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Performance Analysis of P-GEDIR Protocol for Vehicular Ad Hoc Network in Urban Traffic Environments

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Abstract A Vehicular Ad hoc Network (VANET) is a wireless ad hoc network that is formed between vehicles on an on demand basis. In VANETs all the vehicles (nodes) are used as routers and these routers are free to move randomly and organized themselves arbitrarily. A lot of research work around the world is being conducted to design an efficient routing protocol for VANETs. In this paper, we propose a new routing method known as Peripheral node based GEographic DIstance Routing (P-GEDIR), a position-based routing protocol that takes advantage of GEographic DIstance Routing (GEDIR). It may not be possible to find node at the extreme end of the transmission range. Therefore, we have considered an area around the extreme end of the transmission range. Further a mathematical model for the protocol has been designed to determine expected number of successful hops, expected distance to the next-hop node, and expected one-hop progress. The protocol has been simulated using MATLAB. In this work, results clearly show that using the peripheral node is an advantage to maximize the performance of routing protocol in terms of average number of successful hops and expected one-hop progress. The result of P-GEDIR is compared with the existing GEDIR protocol.

Keywords MANET · VANET · Routing protocols · GEDIR · P-GEDIR · Urban environment

1 Introduction

According to World Health Organization (WHO), millions of people around the world die every year because of vehicular traffic accidents and one fourth of all deaths caused by injury. Also about 50 millions of people are injured in vehicular traffic accidents. Take the metropolitan city Delhi in India for example, where plenty of vehicles like car, truck, buses,

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motorcycles etc. runs on the road at any given time. Delhi has huge population and with respect to population, vehicles population in Delhi is large among all metropolitan cities in India. On an average about 600 new vehicles are added in Delhi every day [1]. Department of transportation annual reports says, thousands of people around the Delhi city die every year because of the vehicular traffic accidents and many more are injured.

Road safety is a major factor of vehicular traffic management. The exceptional growth in the number of vehicles in the city with limited road space, careless driving and violation of traffic rules caused large number of traffic accidents. Increasing parking demand with limited parking space and unfamiliar with travel related information is an obstruction to the smooth flow of vehicular traffic, especially in crowded and major commercial areas.

Therefore, to reduce large number of vehicular traffic accidents, improve safety, manage traffic control system, and provide important facilities to drivers and passengers with high and reliable efficiency, computer networking researchers proposed a new wireless networking concept called Vehicular Ad hoc Network (VANET) [2].

In this paper, we present the significant role of routing protocol; especially the position-based routing protocol for VANET. Routing is the process of finding optimal path between source and destination node and then sending message in a timely manner. Routes between source and destination node may contain multiple hops, this condition is more complex than the one-hop communication. Intermediate vehicles can be used as routers to determine the traffic's path along the way. Since the network topology is frequently changing, finding and maintaining routes is very challenging task in VANETs. Traditional topology-based routing protocols [3] are not suitable for VANETs. Position-based routing protocols such as GPSR, GPCR, A-STAR, MFR, GEDIR, etc. are more suitable than other routing protocols. Routing protocols in VANET can be classified into four significant categories as given in the Fig. 1.

In this work, we propose a new position-based routing protocol; Peripheral node based GEographic DIstance Routing (P-GEDIR) which takes advantage of GEographic DIstance Routing (GEDIR) protocol. P-GEDIR improves data delivery in various scenarios of VANETs. Specially, P-GEDIR is designed to efficiently route the packet with less number of hops in city or urban vehicular environments. This routing scheme uses the concepts of peripheral node of the sender's communication range to minimize the number of hops between source and destination.

The rest of this paper is organized as follows. In Sect. 2, VANET is briefly described. In Sect. 3, we describe the routing protocols and data dissemination issues. Sect. 4, presents the related works. In Sect. 5, we introduce the design of P-GEDIR protocol method. Sect. 6 presents the mathematical analysis of the proposed protocol. Simulation results and performance analysis are discussed in Sect. 7. Finally, we conclude this paper in Sect. 8.

