Intersection Area Based Geocasting Protocol (IBGP) for Vehicular Ad Hoc Networks

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Abstract. Geocasting is a special variant of multicasting, where data packet or message is transmitted to a predefined geographical location i.e., known as geocast region. The applications of geocasting in VANET are to disseminate information like, collision warning, advertising, alerts message, etc. In this paper, we have proposed a model for highway scenario where the highway is divided into number of cells. The intersection area between two successive cells is computed to find the number of common nodes. Therefore, probabilistic analysis of the nodes present and void occurrence in the intersection area is carried out. Further, different forwarding zones are used for data delivery. Number of nodes present and void occurrence in the different forwarding zones have also been analysed to determine the successful delivery of data. Our analytical results show that in a densely populated network, data can be transmitted with low radio transmission range. It also shows that selection of forwarding areas depends on the node density in the network.

Keywords: VANET, Geocast, Forwarding area, Intersection Area, Void.

1 Introduction

VANET is a special class of Mobile Ad hoc Network (MANET).A Mobile Ad hoc network is a dynamically reconfigurable wireless network with no fixed infrastructure. Every node in this network behaves like a router to relay a message from one node to another. In MANET; nodes are laptops, PDAs, palmtops, and other mobile devices whereas in VANET [1] nodes are vehicles. In addition, the other characteristics which differentiate VANET from MANET are mobility of nodes; structure of the geographical areas, delay constraint, privacy, etc. The node movement depends on the structure of road or structure of city or terrain etc. While delivering message from source to destination node, if destination node is not within the transmission range of source node then the source node send the message to the destination node with the help of intermediate nodes. The ad hoc network is multi-hop in nature and message delivery depends on the connectivity among the intermediate nodes. The message delivery from one location to another location is done with the help of intermediate nodes. The aim of Geocast routing

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protocols is to deliver a message from one location (i.e. sender) to a predefined location known as Geocast region with optimal number of node and time period. It is desirable that protocols should maintain the low end-to-end delay and high success ratio in delivering message.

The rest of paper is organized as follows. Section 2 presents work related to the geocast protocols. In section 3 overview of our proposed mathematical model is presented. In section 4 nodes presence and void occurrences has been analyzed in the intersection area. In section 5 different forwarding areas are discussed. Finally, the work presented in this paper is concluded in section 6.

2 Related Work

Extensive works have been carried out by researchers, academicians and industries for successfully dissemination of messages from source to destination. There are several projects [2], [3], [4], [5] on VANET i.e. CarTalk, FleetNet–Internet on the Road, NoW (Network on Wheel)] are going on for its deployment in the real world. The main focus of all these projects is to provide safety, and timely dissemination of message from one location to another location. One of the message delivery protocols proposed for VANET tries to deliver a message to a geographic region rather than to a node called geocast routing. Many protocols have been developed for geocast routing such as LAR [6], LBM [7], GeoTORA [8],a modified TORA, GeoGRID [9], a modified GRID, GAMER [10], GRUV [11], etc. A Voronoi diagram based geocast protocol has been proposed in [12]. A comprehensive survey of geocasting protocol is presented in [13]. In [6, 7, 10, 11] authors used optimized flooding techniques for data delivery from source node to geocast region. In all these protocols, a forwarding zone is defined. The forwarding zone is a smaller area which includes source node, intermediate nodes and geocast region. The advantage of defining forwarding zone is that it helps in achieving optimized flooding and reduced routing overheads. Further, it also optimizes the network area. The data from source node is routed to geocast region with the help of intermediate nodes present within the forwarding zone. In [7] author's uses two types of forwarding zone LBM-box and LBM-step. The LBM-box is the smallest rectangle that includes source node and geocast region. The LBM-step is adaptive in nature it does not define the forwarding zone explicitly. The intermediate node which is closer to the smallest circle centered at the geometrical centre of the geocast region forwards the message. In [10, 11] authors have used different forwarding zones that are i) CONE ii) CORRIDOR and iii) FLOOD. The GAMER provides mesh of paths between source node and geocast region. The mesh is created within the forwarding zone. As the traffic density in the network vary with time, both the protocols switches among different forwarding zones according to traffic density in the network. Once, a method fails to deliver message to the geocast region it automatically switches to other method. The main advantages of defining a forwarding zone are i) limited flooding in the network. ii) Reduced routing overheads iii) reduced overall network space. Each intermediate node receiving packet from source node will check its position first. If the receiving node falls within the forwarding zone, it only then forwards the packets to its next hop node, otherwise it discards the packet. None of these protocols considered the road structure since they have been primarily designed for MANET. In [14] authors have designed an analytical model for the performance analysis of Contention-based Geographic Forwarding (CGF) protocol with different forwarding areas. Further, they provide procedure for selecting different forwarding area for data transmission. The three forwarding areas named as Maximum Forwarding Area (MFA), Maximum Communication Area (MCA) and 60° Radian Area (DRA).The MFA is the overlapping area of two circular areas and it depends on the transmission radius, distance between the sender and the destination node.

