Enhanced Junction Selection Mechanism for Routing Protocol in VANETs

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Abstract: *Routing in infrastructure less vehicular ad hoc networks is challenging because of the dynamic network, predictable topology, high speed of nodes, and predictable mobility patterns. This paper presents an enhanced routing protocol specifically designed for city environments. It uses vehicular speed and directional density for dynamic junction selection. Simulation results exhibit increased packet delivery ratio while decreased end-to-end delay when compared with state of the art protocols.*

Keywords: *Greedy forwarding, vehicular ad hoc network, and position based routing.*

Received August 13, 2009; accepted November 5, 2009

1. Introduction

VANETs are the self-organized networks, composed of mobile nodes capable of communicating in infrastructure less environments. Advancement in wireless technologies [33] has helped to integrate the capabilities of wireless networks to vehicles [24] enabling them to communicate without any infrastructure; thus reducing deployment cost. IEEE 802 committee [4] defined standard, IEEE 802.11p [17], for the Wireless Access in Vehicular Environments (WAVE). The Federal Communications Commission (FCC) has allocated 75MHz of bandwidth for short range communications between Vehicle-to-Vehicle communication (V2V) and Vehicle-to-Infrastructure communication (V2I) which operates on 5.9 GHz. Multiple wireless technologies exist such as IEEE 802.11 (Wi-Fi), Bluetooth, WiMax, Cellular, and Satellite Digital Audio Radio Systems (SDARS) but VANETs use Dedicated Short Range Communication (DSRC) [9] due to its low latency and ability to broadcast messages in multiple directions [33]. The range of DSRC is 1000 meters which is suitable for both V2V and V2I. DSRC utilizes bandwidth from 5.850 to 5.925 GHz to increase the productivity and safety of the transportation system [35].

VANETs support a number of applications [19, 28, 34, 35] which improve the performance of transportation system and facilitate the safety on the roads. It also support comfort applications such as chat, web browsing, and video and game downloads. The dynamic nature of network, high speed of nodes, frequent topological changes, and predictable mobility (constrained by the layout of road and traffic regulations) are a few characteristics which make VANETs different from traditional ad hoc networks. The mobility not only changes the topology of the network frequently but also leads to network partitioning resulting in increased packet delay and packet loss. Unlike ad hoc and sensor networks, energy is not an issue for the VANETs because vehicles have rechargeable source of energy. There are many other constraints such as communicating environment (city roads, highways), predictable mobility, and radio obstacles.

This paper presents a new position-based routing protocol which we call 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 properties and characteristics of vehicular ad hoc networks. The existing position based routing approaches are presented in section 3. Proposed routing protocol is described in section 4. Section 5 presents the simulation results and analysis and finally we conclude in section 6.

2. Related Work

Vehicular ad hoc networks have become an active research area for academia and industry due to its applicability in variety of applications, for instance, Intelligent Transportation System (ITS). ITS aims to improve transportation system and safety applications by providing the drivers necessary information related to road and traffic condition [6].

Routing in ad hoc network is a challenging job due to free movement of nodes and rapidly changing topology. The nodes in vehicular ad hoc networks are self-organized and communication is relayed by intermediate nodes. Routing protocols like Ad hoc On Demand Distance Vector (AODV) [30] and Dynamic Source Routing (DSR) [18] are designed for Ad hoc networks especially for MANET applications. The performance of ad hoc routing protocols (e.g., AODV and DSR) in VANETs is extensively studies [11, 19, 27, 29, 31, 34]. Ad hoc routing protocols perform well for static networks but they result in degraded performance when the nodes are mobile because of low communication throughput and poor route convergence. When the nodes are mobile, AODV is not capable of finding, maintaining, and updating routes quickly [34]. Another issue in ad hoc routing protocols is the use of three-way handshake to establish a TCP connection. Therefore, for dynamic network such as VANETs, it is not feasible for TCP to establish a connection under AODV. Thus, some modifications are needed in existing ad hoc routing protocols so that they are customized for dynamic mobile networks [21].

3. Routing in VANETs

It is shown experimentally that position based routing protocols outperforms non-position based schemes [27]. As modern vehicles are equipped with digital maps, GPS receivers, and navigation systems, each node is aware of its own Location-Dependent Address (LDA) [5] via GPS. Therefore, the availability of position in Vehicles motivates to study position based routing for VANETs.

