Performance Analysis of Angular Geographic Distance Based Routing for Vehicular Ad Hoc Networks in Urban Environment

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***Abstract*—In vehicular ad hoc network, routing has become a critical issue in vehicle-to-vehicle communication. Therefore, there are several routing algorithms, which utilize topology information to make routing decisions at each node. We have proposed Angular GEographic DIstance-based Routing (A-GEDIR) protocol for packets transmission in high density urban area. In our protocol, a source node computes the next hop in the region bounded by the tangents drawn from the expected zone to the destination. Further, the next hop is chosen from the nodes available in the bounded region on the basis of maximum progress. In this strategy to attain maximum progress, the node having minimum angle is selected as the next hop to forward the packets towards the destination. The performance of the proposed routing protocol is analyzed in terms of the expected number of successful hops, probability of successful transmission and expected distance to the next-hop node.**

Keywords*—Vehicular ad-hoc networks, position-based routing, angular geographic distance-based routing, expected zone, urban environment.

I. Introduction

The Vehicular Adhoc Network (VANET) is an advanced wireless networking technology that has gained abundance of interest due to its novel applications, such as road safety, traffic management, commerce on wheels, multimedia content sharing, etc. The vehicular network is considered a specific category of mobile adhoc networks that consists of a number of vehicles or nodes, capable of communicating with each other, in the absence of fixed infrastructures [1]. The multi-hop communication in VANET is largely constrained by the high degree of vehicle mobility and frequent disconnections. The joint efforts made by the research community and governmental agencies have resulted in implementing an Intelligent Traffic System (ITS) in order to resolve the traffic congestion and fuel resources [2].

The communication system in VANET is devised with the challenging task of delivering traffic-related information in a cost-effective manner, incurring least possible delays. Such design goals are mandated for ensuring safety and comfort to the travelers [3-4]. Owing to the high expenses and complexity involved in deployment and implementation, majority of the research relies on simulation with the help of several mobility models. These models are standardized to represent the movement pattern of mobile users thereby depicting the position and velocity over time. In inter-vehicular communication, the transmission of messages is quite abrupt, as a result of which it is difficult to discover an efficient route in advance. The vehicles often communicate with the access points, also called Road Side Unit (RSUs) to locate the positions of the intermediate communicating vehicles between source and destination. However, the road side units have a finite range and are placed at a fixed distance from each other, which necessitates efficient routing schemes in the network.

The rest of the paper is organized in the following way. Section II presents a brief survey of work related to position-based routing in vehicular network. Section III highlights our proposed work on Angular GEographic DIstance-based Routing (A-GEDIR) protocol along with the mathematical model in support of our proposed routing strategy. In section IV simulation study regarding the probabilistic analysis of one hop neighbor and probability of existence of destination node in expected region are illustrated. Finally, the work presented in the paper is concluded along with scopes of future work in section V.

II. Related work

Several position-based routing schemes have been proposed to improve vehicular communication in VANETs [1]. In [2] the author have proposed a directional routing method that ensures the delivery of packets to the intended destination using efficient and stable routes. The next-hop is chosen from the vehicles traveling in the same direction as the forwarding vehicle on the basis of the angular directions relative to the destination. The simulation result verifies and confirms the stability of routes chosen for packet transmissions. In another research conducted in [3] a novel position-based routing strategy is provided that accounts for lesser delay in route discovery. The route for next-hop node is decided from the position of a reference point rather than the final destination node. The results obtained from the analytical model shows that the probability of route discovery failure is within bounds. Further, in a study carried out in [4] highlighted the superiority of position-based routing in high-way scenarios. The authors considered several challenges in city scenarios, for instance high-rise buildings, routing loops due to fast traffic movements, etc. In order to overcome such problems, another novel routing