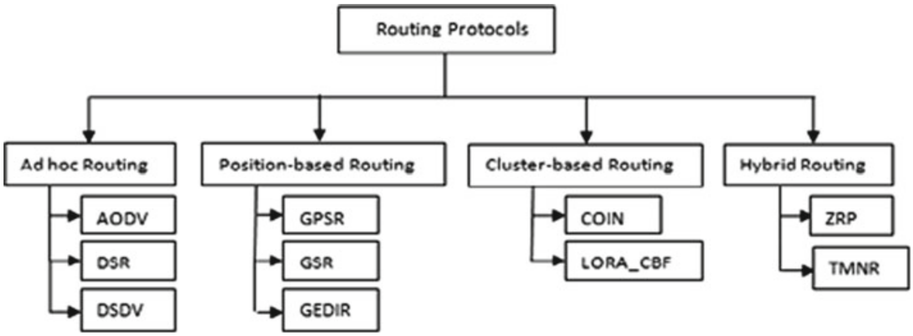


Fig. 1 Classification of routing protocols

2 Vehicular Ad Hoc Network

Vehicular Ad hoc Network (VANET0 is a budding and challenging subclass of Mobile Ad Hoc Networks (MANETs) [4]. A VANET has emerged as one of the most recent research areas for the last one decade. In VANET, vehicles can communicate to each other through multiple paths using intermediate nodes to forward the packets from the source to destination. VANETs are designed to make available drivers with immediate information in two ways: Vehicle-to-Vehicle (V2V) or inter-vehicle communication and Vehicle-to-Roadside infrastructure (base station) (V2R) communication [5] (shown in Fig. 2).

Therefore, VANETs [6] will provide safer and well-organized road in future by communicating information in timely manner to drivers and concerned authorities. VANET is based on short range wireless communication. IEEE 802.11p (modified version of IEEE 802.11a standard protocol) [7,8] is a wireless communication protocol. This protocol is specially designed for VANETs to support safety and non-safety applications. This standard provides wireless devices that are able to communicate between highly mobile vehicles and fixed road side infrastructure units. This mode of operation is known as Wireless Access in Vehicular Environment (WAVE). It will operate in 5.9 GHz frequency band and provides an enhancement to the physical layer (PHY). Medium Access Control (MAC) layer is based on IEEE 802.11 Distributed Coordination Function (DCF) for the Dedicated Short Range Communication (DSRC) standard and was adapted by ASTM and IEEE. DSRC has 75 MHz licensed frequency band divided into 7 different channels with 10 MHz channel bandwidth each. It supports line of sight distance with a range of 1 km and vehicle speed of up to 150 km/h.

VANET support GPS enable vehicles that are equipped with computing mechanism, short range wireless interface and a GPS receiver. A GPS receiver is a device that capable to receive the information sent by the satellites. GPS receiver uses this information to calculate its distance and finally compute its position in the geographical area on the earth in terms of latitude, longitude and altitude. VANET have some important characteristics such as nodes forming the networks are vehicles, restricted vehicle movements on the road, highly mobility of vehicles, rapid change in network topology, and time-varying vehicle density. These characteristics make the VANET a special type of network. The network behavior is greatly affected by these characteristics and many challenges have to be address while deploying the vehicular networks to provide safety and comfort services for the passengers on the roads. In highways, vehicles can move at high speeds and they can communicate with other vehicles

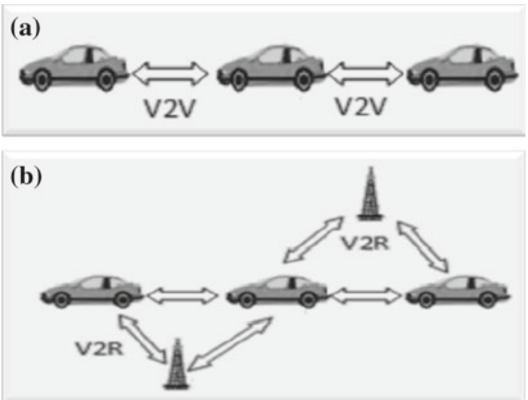


Fig. 2 VANET communication scenarios. **a** V2V communication. **b** V2B communication

within the communication range. But in city or urban areas vehicles are slow and there may be radio obstacles because of buildings and trees. In VANETs, vehicle may join and leave the network much more frequently than other networks. Because of the different traffic density, sometimes it is very difficult to find an end-to-end connectivity when there is no vehicle present that can forward the packet to the destination.