The geocasting is the variant of multicasting, in geocasting source node sends message to a particular geographical area. We divided the geocast method in two phases. In the Phase-I, a source node sends a message to a node inside the geocast region. In the phase-II, the receiving node of the geocast region delivers the message to all the nodes in the geocast region. The node that moves to a geocast region automatically becomes the member of the geocast region. In Phase-II, the message delivery inside the geocast region is done by simple flooding techniques. Here, in this research we have confined our work only on the phase –I. In this work, we have carried out the probabilistic analysis of nodes and effect of various network parameters i.e., transmission range of node, node density on the performance of the network.

3 Proposed Model

We have considered multi-hop environment, because it’s very rare that source and destination node fall within each other’s transmission range. In case there is no direct connectivity between source and destination node, to route the message, intermediate nodes plays a vital role. The intermediate nodes act as relay or next forwarding node. We have considered highway scenario to deliver message from source to geocast region shown in Fig.1.

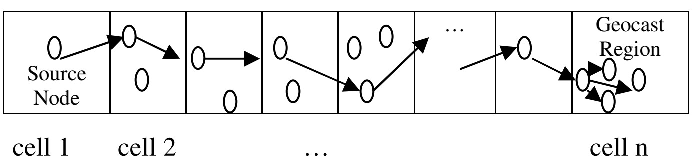

Fig. 1. Simple Scenario of Geocast on Highway

Table 1. Symbol notation

Symbols	Description
N	Total number of nodes in network
A	Area of network
R	Radio Transmission Range
A_1 and A_2	Area within the intersection area
S	Source Node
A_{int}	Intersection area between two successive cell
I	Intermediate Node

In our proposed model we have considered a highway scenario. It is divided in to *n* number cells of rectangular size. The length and width of the rectangular cell is denoted by *L*, and *W,* respectively. We assume that each cell is fully covered by a circular region of radius R. According to our assumption two successive cells share some common area that is denoted as intersection area. In Table 1. We have listed different symbols used in our analysis.

3.1 Computation of Intersection Area

In the Fig.1, we have shown a highway model for geocasting. We assume that at the center of each cell one node is present. The connectivity between center nodes depends on the nodes present within intersection area. Here, we compute the intersection area between two successive cells according to Fig.2.

