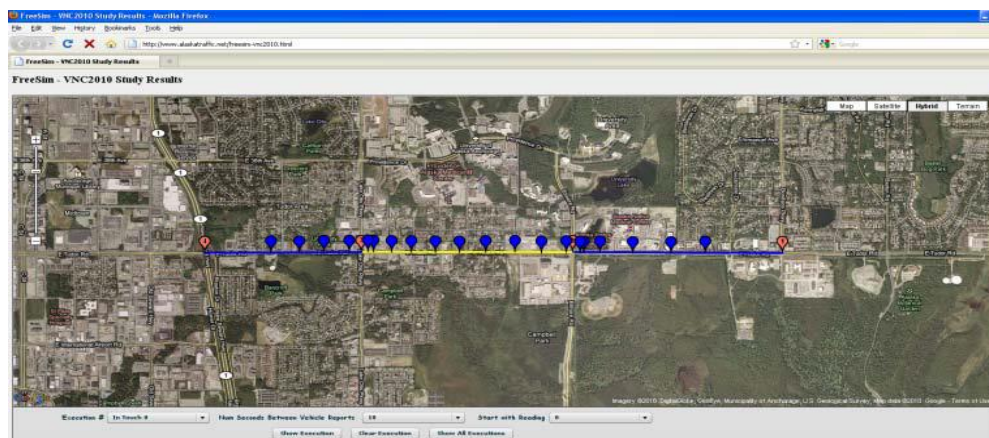


Figure 29. Sample run in FreeSim using vehicle tracking device data (Miller & Menard 2010)

5.1.6. CityMob

Mainly developed to simulate car accidents hence alarm forthcoming vehicles with the exact position to decrease their speed accordingly as well as the direction. Best running environment found was with the network simulator, ns-2. The supported mobility models are: simple, Manhattan and the real downtown models. Vehicles are modeled to run either vertically or horizontally without change in directions in simple model, while in Manhattan model the roads are sectionized to uniform sized block units and vehicles are moving randomly within a single lane and in two opposite directions. In Downtown model, whenever car density area is smaller than or equal 90% of the given map then these dense areas can be represented by their (x, y) coordinates provided that in downtown areas car speed is kept controlled and movement becomes slower. (Martinez, Cano, Calafate & Manzoni 2008)

GUI of CityMob is illustrated in Figure 30.

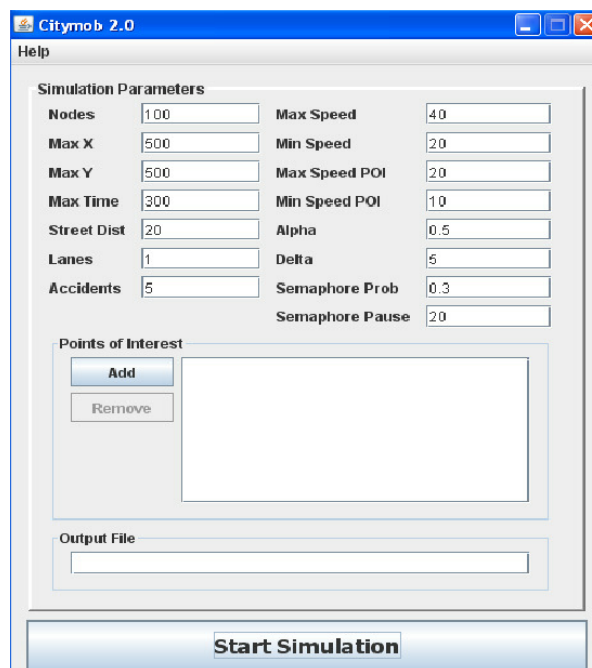


Figure 30. CityMob menu (Ali 2013)

Simulation runs after filling in the required parameters fields properly then hitting “Start Simulation”. The resulted log file should store two types of data. First is the starting point coordinates for each vehicle in terms of (x, y). The second type is the velocity and

displacement for every vehicle in addition to pause position. The log file also states the road segments that contain accidents and traffic jams consequently excluding the damaged nodes till the end of simulation. (Martinez, Cano, Calafate & Manzoni 2008)

Table 3 demonstrates assessment for all studied VANET simulators.

Table 3. Features of different VANET simulators (Mittal & Choudhary 2014)

Metrics	VanetMobiSim	SUMO	MOVE	FreeSim	CityMob
Portability	Yes	Yes	Yes	Yes	Yes
Freeware	Yes	Yes	Yes	Yes	Yes
Open source	Yes	Yes	Yes	Yes	Yes
Console	No	Yes	Yes	NO	Yes
GUI	Yes	Yes	Yes	Yes	Yes
Available examples	Yes	Yes	Yes	Yes	No
Continuous development	No	Yes	No	No	Yes
Ease of setup	Moderate	Moderate	Easy	Easy	Easy
Ease of use	Moderate	Hard	Moderate	Easy	Easy
User defined map	Yes	Yes	Yes	No	No
Ns-2 trace support	Yes	No	Yes	No	Yes
GloMoSim support	Yes	No	Yes	No	No
SWANS support	No	No	Yes	No	No
QualNet support	Yes	No	No	No	No
XML based trace support	Yes	No	No	No	No
Import different formats	Yes	Yes	Yes	No	No

5.2. Network Simulators

5.2.1. NS-2

The NS series are discrete event network simulators mainly developed for academic research. NS-2 is an open source project introduced in 1989 which can simulate wired and wireless networks. VanetMobiSim, MOVE and CityMob simulators are compatible with NS-2. The simulation sequence starts by Topology definition of the map to define the main obstacles and paths obstructions, then Model development to include any previously modeled nodes such as point-to-point device links, Node and link configuration to state the default values of models such as size of transmitted packets, execution, performance analysis to perform statistical analysis upon the resulted timestamped data and conclude the output, then finally Graphical Visualization using tools like GNUplot, MATplot or XGRAPH. (Wikipedia 2017) & (Ali 2013)

GUI of Network Simulator NS-2 is showed in Figure 31.

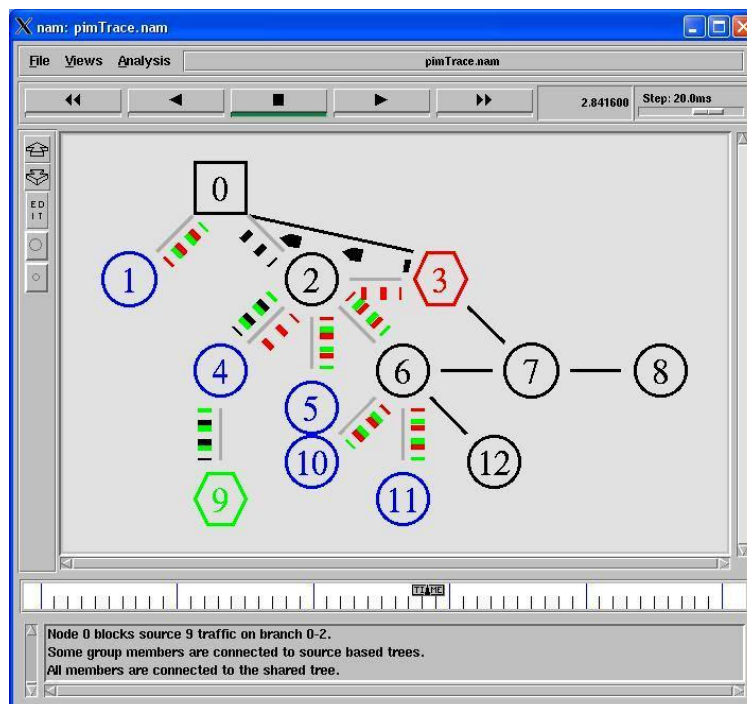


Figure 31. NS-2 GUI (Nicolau & Costa 2012)

5.2.2. OMNeT++

From the developer's website, the simulator is defined as "an extensible, modular, component-based C++ simulation library and framework, primarily for building network simulators". It is known as a Network simulator among the researchers' community though it is a simulation lib. (Varga 2016)

Figure 32 refers to OMNeT++ interface.

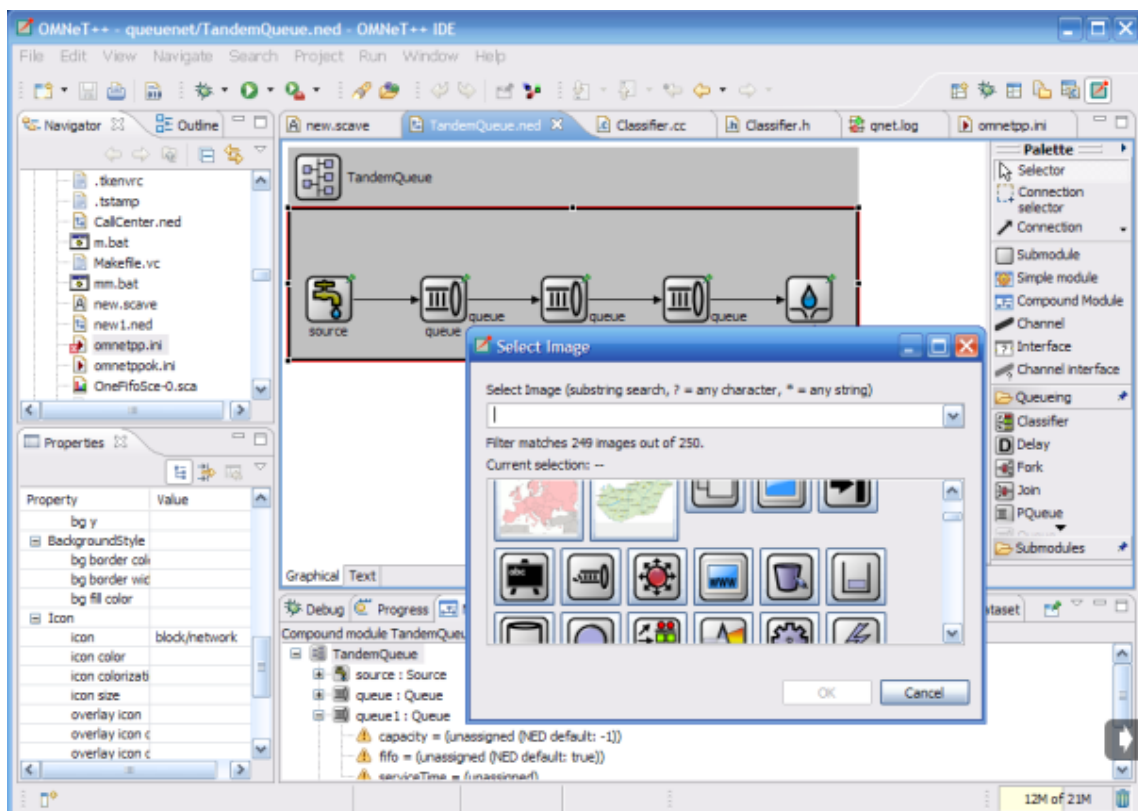


Figure 32. OMNeT++ Graphical NED editor (Varga 2016)

OMNeT++ can simulate wired and wireless network alike as well as compatibility with operating systems like Windows, Mac and Linux. A large range of simulations containing sensor networks, internet protocols, performance modeling and photonic networks can be developed as independent project model framework using OMNeT++ Eclipse-based IDE and other peripheral helping tools. High level language (NED) is used to model the programmed modules which are written in C++. (Varga 2016)

The following are some of the Popular OMNeT++ frameworks:

- **INET Framework** This framework supports network protocols as TCP, UDP, IPv4 OSPF and IPv6, most of MANET protocols, wired and wireless standards as Ethernet, IEEE 802.11. INET acts as the main model library of protocol for OMNeT++. (Ali 2013)
- **INETMANET** A framework to simulate ad hoc networks, developed by Alfonso A. Quintana. (Ali 2013)
- **MiXiM** It has a library which contains various radio propagation models, interference approximation, radio power consumption and wireless Medium Access Control protocols consequently MiXiM is appropriate for simulating wireless network lower layers. (Ali 2013)
- **Castalia** From the author website, this framework is can simulate numerous Networks as: Wireless Sensor Networks WSN and Body Area Networks BAN. The OMNeT++ kernel is the main building block of Castalia which mostly used in wireless channels and radio models to provide realistic measurements. It can be used for evaluating other various types of platforms.
(Athanasios, Boulis & March 2011)
- **Veins** It is a framework for ad hoc network simulation. SUMO mobility generator is used for feeding the simulation as a mobility simulator while OMNeT++ is the network simulator. The two mentioned simulators run in parallel at the same time and are connected through a TCP socket. Veins supports OpenStreetMaps in addition to capability of importing template scenarios containing buildings, speed limits, traffic posts and turns. Path loss is simulated using Two-ray interference model besides the simple obstacle model to simulate signal attenuation.
(Ali 2013)

SUMO and OMNeT++ simultaneous running using Veins is demonstrated in Figure 33.

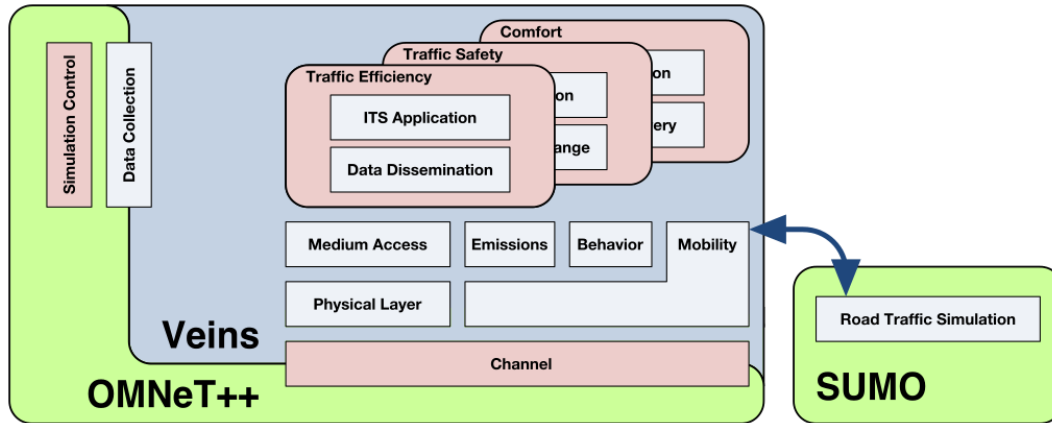


Figure 33. Parallel execution of SUMO and OMNeT++ through Veins (Sommer 2016)

5.2.3. Scalable Wireless Ad hoc Network Simulator (SWANS)

SWANS introduce faster processing and less memory occupation compared to NS-2 as it is a highly scalable wireless network simulator. A Java programmed file is used to feed the required node movement and communication scenario. Ready-made and custom made applications are available for users to use within the application layer of each node. (Martinez, Toh, Cano, Calafate & Manzoni 2009)

5.3. Simulators for VANET

5.3.1. Traffic Network Simulation Environment (TraNS)

Both NS-2 and SUMO are integrated via TraNS to output the required VANET simulation. TraNS can establish maps by inputting XML data format, TIGER and Shapefile maps. Each route loaded, starting point, ending point and amount of vehicles moving in the give route should be stated by the user. For network simulation, essential parameters should be defined like the type of channel, propagation model, routing protocols, MAC type and type of antenna. (Ali 2013)

Two operational modes for TraNS are Network mode and Application Mode. In network mode, an evaluation for VANET applications that do not affect driver's behavior (example: FM Radio broadcast) is carried out. In application mode, an evaluation for collision avoidance, emergency braking and the rest of applications that do affect driver's behavior, is carried out. (Ali 2013)

TraNS graphical user interface can be found in Figure 34.

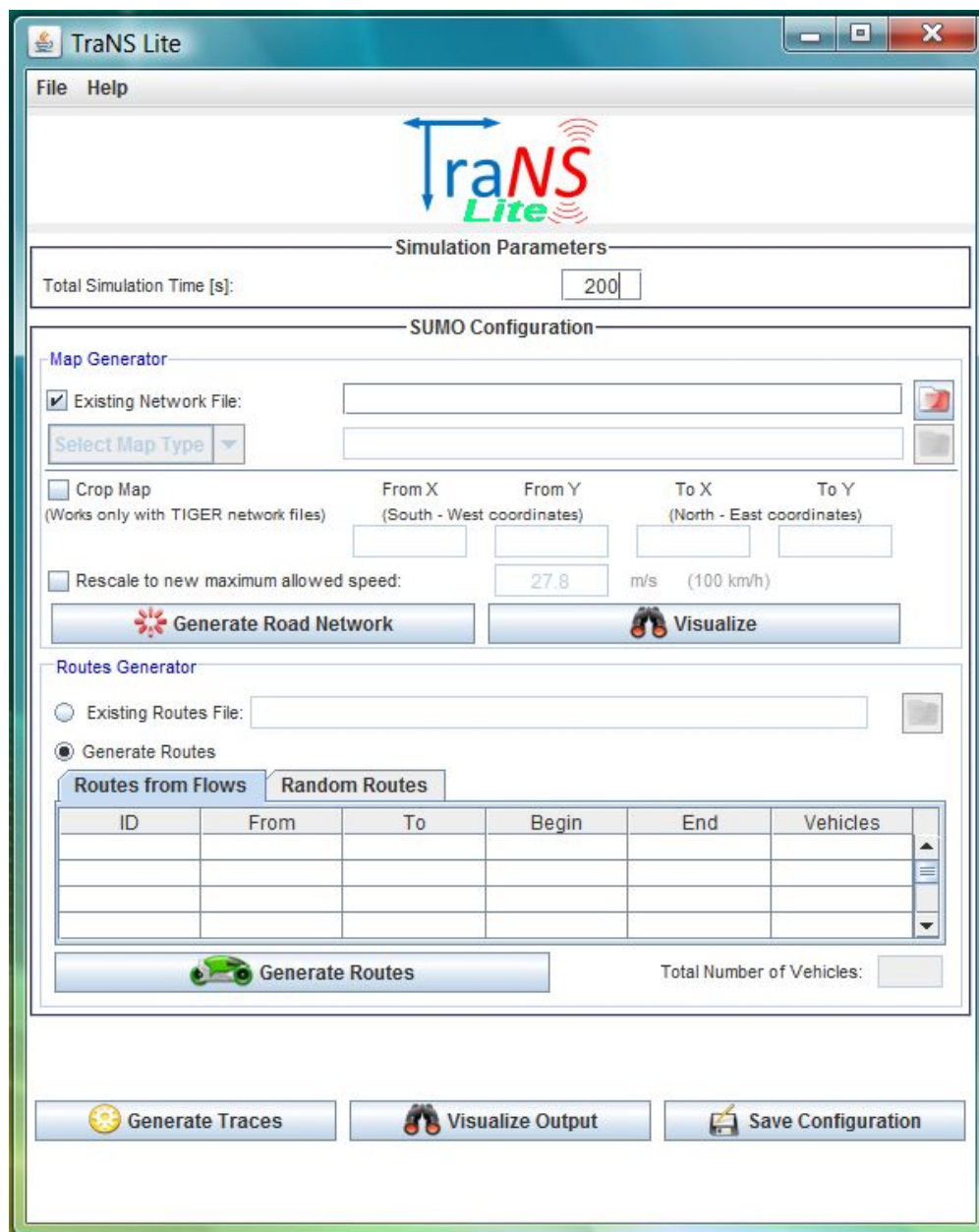


Figure 34. SUMO configuration in TraNS GUI
(Wegener, Piorkowski, Raya, Hellbrück, Fischer & Hubaux 2008)

5.3.2. MobiReal

In MobiREAL, Humans and Vehicles mobility are simulated as a probabilistic function via C++ models. The change in environmental obstacles is submitted as data which are received through applications affects vehicles decision regarding speed and direction. In addition, MobiREAL has the ability to protect pedestrians via an embedded collision avoidance algorithm as well the possibility of simulating more than one mobility model in the same time. (Martinez, Toh, Cano, Calafate & Manzoni 2009)

5.3.3. National Chiao-Tung University network Simulator (NCTUns)

This simulator can simulate various types of network standards as Ethernet-based internet, IEEE 802.11b, IEEE 802.11e, IEEE 802.16d WiMAX, wireless vehicular networks such as V2V and V2I, IEEE 802.16e mobile WiMAX networks and IEEE 802.11p wireless vehicular networks. (Ali 2013)

For more illustrations, refer to Figure 35a and 35b.

