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AN OPTIMIZED GEOGRAPHIC ROUTING PROTOCOL FOR VANETS

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ABSTRACT

Vehicular Ad Hoc Network (VANET), a subset of Mobile ad hoc networks, primarily focuses on traffic safety but now-a-days much research is focused on integrating VANETs with internet. With infrastructure based VANET communication, even connectivity could be established with internet. Effective communication between two nodes within a VANET or with an infrastructure unit is assisted by routing protocols. Hence routing plays a vital role in data communication. Most of the routing protocols of VANET follow greedy approach. Many greedy routing protocols have been proposed by eminent researchers. The performance of these greedy routing protocols depends on the recovery strategy adopted by them. This paper presents a novel approach of applying cartographic concepts to enhance the performance of greedy protocol by minimizing the hop count of the path in perimeter mode using curve simplification algorithm. The results show significant reduction in the number of hops required to deliver data to the destination when compared with GPSR protocol.

Keywords: vehicular networks, routing protocol, geographic routing, greedy algorithm, recovery strategy, ramer Douglas peucker algorithm.

1. INTRODUCTION

In the last two decades, the growth in the automobile industry is tremendous. With the increasing number of vehicles on the road, the safety and comfort of the passengers faces threat. In-vehicle solutions such as security belt, air bag etc. increases the safety of the passengers. Still the increasing number of road accidents and traffic congestion is of great concern. Communication among vehicles has been put forth by the ITS community for a long time. The absence of a wireless protocol to establish communication between vehicles delayed vehicular communication for a longer time. DSRC (Dedicated short range communications) was used initially. With 802.11p-WAVE (Wireless Access in Vehicular Environments) standard, communication among vehicles became easier and faster [1].

Vehicular Ad Hoc Networks primarily categorized as a network for traffic safety has now moved on to infotainment including mobile gaming. Some of the applications of VANET are traffic monitoring services, content distribution, emergency video streaming etc. Irrespective of the application, data need to be communicated. Quantity of data and the sensitivity of the data to be communicated decide the type of routing protocol to be adopted. Hence it is important to select the right routing protocol.

VANET is characterized by frequently changing network topology resulting in disconnected networks, mobility pattern, delay constraints etc. [2]. Routing is broadly categorized into two types: Source routing based protocol and geographic routing based protocol. In Source routing based protocol, the source node provides the path that the data should take to reach the destination whereas the geographic routing protocol use the knowledge of street maps to decide the path the data has to take in order to reach the destination [3]. Based on the data dissemination, the routing protocols are further classified as Unicast (V2V or V2I communication), Multicast (Communication between selected vehicles), Geocast (Multicast within a specific geographical area) and Broadcast (Vehicle to all vehicles within the cellular area). Most of the routing protocols developed for VANET are geographical routing protocols since vehicles follow a specific traffic pattern based on the street maps of that geographical area. Several researchers have done elaborate survey on the routing protocols of VANET. A detailed comparison of routing strategies adopted in VANET is discussed in [4]. A survey of topology based protocols and position based protocols are presented in [5-8]. In [9, 10] geocast and unicast protocols have been discussed. A survey of position based routing is described in [11, 12]. Most of the researchers have concluded that geographic routing will suit VANET environment. Most of the geographical routing protocols follow greedy approach. One such protocol is Greedy Perimeter Stateless routing (GPSR) protocol. This paper focuses on optimizing the hop count in the perimeter mode of the GPSR protocol using Ramer Douglas Peucker (RDP) algorithm.

The rest of the paper is organized as follows: Section II focuses on greedy protocols. In section III Douglas Peucker algorithm has been discussed. Section IV deal with the optimization of right hand perimeter rule using Douglas Peucker Algorithm. Section V has the simulation details and its results and section VI draws the conclusion.

