International Journal of Computational Engineering Research||Vol, 03||Issue, 12||

Geographic Routing In Vanets: A Study

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ABSTRACT

Vehicle Ad hoc Networks are extremely mobile wireless ad hoc networks aimed to support vehicular safety and other viable applications. Vehicle-to-Vehicle (V2V) communication is significant in providing a high degree of safety and convenience to drivers and passengers. Routing in VANET is an important issue. Due to dynamic nature of the vehicles, the networks topological changes are very frequent and hence Position based routing protocols are found to be more suitable to VANETs. In VANETs, Position based routing protocols are used for routing messages in greedy forwarding way. In this study, an evaluation of the existing position based routing protocols in VANETs has been carried out. Different characteristics used for evaluation includes forwarding strategy, recovery strategy, position information and mobility management

KEYWORDS—*VANETs, beacon message, DGRP, A-STAR, VGRS, GPCR, GSR.*

I. INTRODUCTION

Road accidents cause loss of materials and even lives. Accidents are caused mainly because of violation of traffic rules. If we would be able to perfectly perceive the violation of these rules, then its sure that there will be lesser accidents and traffic will be managed more efficiently. Therefore, due to the necessity of the hour and also because of the existence of advanced network technologies, communication community have recently proposed the concept of Vehicular Ad hoc Networks (VANETs). VANETs are a category of ad hoc networks that is aimed to monitor the traffic, which enables the vehicles communication and help in better implementation of traffic rules hence accidents are reduced and the traffic can be managed more efficiently. VANETs are helpful in improving the transportation system, increasing safety of moving vehicles and are also helpful in providing other applications of desire to moving vehicles. Existing wireless networks can also be integrated with these networks to enhance the connectivity while moving. An overabundance of applications concerning to accident aversion, traffic efficiency and infotainment are also enabled with the commercial establishment of vehicular networks. VANETs resemble the operation technology of MANETs in the sense that process of self-organization and self-management criteria remains the same. However, high speed, uncertain mobility and hard delay constraints of the mobile nodes travelling along fixed paths are the differentiating characteristic of VANETs. The rest of this article is organised as follows. In section II various existing Routing protocols in VANETs are explained. Section III specifically Position based routing protocols are elaborated in detail. Finally in section IV a comparison and discussion of the existing geographical based routing techniques have been carried out.

II. ROUTING PROTOCOLS IN VANETS

Routing in VANETs can be broadly classified into: position based/geographic routing, cluster based routing, broadcast routing and geo-cast based routing. In cluster based routing each cluster is represented by a cluster head. Inter-cluster communication is carried through cluster heads whereas intra-cluster communication is carried through direct links. COIN[1] and LORA-CBF[2] are a few examples of this category. Broadcast based routing protocols include simple flooding techniques or selective forwarding schemes to counter the network congestion. BROADCOMM[3] and HV-TRADE[4] are examples of broadcast based routing protocols. Geocast based routing is location based multicast routing protocol. Each node delivers the message to other nodes that lie within a specified predefined geographic region based on ZOR(Zone of Relevance). The philosophy is that the sender node need not deliver the packet to nodes beyond the ZOR. GeoCast[5] and GeoTORA[6] are some examples of the geocast routing techniques. Position based/geographic routing employs the awareness of a vehicle about the position of other vehicles to develop a routing strategy. Previously proposed position based/geographic routing protocols include A-STAR[7], GSR[8], GPSR[9], GPCR[10], DGRP[11] and VGRS[12]. In this paper position based routing protocols are discussed further in more details.

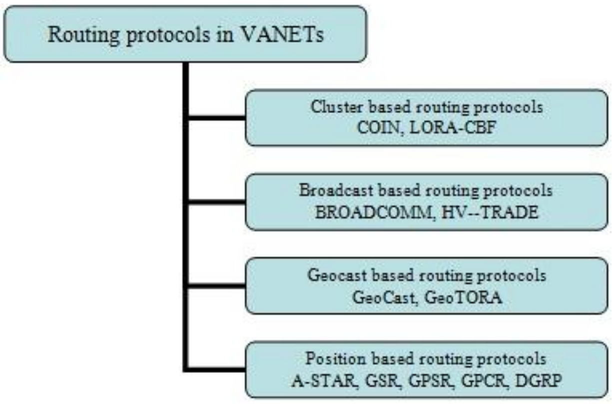

Figure: Categories of routing protocols in VANETs

A. Position Based Routing Challenges

VANETs have certain unique characteristics which make the position based routing in VANETs quite a challenging task[13]. The topology of VANET is highly dynamic owing to the movement of vehicles at very high speed. When two vehicles are exchanging information at such a high speed, frequent disconnection takes place, which make the communication between the vehicles very challenging. The mobility pattern also adds to the challenges as it is very random and depends on traffic environment, roads structure, the speed of vehicles, driver's driving behaviour etc. etc.. The communication environment also keeps on changing between dense and sparse, hence, the routing approach is quite different in both the scenarios. All these challenges add up to make position based routing quite difficult in VANETs.

