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Implementation of GPSR protocol with various mobility models in VANET Scenario

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Implementation of GPSR protocol with various mobility models in VANET Scenario

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Abstract: In Vehicular Ad hoc Networks (VANET), topology varies very frequently because vehicles move in high speed. VANET is deployed on road. In GPSR Protocol, as the data packets are forwarded depending upon on the beacon information sent by neighboring nodes, which contain the location of neighbors. Hence nodes move in mobile nature as they change their positions. Mobile pattern of node is reflected by Mobility Models, as they characterize the movement of users who are mobile on the road, with respect to their direction, velocity and location over a period of time. Mobility models are practiced in implementation of protocols and the pattern by which the mobility models reflect real world practices of vehicles on the roads. Using simple pattern randomly, graph constrained mobility models are common practices while doing research. These models donot describe mobility of vehicles in realistic manner. For instance while accelerating and decelerating in the presence of nearby vehicles, these situations greatly affect the Network performance. Selecting the mobility model which is realistic one is the main focus of this paper. To address the challenges such as high mobility of vehicle nodes on the road and random topology, VANET needs a suitable mobility model to obtain improved Packet Delivery Ratio, Throughput, End to End Delay etc. This paper first implements the GPSR Protocol and then GPSR is analyzed by applying different mobility models such as Random Way Point, Gauss Markov, Manhattan Grid, Reference Point Group and Random direction. Results are analyzed by taking the following parameters: Routing overhead, Throughput, PDR and End to End Delivery. The implementation is carried out using NS—2.35 and Bonmotion is used to create mobility models.
Keywords: GPSR, PDR, NS-2.35, VANET, MANET, ITS, RSU, RWM, RPGM.

1. Introduction

The growing mobile nature of people, the rising number of vehicles on the road and the need for support less communication technology for intelligent transport system (ITS), have made VANET, an important area of research to pursue with Vehicular wireless technologies.

Over the past few decades many amendments have been made to ITS to mitigate congestion due to traffic, to reduce poisonous emissions from vehicles and consumption of fuel, to provide safety to vehicles and making them aware of their surroundings [1]. To achieve the demands of safety applications in VANET scenario, there is a requirement to enhance vehicular communications.

VANET is a type of MANET (Mobile AdHoc Network) in which nodes(vehicles) communicate with one another and with nearby Road Side Units (RSU), which is referred to as vehicle to vehicle and vehicle to infrastructure (V2I) communications.

Being a subclass of (MANET), VANET does not rely on preexisting infrastructure because here the mobility of node is very high. The high mobility and frequently changing topology make it difficult and challenging to successfully deliver the packet from source to destination. In addition to this, there are various characteristics such as no battery constraints, computational power, predictive mobility and disconnecting topology which make the routing requirements of VANET different from MANET. Figure 1 shows the applications for VANET. [1][2]

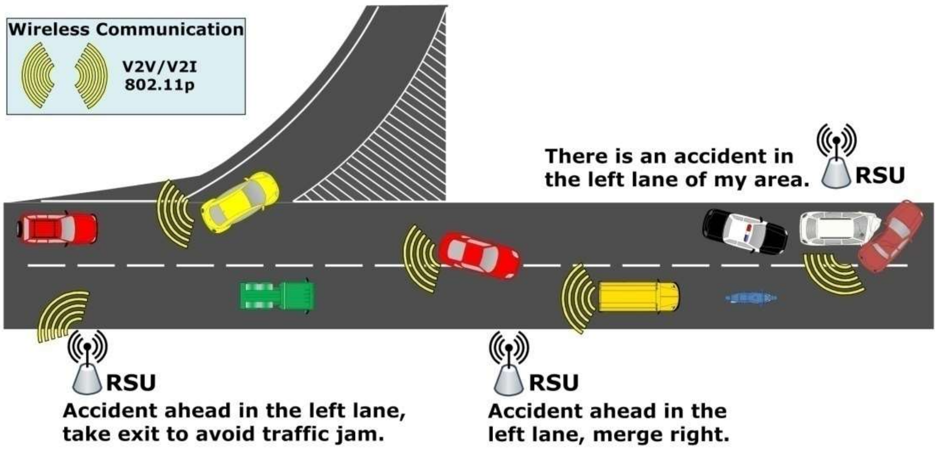


Figure 1. Applications for VANET

Because of expeditious growth in communications among vehicles, there have been many studies carried out about routing protocols, as they are much important for the initiation and maintenance of routes to ease multi hop communication and expand the region of network. The design of routing protocols of VANET is formed for various scenarios by taking the main characteristics and constraints into consideration such as bandwidth limitations, mobility of nodes and interference [3]. As we discussed, VANET has dynamically updating topology and the network can support any kind of application at run time. Hence, uninterrupted research is going on to improve the routing decisions while transmitting the data from source to destination [4].

Mobility models reflect the mobility or movement pattern of vehicle nodes on the road. They are used in implementation of routing protocols.[19] A number of mobility models have been designed for delivering more data packets, less end to end delay, high throughput, less routing overhead and low energy consumed by vehicle nodes including: Gauss Markov[14], Manhattan [11], Random way Point[14], Random direction [16], Reference point Group mobility models[14]. Using simple pattern randomly, graph constrained mobility models are common practices while doing research. These models donot describe mobility of vehicles in realistic manner. For instance while accelerating and decelerating in the presence of nearby vehicles, they can not apply break and move, as each vehicle has to decide the movement while at intersection or crossroads, traffic congestion at red lights etc. [18] All these situations greatly affect the Network performance. Selecting the mobility model which is realistic one is the main focus of this paper.

A number of protocols have been designed on which movement of nodes can be observed. Most of the protocols which have been proposed are based either on theory or simulation. According to the literature, it classifies the protocols into three categories: Proactive, Reactive and Hybrid and it further categorize in to Topology based and Geographic Location or position based protocols [5]. The categorization of all these protocols work on the fact that some protocols use links to know the routes from source to destination or some protocols use geographic position so that the best route can be found from source to destination. Routing protocols are based on geographic position on Unicast mode and they are classified under Hybrid protocols category. In these protocols each node has GPS enabled system and they find the route by sharing the location among their neighbors. Among the protocols based on the Geographic position, GPSR protocol can be cited [6] [7].

