A New Geocast Routing Protocol for VANETs

Sina Gogani Khiabani
Department of Computer Engineering
Istanbul Technical University
Istanbul, Turkey
Email: khiabani17@itu.edu.tr

Sema Oktuğ
Department of Computer Engineering
Istanbul Technical University
Istanbul, Turkey
Email: oktug@itu.edu.tr

2021 6th International Conference on Computer Science and Engineering (UBMK) | 978-1-6654-2908-5/21/$31.00 ©2021 IEEE | DOI: 10.1109/UBMK52708.2021.9558901

***Abstract*— Efficient routing in the vehicular Ad hoc networks (VANET) is a crucial issue, especially in the recent years due to advances in technology and car industry. VANET's rapidly changing topology and high speed of nodes makes routing challenging. Geocast routing is a sub-category of location based routing where the destination of the data is any node in a geographical area. First, we study some works done in this category with different approaches and then we present a new geocast routing protocol without the use of beacon messages where forward progress to the destination, intersection awareness and location prediction are taken into account.**

I. Introduction

Today, the use of cars for urban and suburban traffic has grown rapidly and innumerably. Due to the development of communication and information technology as an advantage, there is a greater need to use intelligent vehicle communication technology in the field of road transport. Now modern cars are equipped with electronic equipment such as in-car sensors, radar, digital maps, etc., which can increase the level of driver information about the car as well as the cars around it. We can prevent many accidents, using radio equipment due to the high speed of radio waves which lets the driver learn important and essential information much faster than usual [1].The main purpose here is to form an inter-vehicle network so that cars can be connected to other vehicles. VANETs can be used as an important communication infrastructure in the transport systems in order to enable traffic management and prevent accidents.

In fact, VANETs are a special type of mobile ad hoc networks (MANET), where nodes are vehicles. Each vehicle can identify the vehicles around it at any time and connect to them to form a network and establish the necessary connections. Vehicles communicate with each other completely autonomously and create a non-structured wireless network.

The design of routing protocols in VANET networks is an important and necessary issue to support VANET-related applications. Of course, due to the high mobility of the nodes and the inherent nature of these networks, vehicles are moving at high speeds, and it is possible for them to change direction at any time, establishing a stable connection between nodes is a difficult task when frequent link failures can happen in these networks. Many routing protocols are designed for MANET networks, but these protocols are not suitable for high-speed nodes in VANETs [2]. Due to the high mobility of nodes in VANETs, geographical and position based protocols are more appropriate protocols. Where, using the node positioning system, the position of the node itself is identified and also the location information of adjacent nodes is sometimes obtained using periodic beacon messages and sometimes without using these messages which guarantees data delivery [3-4].

Geocast routing is a kind of location based routing where the sender wants to send the message to any node in a geographical area. Some of these protocols use beacon messages to inform neighboring nodes of their locations but due to the high speed of vehicles and the changing topology in VANETs, this information may not be accurate or even expired until the decision is made, which leads to incorrect and inefficient decisions and ultimately leads to delay or packet drops. And of course the use of beacon messages can cause network congestion.

In this research, a geocast routing protocol without beacon messages, which is based on self-decision-making approach, will be presented, where sending data packets is divided into two parts. The first part is when the sender node is in the intersection and the second part is when the sender node is between two intersection. It should be noted that in this research, we are trying to send data with the least delay and the highest rate of delivery in the network without using beacon messages.

This paper is oganized as follows. In section II we talk about some related works done in this field. Section III is the full description of the proposed protocol. In secrion IV we examine the protocol and compare it to two other protocols. Section V is conclusion of the work and some ideas and approaches we are thinkining about to use in our future work.

II. Related works

The IGRP (Intersection-based Geographical Routing Protocol) protocol [5] is an intersection-based geographic routing protocol that generally has a similar mechanism to our work. This protocol selects the route that is most likely to be connected and also takes into account the hop count and end to end delay. However, a central control unit as gate needs to gather complete information about the vehicles around it using a location-aware service and use genetic algorithm to select better routes. Therefore, IGRP could not be considered as a fully distributed routing algorithm. Also, considering the complexity of the calculation and the speed of convergence of the genetic algorithm, it could cause some delay-sensitive services to fail. In addition, in this protocol with the assumption of Poisson distribution for all the cars in the network, it calculates the path connectivity which is not realistic in VANETs, especially when there are traffic lights, intersections and obstacles in the network.