3 Routing and Data Dissemination Issues in VANETs

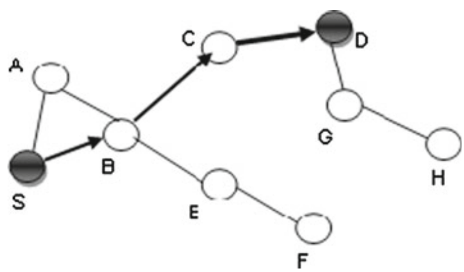
Since the topology frequently changes due to high mobility of nodes causes short communication connections lifetime especially with multi-hop paths. These characteristics degrade the performance of routing protocols. The topology based routing needs to maintain a path from source to destination, but due to rapid movements of nodes, the lifetime of path become very short. In vehicular networks, on highways or urban areas traffic density is high during day time and in rural areas or late night hour's traffic density is less and create a sparsely connected network [9]. As vehicular network support variety of applications, so that routing and data dissemination techniques should support the characteristics and applications of vehicular networks. While in disseminating message there must be categorization of messages (i.e., safety, non safety, casual etc.) and according to priority message should be disseminated. The development and deployment dissemination algorithms should consider the traffic pattern (dense or sparse) over the network and type of applications customer want to access. For example, the dissemination of safety messages should broadcasted in the network on priority over non safety messages. In case, non safety message disseminated through unicast or multicast transmission. Broadcasting in densely populated network introduce broadcast storm problem. Several mechanisms already proposed to mitigate the effect of broadcast storm problem. A robust and efficient routing and dissemination mechanisms need to develop for future deployment of VANETs. While developing such mechanisms, the topology structure, traffic density, interfering objects, latency, etc. should be considered.

4 Related Work

Greedy routing scheme is a loop free and memoryless routing scheme. In the greedy position-based routing scheme, a source node finds the position information of its direct neighbors and selects that neighbor which is nearest to the destination node as the next-hop node.

A GEDIR [10] is a loop free position-based routing algorithm. In GEDIR, a source node forwards packets to its neighbor node that is closest to the destination node. In the Fig. 3, source node *S* has two neighbors *A* and *B*. When source node *S* wants to send a message to destination node *D*, it uses the location information of *D* and for all its direct neighbors to

Fig. 3 GEDIR forwarding method



determine the neighbor B which is closest to D. Now the message is forwarded to B and the same procedure is repeated until the packet reached to D. From the Fig. 3 we can see that path chosen by GEDIR routing methods is $S \rightarrow B \rightarrow C \rightarrow D$.

5 Proposed Work

5.1 Assumptions

The P-GEDIR protocol design is based on the following assumptions [11,12]:

- Peripheral nodes for forwarding packets
- Hello (beacon) control message for next-hop neighbors
- Nodes are equipped with GPS receiver
- Vehicles equipped with digital maps and sensors
- Communication between vehicles using wireless ad hoc network
- No other communication infrastructure
- Maximum forwarding distance is fixed
- Forwarding direction towards destination

5.2 Neighbor Node

A node has a set of one-hop nodes in its transmission range. These one-hop nodes are called neighbor nodes. In dynamic mobile ad hoc network, source node and its neighbors are moving randomly and changing their positions frequently. Each neighbor node updates their information like current location, current time, speed and direction by exchanging the Hello message.

5.3 Peripheral Node

Generally, the neighboring nodes are found one-hop away within the transmission range of the source node. The one-hop nodes are divided into interior nodes and peripheral nodes. A peripheral node is defined as a border node, whose distance from the source node (central node) is exactly R_o, which is equal to the radius of the maximum transmission range R of the source node. Therefore the peripheral node lies furthest away within the transmission range of the source node (shown in Fig. 4).

5.4 Peripheral Node Based GEographic DIstance Routing Protocol

VANET can be improved for better and efficient routing decisions in greedy forwarding method for heterogeneous unevenly random vehicular environment [13]. In this paper, we propose an alternative novel routing protocol; Peripheral Node Based GEographic DIstance Routing Protocol (P-GEDIR) protocol that improves the packet delivery in city vehicular environment where vehicles are distributed unevenly. The P-GEDIR utilizes the peripheral node to avoid sending packet to an interior node within the transmission range of source node. P-GEDIR protocol selects the only peripheral node that is closest to the destination node as the next-hop node for forwarding packet from source to destination, as shown in Fig. 5.