III. POSITION BASED ROUTING

Following are the various Positions based routing techniques available in VANETs:

A. Greedy Perimeter Stateless Routing

Greedy Perimeter Stateless Routing (GPSR) [9] is one of the most important protocols of position based routing. In this approach, greedy forwarding method is used in which the neighbour closest to the destination is used for forwarding the packet. All the devices are equipped with GPS, which provides the current location of the nodes and helps in packet forwarding decision. Each node has information about nodes current position and also its neighbours and the neighbours also assist in making the packet forwarding decision. GPSR protocol is devised into two parts, one is the greedy forwarding and the other is perimeter forwarding. In greedy forwarding, the node that is closest to the destination is used to send the data. As the sender node knows the destination node, so the greedy nodes are chosen (nodes closer to destination) till the packet is delivered to the destination. Perimeter forwarding is used where the greedy forwarding fails that is where there no node closest to the destination. In other words we can say that when no next hop closest neighbour is available for forwarding the data packet, the perimeter forwarding is used. In perimeter forwarding, the nodes in void region are used to forward the packet to the destination making the use of right hand rule. In "right hand rule" [9], the paths are traversed in the clockwise direction in the void regions in order to reach the destination.

Besides some of its characteristics, GPSR suffers from several drawbacks. In case of the vehicular nodes, the greedy forwarding method is highly unsuitable owing to their high mobility. To maintain the next hop neighbour information is very difficult, as it may go out of range. As a consequence it will lead to the packet loss. GPSR suffers from another problem that is the beacons, which may be lost due to channel destruction or bad signal. As a result it can lead to removal of neighbouring formation from location table [14].

As a repair strategy when greedy forwarding fails, GSPR uses planarized graphs. But these too perform well only in highway scenarios where there are no radio obstacles [8]. In case of existence of radio obstacles, their distributed nature may lead to certain partitions of network and may lead to packet delivery impossible. Hence there is a need of position based routing protocols that merge position information with the road topological structure, to make vehicular communication possible in presence of radio obstacles.

B. Geographic Source Routing-GSR

GPSR encounters problems in the presence of the radio obstacles; therefore, there arises a need of a better position routing protocol that can overcome this problem. Geographic Source Routing (GSR) is proposed to solve the same [8]. This routing protocol deals with the problem of the high mobility of the nodes and also makes the use of the road map information. GSR uses “Reactive Location Service (RLS)” to find the destination node. Both the geographic routing and the road route information are used to deal with problem of the radio obstacles in GSR [8]. In case of the highway area where there are lesser obstacles in between the direct communication of the nodes, GPSR works well, whereas in case of city area numbers of obstacles are more which may create problems in direct communication among nodes. Therefore, GSR routing was proposed to deal with challenges faced by GPSR in city environment. In city area also there are two main challenges one is the dealing with the mobility issue of the vehicles and the other is the topological structure of the roads [8]. In GSR the second challenge is dealt by the use of the road map in making the routing decisions. Nowadays the vehicles come equipped with the GPS so making the use of the map routing decision is easy. RLS is used for position discovery in reactive position-based routing which works on the principle of the request and reply method. A source node broadcasts a message “position request” with some identification of the destination node. When a node with the same identification as contained in the broadcasted message receive it, will reply to it with the “position reply” message along with its current location information [8]. The sender node uses the road topology map to find the shortest route to the destination. In GSR the source node finds the shortest path to destination on the graph using simple graph algorithms [16] and mark the packet with destination´s location. In this the packet travels through junctions to reach the destination. GSR use “switch back to greedy” method for local recovery [15].