There has not been any study proposed which analyze the performance of GPSR protocol in VANET Scenario by implementing various Mobility Models. GPSR is one of the position based protocols which requires the obtain ability of physical position information system of the nodes which are participating in a network by utilizing a service like a GPS. They don't need any routing tables to discover the route from source to destination. GPSR requires that every node requires its positions and its neighbor's positions using broadcast messages through GPS enabled system. The topology changes so frequently and lots of data packets are lost while transmitting the information from source to destination. Hence, selection of an efficient mobility model is important to improve packet delivery ratio. [21] Figure 2 describes the Greedy approach and Perimeter approach of GPSR.

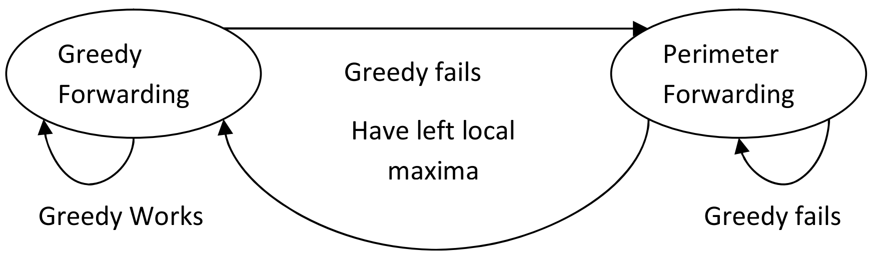


Figure 2. Greedy Approach

The remaining part of the paper is organized as follows: Section II describes an overview of mobility models, section III describes the simulation setup and analysis is described in section IV, section V describes the Results and Discussion and finally section VI describes Conclusion and future work

2. Vehicular Mobility Models

Due to high cost of deploying and testing a new architecture of VANET in real word, simulations provide an environment to simulate the architecture before deploying to the real world. To illustrate the movement pattern of mobile users, mobility model was designed. Mobility model was also designed to monitor how the velocity, location and acceleration of mobile nodes change over time. The simulation factors that impact the performance of VANETs are the mobility pattern of vehicles. Mobility model characterizes the movement and obtain the location of nodes in the network topology at any given point of time. The selection of appropriate underlying mobility model is necessary while evaluating VANET. [8] [9].

For example, movement of nodes in Random way point model is different as compared to the nodes moving in groups [10]. It is also not appropriate to assess the applications where nodes are likely to move in groups using Random Way Point Model. This paper discusses some of the mobility models and performance evaluation of protocol with these models:

2.1 Manhattan Grid Mobility model (MMM)

This model is a generated map based which is used to simulate an urban environment scenario and introduced in [11]. Before the simulation starts, a map which contains horizontal and vertical and roads is produced as shown in Figure 3.[11]This map includes duo lanes, which allow the motion in bilateral directions (for vertical roads it is north-south and horizontal it is east-west) . As the simulation begins, on random basis vehicles are placed on roads. They move in continuous manner on history based speeds. When the vehicle reaches a crossroad, it chooses a direction to flow itself i.e. going straight, turning left, turning right. Between two subsequent vehicles on a lane, a distance is maintained which is called security distance. If the distance between two adjacent vehicles is less than the required minimal distance than the second vehicle decelerates and let the forward vehicle moves away. But it is contrary to Freeway Mobility Model, where a vehicle can change its lane at a crossroads. No control mechanism exists at crossroads, as nodes continue to move without stopping, which is impractical.[18]

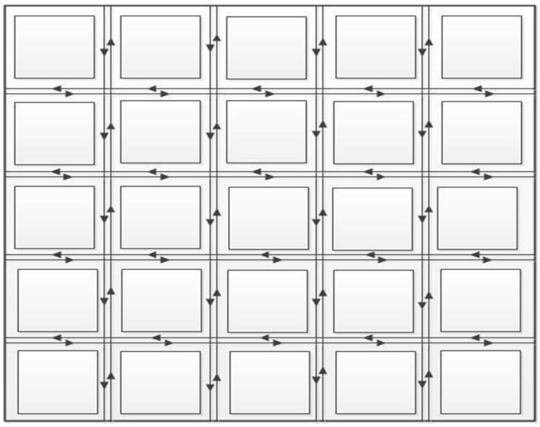


Figure 3. An Example of movement pattern in Manhattan Mobility Model

2.2 Random Way Point Model

In these mobility models the nodes move randomly and freely in mobile nature without any restrictions. Very specifically it can also be told that speed, destination and direction are also chosen arbitrarily and independently of other nodes in a network. John and Maltz first proposed Random way point Model [5]. To evaluate VANET Routing protocols, soon it became a benchmark model in terms of mobility because of its easiness and availability [14].

A pause time is included by this model, between the change in speed or direction. A node initiates the movement by constantly staying in one location for a specific period of time. When this time expires, random destination is chosen by the node within the simulation area and a speed which is equivalently distributed between max *speed and min speed.[20]* Then the mobile node starts travelling at a newly selected speed and towards selected destination. When it arrives, before starting the entire process again, it pauses for a certain period of time [14].

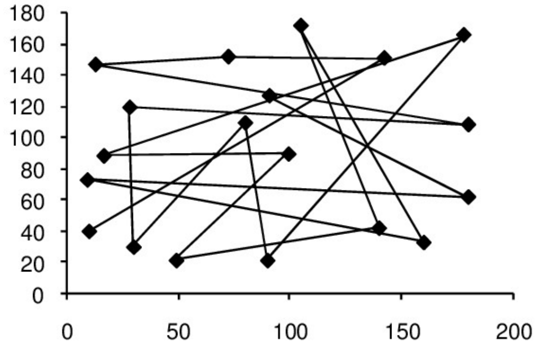


Figure 4. An example of Movement pattern in Random Way Point Model

Figure 4 shows mobility pattern of a mobile node using RWM model staring from a randomly selected position (133,180). The speed of the node is kept uniformly somewhere between 0 and 10 m s^{-1} [14].