In Fig. 5, node A is a peripheral node of source node S, since node A is positioned at maximum transmission range and has the greatest progress towards destination. Therefore

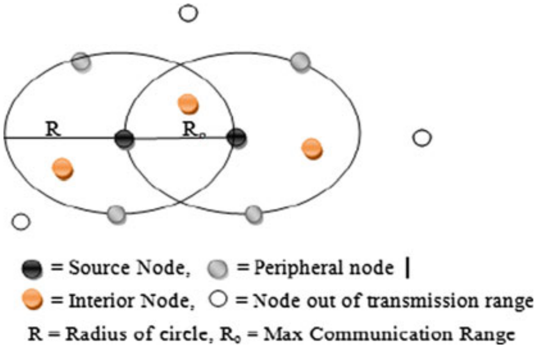


Fig. 4 Peripheral node architecture

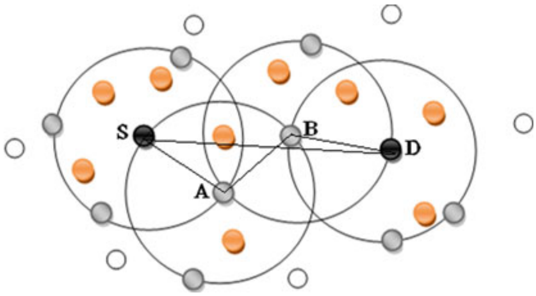


Fig. 5 P-GEDIR packet forwarding method

A is selected as the next-hop forwarding node. Node *A* when receives the message from *S* uses the same method, to find the next-hop forwarding node with greatest progress towards destination. In this case, node *B* is selected as a peripheral node of *A* for forwarding packets to destination. Finally node *B* directly delivers the message to destination node *D*. The whole P-GEDIR method is summarized through data flow diagram in Fig. 6.

6 Mathematical Analysis of the Proposed Protocol

In VANET, a node sends information to all its neighbors that are located within its transmission range. Because of the limited transmission range, the routes between nodes are usually created through several hops in VANETs. Two nodes *A* and *B* in the network are direct neighbors if the distance between them is at most *R*, where *R* is the transmission range which is equal for all nodes in the network. In highly dynamic networks such as vehicular networks, the average number of hops and one-hop progress are considered the important parameters. These key metric are used for performance comparison between different routing protocols.

6.1 Distribution of Nodes in the Shaded Area

In this paper, we study general properties of position-based routing in VANETs. We use a circular region to place the neighboring nodes of vehicular nodes and simulate routing performance for different node densities. For our analysis, the vehicular nodes are considered uniformly distributed over the entire two-dimensional area. All nodes have a maximum transmission range *R*. This also indicates the radius of the circular region for packet transmission. Assume *A* is the area of the transmission range (circular region), λ is the vehicle