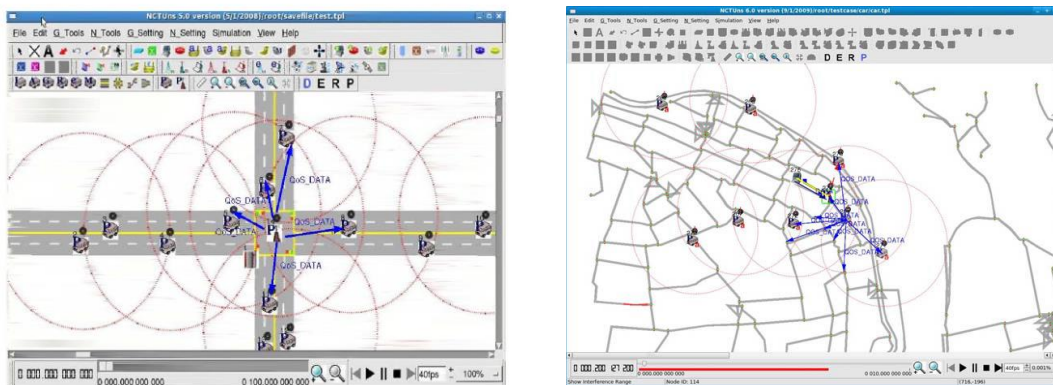


Figure 35.

- a) Creating road network using road network components. (Shie-Yuan Wang, Chih-Che Lin 2010)
- b) Creating road network by importing a road map. (Shie-Yuan Wang, Chih-Che Lin 2010)

As shown in the previous figure, NCTUns is able to create road segments like single and multilane roads, crossroads and lane merging roads either manually using the road network tools or by importing cropped Shapefile maps. It supports adding obstacles and

signal attenuation objects as well as changing position of obstruction object to block the driver's sight or signal path. The number of vehicles and the average distance between nodes are required in case of deploying vehicles automatically to the map, while there exists another way manually by clicking on the place where each vehicle should be inserted to. Five different categories of cars can be set called car profiles. Maximum speed, maximum acceleration and deceleration are defined within each profile. Each car behavior is affected by the so-called Car Agent (CA). This car agent examines the surroundings, neighboring nodes and visual obstacles to formulate the driver's decisions and behavior consequently avoid collisions and car accidents. Figure 36 illustrates adjusting network settings in NCTUns. (Ali 2013)

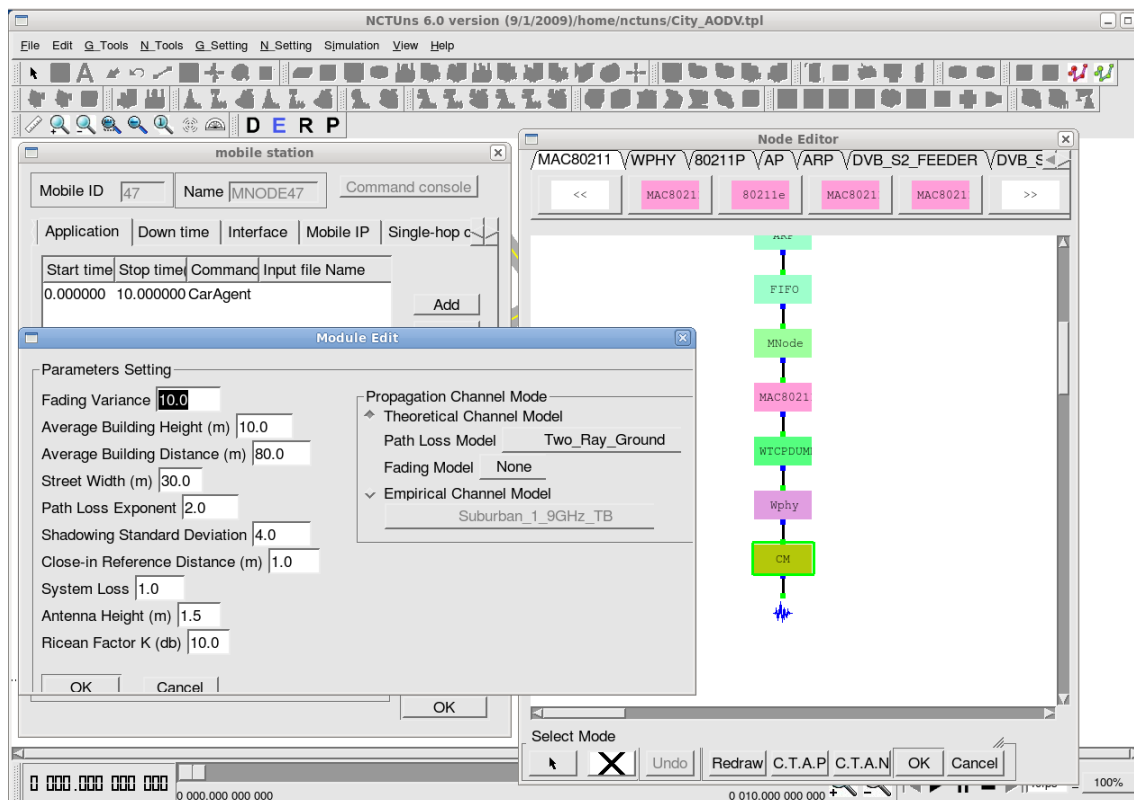


Figure 36. Editing VANET node properties in NCTUns (Ali 2013)

It is obviously noted that NCTUns offers an advanced graphical user interface (GUI) that simplifies plotting network topologies, setting protocol modules for each node starting from the physical layer PHY till Application layer, defining nodes movement, visualizing

network performance outputs and/or the resulted log files' graphs and replaying the of packet transfer trace. (Ali 2013)

NCTUns main advantage is that “its network protocol stacks include the Linux kernel protocol stack, including TCP/IP and UDP/IP, and the user level protocol stack and the MAC and PHY layer protocols”. (Martinez, Toh, Cano, Calafate & Manzoni 2009)

In other words, all Linux applications are supported. Disadvantages of NCTUns found in the dependency on Linux kernel which restrains compatibility to the Fedora Linux software only. Another one is the mismatching between vehicles' mobility model and network simulation which leads to conflict. (Ali 2013)

Figure 37 shows the whole NCTUns architecture.

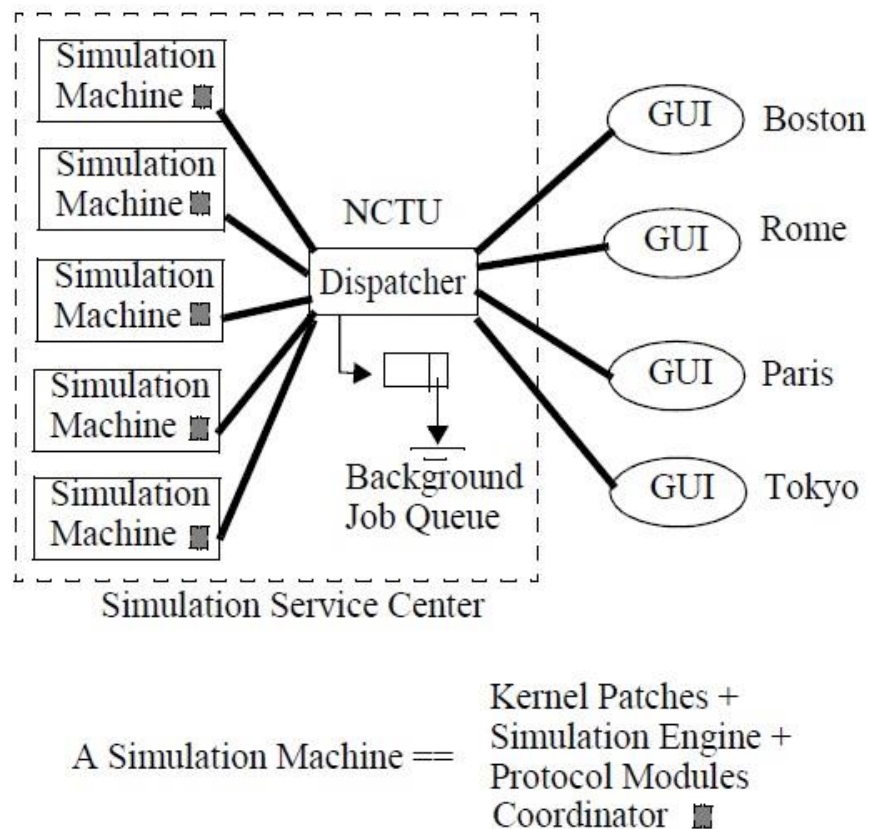


Figure 37. NCTUns 1.0 Distributed Architecture (Wang, Huang & Chou 2012)

As shown in Figure 37, the architecture is distributed as modules not necessarily to be in the same place or even country. Simulation machines are likely to be distant from graphical interface software run, as shown. (Wang, Huang & Chou 2012)

6. ANET SIMULATION REVIEW

6.1. Simulation using MOVE, NS-2 and SUMO

6.1.1. Simulation setup

To initialize the simulation process, several steps should be performed.

Firstly, generating the map that will attain to the desired mobility behavior. The maps used are real maps or maps created manually using a program to create a specific scenario. For creating manual maps, MOVE program is used, where the nodes and edges should be set by the user, as shown in Figures 38 and 39 respectively. The node resembles a crossroad or a traffic light. For each node, an ID and location coordinates-in meters-should be defined. The edge resembles the road connecting nodes. The movement of the vehicles are determined by the placement of the edges. The dimensions of the street and the vehicle maximum speed can also be determined by the user. (Ali 2013)

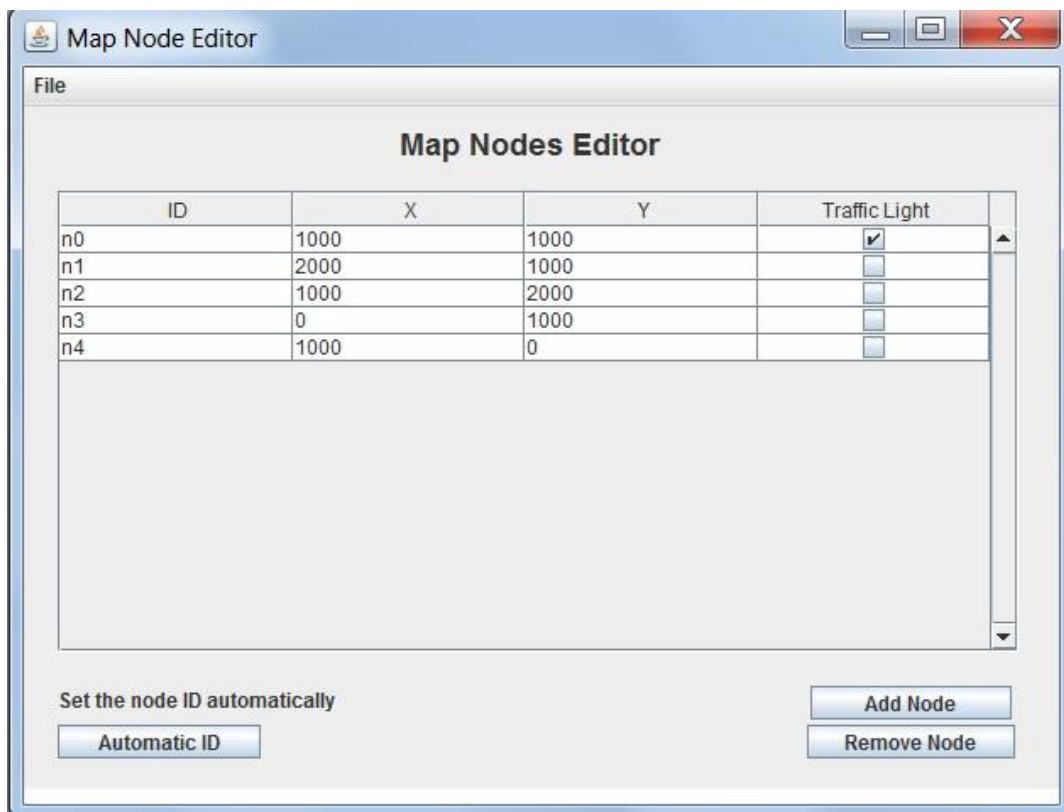


Figure 38. Map nodes (Ali 2013)

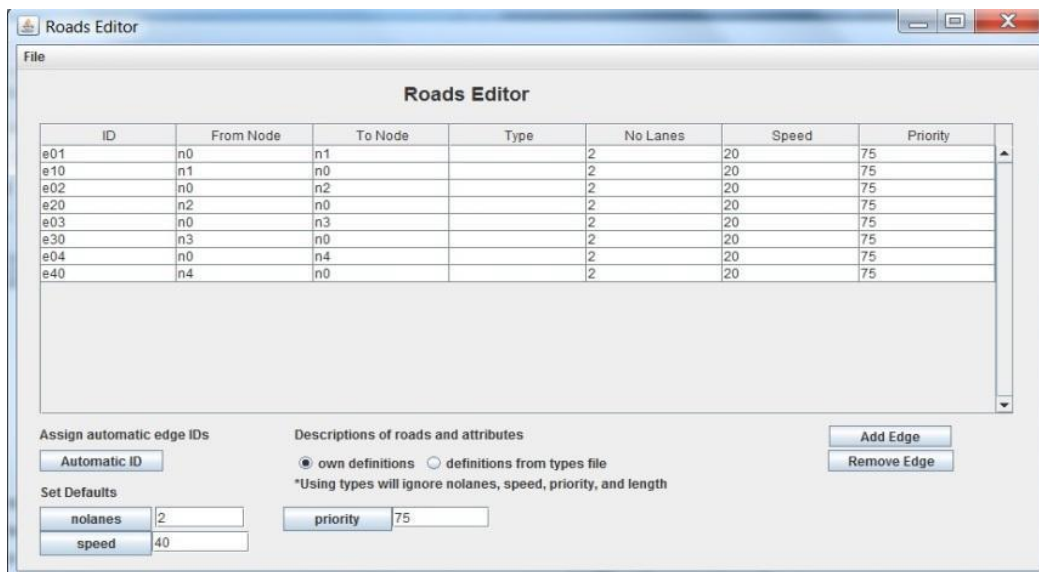


Figure 39. Defining roads (Ali 2013)

Once the nodes and edges files were initiated and saved, the configuration editor tool would combine the files and generate a configuration file that is possibly used by map generator tool to make a map. The other kind of maps used are the real maps, which are gained from VanetMobiSim program to search and analyze “OpenStreetMap.org” and get real maps for cities as shown in Figure 40. (Ali 2013)

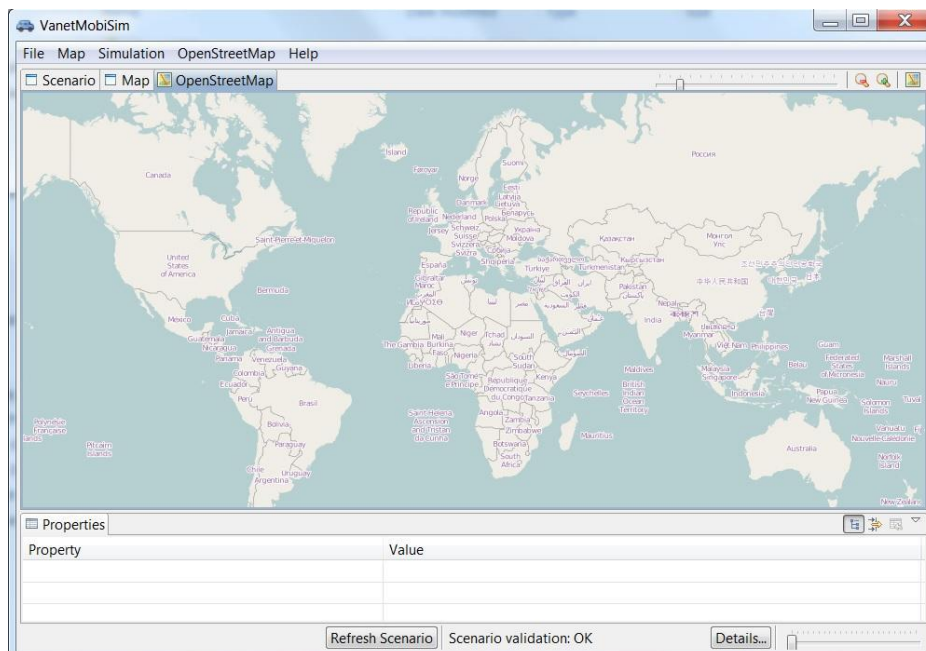


Figure 40. VanetMobiSim (Ali 2013)

Secondly, vehicle's traffic scheme should be defined. In reality, Cars are not moving in complete randomness, they usually transfer between specific points where there is common interest, as offices in the early hours of the day for example. The movement pattern has two options, the random route, where the start and destination points are chosen randomly, and the activity sequences route, where a number of start and stop points are specified. The vehicles follow the rules of the route, as traffic lights, speed limit and road direction. Overtaking is allowed in roads with multilane. Some parameters are specified as start and end time and the number of vehicles in the road. The number of vehicles are determined between the start and end time at equal intervals, each one at a time. (Ali 2013)

The MOVE program definition editor is shown in Figure 41.