2.3 Reference point group mobility model

Another way to simulate group behavior is the Reference point group mobility model which is abbreviated as RPGM. In this model, each node follows a group leader which is called the logical center and belongs to a group. This leader of the group identifies the motion conduct of the group. Around the reference point, all nodes are randomly distributed, which are in group Every node uses its own mobility model and they will be then added to the reference point which then pushes them in the direction of the group. At any point of time, every node follows some direction and has a speed that is evaluated by deviating arbitrarily from leader of the group. This model has various applications. One example is in military battlefield communications, where the group of soldiers moves together. [14]

The group leader: Motion vector $V^t{}_{group}$ represents the motion of group leader at time t. Apart from this, it also tells the motion trends of the whole group. Each member of the group diverges from normal motion vector by some degree. Based on certain predefined paths, motion vector is correctly chosen. [16]

The group members: Movement of group leader significantly affects the movement of the group members. Mobility is assigned for every node with a reference point that follows group movement. Each mobility node could be arbitrarily placed in the neighborhood upon this predefined reference point.

Motion vector V_i^t of Group member, i, which is given as below:

$$V_i^t = V^t_{group} + RM_i^t \tag{1}$$

Where RM_i^t, the motion vector, is a random vector diverged by group member i from its reference point. This vector is an autonomous equivalently distributed random process, length of which is evenly distributed in the interval [0, r_{max}] (r_{max} denotes the maximum allowed distance deviation) and whose direction is evenly distributed in the interval [0,2π]. The motion vector of group leader and of the whole group is V^t_{group} and V_i^t represents the final motion vector. [15]

Figure 5 [15] illustrates three mobile nodes which are moving together as one group. Movement pattern of logical center of each group and the arbitrary motion of mobile nodes within the group are implemented using RWM model. In this model, pause times are not used by individual nodes, while the group is moving. Pause times are used only when the group reference point reaches a destination and all mobile nodes of a group pause for the same period of time. [14]

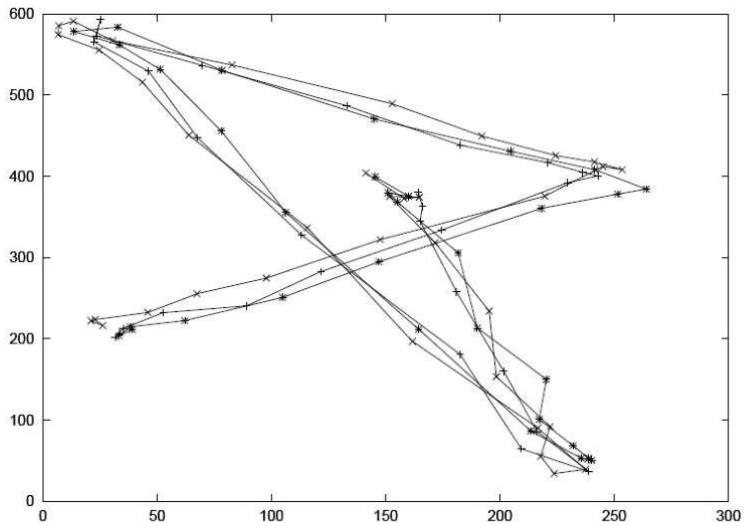


Figure 5. An Example of Movement pattern of Mobile nodes in Reference point group mobility model.

2.4 Gauss Markov Mobility Model

Initially, the gauss markov model was proposed for the PCS Simulation [16], however Ad Hoc network protocols also use this model for simulation. This model was deliberated to adapt different level of randomness using one tuning parameter. At the initial stage, each node is earmarked with a current direction and speed. Movement occurs by updating the speed and direction at fixed intervals of time. The value of parameters at n^{th} instance is evaluated on the basis of direction and speed at $(n-1)^{st}$ instance and a random variable by following expressions:[15]

$$s_n = \alpha s_{n-1} + (1-\alpha)\bar{s} + \sqrt{(1-\alpha^2)s_{x_{n-1}}} \qquad (2)$$

$$d_n = \alpha d_{n-1} + (1-\alpha)\bar{d} + \sqrt{(1-\alpha^2)d_{x_{n-1}}} \qquad (3)$$

Where s_n and d_n denotes new speed and direction of mobile node at n time interval; α is the tuning parameter lies from 0 to 1 and is used to vary the value of randomness, mean value of speed and direction is represented by constants $\bar{s}$ and $\bar{d}$, as $n \to \infty$ and $s_{x_{n-1}}$ and $d_{x_{n-1}}$ represents random variables from a Gaussian Distribution. By using above equations, random values are acquired by keeping $\alpha = 0$ and linear motion by setting $\alpha = 1$. [14]

At each time interval, the current value of parameters (speed, direction and location) evaluates the next location. Following equations describe the position of each mobile node at time interval n.

$$x_n = x_{n-1} + s_{n-1} \cos d_{n-1}$$

$$y_n = y_{n-1} + s_{n-1} \sin d_{n-1}$$

where, (x_n, y_n) and (x_{n-1}, y_{n-1}) are the coordinates of the position of node at time intervals n^{th} and $(n-1)^{st}$, respectively and and s_{n-1} and d_{n-1} are the speed and direction of mobile node respectively at $(n-1)^{st}$ time interval.

Figure 6 shows an instance of movement scenario of a node by using Gauss Markov Mobility Model. The mobile node initiates its movement from the midpoint of the simulation area. As can be observed in the figure, unanticipated stops and abrupt turns can be eliminated in this Mobility Model which can be encountered in other Mobility Models because of the influence of past velocities and directions to future velocities and directions. [14]

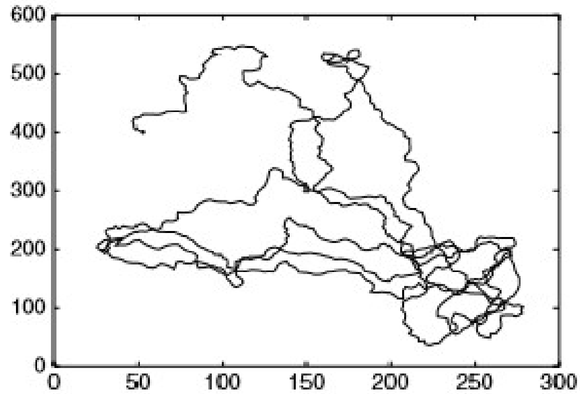


Figure 6. Example of Mobility pattern in Gauss Markov Mobility model

2.5 Random direction Mobility Model

Average number of neighbors produces density waves in RWM model. To overcome this density waves, Random direction mobility model [17] was introduced. The formation of clusters of nodes in one part of simulation area is called density wave. The formation of clusters occurs in the middle area under simulation in RWM Model. The chances of a moving node selecting a new destination that is located in the midpoint of the simulation area or requires travelling through the middle of the simulation area is high. Thus, the mobile nodes appear to assemble, disperse and assemble again. Thus, Random Direction Model was developed [17] to relieve this type of behavior and encourage semi-constant number of neighbors through the entire simulation.