2. LITERATURE REVIEW

Due to high mobility of vehicles constituting the ad hoc network, source based routing will not suit VANETs. This is due to the fact that the routing table available at individual nodes has to be updated continuously. When the routing table gets updated at a node the route may become stale. This increases the overhead of the network. To overcome this researchers have used the greedy approach which ensures good connectivity [13]. Greedy routing is basically geographic routing where nodes forward data based on its position. Since most of the vehicles are equipped with Global positioning system (GPS), the process of identifying a vehicles position is made easier. The position thus acquired is shared with neighbouring vehicles through beacon messages.

Greedy routing in VANET

In the greedy approach, a source node will transmit the data packet to the destination by forwarding the data packet to its one hop neighbor that is closest to the destination. This one hop neighbor will in turn identify its one hop neighbor that is closest to the destination and will forward the data. This process is repeated till the data reached the destination.

The main challenge in using the greedy approach for VANET routing is that in a rural environment where vehicle flow is sparse, identifying its one hop neighbour to forward the data packet becomes highly impossible as most of the times no vehicle will be available within its transmission range to forward the data. The same is also applicable for highway environments if traffic in the highway is less. In city environments, traffic is dense but there are circumstances where high rise buildings often pose as obstacle in reaching the neighbor. In such cases, greedy routing fails. To overcome the difficulty faced in greedy routing, many researchers have come up with several recovery strategies [14].

Brad *et al* [15] and Bose *et al* [16] in their work use perimeter approach as the recovery strategy. Both the protocols start with greedy mode and at nodes where greedy fails they switch to perimeter mode The right hand or left hand perimeter rule is used to identify the next neighbour. This process is repeated till it identifies a neighbor node that is at a one hop distance towards the destination. At that point it switches to greedy mode and the process continues. The main disadvantage of GPSR is that whenever it switches to perimeter mode the performance of the network decreases. Also the route followed by the nodes in the perimeter mode is very lengthy which increases the hop count. The more the network is disconnected higher will be the hop count in the perimeter mode.

Lochert. C *et al*. [17], also uses the greedy forwarding mechanism in greedy perimeter coordinator routing (GPCR). GPCR uses the road pattern which is planar by itself to forward the data packet. Thus this reduces the process of planarization involved in GPSR. GPCR starts with greedy mode towards the junction node. Depending on the direction chosen by the junction node to forward the data and the traffic density it may or may not get into local maxima. The recovery strategy followed in case of local maxima is that it backtracks in a greedy manner to the junction node. The junction node then uses perimeter routing to decide on the route towards the destination. The main disadvantage of GPCR is in distinguishing between junction node and normal node as well as the fact that the junction node does not take into account whether sufficient nodes are in the chosen street to route the message.

The improved Greedy Traffic Aware routing by Moez Jerbi *et al*. [18] takes care of dynamic selection of junction for forwarding messages by considering the traffic density and curve metric distance to the destination. GyTAR also has an improved greedy forwarding mechanism for forwarding messages between two junctions. It takes into consideration the current position, velocity and direction of the neighbouring nodes while forwarding messages to the destination. Hence a neighbouring node in the positive direction is chosen. GyTAR follows carry and forward mechanism till a node comes into its transmission range to overcome the local maxima.

GpsrJ+ has been discussed by Kevin C. Lee *et al.* [19] to improve the recovery strategy in GPSR and GPCR. In GpsrJ+ instead of forwarding packets to the junction node, they are forwarded to the neighbours of the junction node thereby eliminating the overhead involved in identifying the junction node. This results in lesser number of hops when compared with that of GPCR as it bypasses junction nodes.

Kevin C.Lee *et al.* in their work the GeoCross protocol [20] have overcome the problem of cross links in GPCR by detecting and eliminating the cross links as well as maintaining the optimal route information at nodes. GeoCross eliminates the cross links which occur in perimeter mode by piggybacking three fields namely Probe, Unroutable roads and visited faces in the message. The packet delivery ratio of GeoCross is higher than that of GPSR and GPCR.