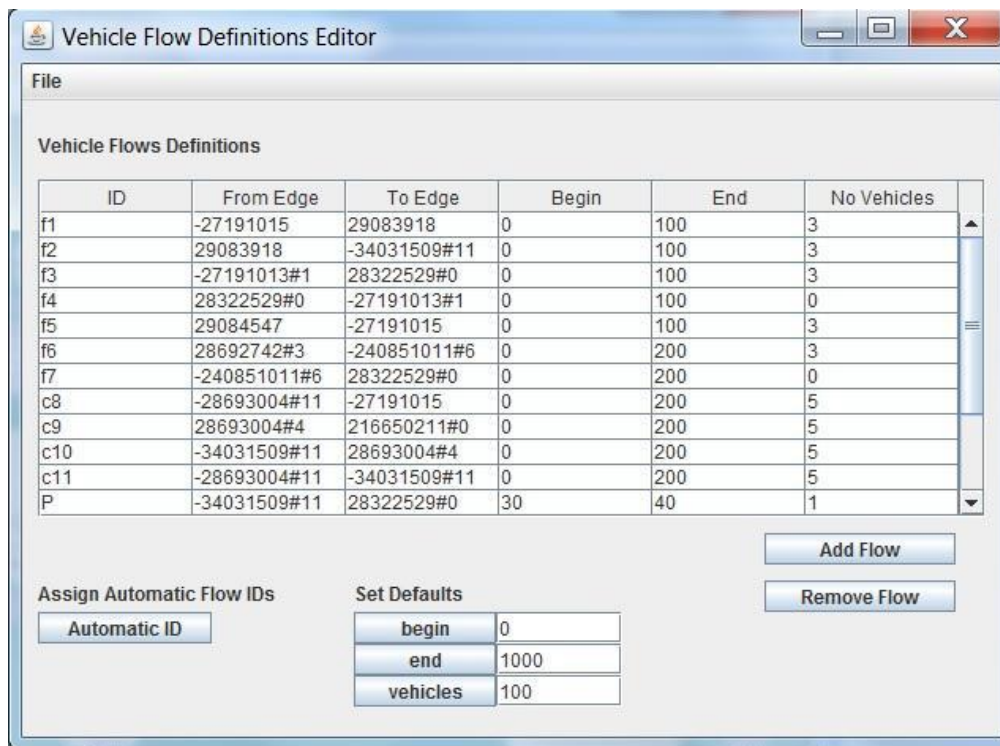


Figure 41. Definition editor in MOVE (Ali 2013)

Further control on the vehicles' actions is provided by the Manual Vehicle Route Editor, which can create special types of vehicles and assigning names for them. The car properties and dimensions can also be specified as in Figure 42 as showed in the next page . (Ali 2013)

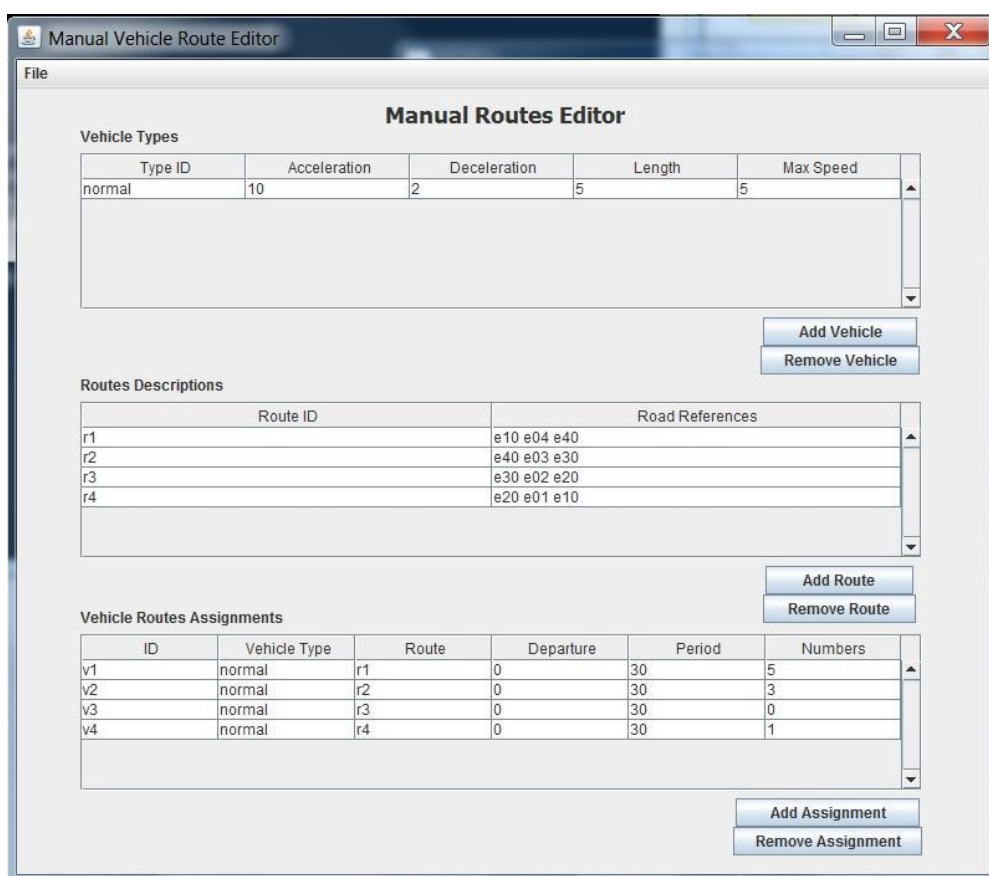


Figure 42. Manual Route Editor in MOVE (Ali 2013)

The route properties can be edited to set the edges of the route between source and destination. To control the flow needed, the car type should be linked to a route with the vehicle routes assignments tool. (Ali 2013)

After setting all the parameters, the mobility simulation takes place. SUMO's visualization tool is used to check the configuration file combining the map and the routes files, to examine the mobility model. SUMO starts the simulation generating a mobility trace file, which is a log file containing the nodes' coordinates in specific time intervals. MOVE's ns-2 script generator can be used to generate scenarios by importing the mobility trace and its map files as in Figure 43 showed in the next page. It is a GUI that can combine the important parameters of the VANET simulations in ns-2 like routing protocol, MAC type and radio propagation model. (Ali 2013)

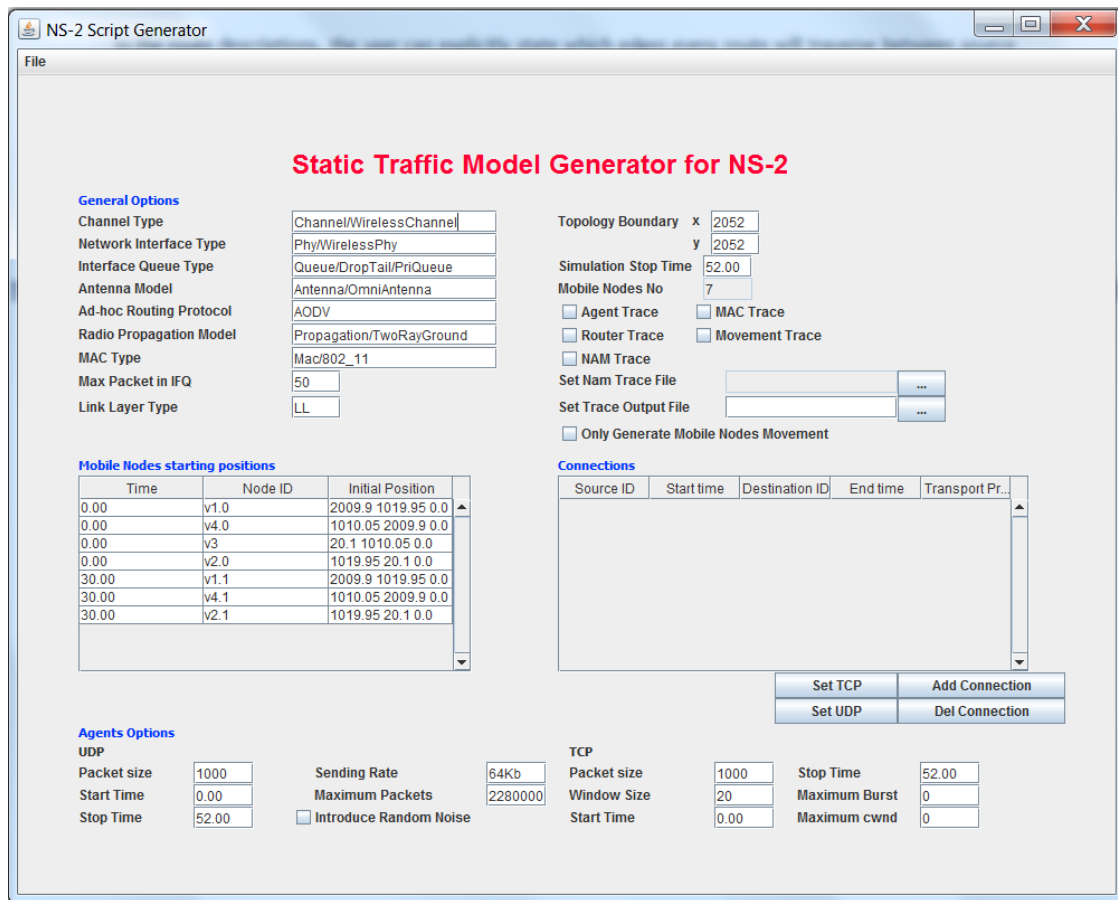


Figure 43. NS-2 script generator in MOVE (Ali 2013)

TCP or UDP packets inside the mobility models are transferred through wireless connections between simulated nodes by the script generator. It also generates a Tool Command Language (TCL) file which can be executed by ns-2. The simulation process is shown in Figure 44 in the next page. (Ali 2013)

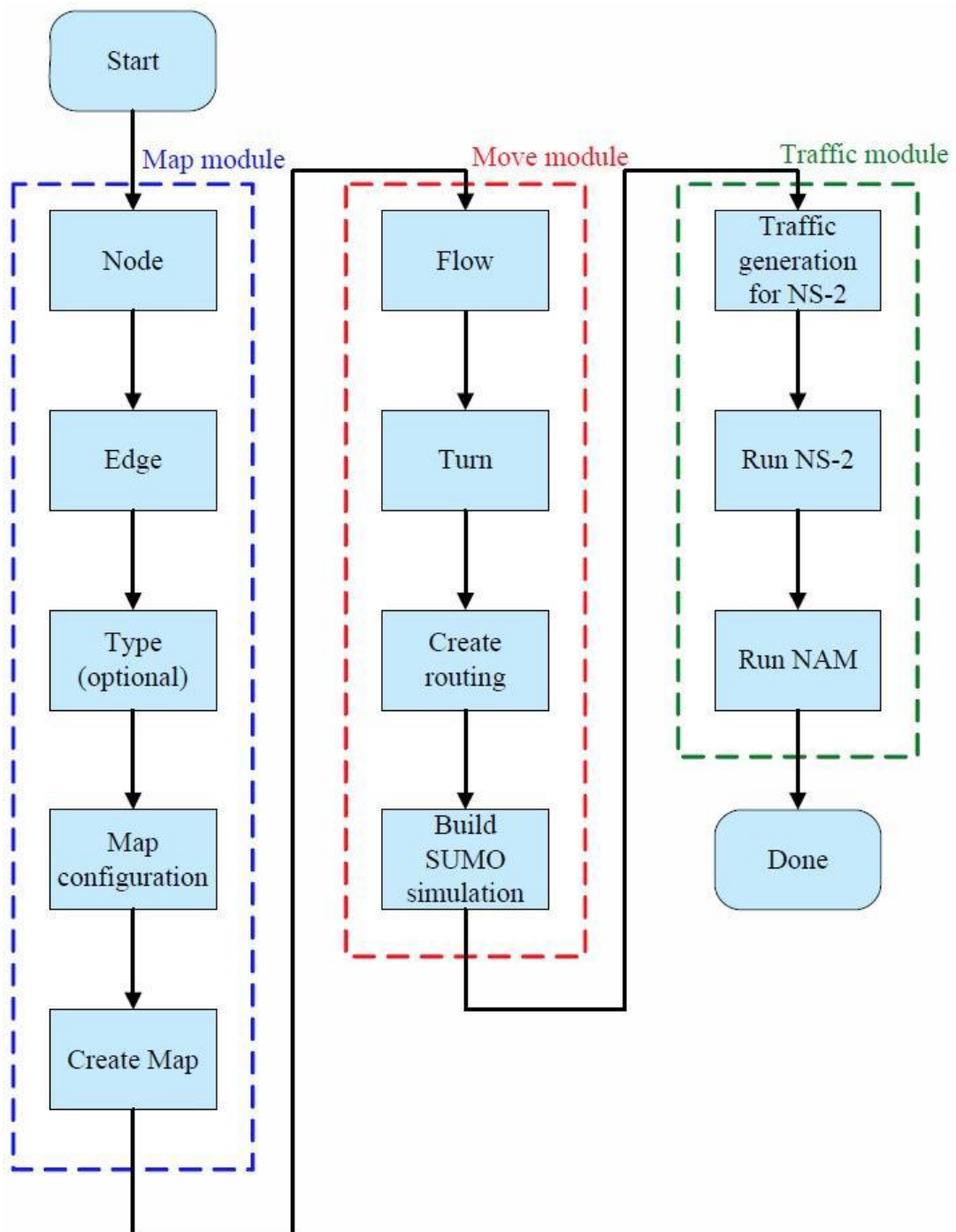


Figure 44. Simulation steps in MOVE (Ali 2013)

After starting the simulation, two files are created by the ns-2. One of them is a .nam file, showing the packets transfer and nodes motion, to help figure an idea about the simulation product. This is done by the ns-2 visualization tool as in Figure 45. (Ali 2013)

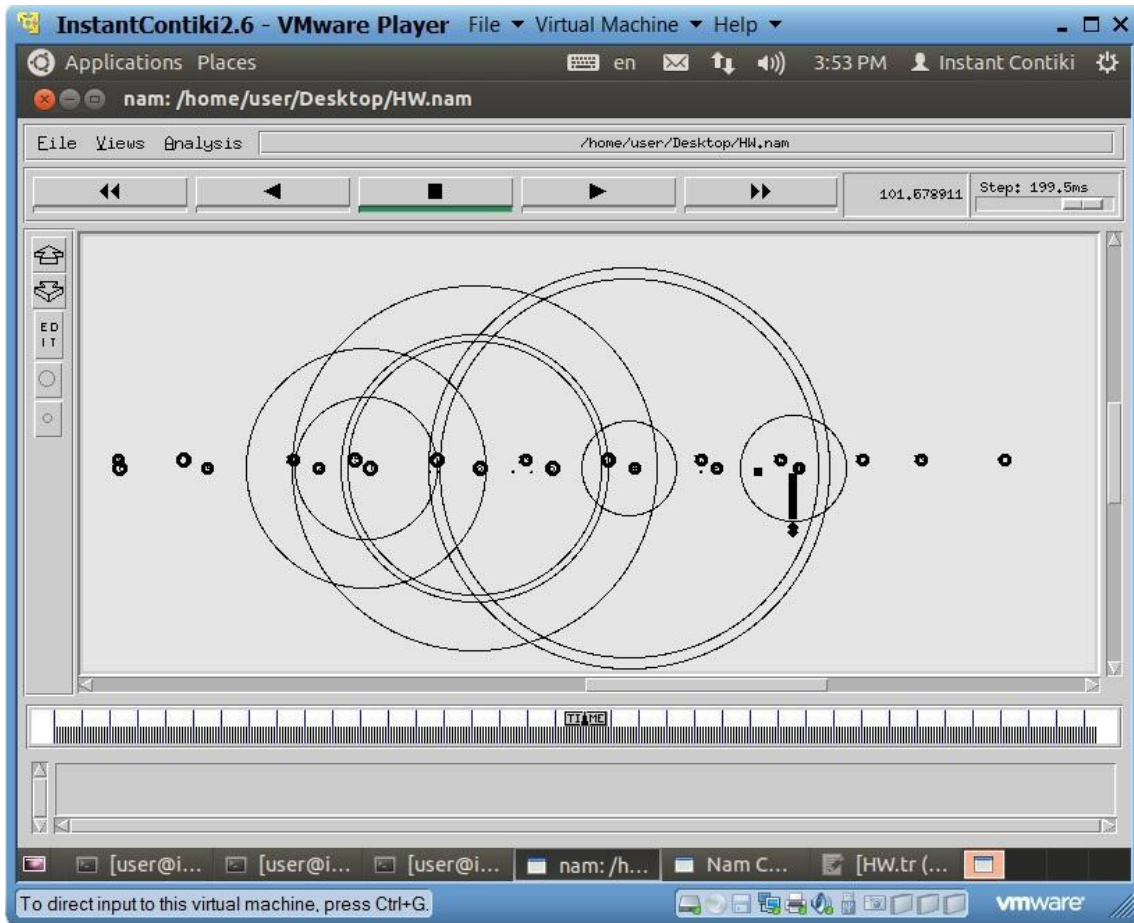


Figure 45. .nam file visualization (Ali 2013)

The other one is a trace file, which works as a record for the transferred packets. It records the time for each packet transferred, received or dropped at each node. There are two types of the trace format, an old type and a new one. In order to get better performance and less loading time and possibility of program crash, the new format is chosen, as it is more compatible with the trace analyzing software. The trace file format is converted to another better format by the trconvert tool. Trace graph GUI is presented in Figure 46. (Ali 2013)

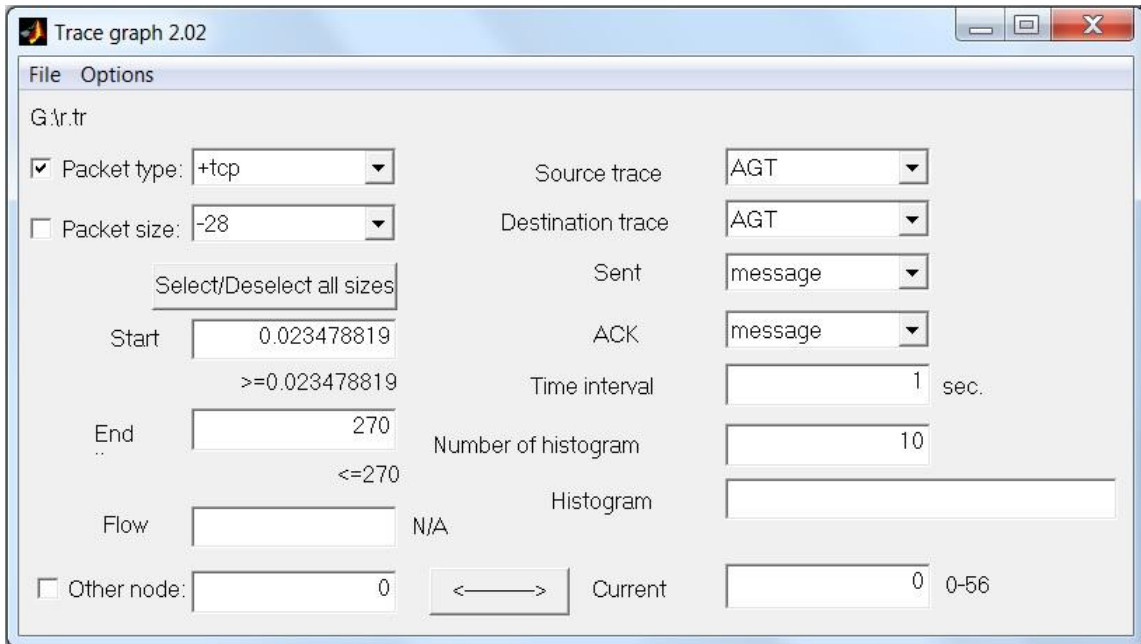


Figure 46. Trace graph GUI (Ali 2013)

We can accomplish more filtration by the trace graph, as deciding which node to inspect and reducing the time taken by data to be calculated and by graphs to be plotted. In addition to packet types filtration to get accurate results. For example, in TCP connections, except for TCP packets all the other packets are not chosen, such as Address Resolution Protocol (ARP), Request to Send frame (RTS), Clear to Send frame (CTS), and Acknowledgment (ACK) packets. Also in UDP, only Constant Bit Rate (CBR) packets are chosen. (Ali 2013)

6.1.2. Scenario 1 – MultiHop Connections

The first scenario concentrates on testing the behavior of routing protocols with multi-hop connections. The scenario consists of a multilane road of 10 km in length. Two car flows in two lanes with different speed, the slower is at 28 m/s and the faster is 33 m/s. The car with the higher speed transmits to the one with less speed (the blue cars). The number of hops between the two cars increases when the fast cars pass the slow cars. This causes a decrease in the output due to increasing the end to end delay. The first scenario visualization by SUMO's GUI is shown in Figure 47. (Ali 2013)



Figure 47. Scenario 1 visualization (Ali 2013)

Simulation setup:

Transmission time: 240 seconds.