Like Random Walk mobility model, random directions are selected by mobile nodes for travelling to the border of simulation area.[20] While moving in that direction, when the boundary of the simulation area is reached, the node takes pause for a specific period of time, chooses another angular direction somewhere between 0 and 180 degrees and continues this process. Figure 7 shows a scenario of movement of mobile node in Random Direction model. Wherein, a mobile node starts its movement through the center of the simulation area or position (250,250) using this Model. [14]

The dots in the figure 7 shows that the node reaches the simulation area then paused and start moving in another direction. Since in this case, the average hop count of this mobility model will be much higher in comparison to other mobility models and the network partitions will also be much higher when compared with other mobility models. [14]

Section III describes the simulation model and section IV describes analysis of the proposed work. Further, section V includes the result and discussion and finally conclusion and future scope is described in section VI.

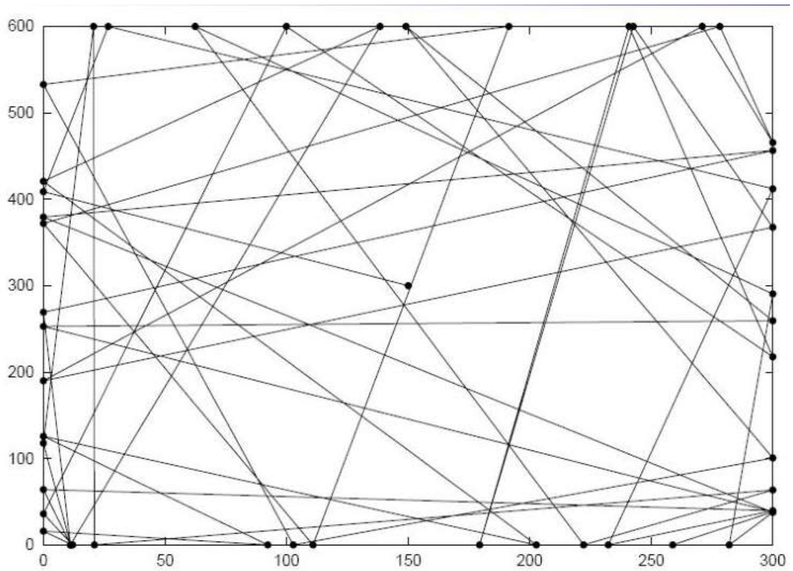


Figure 7. Example of Mobility pattern in Random Direction Mobility model

3. Simulation Setup

This section of the paper gives simulation setup and workflow, to assess the performance of mobility on the performance of GPSR protocol in VANET scenario. The routing protocol is installed in NS-2(version 2.35). Five mobility models: Manhattan grid mobility model, RWM, RPGM, Gauss Markov mobility model and Random direction mobility model were used and the scenarios and movements were generated using the software Bonmotion, which is based on a framework, that TCL script is generated by taking inputs such as number of nodes, mobility model and area. Standard MAC Protocol IEEE 802.11 was used and simulation area was 1200 x 900 m^2. All the nodes had omni directional antennas in simulation. The simulation was done by altering the number of nodes from 10 to 50 and runs for 100 sec. in all the mobility models. Simulation parameters are found in Table 1.

Table 1. Simulation Parameters

Simulation Parameters	Value
Network simulator	NS 2.35
Simulation time	100 seconds
Number of MNs	10,20,30,40 and 50
Simulation Field Area	1200x900m^2
Routing Protocol	GPSR
Index of Randomness	0.5
Packet Size	512Kbps
MAC Protocol	MAC/802.11
Data Rate	1024Kbps
Transport Protocol	TCP
Speed	Minimum- 3 m/s and Maximum= 35m/s
Pause Time	0.05
Antenna	Onmidirectional
Mobility Models	Manhattan Grid, RWM, RPGM, Gauss Markov, Random Direction

4. Analysis

Whenever the research is done it is important to analyze the work which can be presented as: 1. how many packets are getting delivered from source to destination? 2. How fast the messages can be propagated to all active nodes. The most important thing is delivery of messages to all intended nodes. The aim of this work is to assess the effectiveness, performance and efficiency of the proposed work in terms of the following parameters:

4.1 Average throughput: Average throughput is specific to a wireless or wired link. In VANET scenario, we are using wireless scenario and sharing link.

Throughput (Mbps) = number of bytes transferred in the link x 8/total simulation time (μ sec) (1)

4.2 Packet Delivery Ratio (PDR): PDR should have larger value. It is the ratio of the packets which are sent by source divided by the packets which are received by the destination. For better performance of any protocol the packet delivery ratio should be higher.