C. Anchor-based Street and Traffic Aware Routing- A-STAR

Anchor-based Street and Traffic Aware Routing (A-STAR) is one of the position based routing protocol that is developed keeping the city environment in consideration. Routing in city area is a very challenging task owing to the fact that big buildings cover almost all roads and streets. These challenges are being dealt to some extent with the help of the GSR as discussed in the previous section. In A-STAR, two routing schemes are used together that is anchor based routing and spatial based routing [16]. In anchor based routing, before transmitting the packet, the source node adds the source address and the information of the entire intermediate node junction in the header that the packet must travel to reach the destination [16]. Spatial based routing is the routing based on the city map and the road information. Spatial awareness is used to get topology information and different nodes position in the network. Mostly anchor based routing and spatial aware routing are used together [16]. In position based routing, every node sends its current position by a beacon message and every node knows its neighbour nodes. When a source sends message to the destination, it uses the geographic location of the destination.

In case of the city scenario when a source node wants to send data packet to destination, there are buildings between source and destination and there is no node closer to destination. In case of GPSR, the path to the destination is selected on the basis of the right hand rule only and no shorter route is considered. Packets traverse hop-by-hop until it finds a node nearer to the destination. This way of routing is not efficient in terms of time or processing. Both GSR and A-STAR are proposed for the city scenarios. Both of these compute the number of junctions to reach the destination but in addition to these, A-STAR also uses street awareness and traffic information in route finding [17]. In street awareness, A-STAR gets the anchor information according to the street map. A-STAR has two new features in addition to the GSR that makes its working quite different. It uses statistically and dynamically rated maps to find the number of junctions. In case of the statistically rated maps, A-STAR makes the use of the route map of the buses in order to ensure the high connectivity. In dynamically rated maps, A-STAR makes the use of the latest information of traffic to compute the number of junctions to compute the path to destination. For example consider the case where some roads are wider than other so there is more traffic. It means that connectivity is high on wider roads with high traffic (more vehicles). Using this traffic information A-Star assign the weight to the street [17] e.g. more vehicles less weight and less vehicles more weight. The junctions calculated dynamically by this method are more accurate [16].

In case of the city environment the recovery strategies of both the GPSR and GSR i.e. perimeter mode and switch back to the greedy method are inefficient. A-STAR makes use of a new recovery strategy. In A-STAR, the junctions are marked “out of service” and “operational” depending on the junctions able to route the packet to the destination. When a packet faces problem to pass through a junction, that junction is marked as “out of service” and other packets are restricted to traverse that junction until that junction changed to “Operational” state [16]. Whenever a junction is out of order all the nodes in the network are informed about it and their routing tables and city maps are updated with this information so that no node will use that junction as anchor to be traverse to reach destination. In future, when that node becomes operational, all the nodes are again informed about it and their routing tables are updated and that junction may be used for routing in future depending on the requirements. So as compared to other position based routing protocols, A-STAR adopts higher connectivity anchor based paths to find the route towards destination in large city environments.

D. Greedy Perimeter Coordinator Routing-GPCR

Greedy Perimeter Coordinator Routing (GPCR) [10] is another position-based routing protocol. It makes the use of the planar graphs. The streets and the junctions in city form planar graphs. Instead of using the static street maps or any other global or external information like the one used in A-STAR and GSR, GPCR makes the use of the natural planar graphs formed by the streets and junctions. It consists of two processes, one is the main procedure of forwarding the packet that is called as restricted greedy forwarding procedure and the other is the repair strategy, which is based on the topology of real-world streets and junctions so there is no need of graph planarization algorithm as the one used in GPSR. Restricted greedy forwarding is a special case of the greedy forwarding. In the city scenario as the buildings or the obstacles block the signal to be transmitted through, the data packets are routed along the streets only. So in that case the junctions are the only place where the actual routing takes place. The strategy should always be to forward the packet to the node at the junction instead of through the junction. The nodes present at the junction are called as *coordinator* [10]. Whenever a node becomes a coordinator it broadcasts its role that is as being a coordinator and its current location to the other nodes in the network. Depending on the forwarding node is a coordinator or not there are two ways of forwarding. If the forwarding node isn't a coordinator then the packet is forwarded along the street to the next junction. The forwarding node selects those neighbors who lie on the line of extension between the forwarding node itself and its predecessor. Out of these qualified nodes if still there is no coordinator then the next node is chosen on the basis of greedy method in which the node, which is most far from the forwarding node is chosen. If among the nodes in the line of extension is also a coordinator node then one of the coordinator node is chosen randomly. Following this method the packet won't be forwarded across the junction. So now the packet is with the coordinator node, and the decision is to be made as to which street to follow. The neighboring node with the largest progress towards the destination is chosen. This implies a decision on the street that the packet should follow. Although there are lots of improvements in the restricted greedy routing over the greedy routing of the earlier protocols discussed but still there are chances that the packet might get struck in the local maximum. So this requires a repair strategy. The repair strategies of the earlier protocols were based on the graph planarization algorithm based on the connectivity of the individual nodes. This doesn't form any natural planar graph but instead in case of the GPCR the recovery strategy is based on the natural planar graph formed by the street and the junctions. As a result of this the repair strategy of GPCR consists of two parts one is on each junction it has to be decided which street the packet should follow next and the second one in between junctions greedy routing to the next junction, as described above, can be used. If the forwarding node for a packet in repair mode is located on a junction (i.e., it is a coordinator) then the node needs to determine which street the packet should follow next. To this end, the topology of the city is regarded as a planar graph and the well known right-hand rule [9] is applied.