Number of nodes: 18

MAC type: Mac/802_11

Ad-hoc routing protocols: AODV, DSDV and OLSR.

Radio Propagation Model: Free Space.

Transport Protocols: TCP and UDP (Ali 2013)

Results:

At the start of the simulation the output is at its highest level due to the direct connection between the sending and receiving nodes. The output reaches 0.7 Mb/sec. All of the three used routing protocols has shown a significant decrease in output when the fast cars keep overtaking the slow ones, increasing the number of hops between the sending and receiving nodes. DSDV was the first protocol to lose connection; it lost connection at the 80th second. This shows that its operation lasts only for a small number of intermediate hops. On the other hand, OLSR and AODV kept the connection during the whole transmission time while maintaining the same output. It was also clear that AODV connection was more stable. OLSR needed few seconds to re-connect when the connection was lost, causing some zero received bits gaps as shown in Figure 48.

(Ali 2013)

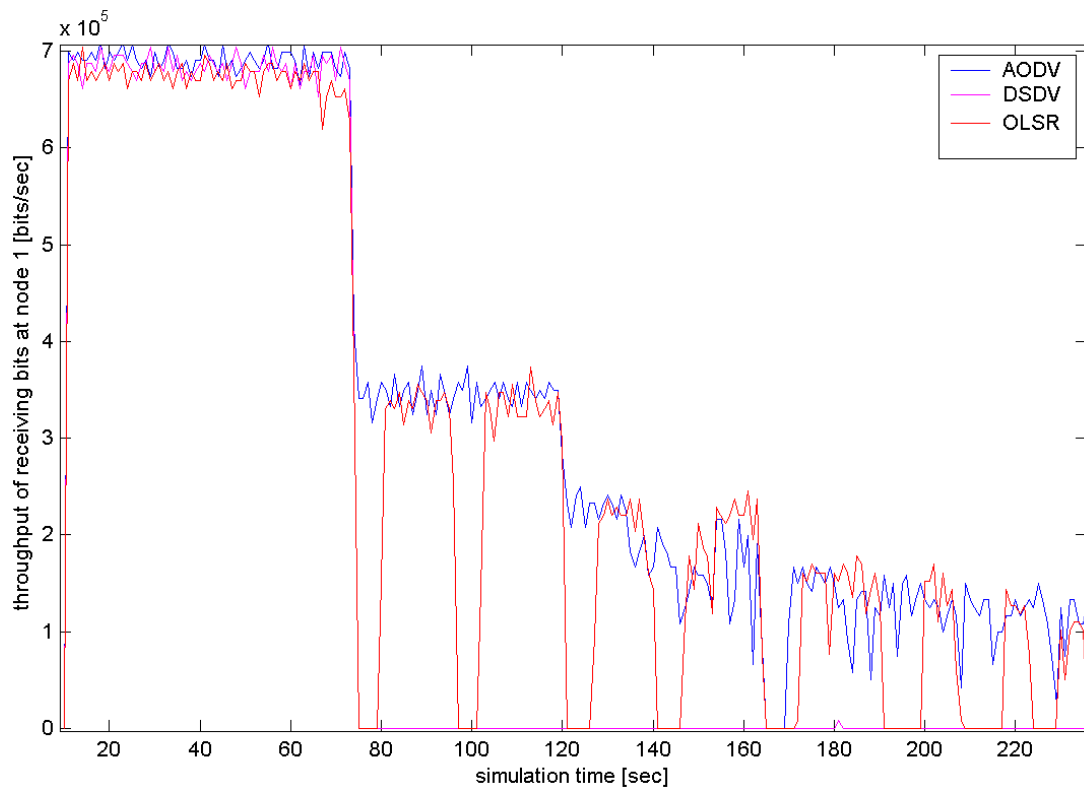


Figure 48. TCP output for Scenario 1. (Ali 2013)

A comparison of the cumulative distribution functions of the delays is shown in Figure 49.

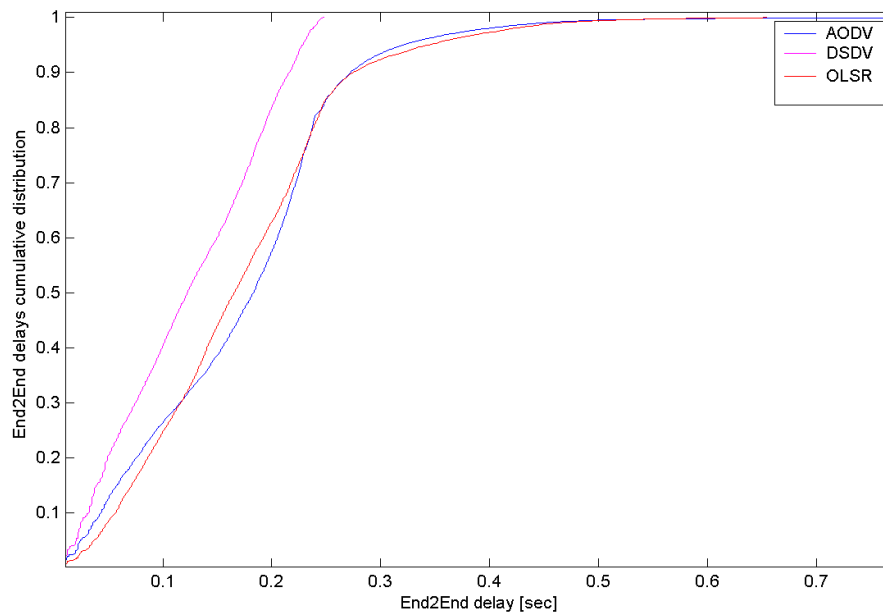


Figure 49. TCP delays in Scenario 1. (Ali 2013)

DSDV recorded the lowest delay. While OLSR and AODV recorded a similar CDF for delay. Using OLSR or AODV for sending packets increases the probability of packets arriving within 0.2 seconds delay to 50%, and the probability for packets arriving in less than 0.3 seconds delay to 90%. (Ali 2013)

The minimum, maximum and average end to end delays in seconds for each routing protocol, and the median and standard deviation (σ) of scenario 1 is shown in Table 4.

Table 4. TCP Packets Delay in Scenario 1. (Ali 2013)

	Minimum E2E Delay	Maximum E2E Delay	Average E2E Delay	σ	Median
AODV	0.0050919920	0.6537681730	0.1716732224	0.28866014	0.50010847
OLSR	0.0098262930	6.3630483810	0.1767772492	0.28858440	0.50025779
DSDV	0.0045719920	0.2477734980	0.1231930545	0.28865030	0.50019508

The three routing protocols seem to keep the connection for a longer time in the simulation when UDP packets are used. The throughput of AODV is lowered a little bit with the increase of the intermediate nodes as shown in Figure 50. (Ali 2013)

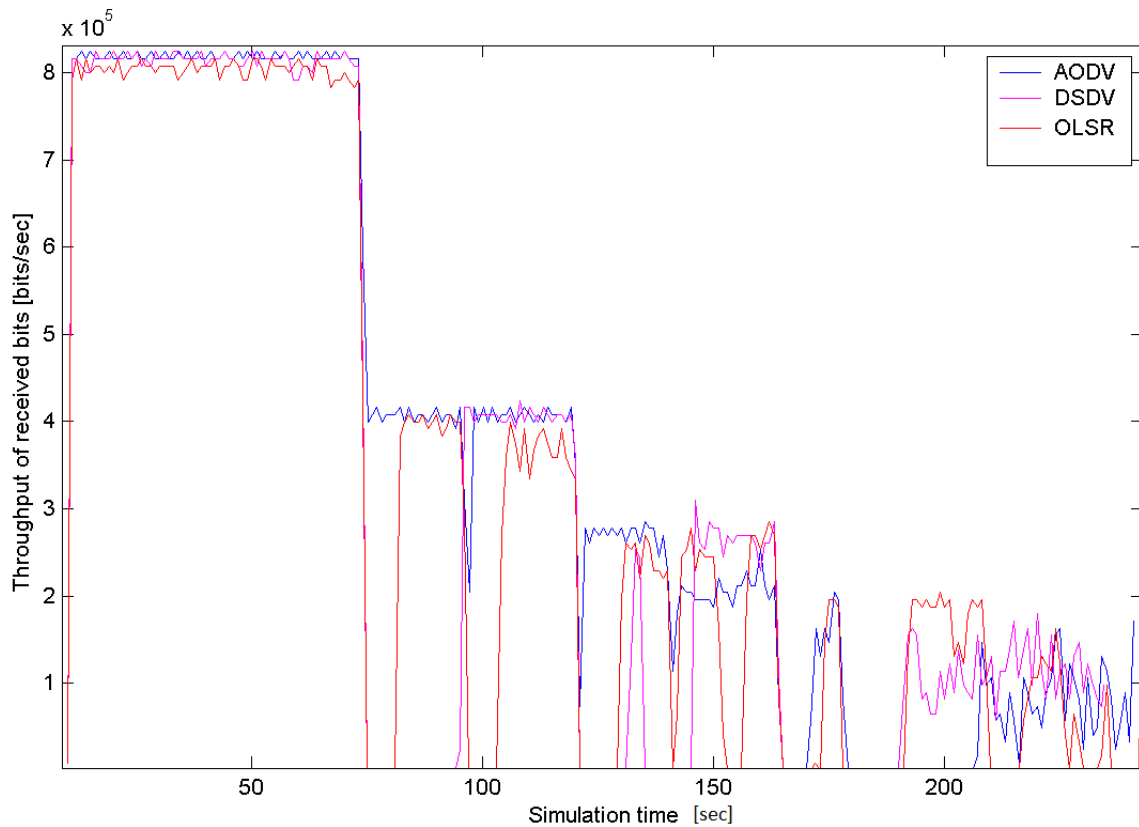


Figure 50. Using UDP packet in Scenario 1 (Ali 2013)

Nearly 70% of OLSR and DSDV packets had an 0.5 second or less delay time, while the percentage in AODV packets was 63% only. In the case of AODV or OLSR, 90% of packets should arrive with a delay less than 2 seconds, while only 85% in the case of DSDV, as shown in next Figure 51. (Ali 2013)

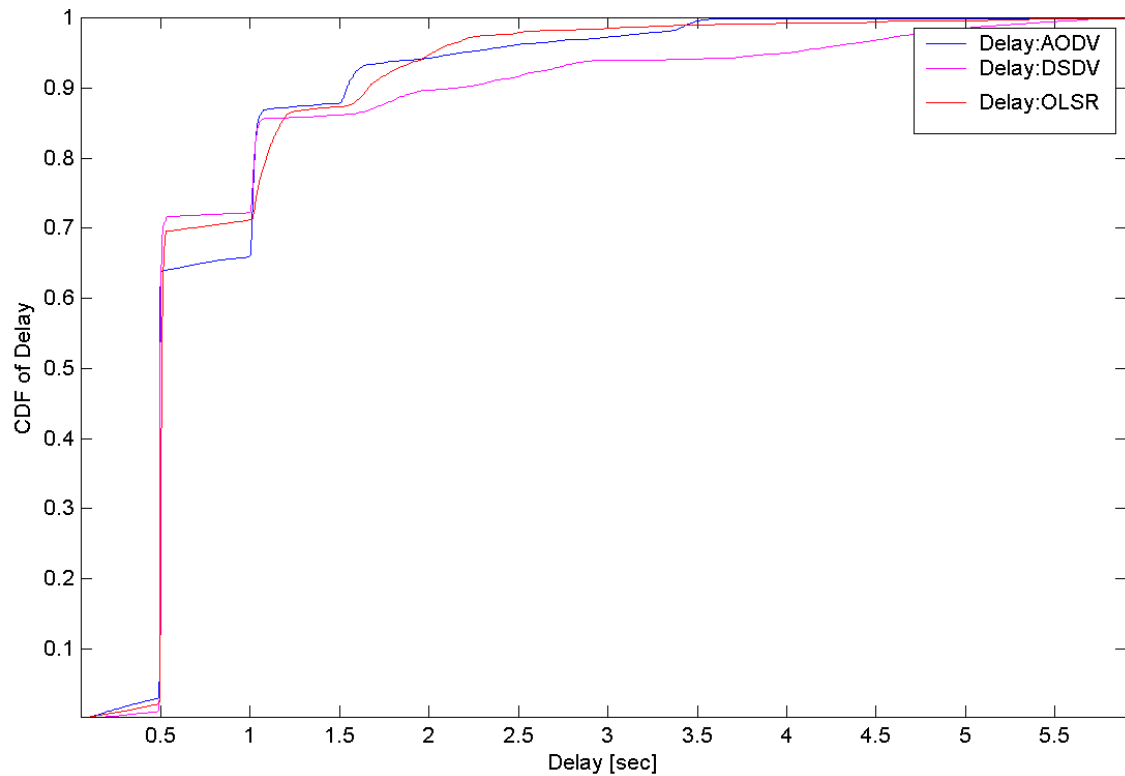


Figure 51. UDP Delay for Scenario 1 (Ali 2013)

The minimum, maximum and average expected delays for AODV, OLSR and DSDV in seconds and their medians and standard deviations in the case of UDP packets are shown in Table 5.

Table 5. UDP Packets Delay for Scenario 1 (Ali 2013)

	Minimum E2E Delay	Maximum E2E Delay	Average E2E Delay	σ	Median
AODV	0.0278405180	47.1854971770	0.8358558674	0.96577239	0.4972212000
OLSR	0.0125719920	13.1781788030	0.8198667509	0.70803833	0.5071783140
DSDV	0.0126519920	5.9846685140	0.9500924252	1.04989802	0.4983542355

Comparing UDP and TCP, it is noticed that the average delay is higher in UDP than in TCP. Previous simulations done by other researchers confirm this comparison results between TCP and UDP packets.

Simulations done by (Gangurde, Waware & Sarwade 2012) show that average delay of the received TCP packets was 0.787624 seconds and for the UDP packets the delay was 1.930832.

Other simulation done by (Giannoulis, Antonopoulos, Topalis, Athanasopoulos, Prayati & Koubias 2006) was to study the difference between TCP and UDP in the quality of service and performance in application of multimedia over wireless networks. The study pointed out that the higher mean for delay was that of the UDP. (Ali 2013)

One of the difference between TCP and UDP which could be the reason of the high delay in UDP, is that in TCP the transmission rate can be reduced by the protocol when packets don't reach their destination, due to the feedback of acknowledgment packets. While in UDP nothing tells the sender to reduce the rate even when the connection to the destination is lost. Therefore, the sender keeps sending and generating packets at the same rate causing the buffers of intermediate nodes to accumulate causing long delays. (Ali 2013)

A comparison of packet delivery ratio between the three inspected routing protocols is shown in Table 5. The packet delivery ratio is defined as the percentage of sent packets which are not dropped neither lost but successfully received at their intended destination.

$$\text{Packet Delivery Ratio} = \frac{\text{Total number of sent packets at source node}}{\text{Total number of received packets at destination node}}$$

Table 6. Packet Delivery Ratio of UDP Packets for Scenario 1. (Ali 2013)

	No. of sent packets	No of received packets	Packet Delivery ratio %
AODV	12990	10356	80%
OLSR	12495	9202	74%
DSDV	13333	8887	67%

AODV is better than both OLSR and DSDV considering packet delivery ratio and also the total number of packets delivered successfully.