PDR = Packets received successfully / Total Transmitted packets (2)

4.3 Average End to End Delay: The time taken by packets to successfully go through all destination nodes is called average E to E delay. Lower the average E to E delay larger is the performance of protocol. It is calculated as follows:

Average EED = Average time taken to deliver packets / Total number of packets sent. (3)

4.4 Routing overhead: Routing overhead is the number of routing packet required for destination. It is defined as follows:

Routing Overhead= total size of all control packets including RERR, RREP, RREQ and hello packets/ total size of data packets which are delivered to the destination (4)

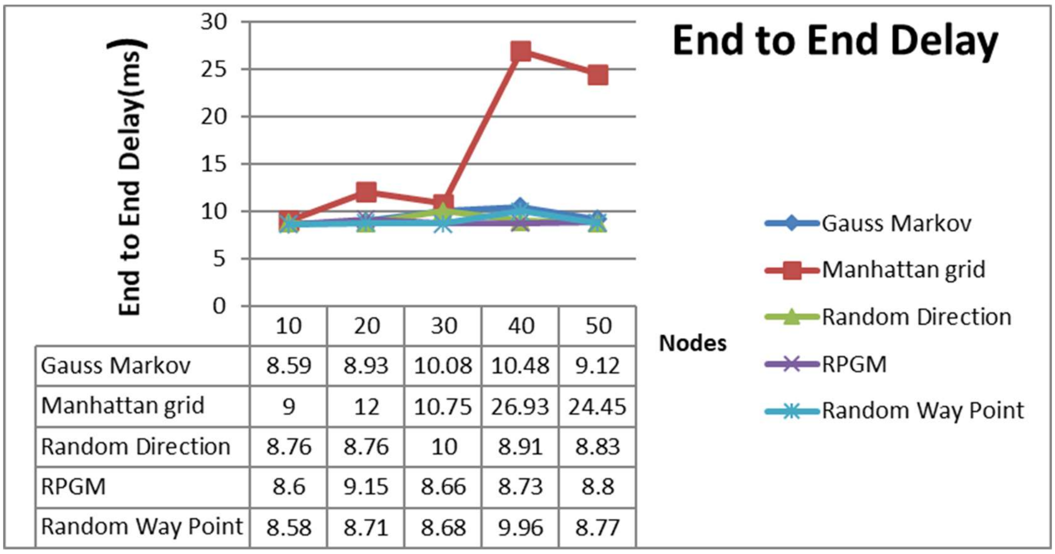
4.5 Average energy: Average energy consumed by nodes is the mean of energies consumed by each node. Larger the energy consumed by nodes less is the performance of protocol.

5. Results and Discussion

This section describes simulation results by varying the number of nodes for each of the performance parameter as described in the previous section using Network Simulator tool and Bonmotion for analysis and plotting. GPSR protocol is used in all cases.

5.1 Impact of Mobility on End-to-End Delay

Figure 8 shows the relation between delays and the number of mobile nodes. More is the value of delay less is the efficiency of these protocols. Simulation is done by varying the number of nodes and keeping the simulation time fixed to 100 seconds and analyzes the impact of mobility model on delay. While analyzing all the models, it can be noticed that Manhattan grid model experiences more delay than others. When the number of vehicles is increasing, it increases and then decreases upto some extent. All other models experience similar behavior except RPGM in which the delay is around 9 msec in every scenario. It can be said that Manhattan mobility model experiences a maximum delay with a 26.93 msec and RWM is having minimum value of 8.58 msec.

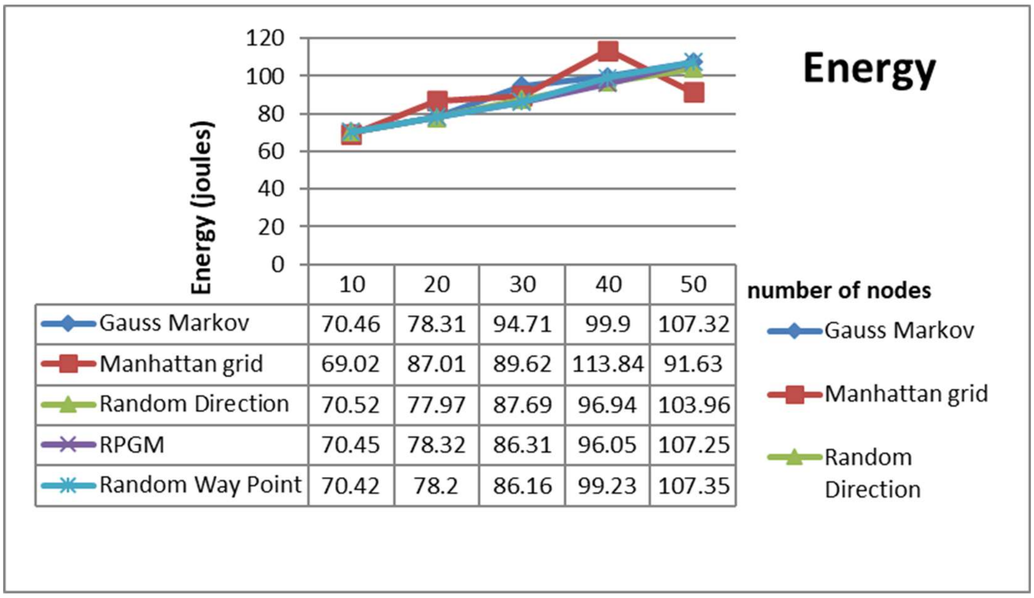


	10	20	30	40	50
Gauss Markov	8.59	8.93	10.08	10.48	9.12
Manhattan grid	9	12	10.75	26.93	24.45
Random Direction	8.76	8.76	10	8.91	8.83
RPGM	8.6	9.15	8.66	8.73	8.8
Random Way Point	8.58	8.71	8.68	9.96	8.77

Figure 8. Impact of End-to-End Delay on Mobility

5.2 Impact of Mobility on Energy

Figure 9 shows the impact of Mobility models on Energy. When the number of vehicles is very less then energy consumption by Manhattan Grid Model is also less than the rest of the mobility models. As the vehicles on road increase than the behavior changes and when it reaches 50 than Gauss Markov, RPGM and RWP have similar and higher values than Manhattan and Random Direction mobility model. While calculating the mean of energy consumed by nodes, Gauss Markov consumes less energy as comparison to all other mobility models .During simulation, simulation time is fixed to 100 sec. The detailed values are depicted in the below table:

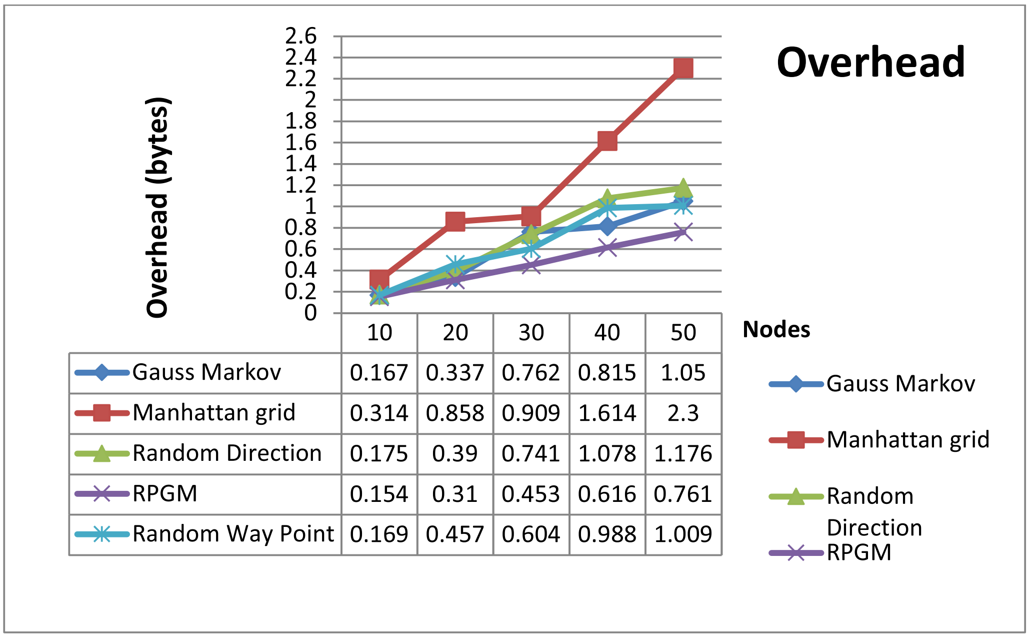


	10	20	30	40	50
Gauss Markov	70.46	78.31	94.71	99.9	107.32
Manhattan grid	69.02	87.01	89.62	113.84	91.63
Random Direction	70.52	77.97	87.69	96.94	103.96
RPGM	70.45	78.32	86.31	96.05	107.25
Random Way Point	70.42	78.2	86.16	99.23	107.35

Figure 9. Impact of Energy Delay on Mobility

5.3 Impact of Mobility on Overhead:

Figure 10 shows the impact of mobility models on Overhead. More is the overhead less is the efficiency of the protocol. It is depicted that Manhattan mobility model experiences more overhead than the other mobility models despite any number of nodes. RPGM have less overhead then all other mobility models. In all the mobility models, overhead is gradually increasing by increasing the number of vehicles on road. The detailed values are tabulated in figure 10. The values lie in the range of 0.154 and 2.3.



	10	20	30	40	50
Gauss Markov	0.167	0.337	0.762	0.815	1.05
Manhattan grid	0.314	0.858	0.909	1.614	2.3
Random Direction	0.175	0.39	0.741	1.078	1.176
RPGM	0.154	0.31	0.453	0.616	0.761
Random Way Point	0.169	0.457	0.604	0.988	1.009

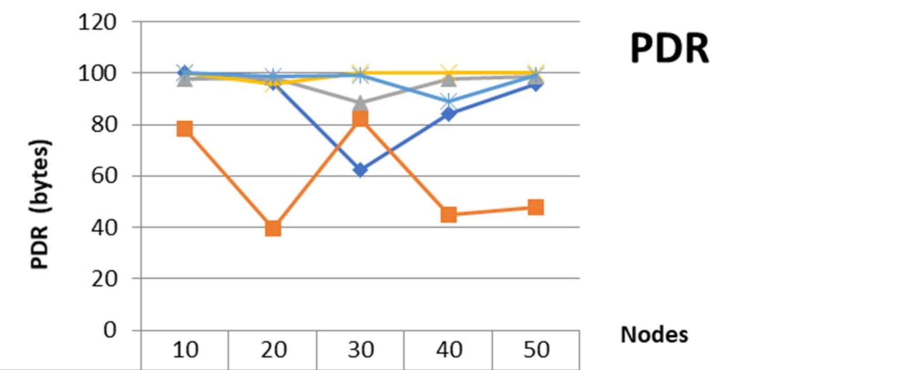
Figure 10. Impact of Routing overhead on Mobility

5.4 Impact of Mobility on PDR:

Figure 11 shows the relation between number of nodes and PDR. It is depicted in figure that that as the number of nodes is increasing; the packets which are getting delivered are decreasing in Gauss Markov mobility model. When the nodes were 10 the value of PDR was in the range between 78.28 and 99.94 and as the number of vehicles reaches 50 the range becomes between 47.67 and 99.94. Hence, it can be observed that maximum value of 99.94 of PDR is achieved in RPGM model and near to this in Random way Point. The detailed values of results are tabulated in Figure 11. Manhattan shows nearly less results of PDR than any other mobility model.

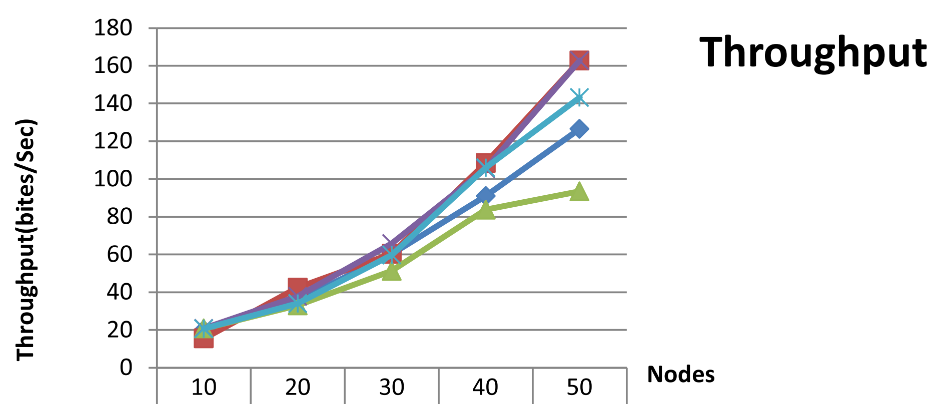
5.5 Impact on Throughput:

Figure 12 shows the relation between Throughput and the number of vehicles on road. Throughput is defined as how many bits are getting delivered in one second. When the nodes are 10, Manhattan mobility model observes lower value and RPGM has the highest throughput. As the nodes are increasing throughput is also increasing, this shows usual behavior. When the nodes are 30, Random Direction mobility model experiences lowest value of throughput and RPGM observes the highest. At the end, Manhattan experiences highest value of 162.72 bits/sec and Random Direction has lowest value of 93.53 bits/sec. The detailed results are tabulated in figure 12.