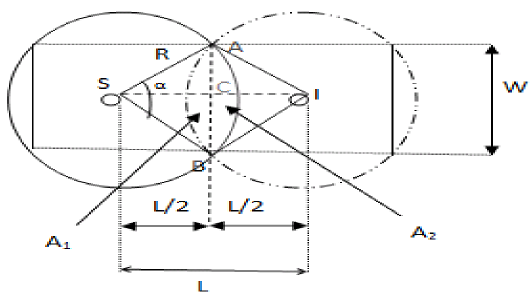

Fig. 2. Shows the intersection area between two cells

The Intersection area is denoted by A_{int}. Where, $A_{int}= A_1+A_2= 2\ A_1$, because the area of A_1 and A_2 are equal. The area of A_{int} computed as follows

The area of sector ABI=Area of sector SAB= $\frac{\alpha}{360} \times \pi R^2$. (1)

The area of triangle SAB and ABI can be calculated as follows. For ΔSAB, SA=SB=R and AB=W and for ΔABI, AI=BI=R and AB=W. According to Heron's area of a triangle it is calculated as

The semi-perimeter of ΔSAB= S' = (SA+SB+AB)/2 = (2R+W)/2. (2)

$$Area = \sqrt{\frac{(2R+W)}{2} \times \left(\frac{(2R+W)}{2} - R\right) \times \left(\frac{(2R+W)}{2} - R\right) \times \left(\frac{(2R+W)}{2} - W\right)}$$

$$= \frac{W}{4} \times \sqrt{4R^2 - W^2}\ . \quad (3)$$

Now, area of $A_1 = A_2 = \left(\frac{\alpha}{360} \times \pi R^2\right) - \left(\frac{W}{4} \times \sqrt{4R^2 - W^2}\right)$. (4)

$$A_{int} = A_1 + A_2 \qquad = 2 \times \left[\left(\frac{\alpha}{360} \times \pi R^2\right) - \left(\frac{W}{4} \times \sqrt{4R^2 - W^2}\right)\right]. \quad (5)$$

Where, $\tan\left(\frac{\alpha}{2}\right) = \frac{W}{L}$ So,$\alpha = 2 \times \tan^{-1}\left(\frac{W}{L}\right)$. Now compute the value of A_{int} by putting the value of α in eq-(5).

$$A_{int} = 2 \times \left[\left(\frac{2 \times tan^{-1}\left(\frac{W}{L}\right)}{360} \times \pi R^2\right) - \left(\frac{W}{4} \times \sqrt{4R^2 - W^2}\right)\right]$$
$$= \left(R^2 \times 2 \times tan^{-1}\left(\frac{W}{L}\right)\right) - \left(\frac{W}{2}\sqrt{4R^2 - W^2}\right). \quad (6)$$

4 Analysis of Presence of Nodes in the Intersection Area

We have considered a multi hop network scenario. If source and destination nodes are not in their direct communication range, intermediate nodes act as a relay node to deliver data from source to destination node. According to our model, we have chosen the intermediate node from the intersection area of two successive cells. The availability of node in the intersection area depends on various network parameters such as node density, radio transmission range, size of the cells, area of the network etc. The nodes in the network are distributed according to 2-D poisson point process. The probability of non- availability of nodes (void) in the intersection area can be calculated as follows. The probability of *m* nodes present within an area A with average node density λ is calculated as

$$p(m) = \frac{(\lambda A)^m \times e^{-\lambda A}}{m!}. \quad (7)$$

The probability of void in the area A_{int} can be calculated as

$p\{A_{int}\ (void)\}$

$$= \frac{\left(\lambda \times \left(R^2 \times 2 \times \tan^{-1}\left(\frac{W}{L}\right)\right) - \left(\frac{W}{2}\sqrt{4R^2 - W^2}\right)\right)^0 \times e^{-\lambda \times \left(\left(R^2 \times 2 \times \tan^{-1}\left(\frac{W}{L}\right)\right) - \left(\frac{W}{2}\sqrt{4R^2 - W^2}\right)\right)}}{0!}$$
$$= e^{-\lambda \times \left(\left(R^2 \times 2 \times \tan^{-1}\left(\frac{W}{L}\right)\right) - \left(\frac{W}{2}\sqrt{4R^2 - W^2}\right)\right)}. \quad (8)$$

4.1 Numerical Results

In Fig.3, we have shown probability of void in the intersection area. The data transmission cannot be possible if no node is present in the intersection area. We have considered different number of nodes with varying transmission range from 100 m to 250 m. We have observed that, initially for transmission range of 100 m, as the number of nodes increases from 100 to 500, the probability of occurring void in the intersection area decreases from 0.6420 to 0.1091. For transmission range 150 m, and 500 nodes, the probability of occurring void in the intersection area becomes 0. For the simplicity we have shown the above result only for up to 500 nodes. The overall behavior we observed that as the number of nodes increases probability of occurrence void is almost zero.