The GeoDTN+NAV explained by P.C. Cheng *et al*. [21] works similar to that of GPSR in case of greedy and perimeter mode. In case of disconnected network in perimeter mode it switches to DTN (Delay tolerant network) mode where the data is stored and carried by that node till the network connectivity becomes better. It then switches to greedy mode. The main disadvantage of this protocol is that it does not guarantee the packet delivery since there is a possibility that the node in DTN mode may move away from the destination.

Anchor based street and traffic aware routing (ASTAR) proposed by B.C.Seet *et al.* [22] identifies anchor paths with good connectivity to improve the packet delivery ratio. As a recovery strategy in local maxima a new anchor path is computed from the local maxima to the destination.

Predictive directional greedy routing in vehicular ad hoc networks by J.Gong *et al*. [23] has two phases: Position first forwarding and direction first forwarding. In position first forwarding it follows greedy approach. The disadvantage of using this approach is that the node closest to the destination might be moving in the direction opposite to that of the source thereby paving way for possible loops in the route. To overcome this they propose direction first forwarding. In this approach the node closest to the destination and moving in the direction same as that of the source will be considered as the forwarding node. In order to reap the benefits of both position first and direction first forwarding they use weighted scores (W_i) calculated for the neighbouring nodes and the current node. In predictive routing weighted scores are calculated for both one and two hop neighbours. Of these neighbours the one with highest score is chosen as forwarder. This reduces the hop count as well as end to end delay.

Junction based geographic routing protocol by S. Tsiachris *et al*. [24] follows greedy approach. In case of local maximum the algorithm uses minimum angle method as a recovery strategy. In greedy approach this protocol will choose the junction node that is closest to the destination as against the immediate junction node chosen by GPCR. This reduces hop count. In case of local maximum, the node where the local maximum has occurred plays a vital role. If the node is an ordinary source or forwarding node it identifies the coordinator node closest to the destination. In the absence of coordinator node it forwards to the ordinary node closer to the destination. The same is followed in case a coordinator node gets into local maximum but based on the priority of the coordinator nodes in the direction of the destination.

3. RAMER DOUGLAS PEUCKER ALGORITHM

Ramer Douglas Peucker (RDP) [25] and [26] algorithm primarily focuses on simplifying a curve composed of line segments to a similar curve approximated by a series of points when compared with that of the original curve. The RDP algorithm reduces the number of points in a curve by drawing a straight line between the two points in a curve among which reduction in number of points takes place. It assumes a distance dimension (tolerance) $\epsilon > 0$. The algorithm further identifies the point that is far away from the straight line and marks it. The farther point is compared with ϵ and if the point is closer to the straight line than ϵ then the point need not be considered as this will not simplify the curve. On the other hand if the point is greater than ϵ then the point is being included for curve simplification. The process is iterated till the last point in the straight line is reached. Finally all the points that are needed to be included in the curve are connected together thereby deriving a simplified curve with fewer points. The choice of value of ϵ plays an important role in the number of reduced points.

4. OPTIMIZED GEOGRAPHIC ROUTING PROTOCOL

The proposed Optimized Geographic Routing Protocol (OGRP) overcomes the disadvantage of increased hop count in the perimeter mode of the GPSR protocol. Our protocol initiates the routing process using greedy approach. When a node encounters a void region the greedy forward mechanism fails and it switches to perimeter mode where it routes the data using right hand perimeter rule. Since the hop count increases with frequently disconnected networks to optimize the path length RDP algorithm is used to reduce the number of hops.

Routing in perimeter mode mostly involves a curve, the number of nodes through which the data has to pass through can be reduced by applying the curve simplification algorithm of RPD thereby optimizing the hop count between the source and destination. The path followed by GPSR and OGRP is depicted in Figures 1 and 2 and it clearly shows that number of hops in perimeter mode is considerably reduced.