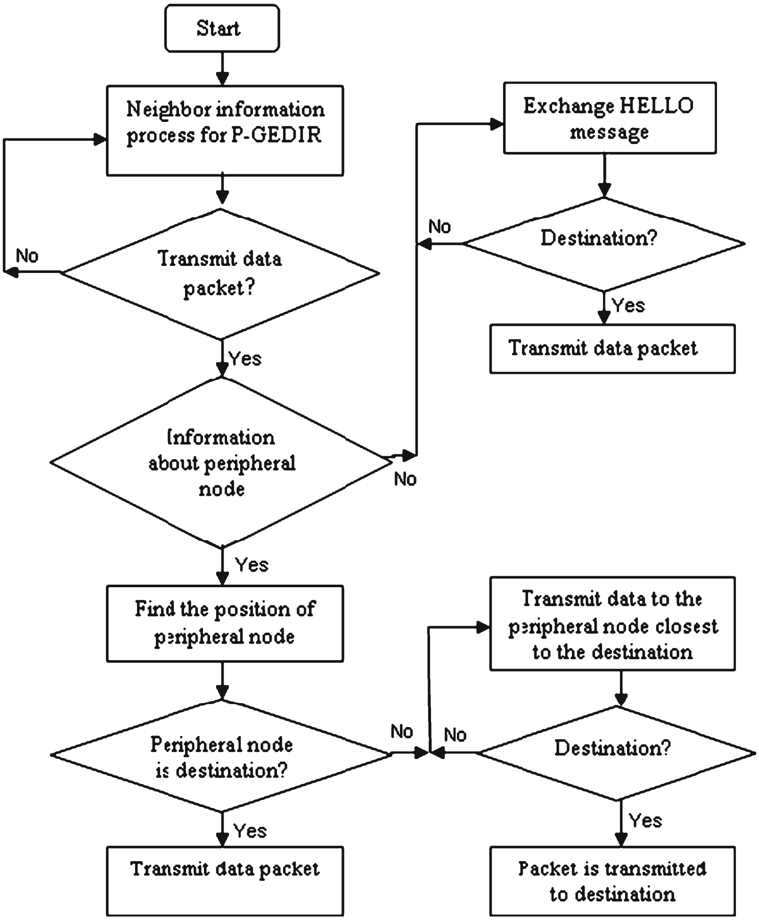


Fig. 6 Flow diagram of P-GEDIR protocol

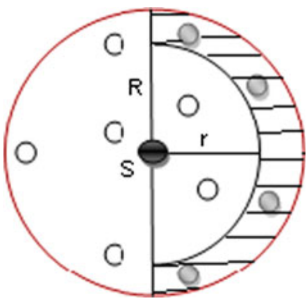


Fig. 7 *Shaded area* having peripheral nodes

density, and N ($N = \lambda\pi R^2$) the number of nodes in the transmission range. For simplicity of our analysis, a node is considered to be a possible forwarder if it is in the half circle of the transmission range of source node towards the destination (the entire shaded area in Fig. 7). Figure 7 shows that neighbor nodes (peripheral nodes) are placed in the given shaded area nearest to the border or on the border of the transmission range of the source node.

According to the practical situation, we use the transmission range R and geometrical (shaded) area of the communication circle can be formulated as:

$$\begin{aligned} S_A &= \frac{\pi R^2}{2} - \frac{\pi r^2}{2} \\ &= \frac{\pi}{2}\left(R^2 - r^2\right) \end{aligned} \tag{1}$$

We assume that availability of nodes in a given region follows Poisson distribution. 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:

$$\begin{aligned} P_{S_A}(X = n) &= \frac{(\lambda S_A)^n \cdot e^{-\lambda S_A}}{n!} \\ &= \frac{\left(\frac{\lambda\pi(R^2-r^2)}{2}\right)^n \cdot e^{-\frac{\lambda\pi(R^2-r^2)}{2}}}{n!} \end{aligned} \tag{2}$$

where λ is the node density. The probability of selecting k nodes out of n nodes is:

$$\begin{aligned} P\,(Y = k) &= \binom{n}{k} p^k q^{n-k} \\ &= \binom{n}{k} (p)^k\,(1 - p)^{n-k} \end{aligned} \tag{3}$$

where p is probability of selecting a node and $q = (1 - p)$ is the probability of not selecting a node. Now probability of selecting exactly k nodes in the given shaded area is [13,14]:

$$\begin{aligned} P\,(k) &= \sum_{n=k}^{\infty}\left[\binom{n}{k}(p)^k\,(1-p)^{n-k}\,.\,\frac{\left(\frac{\lambda\pi(R^2-r^2)}{2}\right)^n \cdot e^{-\frac{\lambda\pi(R^2-r^2)}{2}}}{n!}\right] \\ &= \frac{\left(\frac{p\lambda\pi(R^2-r^2)}{2}\right)^k}{k!} \cdot e^{-\frac{p\lambda\pi(R^2-r^2)}{2}} \end{aligned} \tag{4}$$

Therefore the probability to select at least k nodes in the shaded area of the communication range:

$$\overline{P(k)} = 1 - \sum_{i=0}^{k-1}\left[\frac{\left(\frac{p\lambda\pi\left(R^2-r^2\right)}{2}\right)^i}{i!} \cdot e^{-\frac{p\lambda\pi\left(R^2-r^2\right)}{2}}\right] \tag{5}$$