	10	20	30	40	50
Gauss Markov	99.94	96.29	62.28	84.23	95.76
Manhattan grid	78.28	39.53	82.27	45.1	47.67
Random Direction	97.74	98.26	88.71	97.56	98.62
RPGM	99.94	95.53	99.94	99.94	99.94
Random Way Point	99.94	98.67	99.25	89.05	99

Figure 11. Impacts on PDR



	10	20	30	40	50
Gauss Markov	20.02	35.57	60.19	91.04	126.61
Manhattan grid	15.55	42.34	60.34	108.45	162.72
Random Direction	20.84	32.99	51.25	83.76	93.53
RPGM	20.89	37.8	65.79	105.52	162.8
Random Way Point	20.72	33.96	59.67	105.91	143.19

Figure 12. Impacts on Throughput

Nam files of all mobility models are shown in figure 13. Figure 13 shows mobility pattern analyzed in the simulation of our work. In Manhattan Grid, which is depicted in Figure 13 (a), it can be observed that nodes form crossroads while moving in two directions north-south and east-west. While, in Gauss Markov, nodes move randomly based on index of randomness which is kept at 0.5 in our work. It can be observed in Figure 13(b).

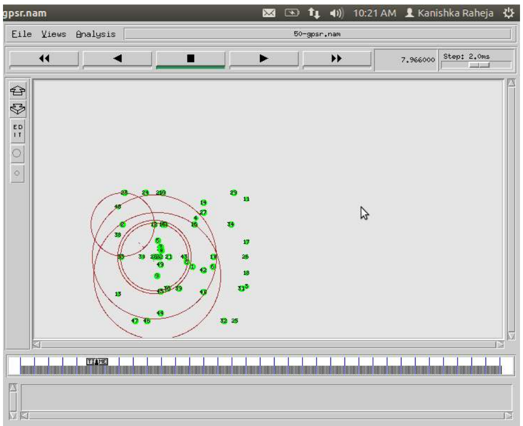


Figure 13(a). Manhattan Grid Mobility model

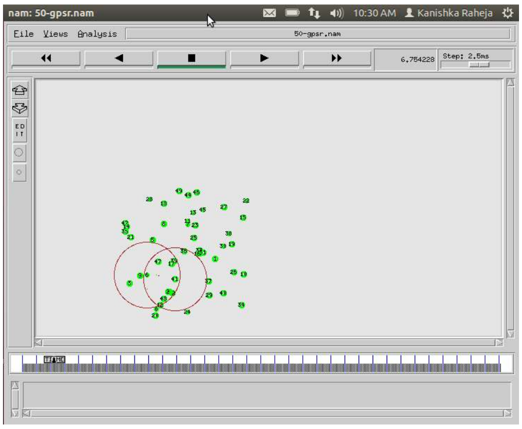


Figure 13(b). Gauss Markov Mobility Model

Figure 13(c) shows the pattern of nodes in Random way Point and Figure 13(d) shows the pattern of Random Direction. In both the models, nodes move randomly in any direction as described in section II. It can be observed that in Random way point, the nodes density occurs in center of the simulation area but this clustering can be eliminated in Random Direction model which disperse the nodes in all direction.

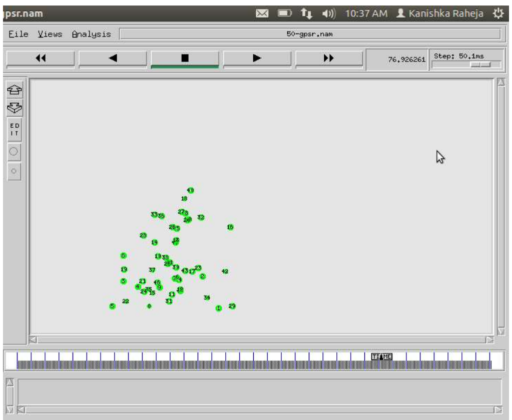


Figure 13 (c). Random Way point Mobility Model

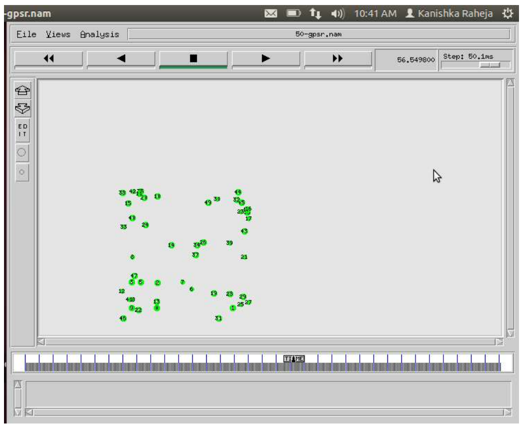


Figure 13(d). Random Direction Mobility model

In RPGM, nodes form groups or clusters with one node in each group there will be one node which will be group leader and all other nodes follow this node. The cluster formation can be noticed in Figure 13(e).