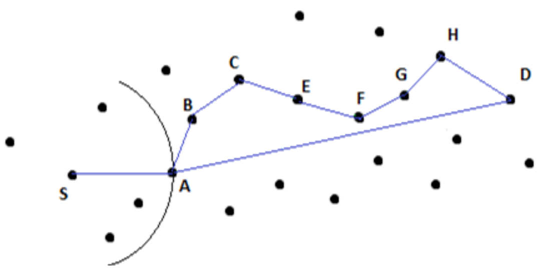

Figure-1. Path in GPSR.

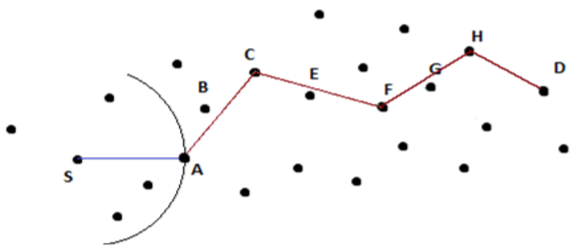

Figure-2. Path in OGRP.

The stepwise reduction in the number of hops in the perimeter mode using Ramer Douglas Peucker algorithm is shown in Figures 3(a) to 3(h). The

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flowchart of the proposed protocol is depicted in Figure-4.

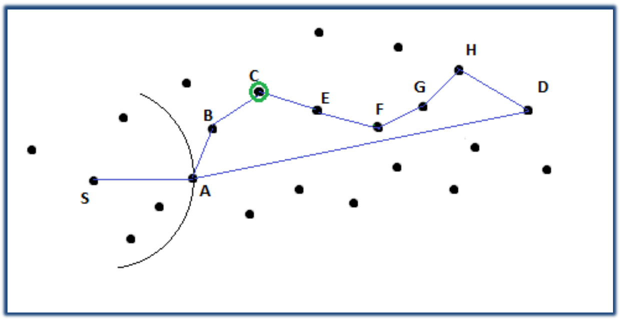

Figure-3(a). Farthest node C from line A-D chosen.

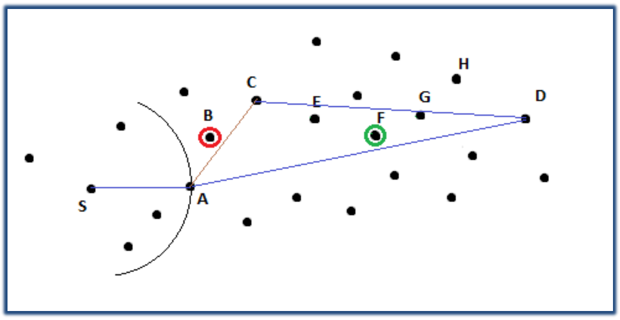

Figure-3(b). Farthest node F from line C-D chosen.

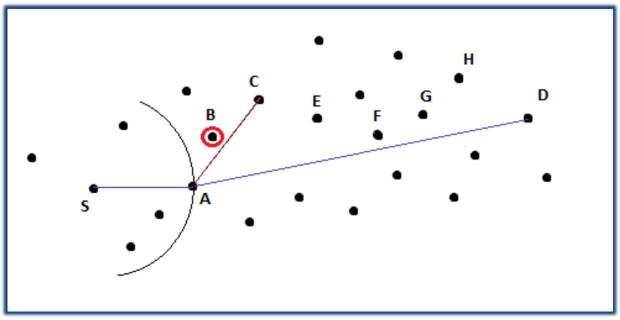

Figure-3(c). Node B eliminated. Path A-C established.

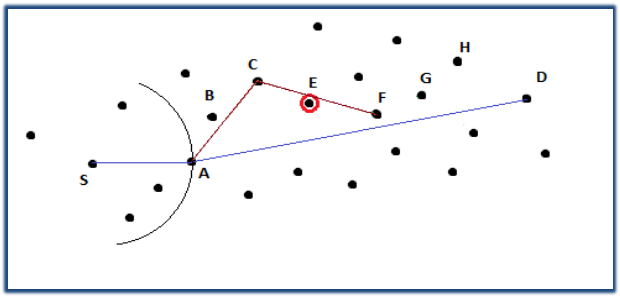

Figure-3(d). Node E eliminated. Path A-C-F established.