scheme is proposed in [5] that utilizes information from geographic maps of a city. The packets are forwarded to next-hop node on the basis of the positions of junctions and street information.
In yet another research made in [6] greedy approach is proposed for position based routing, in which next hop decisions are made at the junctions, also called coordinators. The experimental outcomes validate their work proposal in terms of data delivery performance and route discovery success. A recent research performed in [7] proposes a back-bone assisted hop greedy routing scheme that yields a routing path with least number of intermediate intersection nodes. Moreover, back-bone nodes are introduced to ensure network connectivity about an intersection. The back-bone nodes are capable of forwarding messages in frequently changing topology by tracking the movement of source and destination.
In [8] the authors have developed position-based routing for delay and disruption tolerant networking using polarity. This approach exploits the spatial and temporal modeling of the metropolitan bus network by reusing the existing database of the Bus Information System (BIS). Simulation results have signified the benefits of the routing strategy in terms of higher packet delivery ratio and shorter end-to-end delay. Further in [9] a link-lifetime metric is introduced to support routing in a constantly changing topology with transient communication links. The metric is capable of estimating the residual time for which a link can be used for efficient communication, which further helps to optimize route construction with respect to lifetime. The authors claim that their method does not make assumption of knowledge regarding transmission power, position, velocity or mobility model adopted by the nodes.

III. PROPOSED ROUTING SCHEME

We propose position based Angular Geographic Distance-based routing protocol (A-GEDIR) by improving the progress for discovering next-hop node for packet transmission between the source and the destination node. Some important assumptions regarding the network scenario are provided in the preceding section.

A. Network Assumptions

Some assumptions made regarding the vehicular network deployment scenario are enlisted as following:

- Each node is aware of the exact location of its direct neighbors, i.e. nodes that fall in range of the source node
- A node forwards packets to next hops without establishing routes in advance
- It is presumed that GPS receiver, digital maps and sensors are installed in vehicles (or nodes)
- The nodes communicate in multi-hop manner using wireless ad hoc network
- Maximum forwarding distance varies towards the destination node in the network
- Message-based communication is performed in which large-sized messages are fragmented into small fixed size data packets

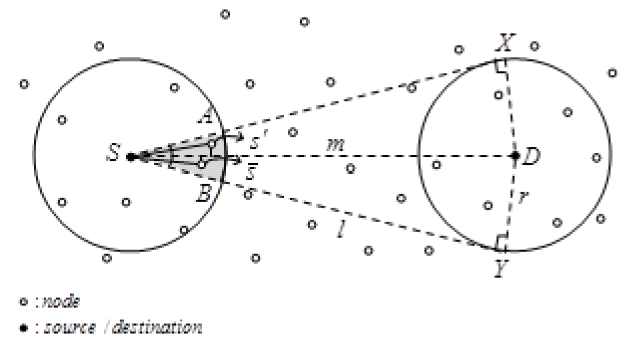

Fig. 1. Vehicular Network Layout

The nodes, with communication radius r, are randomly deployed in a two-dimensional region.We assume the source and the destination nodes are set m distances apart. An angle is formed between the two tangents drawn from source to the range of the destination node. Further, an adjacency matrix is formed to contain information about the nodes that lie in the range of a certain node. For all such neighboring nodes, angles α_1 ,α_2 , etc. between the node and line connecting the source and the destination node are recorded. If the angle made by a node is less than $\alpha/2$, then the node is assumed to lie in the shaded region Figure 1 and should be considered as next-hop for forwarding packets. The distances from the destination node of all the nodes are computed that lie within the range of source node with angle less than $\alpha/2$. Finally, packets are forwarded to the node with the least distance from the destination node. This process is repeated by considering the next hop node as the source node, till the destination node is reached. Following section mathematically analyze the transmission of packets between source and destination.

B. Mathematical Analysis

Owing to the limited coverage spanned by the transmission range of a node, vehicular networks generally support multi-hop communication. Two nodes in the network are said to be direct neighbors if the distance between them is at most r, where r is the transmission range which initially remains constant for all nodes in the network. Eventually, routing packets efficiently to its destined node becomes a challenging task in the multihop environ.
This section highlights the analysis of performance of a routing algorithm that helps in directing packet movement through intermediate nodes. The probability of the packet transmitted from source correctly received by the destination is considered an essential metric to estimate the reliability of routing scheme. This probability can be determined by shading the range of the source node which is enclosed within the angle alpha (α), i.e. the angle between the tangents to the range of destination node and then calculating the probability of the source to successfully transfer packet to the node lying in the shaded region which has the minimum angle and least distance from the destination node.
Clearly, from Figure 1, $S(x_1, y_1)$ and $D(x_2, y_2)$ are source

and destination nodes respectively. Also, $\angle ASB = \alpha$ is the angle between the tangents drawn towards the circle formed by the range of destination node and $\angle s'SB = \alpha_1$ and $\angle \bar{s}SB = \alpha_2$. The distance m between source and destination can be calculated as:

$$m = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2} \quad (1)$$

Now, we derive the angle α by using simple laws of trigonometry.