Diagonal Intersection Based Routing Protocol (DIR) [6] is designed for urban VANET and has three different modes for routing. Packet transmission, route discovery and route maintenance. This protocol creates a set of diagonal intersections between vehicles from source to destination. According to the DIR protocol, the source vehicle first sends the data packet to the first diagonal intersection, the second diagonal intersection, and so on to the last diagonal intersection. DIR can automatically and dynamically select the path between two points with the least delay. This protocol reduces delay and increases packet delivery rate compared to existing routing algorithms. However, maintaining periodic links in this protocol will increase the network overhead.

Intelligent Beaconless Protocol (IB) [7] is a protocol for urban VANETs. This protocol uses the RTS/CTS approach and measures the signal strength, the distance between the source and the destination, as well as the direction. Candidate nodes are selected according to the signal strength and the direction of the next node. Experimental results show that the efficiency of this method is better in the average route delay in urban environments.

GeoTORA uses TORA unicast routing algorithm to geocasting for mobile ad hoc networks [8]. In GeoTORA, message is forwarded using uni casting through vehicles until it reaches a node in the destination region. Then this node floods the area with the message. This geocast routing protocol can work efficient for MANET but in high speed and volatile environment of VANET its performance is not promising.

In [9], authors examine geocast routing in delay tolerant VANETs for time-stable geocast perspective and present a geocast routing protocol that is opportunistic and time-stable. Whith this protocol, vehicles are located in a geocast destination area at predefined time interval. Authors of A-STAR [10] present an anchor-based street and traffic aware routing algorithm for VANETs. It uses bus routes to determine the traffic weight on path to destination and uses street map to find anchors.

In Geo-SID protocol [11] the authors' goal is to perform information dissemination safely within a Zone of Relevance (ZoR) and without the use of Zone of Forwarding (ZoF). The main idea behind this solution is to divide the urban area into a set of zones. In this protocol for every event triggered in a given zone Zi, there are some subzones that represents this ZOR. Here they use RSUs to send the information about this sub-zone to other nodes. When an event is detected by a vehicle, it checks out if this event is in its copy of the scheme that was sent by RSU or not. They use the well-known Slotted p-Persistence broadcasting method, to send the event message which works well if the network is connected. The probability for every node is calculated based on its distance to the next node.

Cache Agent-based Geocasting (CAG) protocol [12] is a geocast protocol in which some nodes are cache agents and some are cache users based on their location. All agents periodically transmit some information to users in their locality. Each user updates information about the agent in their cache agent table and uses it during routing. Cache agent caches the packets unless the receiver gets the packet. In CAG, local cache with each vehicle is maintained by a 'Beaconing System'. When there is a change in location of any vehicle in the network they would inform others.

GeoSPIN's [13] approach for Geocast routing based on Spatial Information in VANETs is divided into two phases. The first phase extracts the movement patterns of each node from its GPS data. The second phase applies a distributed algorithm for routing messages based on the information gotten in the first phase. In phase one they have adopted Ordering Points to Identify the Clustering Structure (OPTICS). This algorithm clusters the nodes based on the density in the data that they get from the GPS. In phase two they perform the message forwarding process.

III. A New Geocast Routing Protocol

This algorithm is divided into two parts. The first part is the function of the protocol between intersections and the second part is the function of the protocol at intersections. In the first part, the parameter of forward progress to the destination is used to select the next sender and in the second part, which is the performance of the algorithm at intersections, the directional greedy approach is used to select an efficient relay node. In the following, the details of the performance of each section are discussed.

A. *Proposed Protocol Between Intersections*

The Protocol has two phases when the sender is between two intersections. Here the parameter Forward Progress is calculated and based on that a weighted dynamic delay time is given to each neighboring node.

Using the criterion of proximity to the destination [14], the geographical progress of the candidate node for relay node selection can be obtained by considering the position of the source node. The RN_i node is a subset of nodes available to be relay candidate nodes. According to the following equation, the progress of the candidate node on route to destination area has a value between 0 and 1. The closer the value obtained in this function to zero, the better candidate node it will be for the next relay node.

$$Progress = f(x) = \begin{cases} \frac{2R - P(RN_i, SN)}{2R}, & if\ D(RN_i, DZC) > R \\ 0 & , if\ D(RN_i, DZC) < R \end{cases} \quad (1)$$

We denote $D(RN_i, DZC)$ as the Euclidian distance between a given RN_i and DZC (Destination Zone Center); R as the radio range, and 2R as the maximum progress. The sum of two segments (P1(RN_i) + P2(RN_i)) composes the geographical advance $P(RN_i, SN)$ of a given RNi towards the DZC, as shown in Fig.1 Here P1(RN_i) defined as the projection of the distance travelled from SN to any RNi, onto the line from SN to DZC. On the other hand, the projection of line RN_i-RN_i' on line SN-DZC defines P2(RN_i).

