Performance Evaluation of VANET Using Realistic Vehicular Mobility

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Abstract. Vehicular Ad-hoc Networks (VANETs) is attracting considerable attention from the research community and the automotive industry to improve the services of Intelligent Transportation System (ITS). As today's transportation system faces serious challenges in terms of road safety, efficiency, and environmental friendliness, the idea of so called "ITS" has emerged. Due to the expensive cost of deployment and complexity of implementing such a system in real world, research in VANET relies on simulation. This paper attempts to evaluate the performance of VANET in a realistic environment. The paper contributes by generating a real world road Map of JNU using existing Google Earth and GIS tools. Traffic data from a limited region of road Map is collected to capture the realistic mobility. In this work, the entire region has been divided into various smaller routes. Vehicular Traffic Flow on these routes has been created using MOVE. The traffic flow generator model of MOVE generates traces of the traffic flow. These traces of different traffic scenario are subsequently used in NS-2 which facilitated the simulation of traffic flow of region under study. The realistic mobility model used here considers the driver's route choice at the run time. Finally, the performance of the VANET is evaluated in terms of average delivery ratio, packet loss, and router drop as statistical measures. The maximum average delivery ratio for varying number of vehicles is observed to be very high as compare to the packet loss. Overall, this experiment has provided insight into the performance of real life vehicular traffic communication.

Keywords: Intelligent Transportation System, Vehicular Ad-hoc Networks, Geographical Information System, Mobility Model Generator for Vehicular Networks, Simulation of Urban Mobility, Network Simulator-2.34.

1 Introduction

As per the World Health Organization (WHO) statistics, more than 1.3 million people worldwide are estimated to be killed each year out of road accidents. According to an online article published in Deutsche Welle [1] by Murali Krishnan dated 29.04.2010, "India's record in deaths has touched a new low, as toll rose to at least 14 deaths per hour in 2009 against 13 the previous year". While trucks/lorries and two-wheelers were responsible for over 40% deaths, the rush during afternoon and evening hours

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were the most fatal phases.[1,2]. Also, as per another article of WHO (article in Times of India, Dipak Kumar Dash, TNN, Aug 17, 2009, 04.10am IST) India leads the world in road deaths. In addition to this, some of the common problems to tackle with are the “Miles of Traffic Jam” on highway and the “Search for best Parking Lot” in an unknown city.

For all the above mentioned reasons, the Government and Automotive Industries today pay lot of attention towards traffic management and regulation of a smooth traffic. They are investing many resources to slow down the adverse effect of transportation on environment, thereby increasing traffic efficiency and road safety. The advancements in technology, in the areas of Information and Communications, have opened a new range of possibilities. One of the most promising areas is the study of the communication among vehicles and Road Side Units (RSUs), which lead to the emergence of Vehicular Network or Vehicular Ad-hoc Network (VANET) into picture. [3].

VANET is characterized as a special class of Mobile Ad hoc Networks (MANETs) which consists of number of vehicles with the capability of communicating with each other without a fixed infrastructure. The goal of VANET research is to develop a vehicular communication system to enable ‘quick’ and ‘cost-efficient’ transmission of data for the benefit of passenger’s safety and comfort. Due to the expensive cost of deploying and complexity of implementing such a system in real world, research in VANET relies on simulation. However, the simulation depends on the mobility model that represents the movement pattern of mobile users including its location, velocity and acceleration over time. A mobility model needs to consider the characteristics of the real world scenario either by a real world MAP obtained from TIGER(Topologically Integrated Geographic Encoding and Referencing) database from U.S. Census Bureau or by taking Satellite images of Google Earth into consideration to simulate a realistic network.

VANET is the ultimate solution to the cooperative driving between communicating cars on road. It has particular features like “decentralized and self-organized network”, composed of high speed moving vehicles. Here the vehicular speed and distribution of data are constrained by the underlying dynamic network topology. [4]

Related work is briefly described in Section 2. In Section 3, the methodology of proposed work is explained along with various tools which are used to carry out the work. Section 4 further discusses the simulation of established network, results & the analysis obtained through simulations conducted. Finally, Section 5 concludes the work presented in this paper..