$$\cos(\frac{\alpha}{2}) = \frac{m^2 + l^2 - r^2}{2ml} \quad (2)$$

$$\alpha = 2\cos^{-1}(\frac{m^2 + l^2 - r^2}{2ml}) \quad (3)$$

Where l can be computed using Pythagoras theorem,

$$l = \sqrt{m^2 + r^2} \quad (4)$$

The area of the shaded region in the communication circle with radius r can be formulated as:

$$S_A = Area(ASB) = \frac{\alpha}{2\pi}\pi r^2 = \frac{\alpha r^2}{2} \quad (5)$$

$$S_A = \left[cos^{-1}(\frac{m^2 + l^2 - r^2}{2ml})\right].r^2 \quad (6)$$

Let λ be the vehicle (node) density, which is equal to total number of nodes divided by total area, i.e.

$$\lambda = \frac{N}{L^2} \quad (7)$$

We further assume that availability of nodes in a given region follows Poisson distribution. Hence, if X is the random variable representing the number of nodes in the shaded area then the probability of n nodes present in shaded area is:

$$P_{S_A}(X = n) = \frac{(\lambda S_A)^n.e^{-\lambda S_A}}{n!} \quad (8)$$

On substituting the value of S_A from above equation, we get:

$$P_{S_A}(X = n) = \frac{(\lambda.r^2.\cos^{-1}(\frac{m^2+l^2-r^2}{2ml}))^n.e^{-\lambda.r^2.\cos^{-1}\frac{(m^2+l^2-r^2)}{2ml}}}{n!} \quad (9)$$

Now, probability of selecting k nodes out of n nodes can be written as:

$$P(Y = k) = {C_k}^n p^k (1 - p)^k \quad (10)$$

Where p is probability of selecting a node and q=(1- p) is the probability of not selecting a node.

$$p = \frac{Area(ASB)}{TotalArea} \quad (11)$$

$$p = \frac{\cos^{-1}(\frac{m^2+l^2r^2}{2ml}).r^2}{L^2} \quad (12)$$

Probability of selecting exactly k nodes is,

$$P(k) = \left(\sum_{n=k}^{\infty}\right)[C_k^n p^k (1 - p)^k].P_{S_A}(X = n) = \frac{(p\lambda S_A)^k.e^{-p\lambda S_A}}{k!} \quad (13)$$

Probability of selecting at least k nodes in shaded region,

$$P(k) = 1 - P(\bar{k}) = 1 - \left(\sum_{i=0}^{k-1}\right)\left[\frac{(p\lambda S_A)^k.e^{-p\lambda S_A}}{k!}\right] \quad (14)$$

Probability for i^{th} node P_i for selecting at least one node in the shaded region is, i.e. for K = 1,

$$P_i = 1 - P(X = 0) \quad (15)$$

$$P_i = 1 - e^{-p\lambda S_A} \quad (16)$$

$$P_i = 1 - e^{-p.\lambda.r^2.\cos^{-1}\frac{m^2+l^2r^2}{2ml}} \quad (17)$$

Now, we calculate the successful transmission probability P_T from source to destination when nodes are used for transmission:

$$P_T = P_{i_1} * P_{i_2} ... * P_{i_n} \quad (18)$$

Let H be a random variable representing the number of hop between source and destination. Finally, the expected number of hops traversed to successfully deliver packets is given by:

$$E[H] = \frac{P_i}{(1 - P_i)} \quad (19)$$

$$E[H] = \frac{1 - P(X = 0)}{P(X = 0)} \quad (20)$$

$$E[H] = \frac{(1 - e^{-p.\lambda.r^2.\cos^{-1}(\frac{(m^2+l^2-r^2)}{2ml})})}{e^{-p.\lambda.r^2.\cos^{-1}(\frac{(m^2+l^2-r^2)}{2ml})}} \quad (21)$$

$$E[H] = e^{p.\lambda.r^2.\cos^{-1}(\frac{(m^2+l^2-r^2)}{2ml})} - 1 \quad (22)$$

IV. Simulation & Performance Evaluation

In this section we provide the simulation results obtained to evaluate the performance of the proposed method. Our scenario consists of $L \times L$ planar network where L=20 with overlapping cluster boundaries with varying number of nodes. We have simulated our proposed computational strategy with MATLAB-r2013a. The geographical region is assumed to be a square area with dimension $20 \times 20 unit^2$. The nodes are deployed using Poisson distribution and initially have identical communication radius of 7 units.

A. *Distribution of Nodes in the Shaded Area and successful transmission from source to destination*

Total number of nodes deployed is 40 and red line represents the route for successful transmission of packet from source to destination.

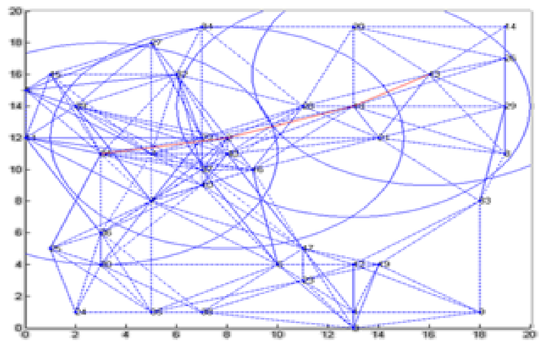

Fig. 2. Distribution of nodes and successful transmission from source to destination

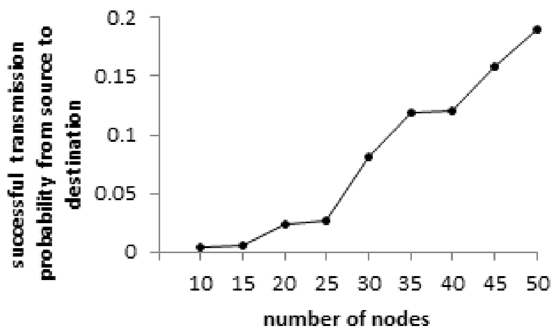

Fig. 3. Successful transmission probability from source to destination

B. *Successful transmission probability from source to destination*

Figure 3 shows the probability for successful transmission of data packet from source to destination in the area when total number of hops is 2 for each case. From the Figure 3, it can be seen that the probability for successful transmission of data packet from source to destination increases with the increase in total numbers of nodes deployed in the geographical region. Therefore, more the number of vehicles more would be the connectivity in the network.

C. *Probability for having n nodes in shaded region and Probability of selecting at least 1 node in the shaded region(NOTE : SHADED REGION refers to SAB area in Figure 1.)*

When number of hops are 2 and total number of nodes are 15 with transmission range r= 7 and λ = 0.0375 then the probability to find n nodes in the shaded region where n = 5 and Probability of selecting at least 1 node in the shaded region is given in table I.

TABLE I. PROBABILITIES OF HAVING N NODES AND OF SELECTING AT LEAST ONE NODE IN SHADED REGION

Node	Probability for having n nodes in shaded region	Probability of selecting at least one node in the shaded region	Next node
Source	0.0018	0.1238	Next hop 1
Next hop 1	0.0044	0.1883	Next hop 2
Next hop 2	0.0313	0.4680	Destination

When number of hops are 2 and total number of nodes are 25 with transmission range r= 7 and λ = 0.0625 then the probability to find n nodes in the shaded region where n = 5 and Probability of selecting at least 1 node in the shaded region is given table II

TABLE II. PROBABILITIES OF HAVING N NODES AND OF SELECTING AT LEAST ONE NODE IN SHADED REGION

Node	Probability for having n nodes in shaded region	Probability of selecting at least one node in the shaded region	Next node
Source	0.0068	0.1454	Next hop 1
Next hop 1	0.0264	0.2884	Next hop 2
Next hop 2	0.1127	0.6507	Destination

