Impact of Directional Density on GyTAR Routing Protocol for VANETs in City Environments

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***Abstract*—Vehicular ad hoc networks are highly dynamic and their topology changes frequently due to high speed of vehicles. This result in disconnected networks, therefore, designing a routing protocol for such network is challenging task. The two most important factors which effect routing in vehicular ad hoc networks are Speed and direction. In this work, we propose a novel routing protocol (E-GyTAR) motivated from GyTAR, which was specifically designed for city environments. This paper presents the effect of speed and direction on routing protocol in city environment. City environment consists of junctions and these junctions are selected dynamically on the basis of vehicular speed and directional density. Simulation results show that E-GyTAR incurs less packet loss, and end-to-end delay.**

Keywords-Greedy Forwarding, Vehicular Ad hoc Network, and Position based Routing

I. INTRODUCTION

VANETs are the self-organized networks, composed of mobile nodes capable of communicating in infrastructure less environments. Advancement in wireless technologies [14] has made it possible for vehicles [11] to communicate with other vehicles without installment of any infrastructure; thus reducing deployment cost.

VANETs support a number of applications [8, 13, 14] ranging from the performance of transportation system to facilitate the safety on the roads. They also support comfort applications such as chat, web browsing, and video and game downloads. The concept of VANETs is derived from Mobile Ad-hoc Networks (MANETs). MANETs are composed of mobile nodes which communicate in infrastructure less environment. In MANETs, every node plays two roles, data terminals as well as data transfer equipments [17]. VANETs follow the same idea of MANETs except that the nodes are vehicles. As the vehicles have greater speed and moves on specific paths like roads, so VANETs have different characteristics than MANETs which make them much more challenging. VANETs are highly dynamic and their topology frequently changed due to high speed of vehicles, causes the network to be partitioned into several parts. One solution is to deploy the access points along the road. Vehicles will not be able to communicate if the distance between them is more than transmission range of the vehicle. The mobility not only changes the topology of the network frequently but it also leads to network partitioning; hence, link failures caused by mobility of nodes poses different challenges for routing in vehicular ad hoc networks. Path breakage due to high mobility of nodes results in substantial increase in packet delay and packet loss. The movement of nodes in VANETs is constrained by the layout of roads as well as by traffic regulations. There are two different communications environments for vehicular ad hoc network; high-way and city environments. In a high way traffic scenario, radio obstacles are less as compared to city environment, and nodes can communicate with others in its transmission range. City environment consists of different type of radio obstacles, for instance, buildings, trees, and other obstacles which degrade the signal strength. Due to low speed of vehicles in city environment, the chances of network partitioning are less whereas in highways, base stations are needed to overcome the problem of network partitioning causes due to high speed of vehicles. The other difference between the two communicating environments is the speed of the vehicles on the road. In a highways, the vehicles move with high speed while vehicles move with low speed in city environment. The routing in city environment is relatively complex than routing in highways [10]. We design the routing protocol by considering the city environment characteristics.

This paper presents a new position-based routing protocol called Enhanced GyTAR (E-GyTAR) for VANETs. It is designed for city environment and considers the real time city environment configuration with bi-directional and multi-lane roads. It takes into account the vehicle's speed and direction to select the junction and route the data packets. The new junction selection mechanism increases packet delivery ratio and decreases end-to-end delay.

The rest of the paper is organized as follows. Section 2 explains the existing position based routing approaches. Proposed routing protocol is presented in section 3. Section 4 presents the simulation results and analysis and finally we conclude in section 5.

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II. Position Based routing approaches

Today modern vehicles are equipped with digital maps, GPS receivers, and a navigation system. Therefore, the availability of position in vehicles motivates the study of position based routing for VANETs. It is shown experimentally that position based routing protocols outperforms non-position based schemes. Position based routing protocols scale well, even in the case of highly dynamic networks. In [5, 8], the authors compare the performance of ad hoc routing protocols (e.g., AODV and DSR) against position-based routing protocols. Many position-based routing protocols have been proposed in literature [1]; a few of them are described here.

Greedy Perimeter Stateless Routing (GPSR) [9] is designed to handle mobile environments. GPSR works well in a highway scenario where the nodes are evenly distributed but suffers in a city environment due to presence of obstacles and because of these obstacles it switches to face routing. Geographic Source Routing (GSR) [11] and Anchor-based Street and Traffic Aware Routing (A-STAR) [12] both are designed for routing in the city environment. Both routing protocols suffer from the simple greedy routing approach (forwarding the packet to the one which is closest to the destination) without taking into account the speed and direction of the vehicle before selecting the destination junction or anchor.