2 Related Work

Research is being carried out in the field of VANET such as Analyzing data dissemination in VANETs, Identifying and studying routing protocols in VANET in terms of highest delivery ratio and lowest end-to-end delay etc. The issues of Security and Privacy also demands great attention. The study of Mobility Models and their realistic vehicular model deployment is a challenging task.[8] Random way Point(RWP)[9] is an earlier mobility model widely used in MANET in which nodes move freely in a predefined area but without considering any obstacle in that area. However, in a VANET environment vehicles are typically restricted by streets, traffic light and obstacles. GrooveSim [10] was the first tool for forecasting vehicular traffic flow and evaluating vehicular performance. It gives a traffic simulator environment which is easy to use for generating real traffic scenario for evaluation. But it fails to include network simulator as it was unable to create traces for network. David R. Choffnes et al. [11] proposed a mobility model named STRAW (Street RAndom Waypoint). This model has taken real map data of US cities and considered the node (vehicle) movement on streets based on this map. This model also has the functionality to simplify the traffic congestion by controlling the vehicular mobility. But still it lacks overtaking criteria that cause convey effect in street as it considered random method which is not realistic. Kun-chan Lan et al.[6] describes a realistic tool MOVE for generating realistic vehicular mobility model. It is built on top of an open source micro-traffic simulator SUMO and its output is a realistic mobility model that can immediately be used by popular network simulators such as ns-2 and qualnet.

3 Proposed Work and Methodology

To evaluate the performance of VANET, there is a need to deploy a real world scenario with all the vehicular constraints. In this paper the experiment was performed by taking a limited bounded region of a real world scenario i.e. “JAWAHARLAL NEHRU UNIVERSITY (JNU), NEW DELHI, INDIA” into consideration. The steps to implement a VANET simulation in this region are as follows:

- Generation of JNU Map
- Creation of Vehicular Traffic flow on this Map
- Simulation of established Network

The detailed procedure in implementing such above mentioned steps are explained in the rest of this paper.

3.1 JNU Map Generation

For creating a real world Map of JNU, Some of the existing tools have been used such as Google Earth, ArcGIS 9 (ArcMap version 9.1), MOVE Simulator (v 2.81)[5,6] and Adobe Dreamweaver CS4.

Satellite image of JNU has been taken from Google Earth shown in Figure 1. This image was further imported into ArcGIS 9 as depicted in Figure 2.

ArcGIS is basically a suite consisting of a group of Geographic Information System (GIS) software products.[12]

NOTE: Google Earth gives latitude and longitude of a particular location whereas ArcGIS maps those latitudes and longitudes to the required coordinate plane with the desired origin in a Two Dimensional Space.

Some of the 2-D Co-ordinates of this Map were not lying in the first quadrant of the 2-D Co-ordinate plane. In order to obtain all the co-ordinates in the first quadrant, the origin was shifted to an appropriate location. Shifting of the old Co-ordinates (x, y) to a new origin (h, k) is given by :

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

Where (X,Y) represents the translated Co-ordinates in the plane with new origin which is further used as the inputs to the Map Node Editor of MOVE Simulator as shown in Figure 3. After creating nodes using Map Node editor, numbers of parameters are defined such as edges between nodes, number of lanes, speed and priority of roads on which vehicle move, with the help of Road Editor of MOVE simulator as shown in Figure 4. Here, a multi-lane scenario of two lanes with 75% road priority has been set. The threshold speed has been considered for each lane in a region of JNU Map as 40m/s. Next a connection was established between nodes via edges by writing an XML code (**.con.xml**)[16] using Dreamweaver CS4. Finally the nodes, edges and connection files are configured into **.net.xml** by using NETCONVERT to create the MAP. Figure 5 depicts the JNU Map created by the above defined tools.