Position based routing protocols scale well even in the case of highly dynamic networks. In [11, 19], the authors compare the performance of ad hoc routing protocols (e.g., AODV and DSR) against the position-based routing protocols. The simulation results show considerable performance improvement in position-based routing protocols and therefore, position-based routing protocols are preferable over non position-based approaches [26]. Many position-based routing protocols have been proposed in literature [1]. Few of them are described here.

Greedy Perimeter Stateless Routing (GPSR) [20] 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 several reasons. Firstly, greedy forwarding suffers in the presence of obstacles because direct communication lack between nodes [21]. Secondly, due to these obstacles, GPSR switches to face routing. Face routing uses longer path to reach the destination resulting in higher delays. Geographic Source Routing (GSR) [24] is designed for routing in the city environment. To acquire the location information of destination node, it uses Reactive Location Service (RLS) [7]. By using digital maps, source *S* knows the position of all the junctions from source to destination *D*. It uses Dijkstra shortest path algorithm to calculate the shortest path from *S* to *D*. The shortest path consists of sequence of junctions (GSR anchors) that the packet has to traverse in order to reach the *D*. As all the data packets in GSR are marked with the location of *S*, *D* and GSR anchors, so GSR does not know if there are enough vehicles on the street to provide the connectivity. Thus, GSR does not consider the vehicular traffic density on the street before selecting the path from *S* to *D*.

Anchor-based Street and Traffic Aware Routing (A-STAR) [32] is a position-based routing protocol designed specifically for inter-vehicle communication in a city environment. City buses are used to determine the anchor paths of higher connectivity. A-STAR removes the limitation of GSR and introduces a new recovery strategy which calculate new anchor path from the local maximum to which the packet is routed. With traffic awareness and new recovery strategy A-STAR outperforms GPSR and GSR [32].

Greedy Perimeter Coordinator Routing (GPCR) [25] is independent of digital map while it is a basic component in the A-STAR and GSR. Digital map is helpful in calculating the path from *S* to *D* based on either Dijkstra shortest path or Dijkstra's least-weight path algorithm. GPCR is based on the idea of always forwarding the data packets to a node on the junction rather than forwarding across the junction. A node located nearest to the junction is known as coordinator. For packet forwarding, restricted greedy approach is used. Coordinator is always preferred over a non coordinator. Once the local maximum occurs, it uses a repair strategy.

Improved Greedy Traffic Aware Routing protocol GyTAR [15] is intersection-based routing protocol which dynamically selects junction to find robust routes within the city. It uses digital map to find the position of neighboring junctions and selects junction dynamically on the basis of traffic density and curvemetric distance to the destination. Score is given to each neighboring junction and the junction with the highest score is selected as a next junction. The selected junction is the one which is closest to the destination and also have the highest traffic density. The improved greedy routing strategy is used to forward the packet between two involved junctions. GyTAR uses carry and forward [22] approach in order to recover from the local maximum.

This mechanism of junction selection results in improved connectivity and thus increases the packet delivery ratio and decreases the end-to-end delay. Before selecting the next junction, GyTAR doesn't consider the direction of vehicles. 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, GyTAR selects J_2 as a next destination junction which is the closest junction to the destination without considering direction of vehicles. As a result, GyTAR suffers from local maximum problem as all the vehicles have moved away. In this scenario, packet may reach current junction resulting in increased end-to-end delay and decreased packet delivery ratio. This problem can be solved by carefully selecting the next junction.

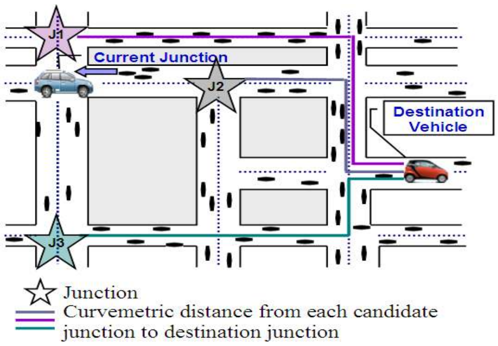

Figure 1. Problem in GyTAR junction selection mechanism.