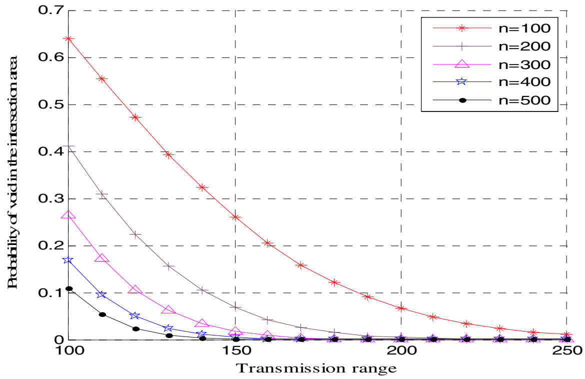

Fig. 3. Shows probability of void in the intersection area with variable number of nodes

Table 2. Probability of occurring void in the intersection region

No of nodes	Transmission Range (m)						
	100	120	150	170	190	200	250
100	0.6420	0.4731	0.2600	0.1590	0.0902	0.0661	0.0105
200	0.4122	0.2238	0.0676	0.0253	0.0081	0.0044	0.0001
300	0.2646	0.1059	0.0338	0.0086	0.0018	0.0007	0.0000
400	0.1699	0.0501	0.0046	0.0006	0.0001	0.0000	0.0000
500	0.1091	0.0237	0.0012	0.0001	0.0000	0.0000	0.0000

In the above we have shown the probabilistic analysis of occurrence of void in intersection area. Now, we will analyze the presence of node in the intersection area by varying different network parameters. Therefore, the probability of m nodes present in A_{int} area can be calculated as

$$p\{A_{int}\ (m)\} = \frac{\left(\lambda\times\left(R^2\times 2\times\tan^{-1}\left(\frac{W}{L}\right)\right)-\left(\frac{W}{2}\sqrt{4R^2-W^2}\right)\right)^m \times e^{-\lambda\times\left(\left(R^2\times 2\times\tan^{-1}\left(\frac{W}{L}\right)\right)-\left(\frac{W}{2}\sqrt{4R^2-W^2}\right)\right)}}{m!} \quad . \tag{9}$$

Where, λ is the expected number of nodes within a unit area. In Fig.4, we have shown probability of nodes present in the intersection area. We have considered different values of transmission range 150, 200 and 250 m. We have shown only 50 nodes for clarity of graphical representation. For our analysis we have considered number of nodes upto 2000. The probability of getting one node in the intersection area is 1, after 30 and 44 nodes when transmission range is 200 m and 250 m. Further, the probability 0.9988 is constant after 19 nodes onwards when the transmission range is 150 m.

Now from the above analysis we have observed that for the better connectivity of the network intersection area should have one node. In the sparsely populated network the transmission range should be high for better connectivity of network. In the dense network, short transmission ranges results good connectivity in the network.

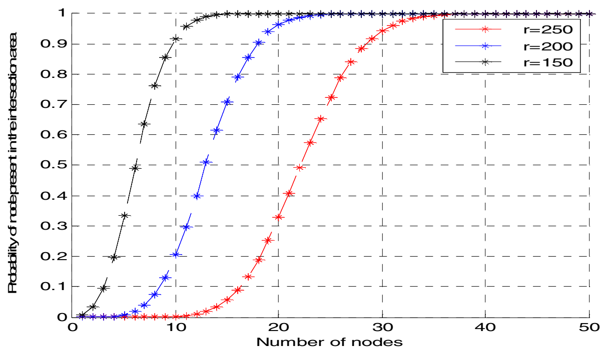

Fig. 4. Shows probability of node present in the intersection area with variable transmission range