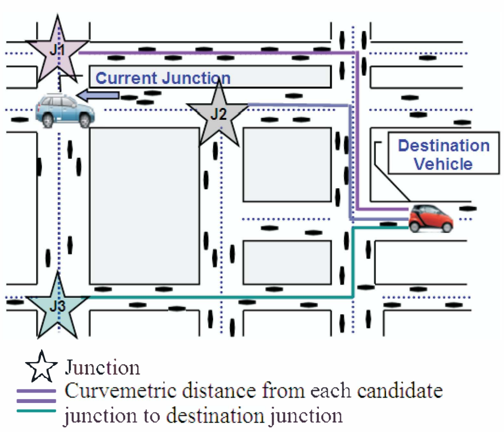

Figure 1. Problem in GyTAR junction selection mechanism.

Improved Greedy Traffic Aware Routing protocol GyTAR [7] is geographic routing protocol which dynamically selects junction on the basis of traffic density and curvemetric distance to the destination in order to find robust routes within the city. The use of digital maps is helpful to find the position of neighboring junctions. The junction who has the highest score is selected as a next destination junction on the basis of vehicular traffic density and curvemetric distance to the destination. Thus, it selects the next junction who has higher vehicular traffic and geographically closest to the destination junction.

GyTAR has some limitations [1, 19]. First, it does not consider the direction of vehicles before selecting the next junction. As a result, GyTAR can select the junction which has higher traffic density but vehicles move opposite to direction of destination as shown in figure 1. In figure 1, all the vehicles moves towards current junction from junction J2. In this scenario, GyTAR selects J2 as a next destination junction without taking into account the directional density i.e., number of vehicles moving in the direction of destination from current junction to junction J2. Second, GyTAR suffers from local maximum problem as all the vehicles have moved away. In this scenario, packet travel towards current junction resulting in increased end-to-end delay and decreased packet delivery ratio. This problem can be addressed by measuring the directional density before selecting the next junction.

III. Enhanced GyTAR routing protocol

Enhanced GyTAR (E-GyTAR) is an intersection-based geographic routing protocol which is the enhanced version of GyTAR routing protocol. It uses directional density to its good effect. It consists of three modules (1) enhanced junction selection mechanism, (2) data forwarding, and (3) recovery strategy.

A. Assumptions

We assume that GPS device is incorporated in vehicles through which vehicle finds its own position. Furthermore, information regarding destination vehicles is provided by a location service like GLS (Grid Location Service) [15] or HLS (Hierarchical location services) [18]. Source vehicle can not route the data packets with out knowing the geographical location of the destination. Junctions are vital component in routing protocols. Most of routing protocols use them as anchors. Packets travel anchor-by-anchor to reach the destination. This information of anchors or junctions is provided by the pre-loaded digital maps. Modern vehicles are equipped with navigation system. This system contains digital maps for navigation purpose which provide street level map. So, it becomes valid assumption under the circumstances.

We also assume that every vehicle is aware of the vehicular traffic density which makes it possible to select the junction having highest vehicular traffic density in the direction of destination. Vehicular traffic density means the number of vehicles between two junctions. A distributed mechanism is proposed to find the vehicular traffic density between two junctions [16]. On the basis of above-mentioned assumptions, we give a detailed description of our proposed routing mechanism.

B. Enhanced Junction Selection Mechanism

In E-GyTAR, junctions are selected dynamically, one by one while taking into account the number of vehicle(s) moving in the direction of candidate junction and curvemetric distance from candidate junction to the destination, and then set the score of each candidate junction accordingly. The junction with highest score is selected as a next destination junction. Thus, packets travel between the two junctions having higher directional density. To assign the score to each candidate junction, we used the formula:

$$(N_j) := \alpha \times \lfloor D_j \rfloor + \beta \times \lfloor T_j \rfloor$$

Where α and β are the weighting factors having value 0.5 each. Number of vehicles moving from the current junction to each candidate junction (directional density) is represented by D_j and T_j represents the curvemetric distance. As shown in Figure 1, the E-GyTAR selects J_3 as a next destination junction on the basis of directional traffic density which causes the packet to travel along the street having higher number of vehicles moving in the direction of destination, thus, reduces end-to-end delay. The other advantage of selecting J_3 as a next destination junction is to avoid the local maximum problem which occurs when selecting J_2 as a next destination junction. It increases the probability of connectivity which effects the packet delivery ratio as well.