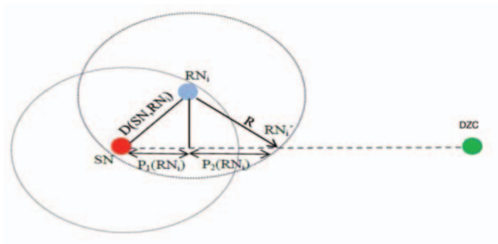

Fig.1 Forward progress

Progress function is defined as P1(RN_i), which may cause collisions, because multiple RN_i can forward packets at the same time when they have the same progress, i.e., P1(RN1) = P1(RN2), as shown in Fig.2 However, RN2 is closer to the line SN-DZC, increasing the progress in this definition, and also SN can transmit the packets to DZC via RN2 with only one hop, which cannot be achieved by RN1. The proposed Progress function gives higher priority to any RN_i, as soon as it is able to transmit packets directly to DZC [14].

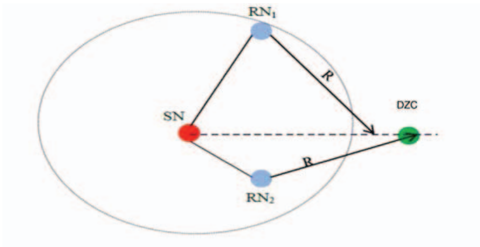

Fig.2 Priority of choosing next relay node

So, we talked about the relay node progress criterion for routing. Now we need to put this criterion in a function and create a weighing function with a value [14].

$$DFD = DFDmax \times (\gamma \times forward\ progress) \quad (2)$$

Equation 2 shows the values of $DFDmax$, γ and Forward Progress. $DFDmax$ [15]is the maximum time a node waits for the first response from one of its neighbors, and this value is considered a fixed value depending on the implementation conditions. γ is weight factor for Forward Progress and as one of the routing parameters. According to the previous section Forward Progress, determines the progress of the relay candidate node towards the origin and towards the destination. Each candidate node calculates the Dynamic Forwarding Delay (DFD) value for itself and after this time interval it will respond to the origin if needed.

B. *Proposed Protocol At Intersections*

When the sender node is at the intersection, the proposed protocol uses another method called greedy directional transmission, which is examined in this section.

When the sender node is at the intersection, protocol changes to directional greedy approach and in fact select the node that is closer to the DZC and in the same direction. In normal greedy approach, due to the multi-directional nature of the vehicle at intersections in VANETs, a loop may occur, so we use the direction and position parameters of the node moving towards the DZC to select the next relay node.

If only the greedy approach is used to select next relay node, it may increase the number of hops as well as delay in the network. The selection of the next hop is done using the weight scoring function [16], which will be calculated as follows.

$$Weighted\ Score_i = \alpha\left(\frac{SD_i}{FD_c}\right) + (1 - \beta\cos(\overrightarrow{V_i}, \overrightarrow{P_{i,d}})) \quad (3)$$

α and β are the weight parameters of position and direction, their value varies according to the implementation conditions and $\alpha + \beta = 1$. SD_i is the shortest distance between node i at the intersection and destination and FD_c represents the shortest distance from the source node to the DZC.

$\overrightarrow{V_i}$ is node i's speed vector and $\overrightarrow{P_{i,d}}$ is a vector between node i and DZC. Using $\cos(\overrightarrow{V_i}, \overrightarrow{P_{i,d}})$ we give priority to nodes with closer direction to DZC.

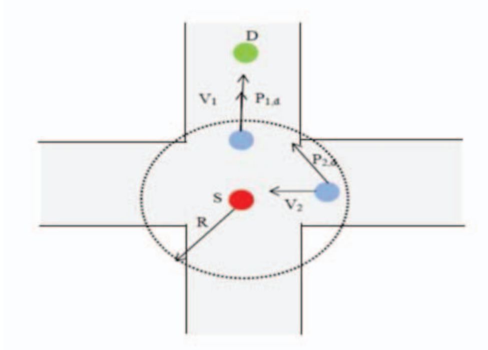

Fig.3 Node selection at intersection

In this section, we use the same approach as in equation 2, but with the difference that when the node is placed at the intersection, we use the weighted score calculated in equation 3 instead of the forward progress, to find the DFD [14].

$$DFD = DFDmax \times (\gamma \times Weighted\ Score_i) \quad (4)$$

In this equation, the weight scoring parameter is the input and the DFD value is the output parameter. γ is also a weight for the Weighted Score and is one of the routing parameters. Also, as in the previous equation, $DFDmax$ is the maximum time when the sender node waits for the first response from one of its neighbors, and this value is considered a fixed value according to the implementation conditions. Final decisions on routing depends on the values coming from this equation. Each node at intersection calculates DFD and waits for DFD amount of time before responding to sender.