4. Enhanced GyTAR Routing Protocol

Enhanced GyTAR (E-GyTAR) is an intersection-based geographic routing protocol which uses GPS to find its own position. The position of destination vehicle can be obtained by using location services such as Grid Location Services (GLS) [22]. Each vehicle is equipped with on-board navigation system which determines the position of neighboring junctions and also provides useful street level information through the use of pre-loaded digital maps. It consists of two modules (1) enhanced junction selection mechanism and (2) data forwarding.

4.1. Enhanced Junction Selection Mechanism

In E-GyTAR, junctions are selected dynamically, one by one while considering the number of vehicles moving in the direction of destination and scoring each candidate junction accordingly. The junction with highest score is selected as a next destination junction and is geographically closest junction to the destination.

Algorithm 1 Pseudo code for Enhanced Junction Selection Mechanism

1. For all candidate junctions 'j'.
2. N_j= the next candidate junction.
3. C_j= the current junction.
4. D_n= curvemetric distance from the candidate junction 'N_j' to the destination.
5. D_c= curvemetric distance from the current junction 'C_j' to the destination.
6. D_p= D_n/D_c (D_p determine the closeness of the candidate junction to the destination point).
7. T= total number of vehicles between 'C_j' and 'N_j' moving in the direction of 'N_j', which represents the directional density.
8. $\alpha+\beta=1$ (the weighting factor for the distance and traffic density respectively).
9. score (N_j):= $\alpha\times[1-D_p]$ + $\beta\times[T]$

The selected junction has the higher number of vehicles moving in the direction of destination. To assign score to each junction, we use the following algorithm. As each vehicle is equipped with digital maps, it knows the position of neighbor junctions. The position of destination is available by using location services, therefore, the forwarding vehicle knows the junction which is closest to the destination and this junction is selected as destination junction. Forwarding vehicle then measures the distance from each neighbor junction to the destination junction. According to algorithm 1.

$$(N_j) := \alpha \times \left[1 - D_P\right] + \beta \times [T] \quad (1)$$

where $D_p = D_n / D_c$. We can have two cases for the value of D_p.

(I) When $D_p < 1, \Rightarrow \alpha \times \left[1 - D_p\right] > 0 \quad (2)$

and this will result in positive score.

(II) if $D_p > 1, \Rightarrow \alpha \times \left[1 - D_p\right] < 0 \quad (3)$

and this will result in negative score. The value of N_j determines the closest junction. Therefore, D_p plays an important role and represents the junction which is geographically closest to the destination junction. Forwarding vehicle also measure the vehicular traffic density from current junction to each neighbor junction. T represents the total number of vehicles moving from current junction to neighbor junction which represents the directional density. The calculation of directional density will be described in next section. The score is set for each junction by using the formula: Score $(N_j) := \alpha \times [1 - D_p] + \beta \times [T]$, where α and β are the weighting factors having value 0.5 each. The junction with highest score is selected as next destination junction, which is also geographically closest junction to the destination. As shown in Figure 1, the enhanced junction selection mechanism selects J3 instead of selecting J2 as a next destination junction on the basis of traffic density in the direction of destination.

After selecting J3 as a next destination junction, enhanced junction selection mechanism avoids the local maximum problem which occurred when selecting J2 as a next destination junction. Selecting junction having highest traffic density in the direction of destination has two advantages. Firstly, forwarding vehicle can easily find the neighbor as enhanced junction selection mechanism selects the junction having highest traffic density in the direction of destination which will reduce the end-to-end delay and secondly, enhanced junction selection mechanism increases the probability of connectivity and also reduces the number of packet lost due to connectivity problem which will eventually increases the packet delivery ratio.

Table 1. Simulation setup.