The problem with GyTAR is that it doesn't take into account the information of direction of each node. As a result, GyTAR can select the junction which has higher traffic density but vehicles move opposite in direction of destination. So there are chances of less connectivity in selected junction which can also effect the routing between junctions as shown in Figure 1. In above figure, GyTAR selects J2 as a next destination junction which is the closest junction to the destination having highest vehicular density but all the vehicles move opposite to the direction of destination. In this scenario, packet may travel towards current junction which increase the end-to-end delay and also affect the packet delivery ratio. This problem can be solved by carefully selecting the next junction.

C. *Routign Between Junctions*

E-GyTAR uses the improved greedy approach to route the packets between the two involved junctions as presented by GyTAR protocol [7]. Each vehicle maintains the neighbor table which is updated periodically in which it records the speed, velocity, and direction of its neighbor vehicles.

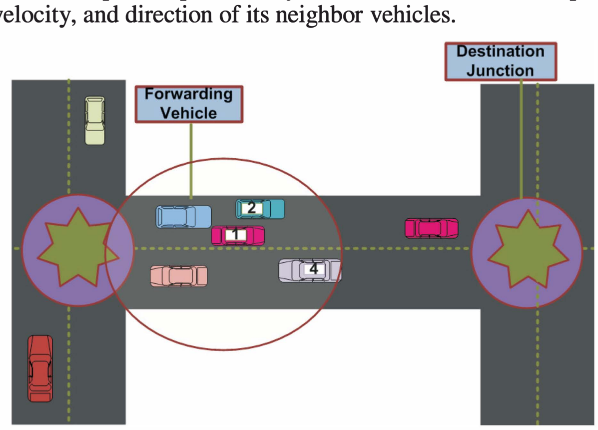

Figure 2. Routing between junctions

When the source vehicle needs to forward the data packets, it consults its neighbor table to find the new predicted position of neighboring vehicles.

When forwarding vehicle wants to forward the packet towards destination junction at time t1, it will consult its neighbor table and finds vehicle (2) is closest vehicle to the destination junction moving in the same direction as the forwarding vehicle as shown in figure 2. Vehicle (1) also moving in the same direction and has greater speed than vehicle (2). Forwarding vehicle will come to know through neighbor table that vehicle (1) will overtake the vehicle (2) at time t2 and it becomes closest vehicle to the destination. So, forwarding vehicle will select vehicle (1) as a next hop. With out the use of prediction mechanism, vehicle (4) will be selected as a next hop.

D. *Recovery strategy*

With the introduction of directional traffic density, curvemetric distance, and improved greedy routing approach, there are still chances that packet gets stuck in local maximum problem. E-GyTAR uses carry and forward approach in order to recover from the local maximum problem. The forwarding vehicle will carry the packet until next junction or another vehicle enters its transmission range.

IV. SIMULATION AND RESULTS

To evaluate the performance of proposed technique, simulations are carried out in a network simulator GLOMOSIM (Global Mobile system Simulator) [3]. To evaluate the proposed technique, other routing protocols (GyTAR and GSR) are also implemented in GLOMOSIM.

The selection of the mobility model for VANETs simulation is important because it should reflect as closely as possible the real vehicular activities. The mobility model also affects the performance of protocols as explained in [4]. The vehicular mobility pattern is generated by using VanetMobiSim [6], which simulates a 2500×2000 m^2 area. VanetMobiSim can support the micro and macro mobility and it is an extension for the CANU mobility simulation environment [2]. Multi-lanes, multi-directional roads, and other road variations are also considered during simulation. All the other parameters are summarized in table 1.

TABLE I. SIMULATION SETUP

SIMULATION/SCENARIO		**PARAMETER SETTING**	
Simulation Time	200s	Number of vehicles	75-200
Map Size	2500 x 2000 m^2	Vehicle speed	35-60 Km/h
MAC protocol	802.11 DCF	Transmission Range	266 meter
Number of intersection	16	Traffic Model	15 CBR connection
Number of roads	24	Packet size	128 byte

In Figure 3, we measured the packet delivery ratio against the different (constant bit rate) CBR traffic. E-GyTAR achieves the highest packet delivery ratio than the other protocols. This is because in E-GyTAR, the junction is selected by taking into account the directional traffic density. It increases the probability of connectivity and thus, increases the packet delivery ratio. While in GyTAR, the path is determined by considering only the traffic density. It does not take into account the number of vehicles moving in the direction of destination.