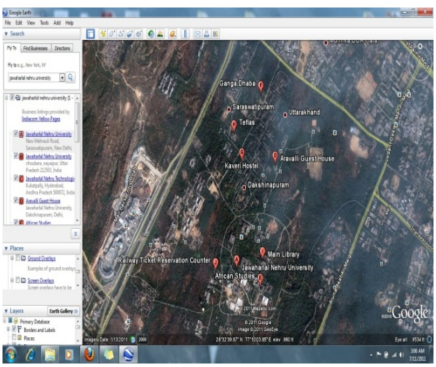

Fig. 1. Satellite Image of JNU

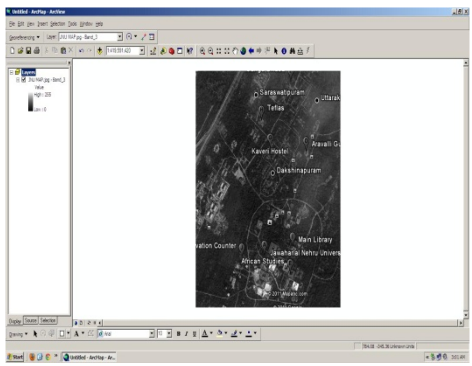

Fig. 2. Imported Image of JNU in ArcGIS

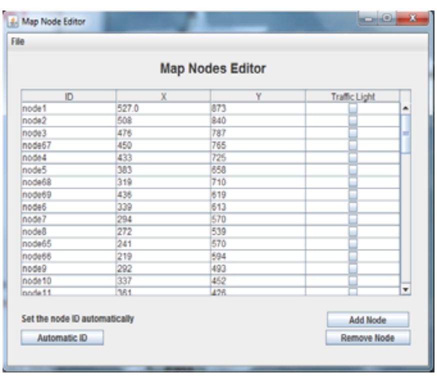

Fig. 3. Map Node Editor of MOVE

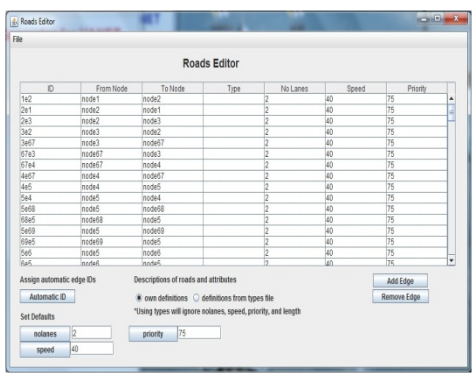

Fig. 4. Road Editor of MOVE

3.2 Traffic Flow

For generating a vehicular traffic flow on the above created Map, SUMO 0.12.3[17] simulator has been used in addition to MOVE simulator. Initially, the Route File in XML (**rou.xml**) was created, in which acceleration, deceleration, maximum speed, length and type of a vehicle were specified (see Table 1). In addition to this, the bounded JNU region has been divided into 36 smaller routes which the vehicles can take. Further, the departure time of a particular vehicle on a particular route which creates the vehicular traffic flow among the nodes has been specified. The vehicle's destination from the source and their turning directions at the intersections, such as right turn, left turn and straight as per their destination were also set as per the driver's route choice at intersection.

Table 1. Types of Vehicle and their Characteristics

Vehicle Type	Max.Acc. (m/s^2)	Max.Dec. (m/s^2)	Length (m)	Max. Speed (m/s)	Sigma
Car A	3.0	6.0	5.0	30	0.5
Car B	2.0	6.0	7.5	30	0.5
Car C	1.0	5.0	5.0	20	0.5
Car D	1.0	5.0	7.5	10	0.5

Different Route files have been created for varying traffic flow consisting of 20,40,60,80,100,120,140,160,180 vehicles. This varying flow has been set by keeping in mind, a constant deceleration and acceleration model in which vehicles do not move and stop abruptly. Map file (.net.xml) and the different Route files (rou.xml) of varying traffic flow were configured to create the corresponding trace files (**sumo.tr**) which can be visualized using SUMO simulator. These trace files basically shows the JNU Map as shown in Figure 5 and the flow of traffic as depicted in Figure 6. After setting the parameters of SUMO, the real world scenario of JNU region can be visualized with vehicles moving on it as depicted in Figure 6 (a), (b) & (c).