Cells Density Data Packet	
Direction	
Road ID	Time
Cell ID	Cell's Center (Position)
Cell's Total Density	Cell's Directional Density

Our protocol uses the same concept of group formation as used in GyTAR to estimate the on-road traffic density. The road is dissected into small cell of fixed size [16] (big circles) as illustrated in Figure 2. Each cell defines a group. The size of the cell depends on the transmission range of the vehicle (around 250 meter). The groups overlap in such a way that each vehicle belongs to at least one group. Each group has a group leader for a given duration. The vehicle which is closest to the center of the cell is selected as a group leader for that particular cell. The centers of the cells are presented in small circles and the vehicles which are group leaders for the particular cell are presented in dark. The group leader is responsible to update the CDP by not only adding the total number of vehicles but also including the number of vehicles moving in the direction of destination in that particular cell in the CDP packet. The vehicle which is about to leave the road initiates the CDP. It will add the road ID, transmission time, list of anchors and the direction, for which the density will be calculated. Packets travel along with these anchor to reach the other intersection as illustrated in Table 1. Upon receiving the CDP, the group leader updates CDP by including the total density and the directional density of the corresponding cell.

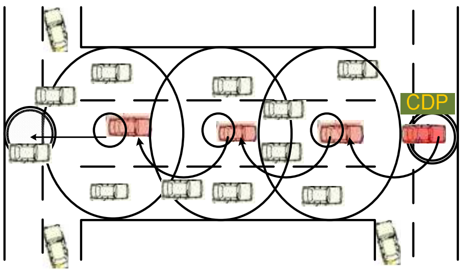

Figure 2. Location-based groups.

Algorithm 2 explains this procedure. The forwarding vehicle F forwards the CDP packet from the end of junction Jend to the beginning of junction Jbegin of the road section between these two junctions (i.e., J_{end}, J_{begin}). The forwarding vehicle F may or may not be the group leader. If it is a group leader, then it will update the CDP packet by including the total density T_d as well as directional density D_d by consulting its neighbor table and then, sends the packet to the vehicle which is closest to the next anchor and so on. When the group leader of the last anchor receive the CDP packet, it will calculate mean and variance of all the directional cells density and calculated density will be forwarded to the destination intersection. When the destination intersection is reached, the CDP is broadcasted to all the vehicles around the intersection and all the vehicles around the intersection will come to know the total direction cell density.

Algorithm 2 Pseudo code for CDP Forwarding

1. *If F is not around J_{begin}, then:*
   - 1.1 *If F is a group leader, then:*
   - 1.2 $T_{d\,i} = N_{i\,b,e} + N_{i\,e,b}$
   - 1.3 $D_{d\,i} = N_{i\,e,b}$
   - 1.4 *NextAnchor= center of cell i+1*
   - 1.5 *end if*
   - 1.6 *F selects neighbors (N) moving towards J_{begin}*
   - 1.7 *If $\exists V \in N$ closer to NextAnchor, then*
   - 1.8 *F forwards CDP to V*
   - 1.9 *Else Store CDP and carry it*
   - 1.10 *end if-else*
2. *Else Broadcast CDP around J_{begin}*
3. *end if-else*

In this way, the traffic density of the road will be calculated. If forwarding vehicle can not find a suitable neighbor towards next anchor, then forwarding vehicle store the CDP and carry the packet until it finds a vehicle which is closest to next anchor. The number of vehicles in cell *i* moving from beginning of junction to the end of junction is presented by $N_{i\,b,e}$ whereas $N_{i\,e,b}$ describe the number of vehicles in cell *i* moving from end of junction to the beginning of junction.

4.2. Routing Between Junctions

E-GyTAR uses the same routing mechanism as proposed in GyTAR protocol and also uses the improved greedy approach to route the packets between the two involved junctions. Neighbor table is maintained by each vehicle in which it records the speed, velocity, and direction of each vehicle. This table is updated periodically through hello messages. When the source vehicle needs to forward the data packets, it consults its neighbor table to find the new predicted position of neighboring vehicles [15].

With the introduction of enhanced junction selection mechanism based on traffic density, curvemetric distance from source to destination, and improved greedy routing approach, there are still chances that packet gets stuck in local maximum problem. E-GyTAR uses carry and forward [22] 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.

5. Simulation and Results

To evaluate the performance of proposed technique, simulations are carried out in Global Mobile system Simulator (GLOMOSIM) simulator [3]. The other position-based 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 [8]. Usually, vehicular mobility models are classified into two categories, the microscopic and macroscopic. Macroscopic mobility consider mobility constraint such as roads, streets, speed limits, number of lanes, traffic density, traffic flow and traffic lights. The microscopic mobility focuses on the vehicle behaviors with each other and with infrastructure [12]. VanetMobiSim [13], which can support the micro and macro mobility, is an extension for the CANU mobility simulation environment [2].