From the Eq. (5), we can easily obtain the probability P to select at least one node within the shaded area with radius R.

$$P = 1 - P\,(X = 0) = 1 - e^{-\frac{p\lambda\pi(R^2-r^2)}{2}} \tag{6}$$

Figure 8 shows the probability of finding at least k nodes in the area S_A when λ are 0.0003 and 0.0005 nodes/km^2. From the Fig. 8, it can be seen that the probability of finding one or more vehicles within the transmission range is close to 1. Therefore, a vehicle should be within the range of at least one other vehicle to maintain connectivity and support multihop routing in the network.

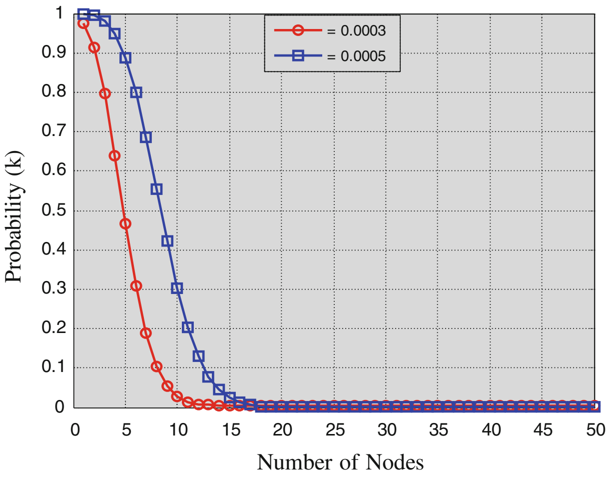


Fig. 8 Probability of at least *k* nodes in the *shaded area*

6.2 Expected Number of Successful Hops

Packet transmission fails if packet not arrives in the shaded area, which happens with probability $q = 1 - p$. We consider the topology effect on the route to the destination. If a packet arrives in the shaded area, it will be forwarded towards the destination by using the neighbor node closest to the destination. Let H is a random variable representing the number of hops upto which link is available between source and destination. Therefore, the probability that there are n links available between source and destination is given by:

$$P(H = n) = (1 - p)\, p^n$$

Then with Eq. (6), the expectation $E(H)$ for the number of successful hops is given as follows:

$$\begin{aligned} E(H) &= \frac{p}{1-p} = \frac{1 - P(X=0)}{P(X=0)} \\ &= \frac{1 - e^{-\frac{p\lambda\pi(R^2-r^2)}{2}}}{e^{-\frac{p\lambda\pi(R^2-r^2)}{2}}} \\ &= e^{\frac{p\lambda\pi(R^2-r^2)}{2}} - 1 \end{aligned} \tag{7}$$

6.3 Expected Distance Between Source and Next-Hop Node

Assume a source node S has n neighbors in the direction of destination node. Let A is the farthest node (peripheral node) of the transmission range R of source node S (as shown in Fig. 6). Let $d_1, d_2, d_3 \ldots, d_n$ denotes the distances between source node and its neighbors [15]. x is the distance between source node and its farthest node, i.e.

$$x = Max_{i=1}^{n} d_i$$

Then we can calculate the expected value of distance x for the peripheral node to send the packet to the destination as follows:

Let $F(x)$ and $f(x)$ be the *CDF* and *PDF* of x. Then,

$$F(x) = P\left[d_1 \le x, d_2 \le x, \ldots, d_n \le x\right]$$
$$= \prod_{i=1}^{n} P\left[d_i \le x\right] = \left(\frac{x}{R}\right)^n$$

Similarly,

$$f(x) = \frac{d}{dx}F(x)$$
$$= \frac{d}{dx}\left(\frac{x}{R}\right)^n = \frac{n}{R}\left(\frac{x}{R}\right)^{n-1}$$