A summary of the results of the first scenario is shown in Figure 52. (Ali 2013)

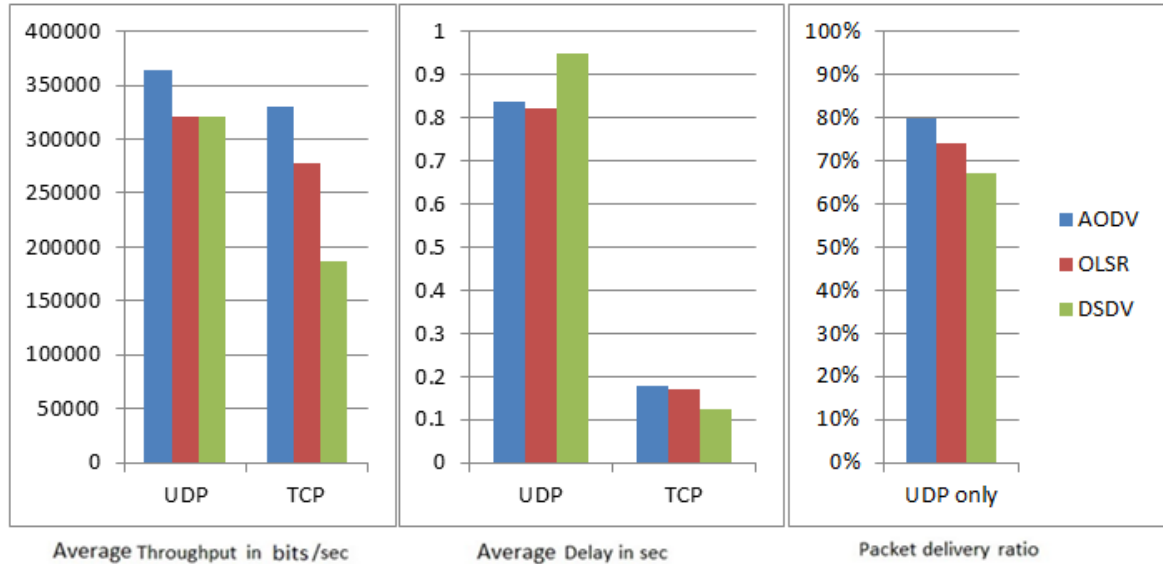


Figure 52. Summary of the results of the first scenario (Ali 2013)

As shown in the figure, the AODV surpassed in the packet delivery ratio and the average throughput. While OLSR is intermediate. The lowest delay is in the case of DSDV although it has poor packet delivery ratio and throughput.

The second step in the simulation of scenario 1 is increasing the speed difference between the two car flows, in order to examine if faster changes in topology will affect the performance of routing protocols. The speed of the high-speed lane will increase to 55 m/s, while the low speed lane will remain as it is with 28 m/s. Simulation time is reduced to 110 seconds. Figures 53 and 54 shows the results for TCP packets in the next page. (Ali 2013)

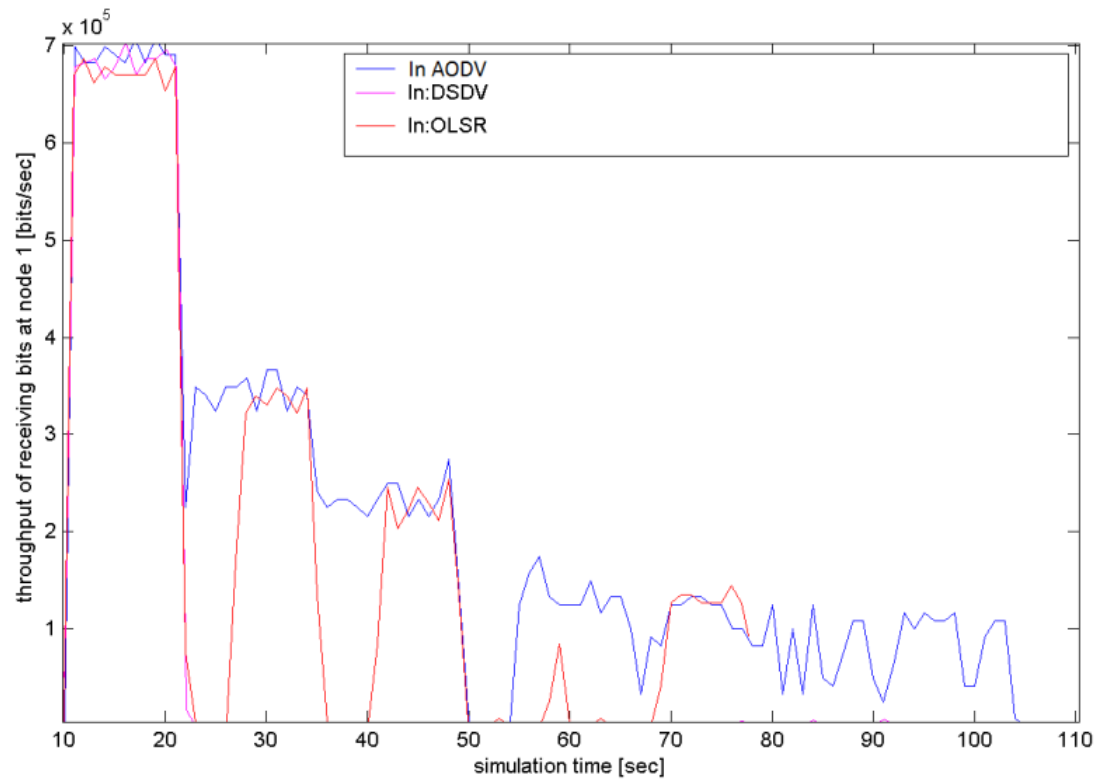


Figure 53. Increasing Speed effect on TCP Throughput in Scenario 1 (Ali 2013)

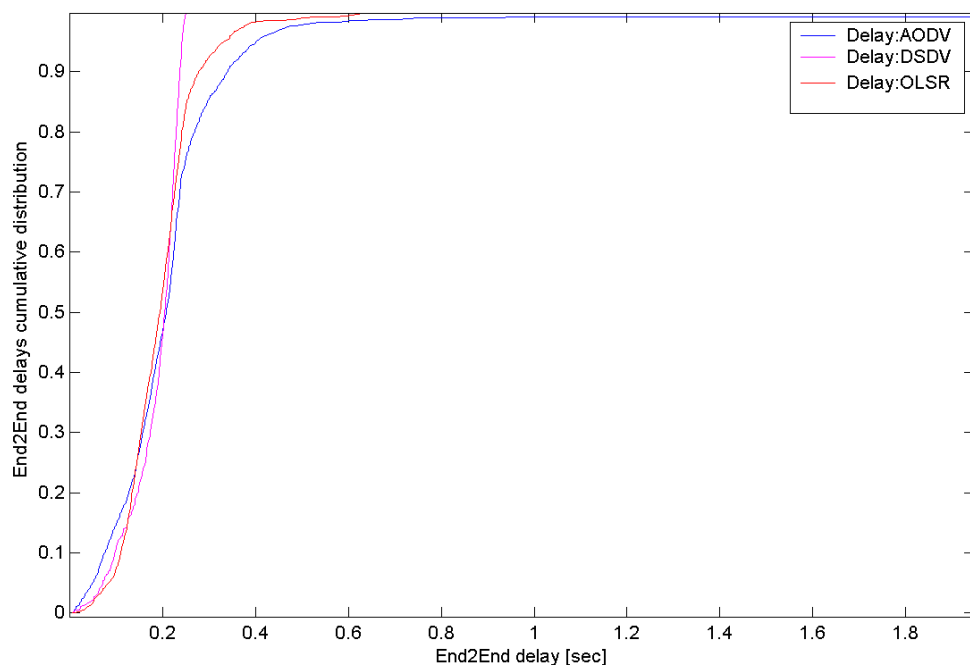


Figure 54. Increasing Speed effect on TCP Delay in Scenario 1 (Ali 2013)

Figure 55 and 56 show the results for UDP packets.

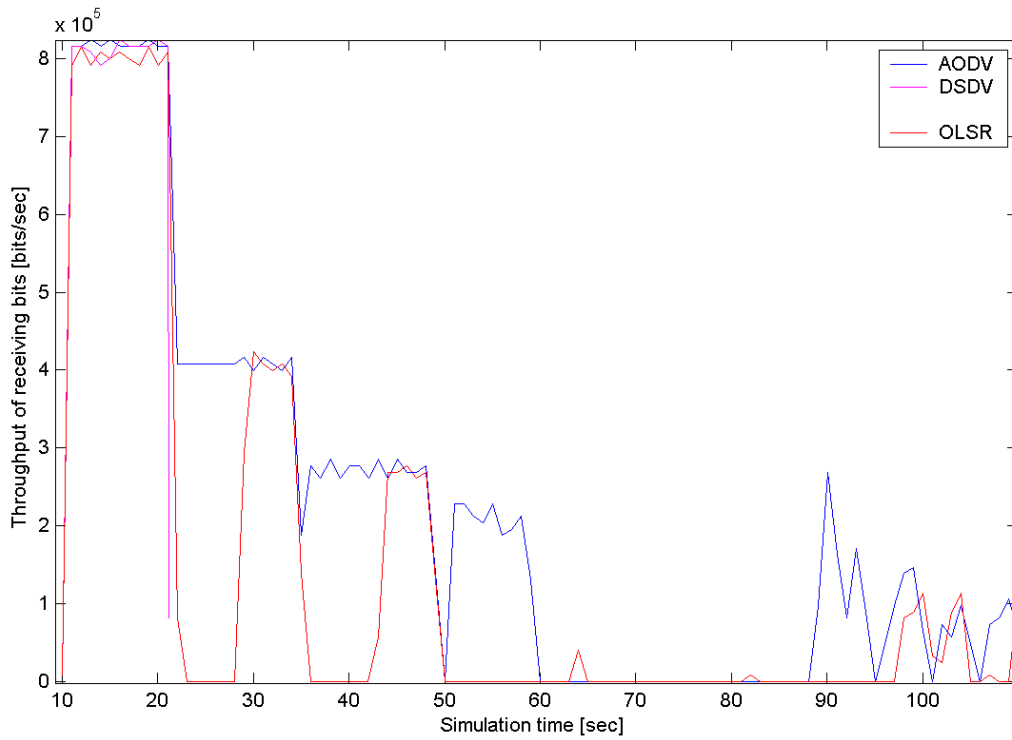


Figure 55. Increasing Speed effect on UDP Throughput in Scenario 1 (Ali 2013)

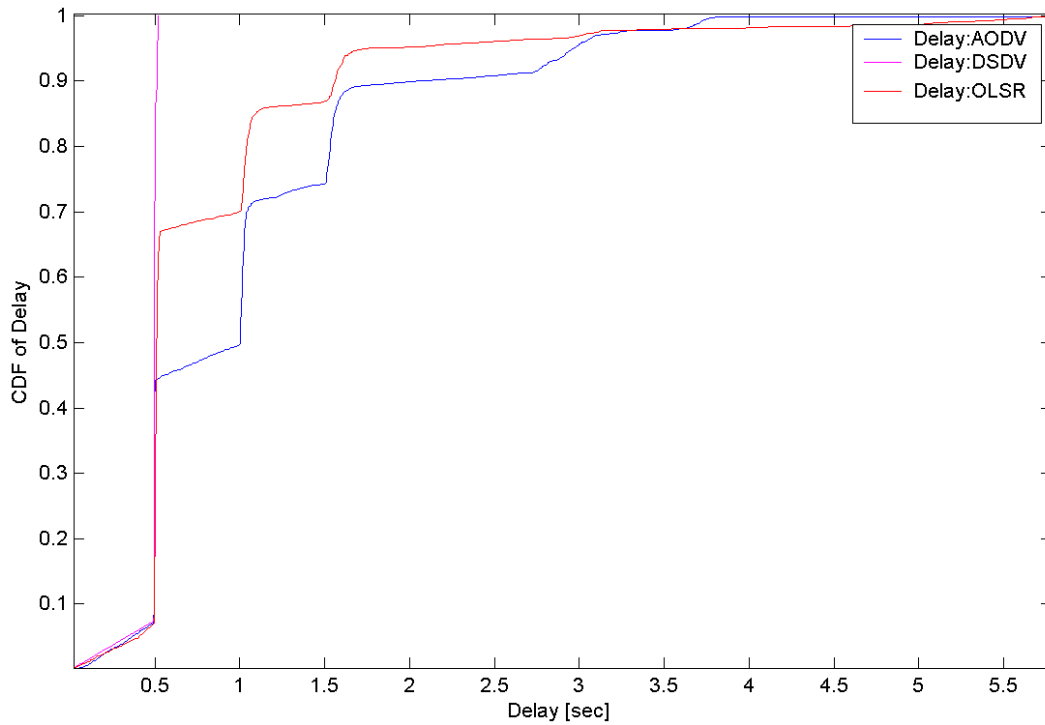


Figure 56. Increasing Speed effect on UDP Delay in Scenario 1 (Ali 2013)

It is noticed that when the speed increased, throughput and packet delivery ratio has decreased.

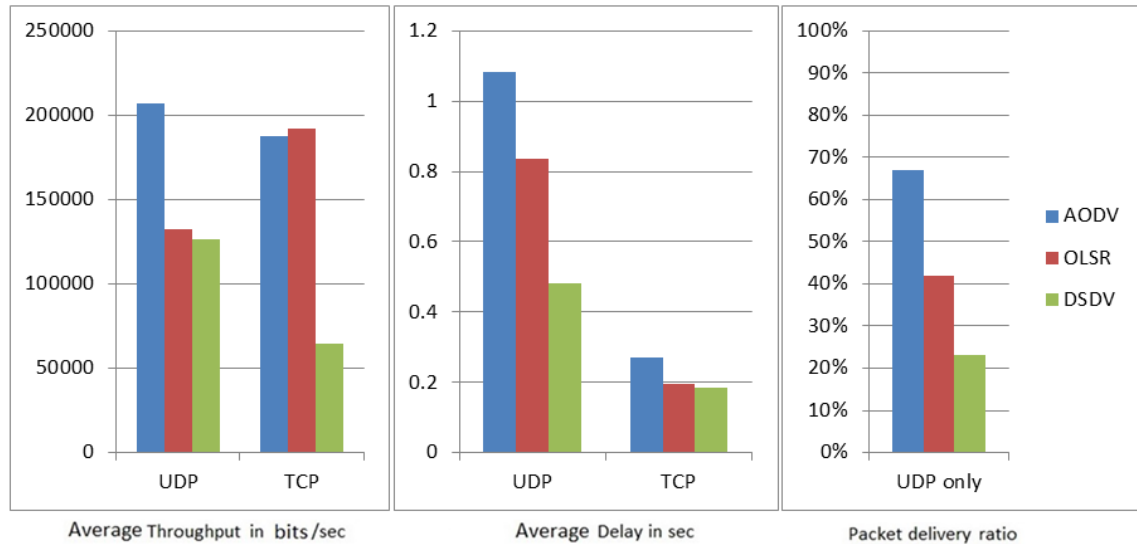


Figure 57. Summary of Results When Increasing Speed in Scenario 1 (Ali 2013)

The most powerful routing protocol with the least reduction in packet delivery ratio is AODV, where it decreased from 80% to 67%. In the case of OLSR, packet delivery ratio was reduced by 32%. While DSDV went from 67% to 23% packet delivery ratio. However, it has the lowest delivery ratio in all simulations. (Ali 2013)

6.1.3. Scenario 2 – Time Delay

The second scenario is mainly concerned by the delay time. The design of the map is made of four streets 1 Km long, intersecting at a crossroads with traffic lights.

Figure 58 shows the map design in the next page.

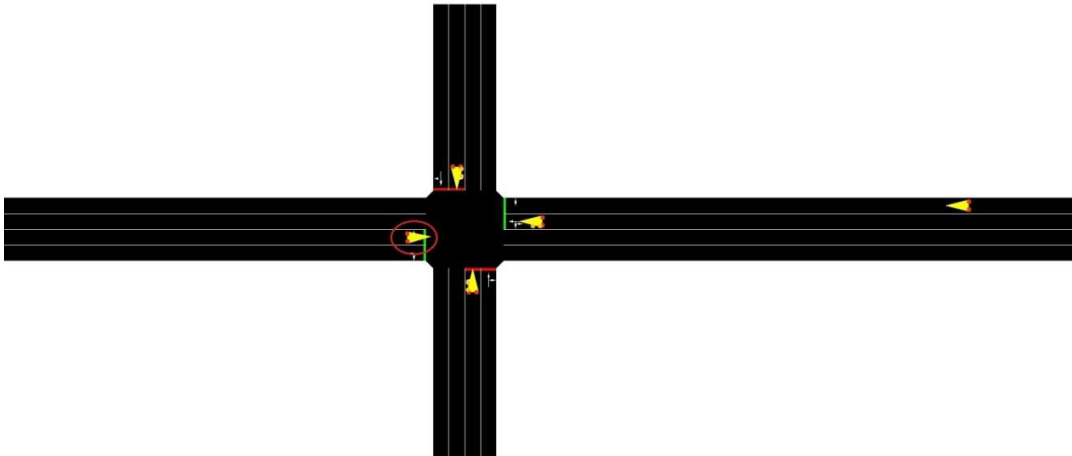


Figure 58. Map of scenario 2 (Ali 2013)

In this scenario, the car with the red circle reaching the crossroad and trying to make a turn. It has to send warning to all the vehicles at the crossroad. There are two cars coming from the left, four cars from the right and six cars from the front. This will require sending packets to the right, left and the front at the same time, and each direction will have different number of hops. A comparison is made between the average delay of packets received by the last car of all directions for the three routing protocols and their CDF. This scenario is basically a safety application so only TCP is tested. (Ali 2013)

Simulation setup

Transmission time: 24 seconds.

Number of nodes: 13

MAC type: Mac/802_11

Ad-hoc routing protocol: AODV, OLSR and DSR

Radio Propagation Model: Two Ray Ground

Transport Protocol: TCP (Ali 2013)

Figure 59 shows the result.