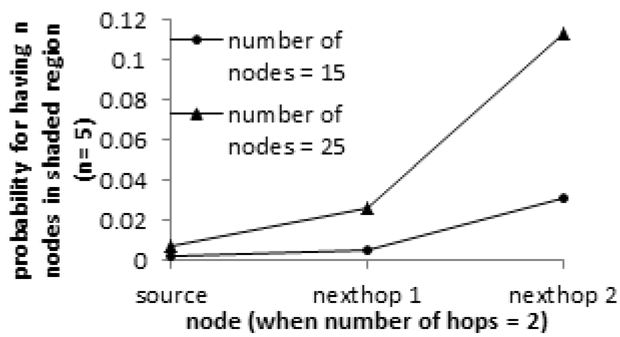

Fig. 4. Probability for having N nodes in shaded region

Comparing the data provided in table I and II, Figure 4 implies that with the increase in the number of nodes the probability for having n nodes in shaded region increases and as the data packets get transmitted from one node to another towards the destination the probability for having n nodes in shaded region increases.

Similarly in figure 5, using data used in table I and II, interprets that with the increase in the number of nodes the probability for selecting at least 1 node in shaded region increases and as the data packets get transmitted from one node to another towards the destination the probability for selecting at least 1 node in shaded region increases. Therefore, a vehicle should be within the range of at least one other vehicle to maintain connectivity and support multi-hop routing in the network.

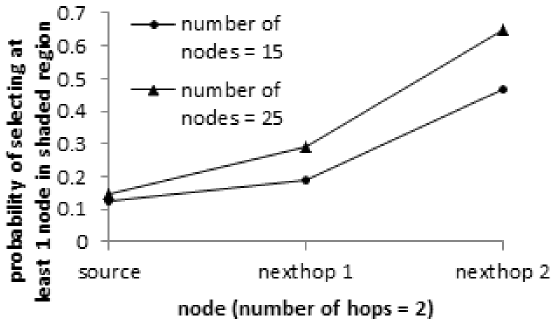

Fig. 5. Probability for selecting at least one node in the shaded region

When number of hops are 3 and total number of nodes are 20 with transmission range r= 7 and λ = 0.05 then the probability to find n nodes in the shaded region where n = 5 and Probability of selecting at least 1 node in the shaded region is given in the following table III:

TABLE III. PROBABILITIES OF HAVING N NODES AND OF SELECTING AT LEAST ONE NODE IN SHADED REGION

Node	Probability for having n nodes in shaded region	Probability of selecting at least one node in the shaded region	Next node
Source	0.0018	0.0954	Next hop 1
Next hop 1	0.0033	0.1268	Next hop 2
Next hop 2	0.0114	0.2283	Next hop 3
Next hop 3	0.0424	0.4401	Destination

When number of hops are 3 and total number of nodes are 30 with transmission range r= 7 and λ = 0.075 then the probability to find n nodes in the shaded region where n = 5 and Probability of selecting at least 1 node in the shaded region is given in the following table IV:

TABLE IV. PROBABILITIES OF HAVING N NODES AND OF SELECTING AT LEAST ONE NODE IN SHADED REGION

Node	Probability for having n nodes in shaded region	Probability of selecting at least one node in the shaded region	Next node
Source	0.0072	0.1259	Next hop 1
Next hop 1	0.0244	0.2362	Next hop 2
Next hop 2	0.0919	0.5097	Next hop 3
Next hop 3	0.1754	0.8893	Destination

Figure 6, using data in table III and table IV, shows that with the increase in the number of nodes the probability for having n nodes in shaded region increases and also as the data packets get transmitted from one node to another towards the destination the probability for having n nodes in shaded region increases.