The expected value of x is,

$$E(x) = \int_r^R x.f(x)dx$$
$$= \frac{n}{R^n}\int_r^R x \cdot x^{n-1}dx = \frac{n}{R^n}\left[\frac{x^{n+1}}{n+1}\right]_r^R$$
$$= \frac{n}{R^n}\left[\frac{R^{n+1}}{(n+1)} - \frac{r^{n+1}}{(n+1)}\right]$$
$$E(x) = \frac{n \cdot \left[R^{n+1} - r^{n+1}\right]}{(n+1) \cdot R^n} \tag{8}$$

6.4 Expected One-Hop Progress

The actual distribution of number of nodes located in a shaded area towards destination as derived in Eq. (4). From Eqs. (4) and (8), we can obtain the expected one-hop progress *EHP* depending on the transmission range R and node density λ.

$$EHP = \sum_{k=1}^{\infty} \frac{\left(\frac{p\lambda\pi(R^2-r^2)}{2}\right)^k}{k!} \cdot e^{-\frac{p\lambda\pi(R^2-r^2)}{2}} . \frac{k.\left[R^{k+1} - r^{k+1}\right]}{(k+1) \cdot R^k}$$
$$= e^{-\frac{p\lambda\pi(R^2-r^2)}{2}} \sum_{k=1}^{\infty} \frac{\left(\frac{p\lambda\pi(R^2-r^2)}{2}\right)^k}{k!} . \frac{k.\left[R^{k+1} - r^{k+1}\right]}{(k+1) \cdot R^k} \tag{9}$$

In Eq. (6), we obtained the probability P to select at least one node within the shaded area with radius R. Therefore, the expected one-hop progress (*EHP*) for a node present in the shaded area can be obtained dividing by (6).

$$EHP = \frac{e^{-\frac{p\lambda\pi(R^2-r^2)}{2}}}{1 - e^{-\frac{p\lambda\pi(R^2-r^2)}{2}}} . \sum_{k=1}^{\infty} \frac{\left(\frac{p\lambda\pi(R^2-r^2)}{2}\right)^k}{k!} . \frac{k.\left[R^{k+1} - r^{k+1}\right]}{(k+1) \cdot R^k}$$
$$= \frac{1}{e^{\frac{p\lambda\pi(R^2-r^2)}{2}} - 1} . \sum_{k=1}^{\infty} \frac{\left(\frac{p\lambda\pi(R^2-r^2)}{2}\right)^k}{k!} . \frac{k.\left[R^{k+1} - r^{k+1}\right]}{(k+1) \cdot R^k} \tag{10}$$

Table 1 Parameter setup

Parameter	Value
Simulation area	2000 m × 2000 m
Transmission range	200 m
Number of nodes	0–200

7 Results and Performance Analysis

VANETs basically employ multi-hop communications, where message is forwarded from source to destination through multiple paths using intermediate nodes. In city vehicular traffic environment, there are many intersections with traffic signs. To communicate with other vehicles, a packet is passed from one intersection to another intersection. In this section, we have evaluated the performance of our proposed routing protocol for vehicular networks where results obtained through simulation. To simulate an unbounded area, only nodes located at a distance larger than the transmission range R away from any peripheral of the area are considered for packet transmissions. We use GEDIR routing protocol for comparison with P-GEDIR.

In this section, some results obtained through MATLAB simulator are presented. The performance of P-GEDIR is computed analytically and numerically both. Based on the simulation parameters given below, we have simulated the protocol with a variable number of nodes from 0 to 200 and node densities. We use a 2000 m × 2000 m square area and a transmission range of 200 m for simulation. In the simulations, results have been computed in terms of one-hop progress and average number of successful hops between source and destination Table 1.

7.1 One-Hop Progress

Figure 9 shows the corresponding result for one-hop progress. From the Fig. 9 we can observe that as the number of nodes increases, the one hop progress initially increase rapidly. After the