Results:

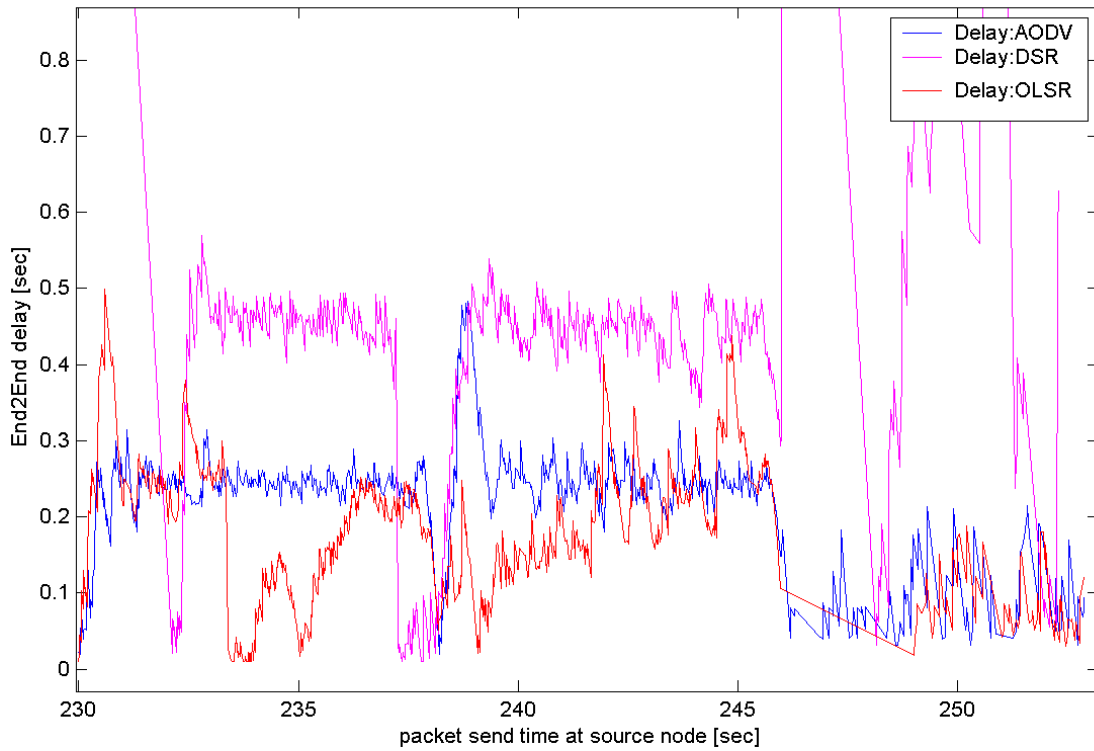


Figure 59. Throughput of Scenario 2. (Ali 2013)

As the results are plotted in Figure 59, it appears that DSR had the highest delay. While OLSR had higher delays in some packets compared to AODV. However, OLSR had the lowest average delay.

The minimum, maximum and average delay in seconds for all the three routing protocols, and the median and standard deviation (σ) of scenario 2 is shown in Table 7.

Table 7. Delay of TCP Packets in Scenario 2. (Ali 2013)

	Minimum Delay	Maximum Delay	Average Delay	σ	Median
AODV	0.019792458	0.4837698690	0.2206338077	0.073508	0.23909524
DSR	0.010026237	2.1401044990	0.4346695705	0.263983	0.44614249
OLSR	0.010026436	0.4992087260	0.1781333058	0.087942	0.18036488

Considering the results of Figure 59 and the standard deviation in Table 7, it seems that the reason for the high average delay of DSR is that some packets have a very high delay

up to 2 seconds. It also appears that OSLR is the most suitable for this kind of safety applications, as it has the lowest average delay and the lowest deviation. (Ali 2013)

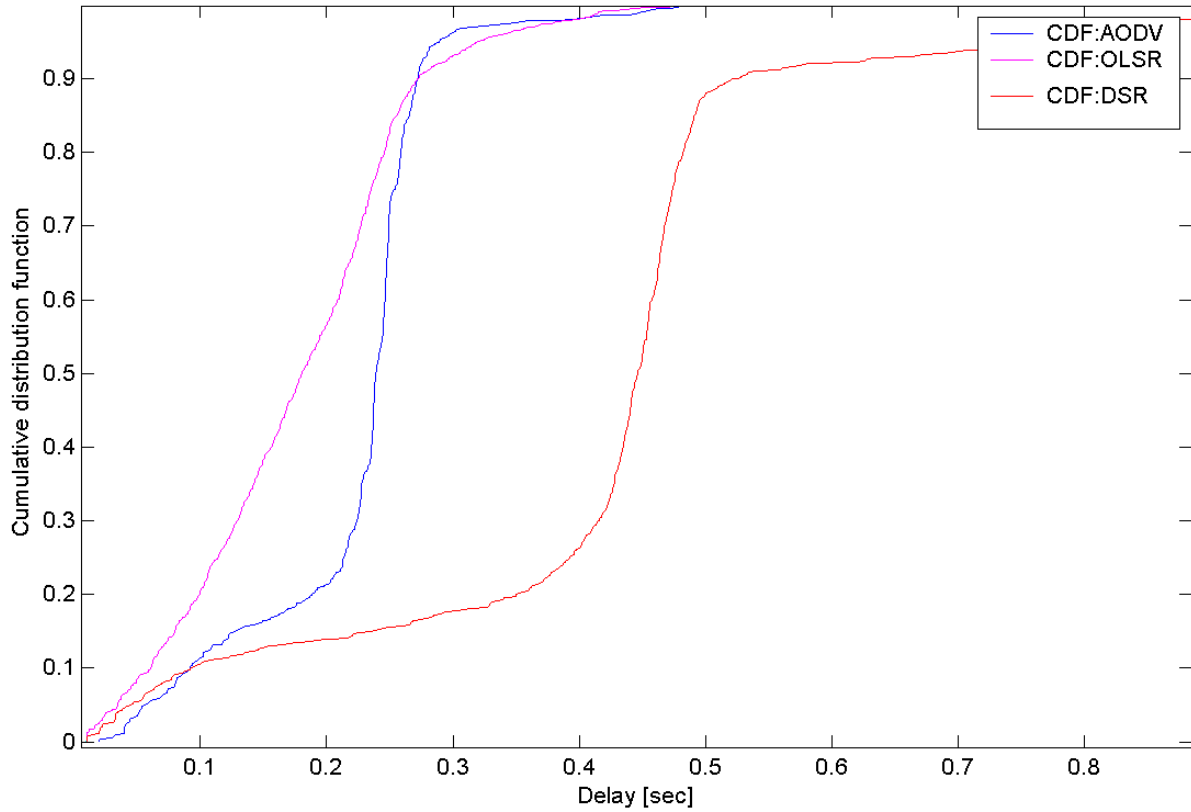


Figure 60. Delay of Scenario 2 (Ali 2013)

As seen in Figure 60, OLSR packets had the least delay as it recorded 50% of the packets are received with a delay of less than 0.24 seconds, while DSR recorded 12% only and AODV 20%. 80% of the packets were received within 0.24 seconds in case of OLSR, while it took 0.27 seconds for AODV and 0.5 seconds for DSR. (Ali 2013)

6.1.4. Scenario 3 – Interference Effect

This scenario is concerned about testing the effect of interference on different routing protocols. It consists of a multilane road containing three car flows, the cars speeds are 20, 22 and 24 m/s and they can overtake the others. Starting from the 40th second, packets are sent from the red car to the blue one. Interference is caused to the blue circled communicating cars by two other cars (circled in red) when they start to communicate at

the 70th second. To increase the interference, another pair of cars (circled in green) start to communicate at the 100th second. Observations are made to the blue circled car, where throughput of received bits and packet delivery ratio (in case of UDP connection) are considered. The cars different positions in different time intervals are shown in Figure 61. (Ali 2013)

Scenario 3 at Second 40



Scenario 3 at Second 70



Scenario 3 at Second 100



Figure 61. Cars positions at different time intervals (Ali 2013)

Simulation setup:

Transmission time: 90 seconds.

Number of nodes: 21

MAC type: Mac/802_11

Ad-hoc routing protocol: AODV, DSDV, DSR, and OLSR.

Radio Propagation Model: Two Ray Ground.

Transport Protocol: TCP and UDP (Ali 2013)

Results:

Throughputs of AODV, DSDV, DSR, and OLSR when using TCP packets are plotted in Figure 62 showed in the next page.

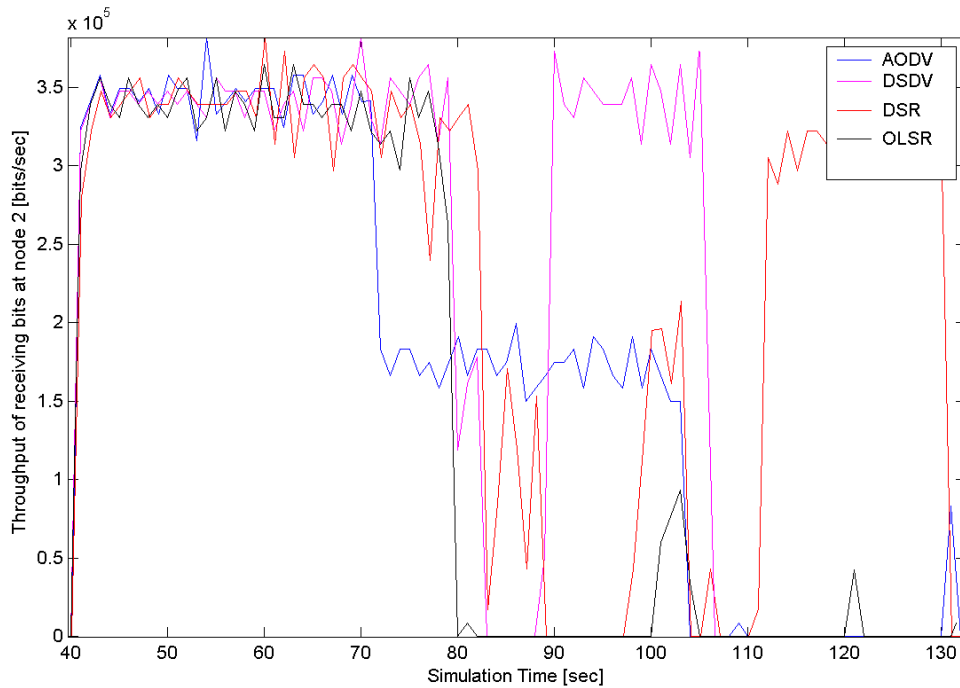


Figure 62. TCP throughput in scenario 3 (Ali 2013)

The results show that OLSR has the weakest ability to keep the connection, it lost connection after the first interference at the 80th second. While only DSR had the ability to keep its connection even after the second interference in the 100th second. (Ali 2013)

A comparison between throughput and UDP packets is shown in Figure 63.

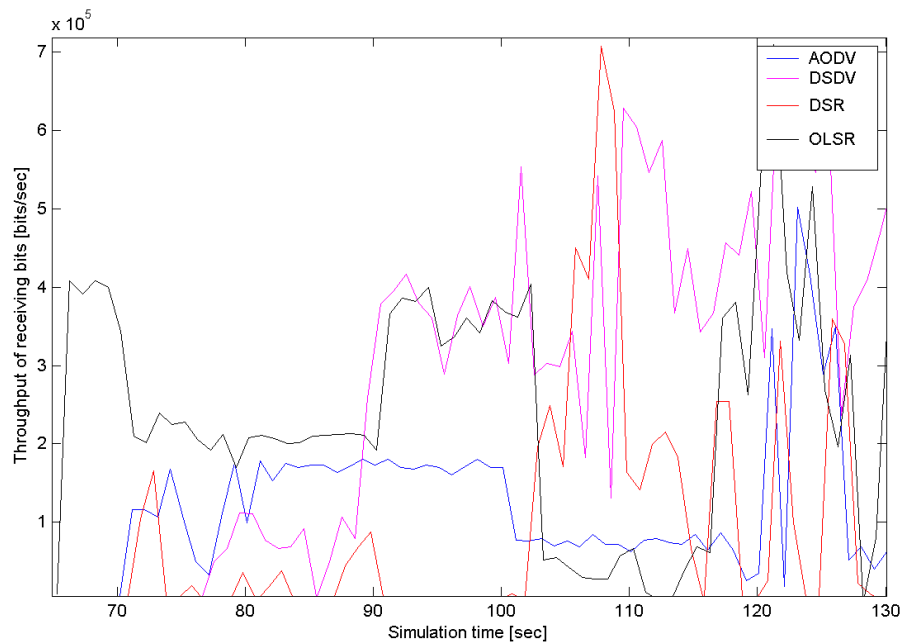


Figure 63. Comparison between throughput and UDP packets in scenario 3 (Ali 2013)

In the case of using UDP, the results show that OLSR has the highest ability to keep the connection during all the simulation time, and is not affected by interference. A comparison between the average throughput of all the four routing protocols for both UDP and TCP connections, in addition to the packet delivery ratio for UDP is shown in Figure 64.

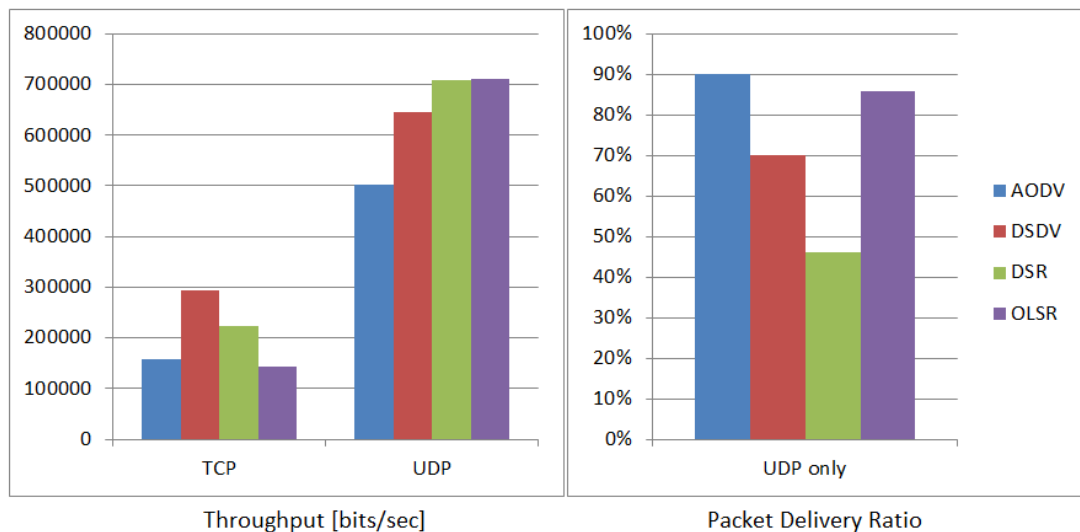


Figure 64. Summary results of Scenario 3 (Ali 2013)

6.2. Simulation using VNSim

6.2.1. City and highway Simulation scenarios

This part shows some simulation scenarios made by the VNSim simulator, some of them are created and some are real simulation. It also presents the results of these simulations and how can these results be used by VANET developers and users.

One of the important things to consider in some of the applications spread on VANETs is the traffic operations and maintenance, as dynamic route planning, adaptive control in intersections and weather conditions publishing.

6.2.2. Traffic Coordination in Intersections

A lot of research is ongoing on the traffic coordination in intersections, as it is one of the most important topics in the VANET applications. In this section, a VANET application

of an adaptive traffic light system and the steps of deploying it in VNSim is presented. The system is based on wireless connection between vehicles and fixed controller nodes placed in intersections. This application could result in a remarkable improve of traffic fluency in intersections. It also shows privilege over other designs concerning cost and performance. (Cristea, Gradinescu, Gorgorin, Diaconescu & Iftode 2009)

The aim of this VNSim project is to prevent accidents and traffic jam in intersections. Using wireless connection between vehicles and traffic lights, the traffic lights can get continuous “vision” of the traffic, which affect the signal plans they make, as shown in Figure 65. It can also warn drivers if there is a potential of an accident in intersections. (Cristea, Gradinescu, Gorgorin, Diaconescu & Iftode 2009)

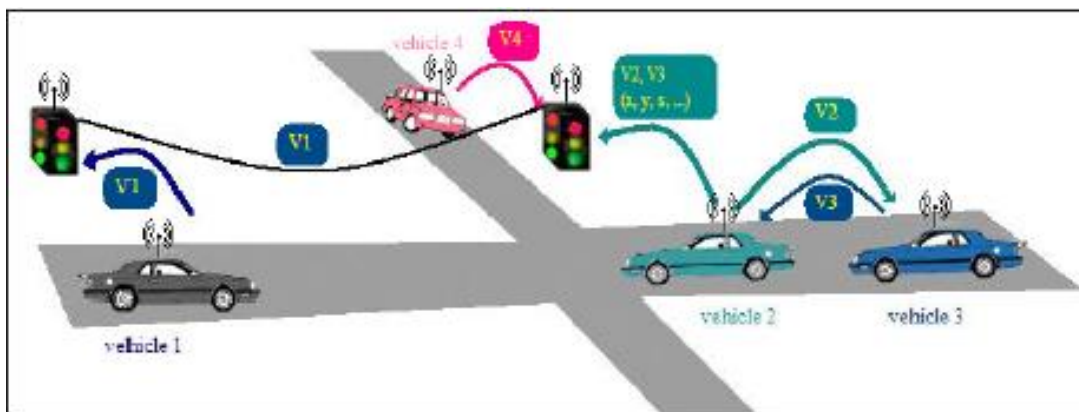


Figure 65. Communication between traffic lights and vehicles

(Cristea, Gradinescu, Gorgorin, Diaconescu & Iftode 2009)

In order to simulate this application, a data dissemination system should be provided to allow the information to flow between vehicles and between vehicles and traffic lights. The data distribution system was made in a way that allows vehicles to transmit information they have about other vehicles to all vehicles in their range, according to the Traffic View system. (Cristea, Gradinescu, Gorgorin, Diaconescu & Iftode 2009)

The simulation of the application in VNSim shows that there is high load on the network caused by the great amount of unnecessary data. Wireless interference causes a decrease in the probability of successful transmissions in the case of large packet size. This could

be solved by applying aggregation mechanisms, such as using a probabilistic scheme where a leader vehicle transmits the information. This vehicle is selected in a random way with a probability depending on the traffic density. The results of this method were remarkable decrease in the load on the network, without affecting the functionality of the solution.

Due to the dissemination algorithm, the traffic light control could be applied which can make a signaling plan suitable for the intersection. The traffic light can collect data of traffic metric values (flows, delays) from the crossroads, as it is a node in the data dissemination system. Some traffic engineering methods are used to calculate the optimum cycle length and the green split phases, such as Webster's formula. (Cristea, Gradinescu, Gorgorin, Diaconescu & Iftode 2009)

A simulation scenario based on a real map was made on a four-way intersection in Bucharest during rush hour. The simulation examined the efficiency of the algorithm. The results appear to be a reduction in the traffic jam in the intersection when applying the data dissemination system, as well as a reduction in the total delay time for all vehicles by 28%, as shown in Figure 66 in the next page.