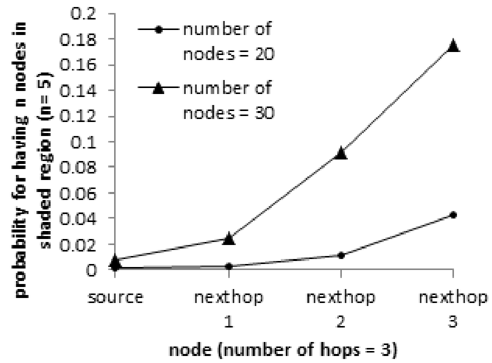

Fig. 6. Probability for having n nodes in shaded region

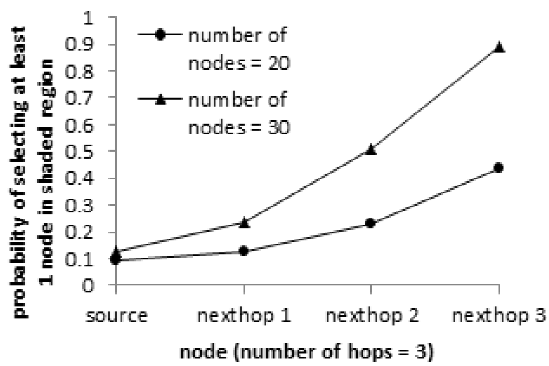

Fig. 7. Probability for selecting at least one node in the shaded region

Similarly figure 7,using data in table III and table IV, interprets that with the increase in the number of nodes the probability for selecting at least 1 node in shaded region increases and as the data packets get transmitted from one node to another towards the destination the probability for selecting at least 1 node in shaded region increases. Further, a vehicle should be within the range of at least one other vehicle to maintain connectivity and support multi-hop routing in the network.

V. COMPARISON BETWEEN A-GEDIR AND GEDIR (DATA OF GEDIR TAKEN FROM [10])

Figure 8 and 9 shows the performance comparison between GEDIR and A-GEDIR, interpreting that the average number of successful hops for both GEDIR and A-GEDIR increases as the number of nodes and node density increases. But for A-GEDIR, number of successful hops is significantly lower than GEDIR. When the number of nodes is 100 (in Figure 8), the number of successful hops for A-GEDIR is 0.7427 whereas for GEDIR it is 1.175. Similarly, from Figure 9, when node density is 0.0001, the number of successful hops for A-GEDIR is 2.16 whereas for GEDIR it is 22.5.Hence A-GEDIR is more efficient and gives more optimized results than GEDIR.

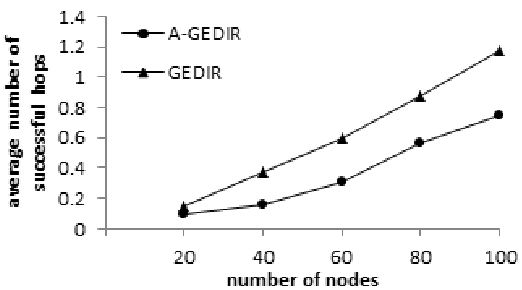

Fig. 8. Average number of successful hops

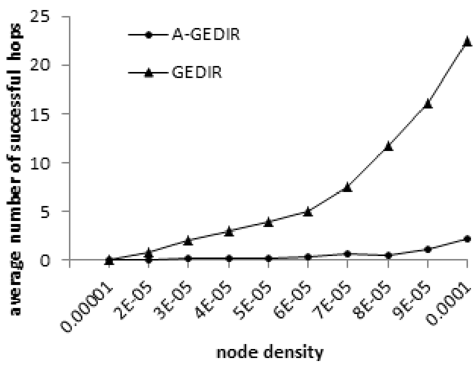

Fig. 9. Average number of successful hops

VI. Conclusion

In this work, we have proposed Angular Geographic Distance Routing (A-GEDIR). The main design goal of A-GEDIR method is to select the most optimize node to route data packet in VANETs. A-GEDIR optimizes the forwarding behavior based on the optimizing the number of hops and computing the shortest path between the source and destination by considering angle formed by the tangents from source node (center) to the destination range(circle formed) to achieve the high reliability and precision while forwarding the packet to next node. Simulation results show that A-GEDIR gives better performance than GEDIR in terms of average number of successful hops. As for future works, further research work is being conducted in the field of vehicular ad hoc networks to revolutionaries intelligent transportation system.

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