E. Directional Greedy Routing Protocol-DGRP

It is like GPSR in the way it uses two forwarding strategies greedy and perimeter. But unlike GPSR its decision of next hop doesn't only depend on one hop neighbour location information but also their speed and direction of motion. To get the most accurate current position of the nodes, GPSR need to send the beacon message very frequently. But owing to the high speed of the vehicles there are still chances of packet dropping no matter how frequently the packet is sent. In DGRP [11], speed and direction are also taken into account to predict the most accurate next hop neighbour so that the chances of packet dropping are least. It makes the use of the location prediction method in which each node can find its speed and direction information provided by GPS. This information is passed to 1-hop neighbours in beacon packets. Each node updates its neighbour's information in its neighbouring table from these beacons [11]. For example, if position of the node X at time t_0 is (x_a, y_a) and at time $(t_0 + t_b)$ is (x_b, y_b), where t_b is beacon interval, then direction and speed of A can be found using the following equations,

$$\Theta_A = \tan^{-1} Y_b\text{-}Y_a / X_b\text{-}X_a \qquad (1)$$

$$Speed_X = ((X_b\text{-}X_a)^2 + (Y_b\text{-} Y_a)^2)^{1/2} / t_b \qquad (2)$$

Node A can find the current position of (X_c, Y_c) of node Y at time t_1 using the information available in the neighbouring table as follows:

$$X_c = X_c' + speed_Y * (t_1 - t_0) * \cos(\Theta_Y) \qquad (3)$$

$$Y_c = Y_c' + speed_Y * (t_1 - t_0) * \sin(\Theta_Y) \qquad (4)$$

Where, $speed_Y$: indicates the speed of node Y, t_0: previous position update time, and (X_c', Y_c') : position of node at time t_0. In this way each node can predict the location of any of its 1-hope neighbours, irrespective of the beacon interval. This leads to reduction in accurate location problem and number of the retransmissions.

F. Novel Geographic Routing Strategy-NGRS

Like DGRP, VGRS[12] also broadcasts the beacon messages periodically to obtain the information of the neighbouring vehicles. The beacon message consists of position, velocity, and direction as acquired by GPS. When a vehicle knows that it is located at the intersection, it broadcasts a beacon message to inform its neighbouring vehicles. The routing takes place in two scenarios, whether the node is at straight road or on the intersection. In case of the straight road scenario, the greedy forwarding is used. But the greedy forwarding in this case is different from the greedy forwarding in case of GPSR. In this case the concept of vector is used to choose the next hop so that accuracy can be improved. In case of the intersection node the greedy mode is changed to the predictive mode. This protocol suffers from the local maximum problem for which right hand rule is used to forward the packet to the intersection for the decision-making.

IV. DISCUSSION AND CONCLUSION

In the previous sections, we discuss extensively the various position based routing protocols in VANETs given the challenges identified in their environments. Now, we revisit the routing protocols proposed for VANETs that were surveyed in Section III and summarize and compare the properties they can achieve in Table I. From this table, we can conclude that there is a gradual improvement in the routing protocols but none of the protocols have developed an effective routing strategy.

Evaluation Strategy	GPSR	GSR	A-STAR	GPCR	DGRP	VGRS
Forwarding strategy	Greedy forwarding	Reactive location service	Anchor based routing	Restricted greedy routing	Greedy forwarding	Greedy mode (straight road) and predictive mode (intersection)
Recovery strategy	Right hand rule	Greedy mode	New anchor path	No use of planar graph	Perimeter mode	Right hand rule
Position information	Packet forwarding	Message broadcasting	Traffic awareness rated map	Beacon message (position)	Beacon message (position, velocity, direction)	Beacon message (position, velocity, direction)
Mobility movement	Random wave point	Optimal velocity model	M-grid model of Manhattan	Real city scenario	Manhattan mobility model	MOVE, SUMO

TABLE 1: COMPARISON OF ROUTING PROTOCOLS

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