(Cristea, Gradinescu, Gorgorin, Diaconescu & Iftode 2009)

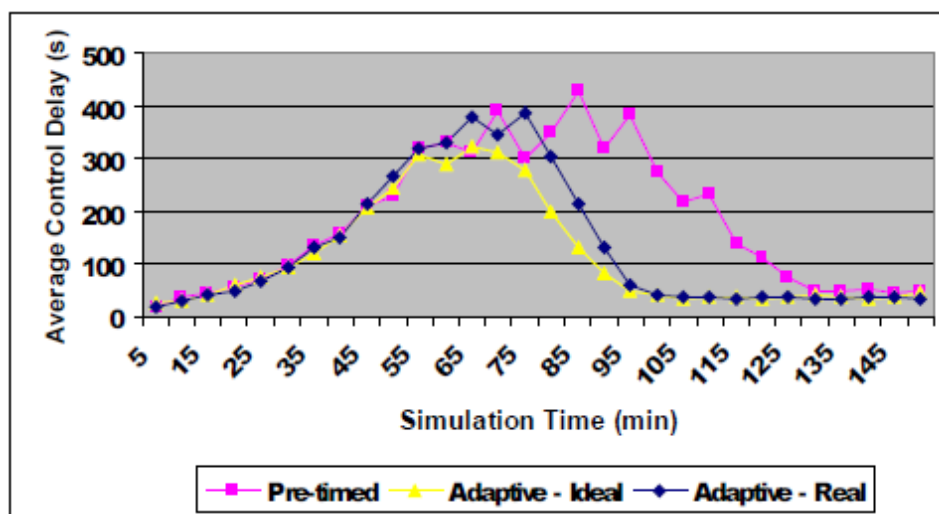


Figure 66. Average control delay

(Cristea, Gradinescu, Gorgorin, Diaconescu & Iftode 2009)

A module for calculating pollutant emissions and fuel consumption is also added to the VNSim simulation, by using the data collected as vehicle speed and acceleration. Adding to the results of the system was an improvement of fuel consumption and carbon emissions of 6.5% due to the reduction in congestion.

6.2.3. Best Route Computation

In order to reduce traffic jams, the best solution is to find the best and shortest way to reach the destination. Another VANET application is used to prove that ad-hoc communications can be a solution to the traffic problem.

Some aspects should be considered during the simulation to get a dynamic routing application. First a broad area which contains a large number of vehicles should be selected. This application would affect the movement of the vehicles. As it informs the drivers about the roads with less traffic, which will make them switch to that road decreasing the congestion on the crowded roads. This is the reason that the simulator should combine the vehicle mobility module and the application module in order to represent the dynamic route changes.

(Cristea, Gradinescu, Gorgorin, Diaconescu & Iftode 2009)

For studying the dynamic route computation with VNSim, there were two different methods. One is using only the ad-hoc network for all information exchanges. The other depends on the fixed nodes present in intersections to assist the communication.

(Cristea, Gradinescu, Gorgorin, Diaconescu & Iftode 2009)

In the first method, the route is calculated for each vehicle before the start of the journey. The calculations are based on the distance, the type of roads and the tendency of drivers to take the main roads. After the start of the journey, re-calculations continue as new data is sent by the ad-hoc network about traffic conditions.

However, rerouting for all the vehicles to the same route will not solve the problem. This was clarified by the simulation experiments, when all the vehicles use the application, it only shifts the congestion to another road. The travel time improvements only happened when some of the vehicles use the application. In this case, the best suggestion is the use of fixed-nodes in intersections that can communicate with the vehicles and interconnected by a separate highspeed network. However, this solution still needs a large-scale infrastructure, which exists only in some of the large cities. The fixed-nodes collect data about the traffic and communicate with the other fixed-nodes to compute the best route plan and send this information to the vehicles.

6.2.4. Highway Lane Reservation

One creative idea for VANET applications is to implement a time guarantee system, similar to trains and planes, to the highway system. This is done by an “entry slot” reservation for the vehicle in a specific lane of a highway in return for a premium price. The number of reservations per lane is limited to their carrying capacity. This could guarantee the trip duration between any two points on the highway as it will prevent traffic jam in this lane. It will also decrease accidents.

(Cristea, Gradinescu, Gorgorin, Diaconescu & Iftode 2009)

However, this system needs some subsystems to be implemented. It must have a reservation system where drivers can make the reservations of the time-slot and the specific lane. Furthermore, there must be a system to ensure that no driver without reservation is on any of the lanes. For example, by putting RFID tags on the valid vehicles and placing RFID readers on the road. A model of the system is shown in Figure 67.

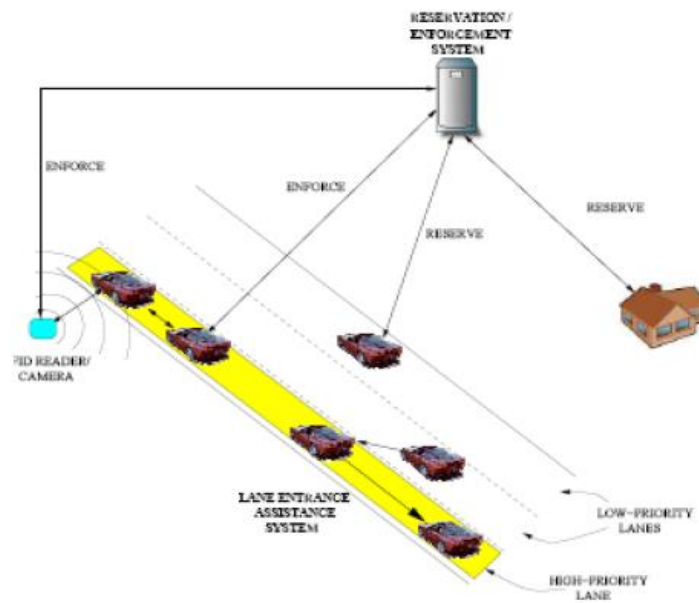


Figure 67. Lane reservation model

(Cristea, Gradinescu, Gorgorin, Diaconescu & Iftode 2009)

Entering and leaving the lane should also be guided by a VANET. Since the lane will be working in almost maximum capacity most of the time, the entering and leaving vehicles should make the least disturbance to the lane. Using a VANET protocol, the entering vehicle should ask first for permission.

(Cristea, Gradinescu, Gorgorin, Diaconescu & Iftode 2009)

Such a large-scale traffic application will need a powerful simulation tool to evaluate it. It will also need the application code at each node to be simulated. The ability of VNSim to handle this lane reservation system is being examined.

(Cristea, Gradinescu, Gorgorin, Diaconescu & Iftode 2009)

6.3. Simulation using JNU – Traffic scenario

In order to judge VANET, and decide how efficient it really is, simulation in an actual scenario is vital, which must take into account all possible limiting factors. In the conducted study, the investigation examines a particular area in a real situation,

Jawaharlal Nehru University (JNU), New Delhi, India. To proceed with the VANET simulation there, the next steps were followed:

- The JNU Map was created
- Vehicular Traffic density was shown on the JNU Map
- Special consideration was given simulating traffic lights at junctions

The basic target of this simulation is to investigate specifics of carrying out these three steps.

6.3.1. JNU Map Generation

Applications such as Google Earth, Adobe Dreamweaver CS4, MOVE Simulator (v 2.9), and ArcGIS 9 (ArcMap version 9.1) were utilized in order to generate a realistic version for JNU. Figure 1 shows from Google Earth JNU satellite images, and Figure 2 demonstrates how the it looks like in ArcGIS 9; a geographic information system (GIS), which helps compile, analyses, and create maps through providing geographic information. (Nidhi & Lobiyal 2012)

Note: While Google Earth gives the coordinates for a specific position (latitude and longitude), ArcGIS projects them to the coordinate plane needed with the required origin in a 2D space.

In this map, some 2D coordinates were not located in the first quadrant, and hence to solve this issue, the origin itself was moved to a more suitable position. Coordinates x and y were transformed to another origin h and k , where the coordinates are related by equation 21.

$$X = x + h; \quad Y = y + k \quad (21)$$

In the equations, X and Y are the coordinates of the location in the new plane. The inputs to the MOVE Simulator's Map Node Editor are some specific junction coordinates with traffic lights. (Nidhi and Lobiyal 2012)

While Map Node editor is used to make nodes and traffic lights, MOVE simulator is used to depict aspects like the velocity of the vehicles, and the number of streets, and their priority. Refer to Figure 4 for a sample. In this case, there are two lanes, which have a priority of 75%, and the velocity is supposed to be 40m/s. After that, an XML code (.con.xml) is written with Dreamweaver CS4, to connect the edges and nodes. Lastly, NETCONVERT is used to set up the connection files, nodes and edges into .net.xml to create the Map. Figures 68, 69, 70 and 71 show how these applications create the JNU Map.

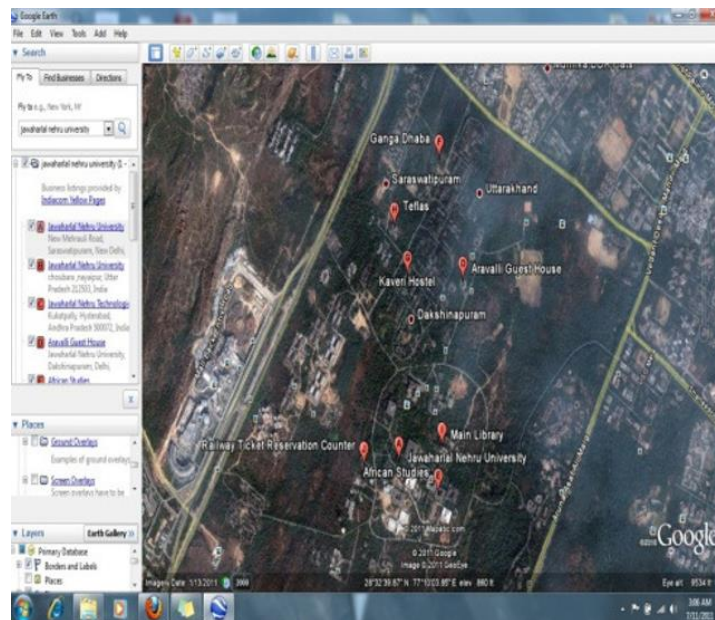


Figure 68. JNU Satellite Image. (Nidhi & Lobiyal 2012)

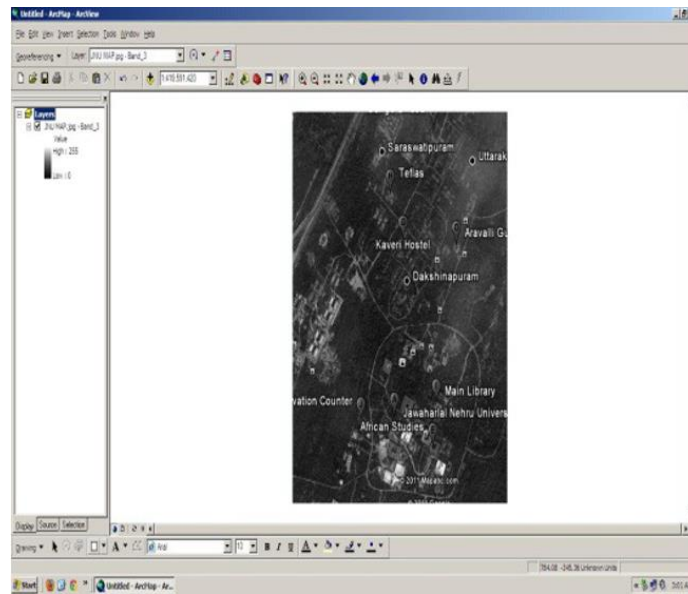


Figure 69. ArcGIS JNU Imported Image. (Nidhi & Lobiyal 2012)

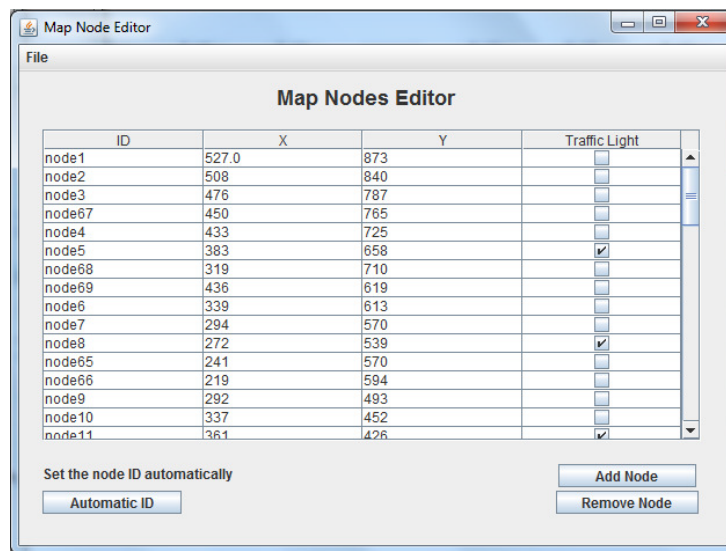


Figure 70. MOVE Map Node Editor (Nidhi & Lobiyal 2012)

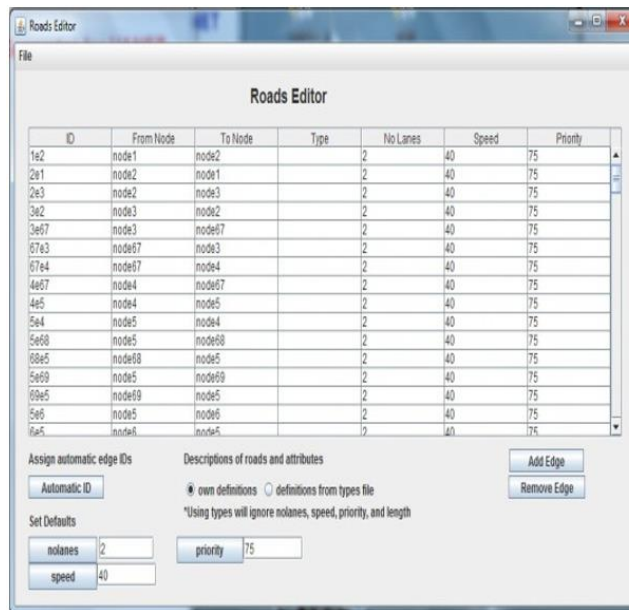


Figure 71. MOVE Road Editor (Nidhi & Lobiyal 2012)

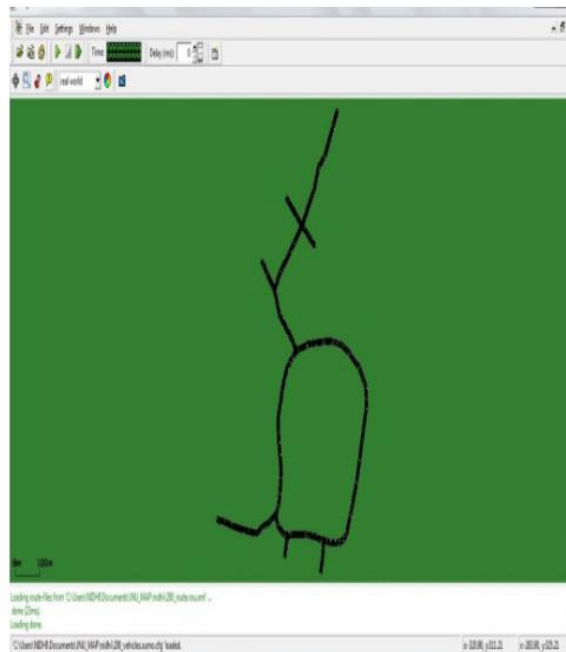
6.3.2. Traffic Flow

In order to represent the movement of vehicles, after acknowledging traffic lights on the Map, two simulators are used: SUMO 0.12.3 and MOVE simulators. First of all, features like the acceleration, deceleration, type of car and maximum velocity are included in the XML Route File (rou.xml) as shown in Table 8. Note that the specified JNU 'province' is broken down into 36 paths, which are used by the cars. In addition, the exact time a specific car departs a specific route is indicated, since it helps determine the traffic flow. Moreover, a driver specifies the beginning and arrival point, as well as all the turning points, and directions at junctions intended for the trip. Not to mention that different case scenarios with traffic light at all junctions are scrutinized, in order to study the clustering effect at crossings, plus to adjust how vehicles move in various directions. (Nidhi & Lobiyal 2012)

Table 8. Vehicle categories and features (Nidhi & Lobiyal 2012)

Vehicle Type	Max. Acc. (m/s ²)	Max. Dec. (m/s ²)	Length (m)	Max. Speed (m/s)
Car A	3.0	6.0	5.0	30
Car B	2.0	6.0	7.5	30
Car C	1.0	5.0	5.0	20
Car D	1.0	5.0	7.5	10

To represent variable traffic flow of 10,20,30,40,50,60,70 cars, different route files with traffic lights at junctions were used. Regarding speed, the vehicle model has been carefully specified, where cars pick up pace and slow down at a constant rate. In addition, Map file (.net.xml) and dissimilar route files (rou.xml), with different traffic volume were set up to make trace files (sumo.tr), to be simulated by SUMO simulator. As illustrated in Figure 71, the function of those trace files is to represent the JNU Map. Refer to Figures 72 and 73 to depict the traffic density and vehicles clustering effect because of traffic lights at junctions. It is possible to envision a real-life situation of the JNU area, with cars in motion, after defining SUMO's criteria, as Figures 72, 73 and 74 show. (Nidhi & Lobiyal 2012)

**Figure 72.** JNU Map SUMO visualization (Nidhi & Lobiyal 2012)

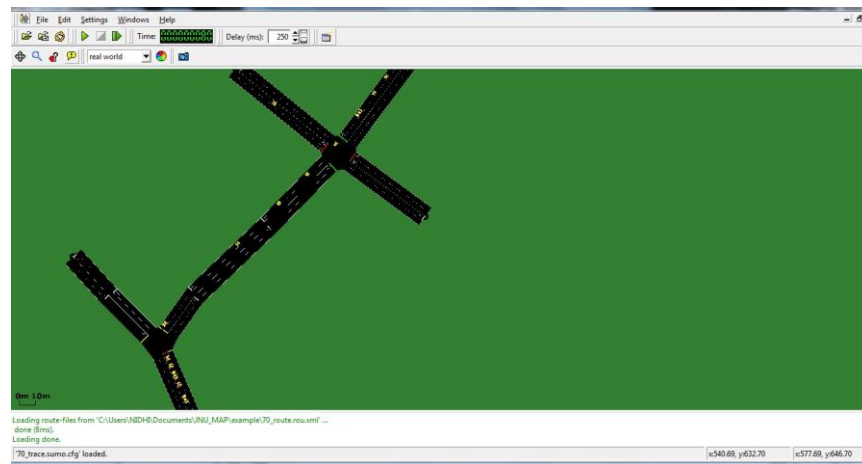


Figure 73. Clustering vehicles and vehicular flow (a) (Nidhi & Lobiyal 2012)

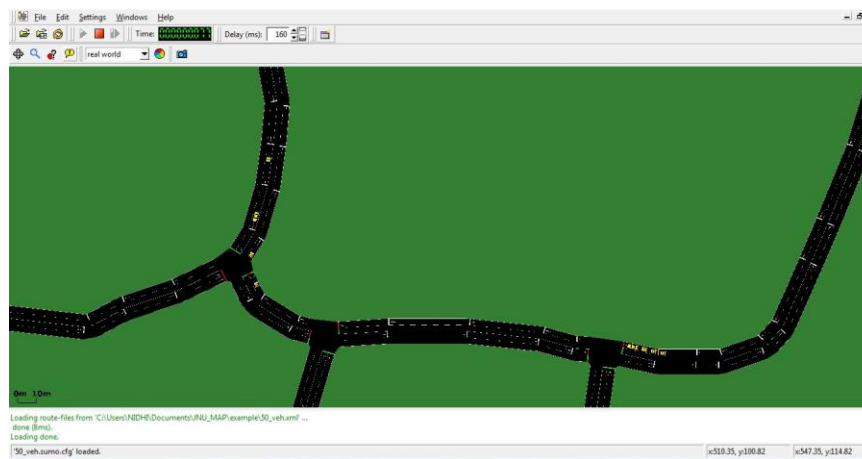


Figure 74. Clustering vehicles and vehicular flow (b) (Nidhi & Lobiyal 2012)

6.3.3. Traffic Light Simulation

Traffic lights are set up at the junctions demonstrated in Figure 72 and 73, which have the purpose of simulating the clustering effect of the vehicles. The Traffic Model Generator of MOVE and Network Simulator (NS-2.34) are used to mimic the vehicular flow.