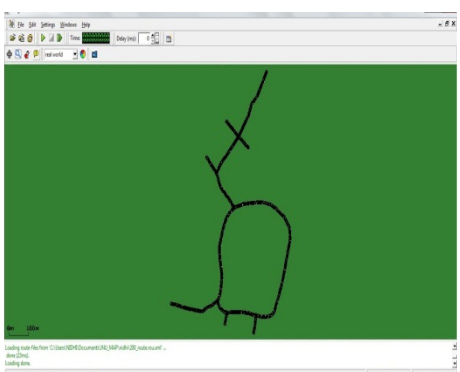

Fig. 5. SUMO visualization of JNU Map

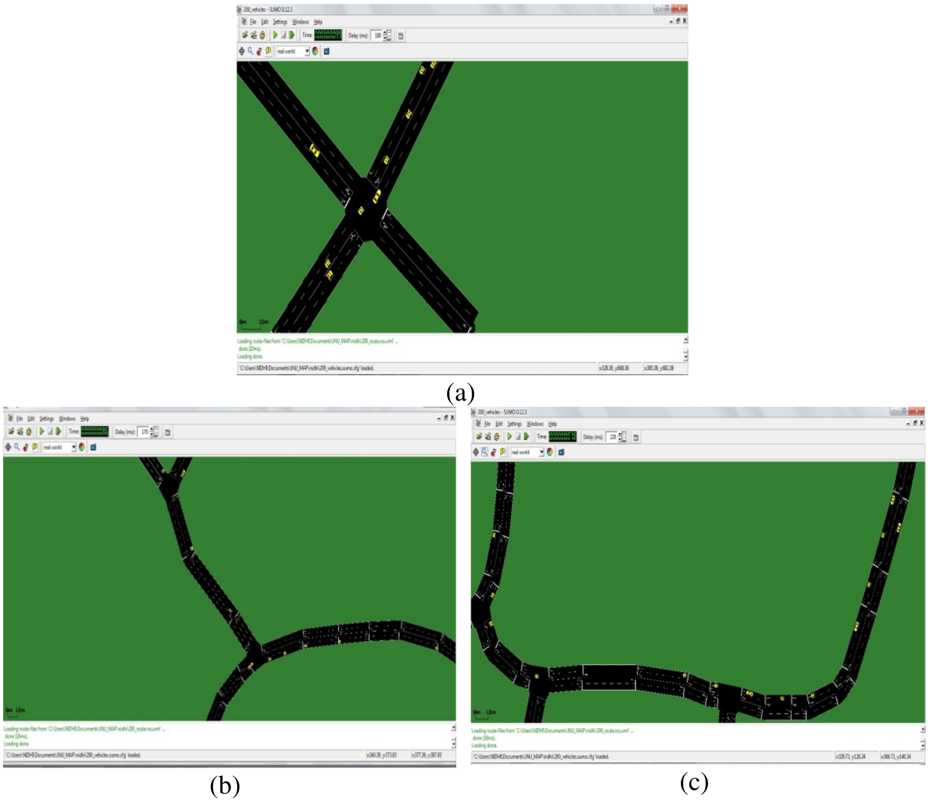

Fig. 6. (a) Vehicular Traffic at intersection, (b) and (c) Traffic Flow

4 Simulation

In order to simulate the established network, communication was established among the vehicular traffic flow, using Traffic Model Generator of MOVE and Network Simulator (NS2.34) [18].

The Traffic Model generator of MOVE simulator was used to create the **trace file** of the vehicular flow, by interfacing traffic flow created in section 3.2 with the JNU MAP created in section 3.1. The output was a trace file that contains the information of realistic vehicular flow of the map, which can be further used in NS2.

Various parameters were considered for establishing the communication among vehicles. For example, a vehicular traffic flow was deployed using 802.11 Ad-Hoc radio mode with transmission range of 250 meters. The other parameters used are discussed in Table 2.

Table 2. Network parameters

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	20,40,60,80,100,120,140,160,180
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)

As mentioned above, the simulation was conducted using NS2. The simulation covers 600349 m^2 area and the following parameters has been setup for traffic flow between nodes.

Table 3. Parameters of Traffic Flow between nodes

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

After setting up the network and traffic flow as discussed above, the simulation was conducted by taking 3 CBR's at three different nodes for a traffic scenario of 20 vehicles initially. Further, all the traffic parameters as given in table 3 were kept constant for varying traffic of 40, 60, 80,100,120, 140,160 and 180 vehicles.

4.1 Simulation Results

The impact of realistic vehicular mobility (using various tools as discussed in Section 3), on the performance of ad-hoc routing protocols has been evaluated in this section.

The driver route choice behavior has been simulated in a real world, where all possible routes from the source to destination are defined and the driver needs to decide about which route has to be taken from among all possible routes at any intersection. Our simulation concentrates on selecting the probability of choosing a route at the intersection. This probability directly determines the number of vehicles on a particular route. The data in terms of packets are transmitted to facilitate communication among vehicles. In order to study the behavior of communication, the parameters like delivery ratio, packet loss and router drop has been considered which are discussed in the subsequent sections.

4.1.1 Average Delivery Ratio

Delivery Ratio implies the ratio of number of packets successfully delivered to the number of packets sent.