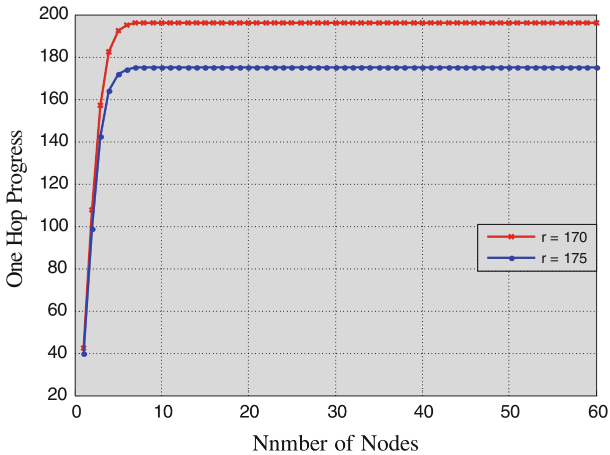


Fig. 9 Expected one-hop progress

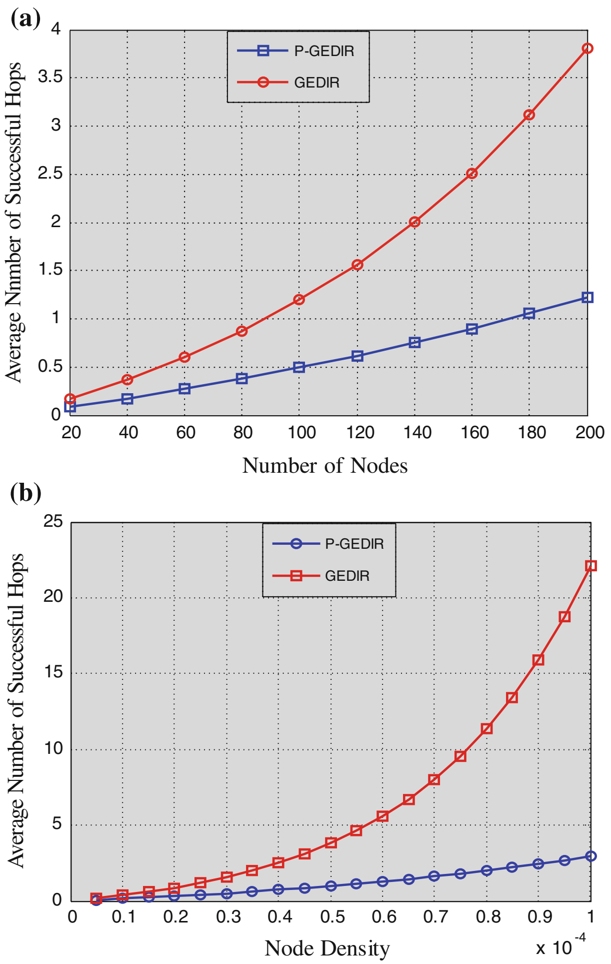


Fig. 10 Average number of successful hops

number of nodes reaches 10, the one-hop progress remains constant at about 196.1016 and 174.9050 m and then gradually reaches 196.1026 and 174.9056 m for two different values of radius r, 170 and 175 m respectively. As the radius r is decreases, the number of nodes in the shaded area is increases. Therefore, the expected one-hop progress attains quickly the maximum transmission range R.

7.2 Average Number of Successful Hops

In this section, we have shown the performance comparison between GEDIR and P-GEDIR. We considered the average number of successful hops is an essential performance measure for VANET and the results for which are shown in Fig. 10. At first, we notice that the average number of successful hops for both the protocols clearly increase as the number of nodes and node density increases. But for P-GEDIR, number of successful hops is significantly lower than GEDIR due to using the peripheral node for packet transmission only. This difference is clearly evident from the Fig. 10a, when the number of nodes is 200, the number of successful hops for P-GEDIR is 1.2280 and for GEDIR it is 3.8105. Similarly, from the Fig. 10b when node density is 0.0001, the number of successful hops for P-GEDIR is 2.9529 and for GEDIR it is 22.1407.

8 Conclusion and Future Works

In this work, we have proposed a new position-based routing protocol that we call Peripheral node Geographic Distance Routing (P-GEDIR). The main design goal of P-GEDIR method is to select the appropriate peripheral node to route data packet in VANETs. P-GEDIR optimizes the forwarding behavior based on the one-hop neighbor information received in Hello packet exchange process. It reduced the forwarding delay and considers constant forwarding distance between two neighboring nodes to achieve the high reliability. Simulation results shows that P-GEDIR gives better performance than GEDIR in terms of average number of successful hops and one-hop progress. As for future works, VANETs needs more research which could lead to further improvements in vehicular ad hoc routing.

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Author Biographies

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