(Nidhi & Lobiyal 2012)

MOVE's Traffic Model Generator allows dynamic mobility, as it outputs the traffic simulation file, which is required for the simulation. Traffic simulation files need some specifics which have already been taken care of; the combination of traffic lights with

traffic flow, and the JNU Map. These files which are generated for different cases are used in NS-2, which allowed investigative study for simulation. (Nidhi & Lobiyal 2012)

To maintain a form of connection among the cars, multiple specifics had to be taken into consideration. One of which is the traffic flow, which was set up using the IEEE 802.11 standard, with a range of transmission of 250 meters. The rest of the specifications are mentioned in Table 9.

Table 9. Network criteria (Nidhi & Lobiyal 2012)

Parameters	Values
Channel Type	Wireless Channel
Propagation Model	Two Ray Ground Model
Network Interface Type	Wireless Phy
MAC Type	802.11
Interface queue	DropTail/Pri Queue
Link Layer Type	LL
Anetnna	Omni Antenna
Ifqlen	50
Varying No. of Nodes	10,20,30,40,50,60,70
Routing Protocol	AODV
Topology (X,Y) Co-ordinates	(659, 911)
Transmit Power, Pt	0.2818
Channel Frequency	2412e+6
RXThresh	3.65262e-10
CSThresh	(Expr 0.9 * RXThresh)

Covering a region with an area of 600349 m², this simulation uses some criteria for the flow of traffic, as shown in Table 10 in the next page.

Table 10. Traffic flow parameters (Nidhi & Lobiyal 2012)

Parameters	Values
Agent	UDP
Packet_size	1000
Application_Traffic	CBR
CBR Rate	64kbps
CBR_max_pkts	2280000
CBR interval	0.05micro sec
Different RNG seed	2,4,6,8,10

With the vehicular flow and the network ready, the simulation was done, using 25% of the vehicles sending CBR traffic, at first using 10 vehicles. The first half of those was in direct connection, while the others acted as routers. Note that the specifics mentioned in Table 10 were all non-changing, with the exception of the number of vehicles. This was always considered to be 5% of the number of vehicles 20,30,40,50, 60 and 70 respectively. (Nidhi & Lobiyal 2012)

6.3.4. Simulation Results

In the next part, the effect of actual vehicular mobility on how ad-hoc routing protocols function has been investigated and studied.

The relation between the routes a driver picks, and traffic lights at junctions is simulated to it a real-world situation. Here, every possible path from the source to the target is considered, and depending on the driver's decision, routes are selected. Traffic lights are vital at junctions, since they adjust the vehicular movement, when they are in opposite directions, and cause the clustering effect, as cars are blocked from moving by a red traffic light. Hence, the density of vehicles at junctions is high, which in turn makes them more connected, but the downside is that the ratio of packets reaching their destination falls. (Nidhi & Lobiyal 2012)

This simulation is more focused on the chance of selecting a path at a junction. That 'chance' probability directly decides the volume of cars on that path. The data is sent to improve the connection between the cars. To investigate details of the connection, factors like packet loss, router drop and delivery ratio are considered. This is elaborated up next. (Nidhi & Lobiyal 2012)

6.3.4.1. Average Delivery Ratio

Delivery Ratio is the proportion of packets delivered, over the ones sent. It is computed by dividing the average number of packets delivered by the number of packets sent.

In order to simulate it according to the traffic volume, different cases were considered, with values increasing by tens. For each one, the ratio was evaluated 5 times, by changing the seed by twos. The final value was an average of 5, and the equation used for the calculation goes as in equation 22.

$$\begin{aligned}
 APR &= \left(\sum_{k=1}^5 PR \right) / 5 \\
 APS &= \left(\sum_{k=1}^5 PS \right) / 5 \\
 ADR \% &= (APR/APS) * 100
 \end{aligned}
 \tag{22}$$

Where PR is the Packet Received, PS is the Packet Sent, APR is the Average Packet Received and finally APS is the Average Packet Sent. Table 11 shows the results in the next page.

Table 11. The relation between number of vehicles and average packet delivery Ratio (ADR) %

No. of Vehicular Traffic	Packet Delivery Ratio %
10	87.68 %
20	82.05 %
30	76.76 %
40	57.13 %
50	52.42 %
60	46.02 %
70	16.61 %

Figure 75 states the Traffic volume against delivery ratio.

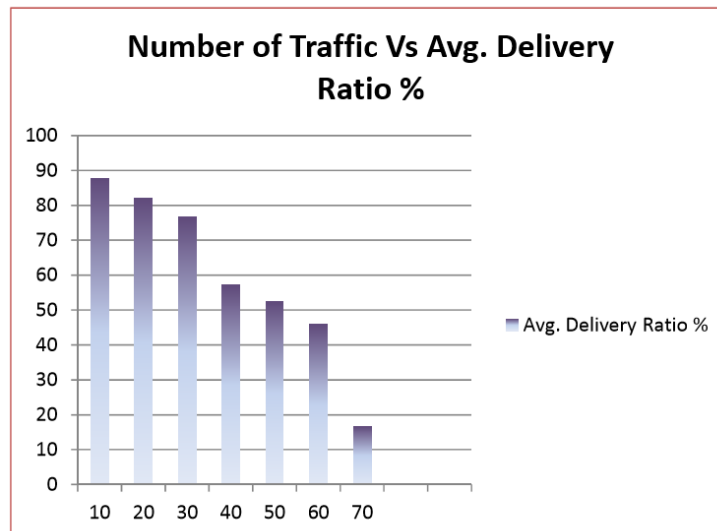


Figure 75. Traffic volume VS packet delivery ratio (Nidhi & Lobiyal 2012)

As shown in Figure 75, as the number of vehicle, or nodes increases, packet delivery ratio decreases, which makes absolute sense, because this increases the collision. Nonetheless, the higher the node density is the more they stay connected. Therefore, this presents an irony. (Nidhi & Lobiyal 2012)

6.3.4.2. Router Drop

For each traffic scenario, the ratio by which a router drops a packet is computed by dividing the average number of packets dropped by the router by the number of packets sent, as in equation 23.

$$RD \% = \left(\sum_{k=1}^5 \frac{RD}{PS} \right) * 100$$

(23)

Where RD% is the Router Drop %

6.3.4.3. Packet Loss

Similar to the previous ratio, the ratio of packet loss is computed by dividing the average number of packets lost by the number of packets sent, as in equation 24.

$$PL = (PS - PR)$$

$$PL \% = \left(\sum_{k=1}^5 \frac{PL}{PS} \right) * 100$$

(24)

Where PL is the Packet Loss.

The conclusion of the results of the Packet Loss and Router Drop ratios for variable vehicle flow is illustrated in Table 12 and Figure 76.

Table 12. Relation of traffic volume with router drop and packet loss.
(Nidhi & Lobiyal 2012)

No. of Vehicular Traffic	Router Drop %	Packet Loss %
10	12.31 %	12.32 %
20	06.71 %	17.95 %
30	23.09 %	23.23 %
40	36.97 %	42.86 %
50	40.62 %	47.58 %
60	41.28 %	53.98 %
70	55.45 %	83.39 %

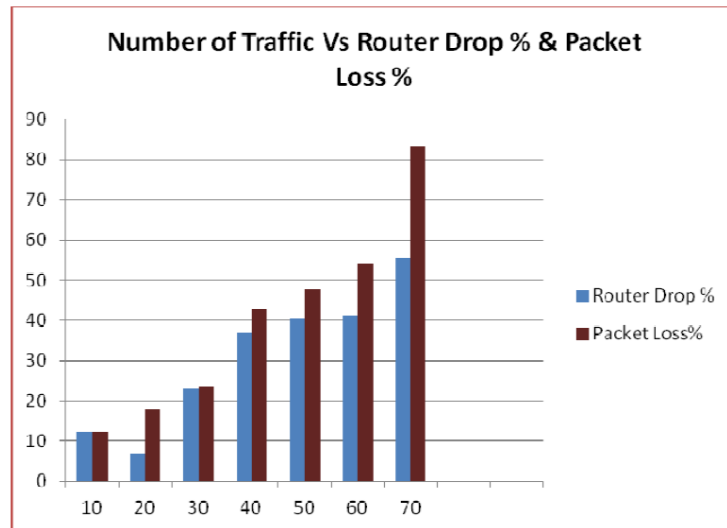


Figure 76. Graphical relation between traffic volume and router drop plus packet loss (Nidhi & Lobiyal 2012)

The results of the simulation show that traffic lights at junctions increase the rate of packet collision, and reduce the transmission rate, as illustrated in Figure 76. The reason for this is the high node density at junctions, until traffic lights become green. This is also the cause for the high packet collision rate, since they are sent at the same time. In addition, delivery ratio seems to have kept on falling, because it totally relies on the gathered cars at junctions. If this is analyzed, it can be concluded that although the cars are more connected, the delivery rate falls.

The relation between the number of cars and router drop plus packet loss is shown in Figure 75. Packet drop could be because of a router, or a vehicle, but packet loss percentage takes the ones which vehicles drop. According to Figure 75, router drops were a little less than packet loss percentage. The reason for this is that it is more likely for packets to fall in the end. It is also obvious from the graph that a drop by the router is not uniform; it doesn't have a pattern. Drop rate is higher because of traffic lights at junctions, which cause the clustering effect. (Nidhi and Lobiyal 2012)

7. CONCLUSION

With simulations and scientific papers as basis, it is possible to conclude that the perfect VANET simulator, which considers every limiting factor, does not exist just yet. Every single one was basically meant for simulating MANETs, but were then adjusted so as to include the capabilities of VANET. Using middleware is also one other way to merge a robust mobility simulator along with a regular network simulator, like the merging of NS2 and SUMO, joined by MOVE, which was used in this paper. Nevertheless, the problem with this approach is that it does not take into account how messages, including warnings affect a driver, which is a critical factor, since the driver's reactions are variable; this makes the simulation procedure quite complex. Henceforth, coming up with better versions of VANET simulator is extremely advised. A more realistic simulator would have features such as simulating more routing protocols, the capability of loading a map, along with its traffic regulations, and giving random, actual car movement, simulated by real data, collected through surveys.

In chapter 6, some of the discussed simulations were based on actual maps from cities, and node movements which were totally random, thereby making it more realistic. The rest were incorporated and designed with the purpose of analyzing certain criteria.

In a round robin manner, the traffic light case scenario was a crucial technique, as it helped in adjusting vehicular flow. When it comes to sending data however, it turned into an obstruction, because the packets dropped, since a lot of packets were getting transmitted together.

Consequently, research results show that usage of RSUs helps in reducing packet drops, because they still manage to forward packets, even if they are dropped at junctions. Hence, using RSU at junctions in simulations seems to be where research is heading.

DSR gives great throughput, but keeps disconnecting and has delays. Although DSDV has less delays, it does not have a very stable connection, and has low throughput. Based

on simulations, AODV is considered to be the most powerful routing protocol; it gives the best rate of packet delivery, throughput, and least loss in connection in most simulations.

Another conclusion from the simulation was regarding the UDP and TCP transport layer protocols. Even though UDP possess higher throughput, delays are quite high. It is recommending that for upcoming research, more focus should be given to analysis and contrasting between TCP and UDP in VANETs.

REFERENCES

- Miller, Jeffrey, and Timothy S Menard. 2010. "Proceedings of the Second IEEE Vehicular Networking Conference." FreeSim_Mobile: A novel approach to real-time traffic gathering using the apple iPhone. New Jersey. Accessed December.
- Gajbhiye A., Vimmi, and Ratnaprabha W. Jasutkar. 2013. "Study of Efficient Routing Protocols for VANET." International Journal of Scientific & Engineering Research 4 (3).
- Ali, Hayder Mohammed. 2013. "Simulation and Analysis of Vehicular Ad Hoc Networks in Urban and Rural Areas." Master thesis, Technology Department, University of Vaasa, Vaasa.
- Salim Allal, and Saadi Boudjit. 2013. "Geocast Routing Proposal for VANETs : Survey and Geometry-Driven Scheme Proposal." Journal of Internet Services and Information Security (JISIS) 3 (1/2): 20 - 36. <<http://isyu.info/jisis/vol3/no12/jisis-2013-vol3-no12-02.pdf>>
- Marwa Altayeb, and Imad Mahgoub. 2013. "A Survey of Vehicular Ad hoc Networks Routing Protocols." International Journal of Innovation and Applied Studies (Innovative Space of Scientific Research Journals) 3 (3): 829-846. <<http://www.issr-journals.org/ijias/>>
- Boban Mate, and Tiago T. V. Vinhoza. 2011. Modeling and Simulation of Vehicular Networks:. Research paper, USA and Portugal: IEEE JSAC. <http://mateboban.net/mboban_modeling_simulation_chapter.pdf>
- Valentin Cristea, Victor Gradinescu, Cristian Gorgorin, Raluca Diaconescu, and Liviu Iftode. 2009. "Simulation of VANET Applications." Chap. XIV. IGI Global.
- Khairnar D. Vaishali , and Dr. S.N. Pradhan . 2010. "Mobility Models for Vehicular Ad-hoc Network Simulation." International Journal of Computer Applications (0975-8887) 11 (4).
- Jerome Harri, Fethi Filali, and Christian Bonnet. 2006. Mobility Models for Vehicular Ad Hoc Networks: A Survey. Department oof Mbile Communications, Institut Eur'ecom, Sophia-Antipolis: Institut Eurecom.
- Martinez J., Francisco , Juan-Carlos Cano, Carlos Tavares Calafate, and Pietro Manzoni. 2008. "Citymob: a mobility model pattern generator for VANETs." IEEE Communications Workshops. IEEE Xplore.
- Koivo, Heikki, and Mohammad Elmusrati. 2009. *Systems Engineering in Wireless Communications*. John Wiley and Sons, Ltd. doi:ISBN 9780470021781.

- Larson, Kenneth. 2016. *Be Nice*. November. <www.endroadrage.net>
- Lee, Kevin C., Jiajie Zhu, Jih-Chung Fan, and Mario Gerla. 2009. "Histogram-based density discovery in establishing road connectivity." Vehicular Networking Conference (VNC). IEEE. doi:10.1109/VNC.2009.5416393.
- Liu, K. J. Ray, Ahmed K. Sadek, Weifeng Su, and Andres Kwasinski. 2009. *Cooperative Communications and Networking*. New York: Cambridge University Press. doi:ISBN 978-0-521-89513-2.
- Mahajan, Atulya, Niranjana Potnis, Kartik Gopalan, and A. Wang. December 2006. Urban Mobility Models for VANETs. Computer Science, Florida State University, In Proc. of the IEEE Workshop on Next Generation Wireless Networks.
- Padmini, Misra. 2000. "Routing Protocols for Ad Hoc Mobile Wireless Networks." <http://www.cis.ohio-state.edu/~jain/cis788-99/adhoc_routing/index.html>
- Mittal, Narendra Mohan, and Savita Choudhary. 2014. "Comparative Study of Simulators for Vehicular Ad-hoc Networks (VANETs)." International Journal of Emerging Technology and Advanced Engineering 4 (4). <http://www.ijetae.com/files/Volume4Issue4/IJETAE_0414_93.pdf>
- National Instruments, Administrator. 2014. "OFDM and Multi-Channel Communication Systems." National Instruments. <<http://www.ni.com/white-paper/3740/en/>>
- Nidhi, and D.K. Lobiyal. 2012. "Performance evaluation of realistic VANET using traffic light scenario." International Journal of Wireless & Mobile Networks (IJWMN) 4 (1). doi:10.5121/ijwmn.2012.4118.
- Vaity P., Nayana, and Dynaneshwar V. Thombre. 2012. "A Survey on Vehicular Mobility Modeling: Flow Modeling." International Journal of Communication Network Security 1 (4).
- Pradhand, S. N., and Vaishali D. Khairnar. 2010. "Mobility Models for Vehicular Ad-hoc Network Simulation." International Journal of Computer Applications (0975 – 8887) 11 (4). <<https://arxiv.org/ftp/arxiv/papers/1304/1304.5189.pdf>>
- Menard S, Timothy, and Jeffrey Miller. December 2010. "FreeSim_Mobile: A novel approach to real-time traffic gathering using the apple iPhone." Proceedings of the Second IEEE Vehicular Networking Conference VVNC 2010. New Jersey.

- Spaho, Evjola, Leonard Barolli, Gjergji Mino, Fatos Xhafa, and Vladi Kolici. 2011. "VANET Simulators: A Survey on Mobility and Routing Protocols." *Broadband and Wireless Computing*. IEEE. doi:10.1109/BWCCA.2011.11.
- Think Link, Administrator 2016. "The Doppler Effect." Think Link. <<https://www.thinglink.com/scene/733381541912117250>>
- Wang, S.Y., C.H. Huang, C.L. Chou, C.C. Hwang, T.H. Yan, Z.M. Yang, C.C. Chiou, and C.C. Lin. n.d (2012). "*The NCTUns 1.0 Network Simulator*."
- Wang, Shie-Yuan, and Chih-Che Lin. 2010. "NCTUns 6.0: A Simulator for Advanced Wireless Vehicular Network Research." *Vehicular Technology Conference (VTC 2010-Spring)*. <<http://ieeexplore.ieee.org/document/5494212/>>
- Wikipedia (2017). "Two-ray ground reflection model". <https://en.wikipedia.org/wiki/Two-ray_ground-reflection_model>