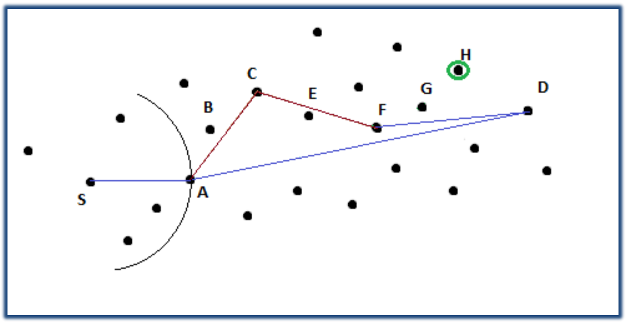

Figure-3(e). Farthest node H from line F-D chosen.

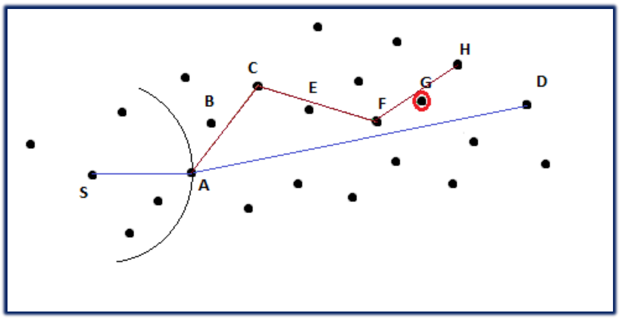

Figure-3(f). Node G eliminated. Path A-C-F-H established.

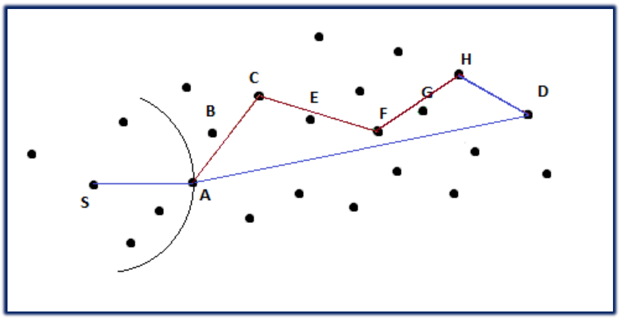

Figure-3(g). No farther nodes to choose.

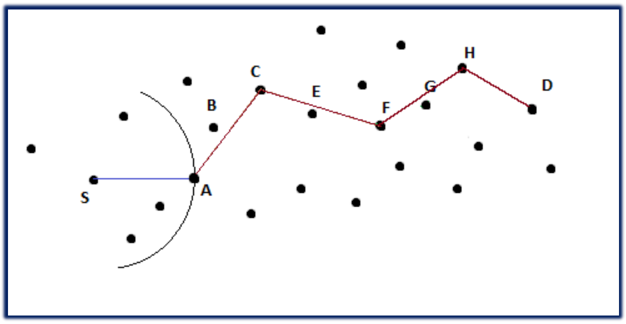

Figure-3(h). Path A-C-F-H-D established.