For calculating delivery ratio with respect to the number of vehicles, different traffic scenarios were simulated with varying number of vehicles in multiples of 20. For each scenario, delivery ratio was calculated for 5 simulation runs by changing the seed in multiples of 2. The Average delivery ratio for each scenario was an average of 5 simulation runs and it is calculated as follows:

$$\text{APR} = \left(\sum_{k=1}^{5} \text{PR for seed } (2\text{k})\right)/5$$

$$\text{APS} = \left(\sum_{k=1}^{5} \text{PS for seed } (2\text{k})\right)/5$$

$$\text{ADR \%} = (\text{APR}/\text{APS}) * 100$$

Where, PR = Packet Received, PS = Packet Sent, APR = Average Packet Received and APS = Average Packet Sent.

The summary of results obtained is shown in table 4 and the results are further analyzed graphically in figure 7. It can be observed that the choice of route at intersection points can significantly affect the simulation results.

Table 4. Number of Traffic and Avg. Delivery Ratio (ADR) %

Vehicular Traffic	**ADR %**
20	96.6%
40	91.9%
60	91.3%
80	98.5%
100	95.5%
120	93.5%
140	96.7%
160	73.3%
180	95.9%

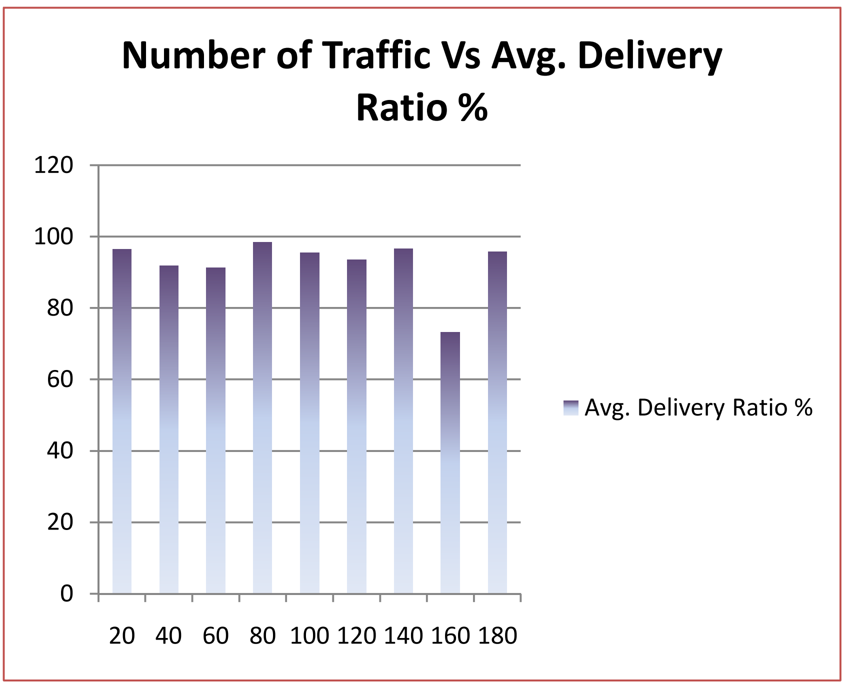

Fig. 7. Number of Traffic Vs Avg. Delivery Ratio%

4.1.2 Router Drop

Router Drop for each traffic scenario is calculated by taking the average of Router Drop to the packets sent with the multiples of seed values as shown below :

$$\text{RD \%} = \left(\sum_{k=1}^{5} \frac{\text{RD}}{\text{PS}} \text{ for seed } 2\text{k}\right) * 100$$

Where, RD % = Router Drop %

4.1.3 Packet Loss

Packet loss is calculated by taking the average of packet loss to the packets sent with the multiples of seed values :

$$\text{PL}= \sum_{k=1}^{5}(\text{PS} - \text{PR})\text{for seed } 2\text{k}$$

$$\text{PL \%} = \left(\sum_{k=1}^{5} \frac{\text{PL}}{\text{PS}} \text{ for seed } 2\text{k}\right) * 100$$

Where, PL = Packet Loss.

The results obtained for Router Drop and Packet Loss are summarized in table 5 for varying vehicular traffic. This is further illustrated in figure 8.