5.1. Simulation Setup

The vehicular mobility pattern is generated by using VanetMobiSim, which simulates a 2500×2000 m^2 area. Node mobility is simulated against 16 numbers of intersections and 24 bi-directional roads with multi lanes as shown in Figure 3. Vehicles are distributed randomly over the roads and start moving on both directions. Car following model or intelligent driver model [13] is used for the movement of vehicles on the roads. All the other parameters are summarized in Table 2.

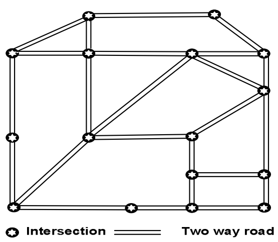

Figure 3. City simulation area.

Table 2. Simulation setup.

Simulation/Scenario		Mac/Routing	
Simulation Time	200s	MAC protocol	802.11 DCF
Map Size	2500 x 2000 m^2	Channel Capacity	2 Mbps
Mobility Model	VanetMobiSim	Transmission Range	266 meter
Number of intersection	16	Traffic Model	15 CBR connection
Number of roads	24	Packet sending rate	0.1–1 seconds
Number of vehicles	75-200	Weighting factors (α, β)	(0.5;0.5)
Vehicle speed	35-60 Km/h	Packet size	128 byte

5.2. Results and Discussion

Packet delivery ratio, end to end delay, and routing overhead are used as performance metrics. These metrics are discussed in detail in [15].

5.2.1. Packet Delivery Ratio

Figure 4(a) shows 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 path is determined by considering the traffic density in the direction of the destination. This allows the packet to travel along the street which has the higher connectivity in the direction of the destination. While in GyTAR, the path is determined by considering only the traffic density.

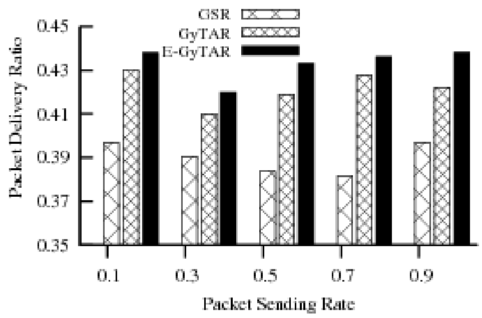

Figure 4 (a). Delivery ratio vs. packet sending rate (175 odes).

It does not take into account the number of vehicles moving in the direction of destination. Thus GyTAR may selects the street which has higher connectivity but not enough vehicles moving in the direction of destination instead of street which has less connectivity but has more than enough vehicles moving in the direction of destination. GSR doesn't have a dynamic junction selection mechanism. Thus, GSR computes the complete sequence of junctions through which the packet has to travel to reach the destination. GSR does not consider vehicular density on the street, so it suffers from the connectivity problem on some sections of the street.

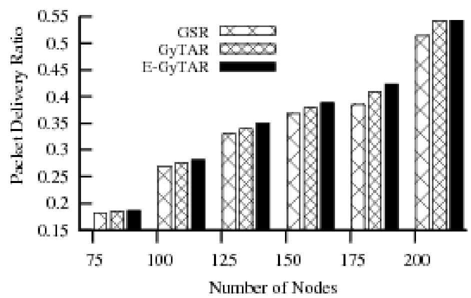

Figure 4 (b). Delivery ratio vs. number of nodes at 5 packets/sec.

Figure 4(b) illustrates the effect of increasing network traffic density. The packet delivery ratio increases as the number of node increases which increases the probability of connectivity and also reduces the number of packet lost due to connectivity problem. It is observed that when the network traffic is more than 200, then the number of vehicles moving in the direction of destination does not matter because by using improved greedy routing strategy the packet will still reach the destination, even if there are not enough vehicles moving in the direction of destination, because there are enough vehicles moving in opposite direction.

5.2.2. End-to-end Delay

GyTAR and E-GyTAR achieves much lower end-to-end delay than GSR. This is because GSR first computes the sequence of junctions before transmitting a packet without considering the traffic density which causes delay.