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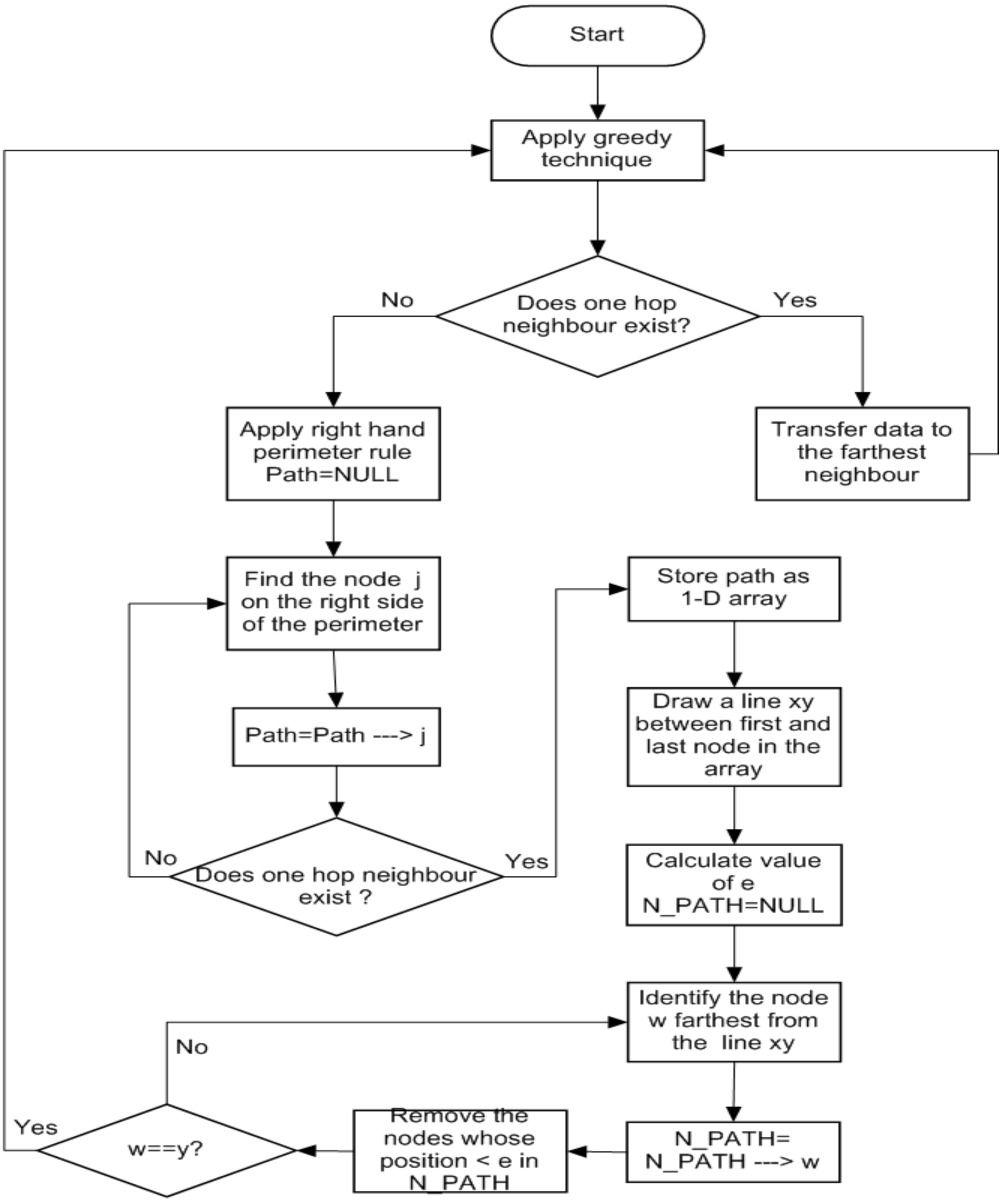

Figure-4. Flowchart for optimized geographic routing protocol.

A. Pseudocode of OGRP

Begin

Step 1: Start with greedy mode

Step 2: Greedy mode

a. Identify the neighbour closest to the destination
b. Forward the packet to the chosen neighbour
c. Repeat steps 2a. and 2b. as long as there is a one hop neighbor towards the destination
d. If there is no neighbour closer to the destination, go to step 3

Step 3: Perimeter mode

a. Follow either right hand or left hand perimeter rule so that there are no loops in the path
b. Store the path obtained in step 3a as a one dimensional array

Step 4: Ramer Douglas Peucker algorithm

a. To find the shortest distance between points in a curve, set epsilon (e) > 0 and maximum_distance=0
b. Draw a straight line between the start node and end node of the perimeter route.
c. Identify the node x farthest from the line and compare it with e.