Table 5. (Number of vehicular traffic) Vs (Router Drop and Packet Loss%)

No. of Vehicles	RD %	PL %
20	3.39%	3.39%
40	8.24%	8.12%
60	8.61%	8.61%
80	1.49%	1.40%
100	4.59%	4.54%
120	6.57%	6.50%
140	3.52%	3.33%
160	26.72%	26.68%
180	4.23%	4.01%

Our Simulation results suggest that increasing number of vehicular traffic may deteriorate packet transmission rate as in case of node 160 shown in Figure 7. This happens due to the random collision of packets. Further, it was observed that this scenario was not linearly increasing or decreasing since the collision of packets completely depends on the routes taken into consideration by the driver at run time. Packet delivery ratio was always more than 90% except for 160 nodes where the packet delivery ratio was observed to be as 73.3%. This phenomenon can be explained by deployment and movement of vehicles in a given scenario. It seems that the connectivity between the vehicles get reduced for this scenario.

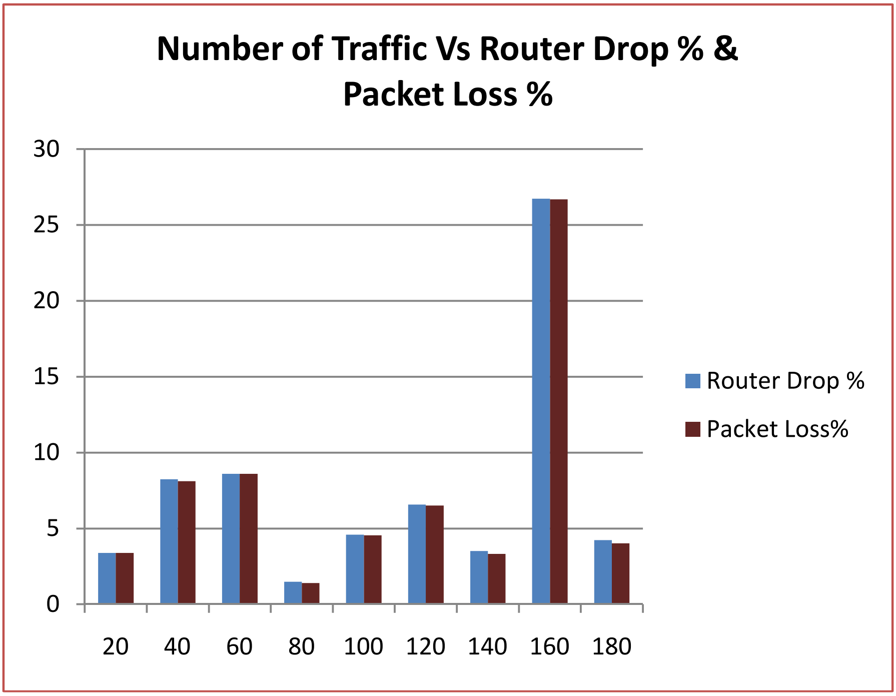

Fig. 8. Vehicular Traffic Vs (Router Drop% & Packet Loss%)

Figure 8 shows the effect of varying number of vehicles on packet loss and router drop together. A packet may be dropped by a vehicle or by a router. The packet loss percentage is considered as packets dropped by vehicles. Further in figure 8, it is quite evident that the percentage of packet loss was slightly more than router drops. This happens because of higher chances of packet being dropped at the end rather than being dropped at intermediate nodes. Here, again from the figure, it is quite evident that both the packet loss and router drops were below 10% except in the case of 160 nodes. As explained for the case of lower deliver ratio in Figure 7, the drop rate was higher due to low connectivity.

5 Conclusion

In this paper, we have obtained an in-sight idea of simulating real world scenario of VANET. As it is not easy to deploy and implement such a complicated system in real world before knowing the impact of all parameters used in VANET, a small real world area i.e. our University, JNU itself, was taken into consideration, for studying the impact of mobility in the VANET. Traffic movement has been deployed across the area under consideration using one of the realistic vehicular mobility models. The behavior of this network was simulated using NS2 to study the impact of driver's choice on packet transmission over V2V communication using AODV routing protocol and IEEE 802.11 standard.

The performance of the network has been evaluated by taking delivery ratio, packet loss and router drop as statistical measures. The average delivery ratio for various scenarios such as varying number of vehicles with constant power transmission range of 250m and frequency of 2.4GHz was observed to be 92.57% whereas packet loss was 7.39%. It is concluded from the results that with the increase in transmission range, there would be a corresponding marginal increase in delivery ratio and decrease in packet loss.

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