5 Forwarding Areas in the IBGP

In our above discussion, we have given analysis of presence and absence of nodes in the intersection area for varying node density, and radio transmission ranges. Now, we have used different forwarding zones based on radian area according to [14]. The advantage of forwarding zone, it reduces the network overheads and network space for data delivery since the nodes that fall outside the forwarding zone do not participate in message delivery. In [14], a fixed radian area considered is of 60^0. In our model we have chosen various value of radian area by varying the value of α shown in Fig.5. The value of radian area is changes with varying value of W and L.

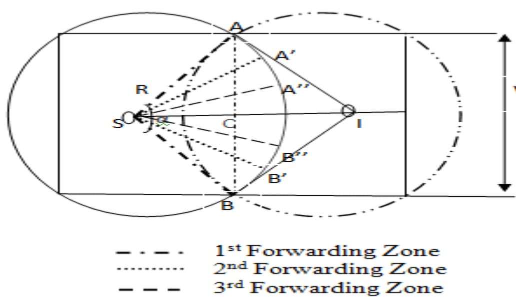

Fig. 5. Shows different forwarding zones of IBGP

5.1 Computation of Forwarding Areas

The radian area of angle α, i.e. the area of sector SAB $= \frac{\alpha}{360} \times \pi R^2 = \frac{2\times \tan^{-1}\left(\frac{W}{L}\right)}{360} \times \pi R^2 = R^2 \times tan^{-1}\left(\frac{W}{L}\right)$. Now we have defined three different radian forwarding zones according to Eq-(10).

$$RadianForwardingarea = \begin{cases} \alpha_1 \ ; \text{ where SAB} = \tan^{-1}\left(\frac{W}{L}\right) \times R^2, AC = \frac{W}{2} \text{and SC} = L/2 \\ \alpha_2 \ ; \text{Where SA}'B' = \tan^{-1}\left(\frac{W}{2L}\right) \times R^2, AC = \frac{W}{4} \text{and SC} = L/2 \ . \\ \alpha_3 \ ; \text{ Where SA}''B'' = \tan^{-1}\left(\frac{W}{4L}\right) \times R^2, AC = \frac{W}{8} \text{and SC} = L/2 \end{cases} \quad (10)$$

Probabilistics analysis of void occurance in the different forwarding area can be calculated as

$$\text{p\{Radian Forwarding area } \alpha_1 \text{ (void)\}} = e^{-\lambda\times\left(\tan^{-1}\left(\frac{W}{L}\right)\times R^2\right)}. \quad (11)$$

$$\text{p\{Radian Forwarding area } \alpha_2 \text{ (void)\}} = e^{-\lambda\times\left(\tan^{-1}\left(\frac{W}{2L}\right)\times R^2\right)}. \quad (12)$$

$$\text{p\{Radian Forwarding area } \alpha_3 \text{ (void)\}} = e^{-\lambda\times\left(\tan^{-1}\left(\frac{W}{4L}\right)\times R^2\right)}. \quad (13)$$

5.2 Numerical Results

In Fig.6 shows the occurrence of void in different forwarding areas. We have fixed the number of nodes as 500 and vary the transmission range from 250 m to 500 m. The probability of occurrence of void in different forwarding areas is clearly shown in Fig 6(a), Fig 6(b) and Fig 6(c). In first forwarding zone the probability of occurrence of void is 0.5099 x10^{-7} for transmission range of 250 m. In 2nd and 3rd forwarding area probability of occurrence of void is 0.4865 x10^{-22} and 0.4926 x10^{-22}, respectively for transmission range 250 m. The probability of occurrence of void is zero for 1st forwarding area for transmission range 320 m and for 2nd and 3rd area is zero after transmission range 280 m. In 1st forwarding area to provide better connetcivity in the network data should be transmitted using 320 m transmission range or above and for the other two zones it should be higher than 280 m.