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d. If the node x's distance is greater than epsilon, split the line into two line segments: start node to node x and node x to end node.
e. Eliminate the nodes whose distance are less than epsilon
f. Repeat step 4c to 4e for each line segment till no more line segments can be formed
g. Form the final route with the available line segments

End

B. Time complexity analysis

The time complexity of Greedy Forward is O(N). In Perimeter routing the Right Hand forward implements the right-hand rule of traversing through nodes forming a polygon. The time complexity to perform the right-hand traversal operation is,

O(cN)=O(N)

where N is the number of neighbors in the polygon and c (0 < c < 1) is the time taken to perform NORM (normalizes argument in radians by repeatedly adding 2π). Face-Change operation is performed when a node enters perimeter mode to check whether the traversed edge is entering into a loop. If it enters a loop the packet is dropped. The worst-case time complexity in perimeter mode for Face-Change is $O(N^C)$. So the worst-case ime complexity of GPSR Routing is $O(N^2)$.

Partitioning the input polyline with „N" vertices require identifying all the vertices which intersect the support line. This is done in time O(N). For an N vertices input polyline expected time-complexity is described by the linear recursion,

(N) = 2T(N⁄2) + O(N).

The solution to this scenario is explained in Master's theorem where,

T(N) ∈ O(NlogN).

Number of polylines "L" in the output is less than the number of output vertices "M". Thus the worst-case time complexity is O(MN) where N and M are the number of vertices in the input and output polylines respectively.

The above time complexity calculations clearly show that even under worst case scenario, optimizing the path length using Ramer-Douglas-Peucker algorithm will result in better performance than the existing GPSR algorithm.

5. SIMULATION AND RESULTS

The simulation has been carried out using Open Street Map (OSM) and the traffic simulator SUMO v.19 and the network simulator NS-2.34.

The simulations were done in a two lane grid topology of size 1000m x 1000m with varying vehicle densities. The performance of the protocol has been analyzed in fixed traffic pattern as well as random traffic pattern. The vehicle density varies between 10/Km to 40/Km with a variable speed of 20km/hr to 60km/hr. The propagation model used is two-ray ground model with a transmission range of 250m and a constant bit rate data packet with a size of 512bytes. The data packets have been transmitted at the rate of 2packets/s. The simulation runs have been carried out 8 times for a period of 1000s/simulation and the average values were used to represent performance of the proposed protocol. The value of e is varied between 0.4 and 0.7 to analyze the number of hops. The performance of the proposed protocol is shown in Figure-5.

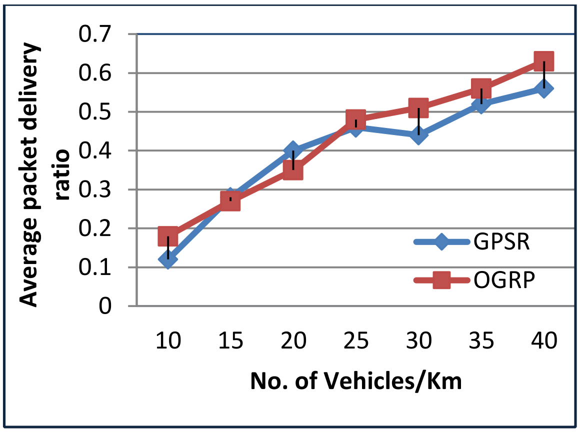

Figure-5(a). Packet delivery ratio.

The packet delivery ratio is shown in Figure-5a. It is seen that as the vehicle density increases the delivery ratio also increases. But in a trial run where the vehicle density is > 50, it was observed that the delivery ratio decreases due to frequent changes in the network connectivity. From the figure it is evident that the packet delivery ratio of OGRP is better than GPSR. This is due to avoidance of loops in the perimeter mode by OGRP thereby increasing the packet delivery ratio.