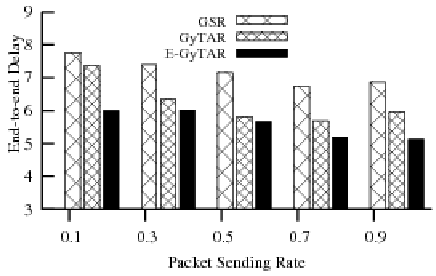

Figure 5 (a). End-to-end delay vs. packet sending rate (175 nodes).

Also, packet that suffers from local maximum is stored in suspension buffer for a longer period of time than in E-GyTAR and GyTAR as shown in Figure 5(a). While in GyTAR, a selection criterion is based on traffic density. 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.

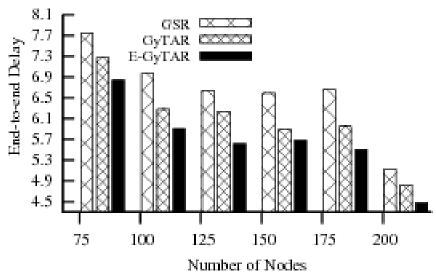

Figure 5 (b). End-to-end delay vs. number of nodes at 5 packets /sec.

Figure 5 (b) shows decrease in end-to-end delay with the increase in network density. As the network density increases, the probability of packets being routed will be increased instead of being held in suspension buffer which will decrease the end-to-end delay for all the three protocols.

5.2.3. Routing Overhead

Figure 6 (a) shows the routing overhead of all three protocols with respect to data sending rate. Routing overhead increases with increase in packet sending rate for all protocols. It happens because decrease in packet sending rate means less number of packets delivered to the destination and eventually increased routing overhead. Similarly, decrease in packet sending rate decreases the routing overhead. Thus at 0.1 packet sending rate, the routing overhead is minimum for all three protocols and gradually routing overhead increases with increase in packet sending rate.

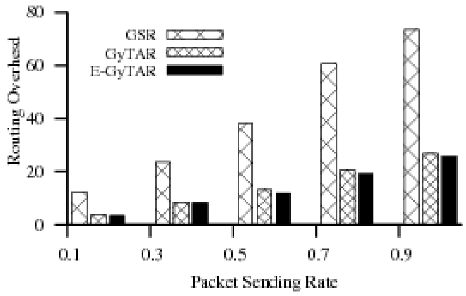

Figure 6 (a). Routing overhead vs. packet sending rate (175 nodes).

GSR shows higher routing overhead than GyTAR and E-GyTAR. This is because GSR sent greater number of control messages in order to obtain the position of neighbors. The number of hello messages needed for GSR is described in [24], which is three times greater than GyTAR and E-GyTAR. Figure 6(b) shows that routing overhead increases with increase in vehicle density for all the three protocols.

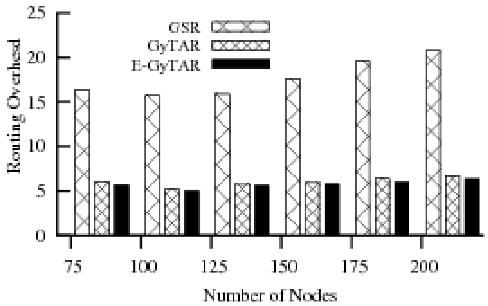

Figure 6 (b). Routing overhead vs. number of nodes at 5 packets sec.

This is expected since the control messages depend on the number of nodes. As the number of nodes increases, the routing overhead also increases. The routing overhead of E-GyTAR is lower than the other two protocols. This is because E-GyTAR delivered higher number of packets to the destination which reduces the routing overhead.

6. Conclusions

This work presents E-GyTAR protocol which selects junction automatically on the basis of direction as well as density of vehicles. E-GyTAR achieves higher packet delivery ratio and lower end-to-end delay than GyTAR.

In future, it would be interesting to investigate the behavior of E-GyTAR, GyTAR, and GSR in the presence of one-way road. Also, using one-hop information to predict the future neighbors may result in enhanced performance. Furthermore, investigations will be carried out to see whether dynamic junction selection mechanism is appropriate or the mechanism which calculate all the junctions at the source, when both mechanisms have the information about the traffic density on the roads.

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