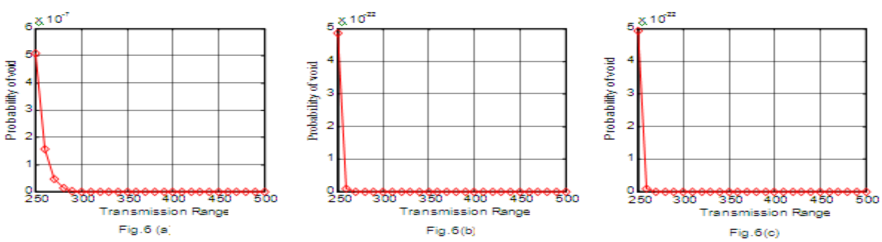

Fig. 6. Shows probability of void in different Forwarding Areas

Probabilistics analysis of presence of nodes in different forwarding areas can be calculated as

$$\text{p\{Radian Forwarding area } \alpha_1 \text{ (m)\}} = \frac{\left(\lambda R^2\times tan^{-1}\left(\frac{W}{L}\right)\right)^m \times e^{-\lambda\left(R^2\times\tan^{-1}\left(\frac{W}{L}\right)\right)}}{m!}. \quad (14)$$

$$p\{\text{Radian Forwarding area } \alpha_2 \text{ (m)}\} = \frac{\left(\lambda R^2 \times tan^{-1}\left(\frac{W}{2L}\right)\right)^m \times e^{-\lambda\left(R^2 \times tan^{-1}\left(\frac{W}{2L}\right)\right)}}{m!}. \quad (15)$$

$$p\{\text{Radian Forwarding area } \alpha_3 \text{ (m)}\} = \frac{\left(\lambda R^2 \times tan^{-1}\left(\frac{W}{4L}\right)\right)^m \times e^{-\lambda\left(R^2 \times tan^{-1}\left(\frac{W}{4L}\right)\right)}}{m!}. \quad (16)$$

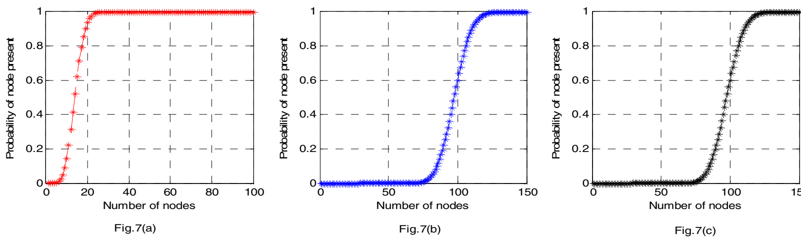

Fig. 7. Shows probability of node presence indifferent Forwarding Areas

In Fig 7 shows the probability of presence of nodes in different Forwarding Areas for a fixed transmission range of 250 m. We have shown the result only for up to 100 nodes. In Fig.7(a), after 30 nodes in the first forwarding zone nodes are always present. In Fig.7(b) and Fig.7(c) till 61 nodes there is no node present but after 139 nodes, there are always nodes present in 2nd and 3rd forwarding zone. Therefore, we can observed that in low density network 1st forwarding zone should be considered and when the number of nodes are above 60 nodes, 2nd and 3rd forwarding zone should be considered.

6 Conclusion

In this paper we have analyzed the impact of node density, transmission range, network size on network connectivity for a highway scenario. In this work we have computed the probability of presence of common nodes between successive cells in a linear route. We have also investigated the impact of three different forwarding zones for data transmission on the network connectivity. From the analysis of simulation results we have that for higher number of nodes and transmission range, the probability of void occurrence in the intersection area is low. But, for better network connectivity and uninterrupted data transmission intersection area should have at least one node. Further, it also suggests that if the number of nodes is small, the probability of void occurrence is high.

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