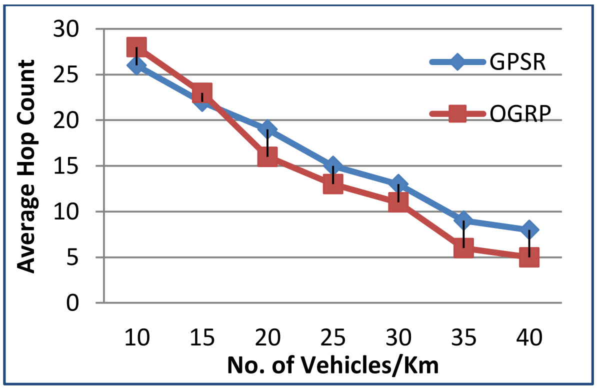

Figure-5(b). Average hop count.

The average hop count of the protocols OGRP and GPSR are shown in Figure-5b. The figure clearly shows that OGRP has lesser number of hops than GPSR. This is due to the fact that using the curve simplification algorithm in the perimeter mode it is possible to identify the intermediate nodes towards the destination within the transmission range instead of the immediate node. This considerably reduces the number of hops made to reach the destination.

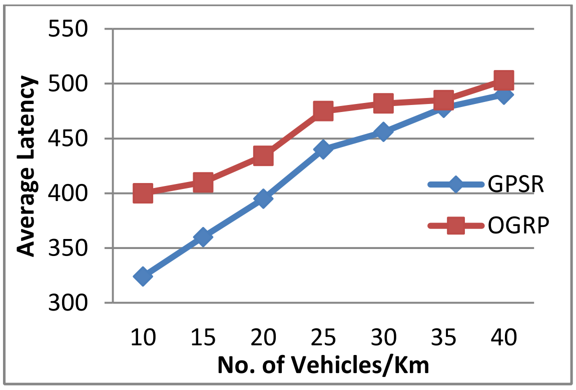

Figure-5(c). Average end - end delay.

The average end-end delay is shown in Figure-5c. The average delay of OGRP is higher than GPSR when the vehicle density is lesser. As the density increases, the average delay is almost similar to that of GPSR. The increase in the delay time is due to the path identification in perimeter mode and then eliminating the intermediate nodes. As the vehicle density increases the frequency at which the vehicles switch to perimeter mode reduces which enables OGRP to behave similar to that of GPSR.

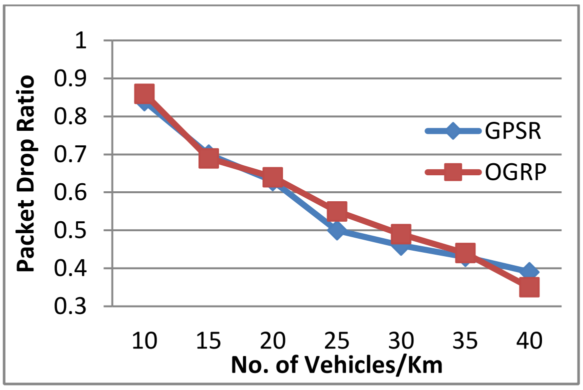

Figure-5(d). Packet drop ratio.

The average packet drop ratio is shown in Figure-5d. An improved packet delivery ratio showed in Figure-5a in turn results in a reduced drop rate. As is evident from the figure, the drop rate of OGRP is considerably less or almost similar to that of the GPSR.

6. CONCLUSIONS

Recovery strategies adopted for greedy routing plays a crucial role in the efficiency of the routing protocol. The OGRP protocol focused on reducing the number of hops a packet has to come across in the perimeter mode using RPD algorithm. The time complexity analysis for worst case scenarios without RPD algorithm and with RPD algorithm has been carried out. Based on the analysis, it is concluded that the path established by GPSR can be further optimized by reducing the hop-count using the Ramer-Douglas-Peucker algorithm. The same has been proved by the simulation results.

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