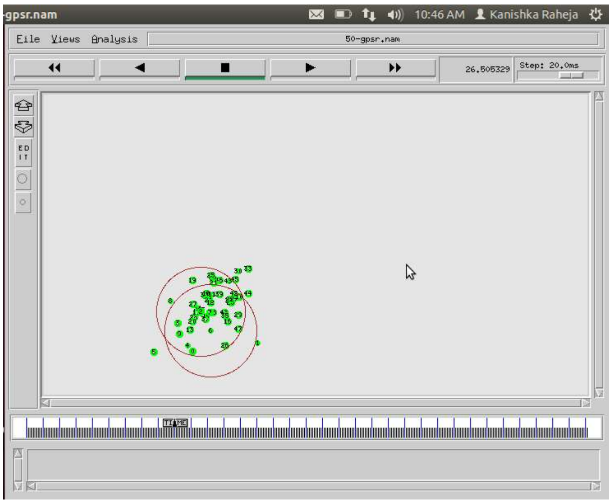


Figure 13(e). RPGM model

6. Conclusion and Future Work:

Mobility models play a vital role in precise simulation of performance of routing protocol in Vehicular AdHoc Networks. In this work the sensitivity of mobility details of different mobility models in VANET was analyzed using GPSR protocol. We discussed five mobility models- Manhattan, Gauss Markov, Random Way Point, Reference Point Group and Random Direction Mobility Model that highlights the movement pattern of vehicles at various levels in detail. This work is based on Network simulator tool, which is used for implementing GPSR protocol and Bonmotion, by which mobility models were generated. Results show that formation of clusters at intersection and movement of vehicles at cross roads affects the PDR and delay. RPGM shows better results in terms of Throughput, Packet Delivery Ratio, overhead and to some extent in delay. The proposed work and simulated results may serve as guidelines for design of modern traffic control mechanisms. In future, the work can be extended and add an algorithm to introduce security into this.

References

[1] Dimitrakopoulos G and Demestichas P. Intelligent Transportation Systems. 2010. *IEEE Vehicular Technology Magazine*. vol. 5. no. 1.pp. 77-84. doi: 10.1109/MVT.2009.935537.

[2] Zhang X, Cao X, Yan L and Sung D.K. 2016. A Street-Centric Opportunistic Routing Protocol Based on Link Correlation for Urban VANETs. *IEEE Transactions on Mobile Computing*. vol. 15. no. 7. pp. 1586-1599.doi: 10.1109/TMC.2015.2478452.

[3] Tripp-Barba C, Zaldívar-Colado A, Urquiza-Aguiar L and Aguilar-Calderón JA. 2019. Survey on Routing Protocols for Vehicular Ad Hoc Networks Based on Multimetrics. *Electronics*. 8(10):1177. https://doi.org/10.3390/electronics8101177.

[4] Li F and Wang Y, "Routing in vehicular ad hoc networks: A survey. 2007. *IEEE Vehicular Technology Magazine*, vol. 2, no. 2, pp. 12-22, doi: 10.1109/MVT.2007.912927.

[5] Junior J A, Emilio C. G. Wille. 2018. Routing in Vehicular AdHoc Networks: Main Characteristics and Tendencies. Journal of Computer Networks and Communications, Article ID 1302123, 10 pages. https://doi.org/10.1155/2018/1302123.

[6] Karp B and Kung H. 2000. GPSR: Greedy Perimeter Stateless Routing for wireless networks. *ACM MobiCom*, no. MobiCom, pp. 243–254.

[7] Bengag A and Boukhari M El. 2018. Classification and comparison of routing protocols in VANETs. *International Conference on Intelligent Systems and Computer Vision (ISCV)*, pp. 1-8. doi: 10.1109/ISACV.2018.8354025.

[8] Bai F, Helmy A. A Survey of mobility models. Wireless AdHoc Networks. *University of Southern California.pp 1-30.*

[9] Mahajan A, Potnis N, Gopalan K, and. Wang An-I A. Evaluation of Mobility Models for vehicular AdHoc Network Simulations. Pp 1-13.

[10] Bai F, Sadagopan N and Helmy A. 2003. IMPORTANT: a framework to systematically analyze the Impact of Mobility on

Performance of Routing Protocols for Adhoc Networks. *IEEE INFOCOM 2003. Twenty-second Annual Joint Conference of the IEEE Computer and Communications Societies (IEEE Cat. No.03CH37428)*, San Francisco, CA, pp. 825-835 vol.2, doi: 10.1109/INFCOM.2003.1208920.

[11] Mahajan A, Potnis N, Gopalan K, and. Wang An-I A. Evaluation. 2010. Urban mobility models for VANETs. *Computer Science, Florida State University.*

[12] Khairnar V.D, Pradhan S.N. 2011.Mobility Models for Vehicular Ad-hoc Network Simulation. *IEEE Symposium on Computers & Informatics*.460-465.

[13] Broch J, Maltz D. A., Johnson D. B., Hu Y.-C., and Jetcheva J. 1998. A performance comparison of multi-hop wireless ad hoc network routing protocols. *Proceedings of the Fourth Annual ACM/IEEE International Conference on Mobile Computing and Networking (Mobicom98), ACM.*

[14] Camp T, Boleng J and Davies V. 2002. A survey of mobility models for ad hoc network research. *Wireless communications and mobile computing*. 2:483–502 (DOI: 10.1002/wcm.72).

[15] Jayakumar G and Ganapathi G. 2008. *Journal of Computer Systems, Networks, and Communications.* Article ID 860364, 1-10. doi:10.1155/2008/860364.

[16] Liang B., Haas ZJ. 2003. Predictive Distance- Based Mobility Management for Multidimensional PCS Networks. *IEEE/ACM Transactions on Networking,* Vol.11, No. 5.

[17] Royer E, Melliar-Smith PM, Moser L. 2001. An analysis of the optimum node density for ad hic mobile Networks. *Proceedings of the IEEE International Conference on Communications (ICC).*

[18] Djenouri, Djamel & Soualhi, Wassim & Nekka, Elmalik. 2008. VANET's mobility models and overtaking: An overview. *3rd International Conference on Information and Communication Technologies: From Theory to Applications, ICTTA.* 1 - 6. 10.1109/ICTTA.2008.4530189.

[19] Gaikwad D S and Zaveri M. 2011. VANET Routing Protocols and Mobility Models: A Survey. *Springer- Verlag Berlin Heidelberg. CCIS 197*, pp.334-342.

[20] Lashari, Haque & Ali, Husnain Mansoor & Massan, Shafiq-Ur-Rehman. 2019. A Study of Mobility Models for UAV Communication Networks. Special. 276-297. 10.17993/3ctecno.2019.specialissue2.276-29.

[21] Silva, Andrey & Reza, K. & Oliveira, Aurenice. 2018. An Adaptive GPSR Routing Protocol for VANETs. 1-6. 10.1109/ISWCS.2018.8491075.