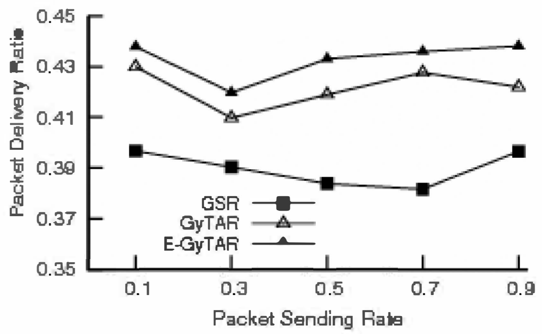

Figure 3. Delivery ratio vs. packet sending rate (175 Nodes)

GSR achieves the lowest packet delivery ratio among all the other protocols. This is because in GSR, the source computes the path which the packet has to traverse in order to reach he destination. It does not take into account the vehicular traffic; hence, it may use those parts of street which has less connectivity which decreases packet delivery ratio.

Figure 4 illustrates the effect of increasing network traffic density. Probability of connectivity increases by increasing the number of vehicles which in turn, increases the packet delivery ratio. So, packet delivery ratio increases by increasing the number of nodes for all three protocols.

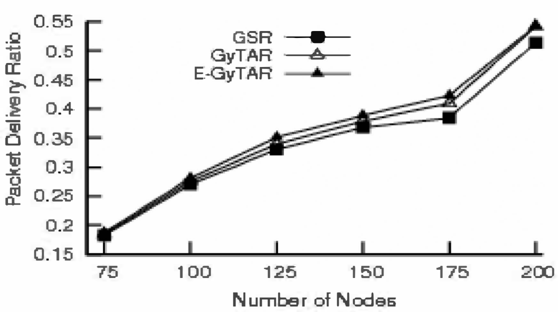

Figure 4. Delivery ratio vs. number of nodes at 5 packets/sec

It has been observed that by increasing the network traffic, the impact of directional traffic density on the routing protocol is substantial decreased because of the fact that, there are enough vehicles moving in opposite direction to provide the connectivity.

GSR does not consider the traffic density which causes delay as shown in Figure 5. GyTAR achieves much lower end-to-end delay than GSR. This is because of the fact that GyTAR uses traffic density during junction selection mechanism but it still selects a junction which has less connectivity in the direction of destination as compared to selects a junction which has higher connectivity in the direction of destination (directional traffic density).

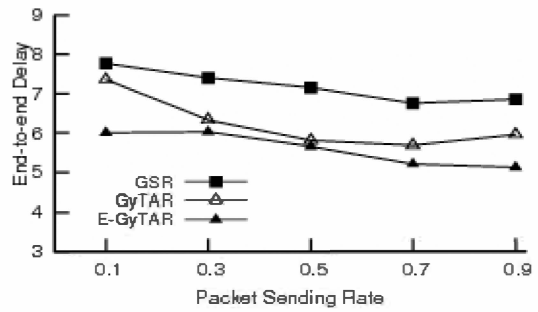

Figure 5. End-to-end delay vs. packet sending rate (175 nodes)

In other words, it may be possible that GyTAR may select the junction which has higher connectivity but not enough vehicles moving in the direction of destination which causes delay. Figure 6 shows decrease in end-to-end delay with the increase in network density. This is because by increasing the network density, the probability of connectivity will be increased which results in decrease end-to-end delay for all the three protocols.

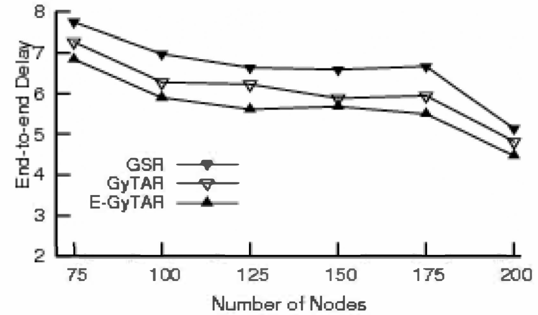

Figure 6. End-to-end delay vs. number of nodes at 5 packets /sec

V. CONCLUSION

This work presents Enhanced-GyTAR protocol based on GyTAR protocol and also shows the impact of directional density on routing protocol for vehicular ad hoc networks especially in city environments. E-GyTAR achieves higher packet delivery ratio and lower end-to-end delay than GyTAR.

As for as future work is concerned, we are currently studying different strategies to make the routing protocol more adaptive to the situation by considering both directional traffic density and non-directional traffic density. We are also investigating different distributed methods for vehicular traffic estimation.

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