C. *The function of selecting the RN subset of neighbor nodes in the proposed method*

In this method, we have two areas around the sender node, Positive Progress Area (PPA) and Negative Progress Area (NPA). Fig.4 shows the division between these two areas.

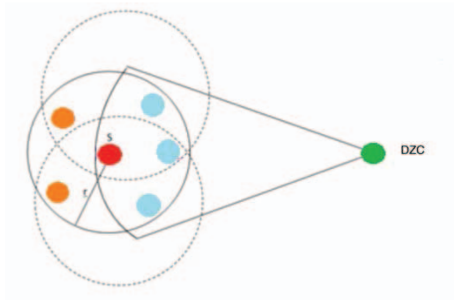

Fig.4 Limiting number of candidate nodes

Any node whose location is closer to the DZC than the source node is in the positive progression range. And nodes that do not progress to the destination will be in the negative range and include the rest of the neighboring nodes. Using this restriction method will reduce the number of candidates for the next relay selection.

The technique here uses a three-step hand-shaking mechanism to select and send messages. The main point of this method is the power of covering the neighbors. To do this, instead of using control and beacon messages, it uses the data packet from the beginning. In the first step, the source node sends the data packet with maximum power to reach the neighbors and then waits for the first response of one of the neighbors as much as DFDmax. Nodes that have received the complete and correct data packet calculate their scoring function, given that it is between the intersection or at the intersection. The higher priority candidate node sends a response message for the source node and other nodes and waits for the selection message from the source node. Each neighbor in the positive progress area that received the response message cancels its timer and deletes the message containing the data. When the sender node receives a response, it publishes a selection message to all nodes in the range. This message contains the ID of the selected node by the sender node. Each node that receives the selection message checks to see if it has been selected as the next step. If the node is not selected, it cancels its timer and removes the data packet from its buffer and returns to the original state. PACK (Passive Acknowledgement) is used to confirm the acceptance of the selection message by the selected node. In fact, the packet containing the data of the new sender node is used as a PACK to confirm the acceptance of the previously selected message. In the last step, when the packet containing the data reaches the destination, ACK is used instead of PACK to confirm the acceptance of the selection, because in the last step, the destination node will no longer send the packet

IV. Results

In this chapter, we review and analyze the implementations of the proposed protocol. We compare the results with two common routing protocols, AODV [17] and GPSR [18]. We have chosen these two because in our work the intended ZOR is far from the source so the typical flooding of the network would not have good results. NS2 software has been used to implement the proposed protocol. This simulator is installed on Linux operating system. In this simulation, the same conditions are considered for all three implemented protocols as in the proposed protocol.

A. Simulation Environment

NS2 software is a computer network simulator which is event-based and object-oriented. Initially, this software package was designed to simulate and implement wired networks. Today, this software is also used to simulate wireless networks, and according to studies, it is still one of the most widely used simulators in wireless networks. This software is written by C ++ and OTcl programming languages and is one of the best simulation tools for local and wide area networks.

Here the proposed method is compared to AODV and GPSR which are two well known protocols in VANET. We use these two protocols instead of some of geocast's well know protocols because in our approach the ZOR is far from the source so the usual flooding method that is often used in geocast protocols would have poor results. The performance of the proposed method is evaluated with end-to-end delay, overhead and packet delivery rate. Table.1 shows the parameters used for simulation.

The network scenario is randomly generated and has been tested with different number of nodes. In the following section we will take a look at the results and the comparison between these three protocols.

TABLE 1 SIMULATION PARAMETERS

Parameter	Value
Simulation Area	2800*2800 m
Simulation Time	500 s
Number of Nodes	50-350
Vehicle Velocity	20-60 Km/h
Transmission Range	250 m
Mac Protocol	IEEE 802.11
Data Packet Size	128 bytes
Channel Bandwidth	2 Mbpa
Packet Rate	0.5-5 Packet/s
Weighting Factors α , γ , β	(0.5, 0.01, 0.5)

B. Performance Results

Fig.5 shows the packet delivery rate based on the number of vehicles in the mentioned protocols. In mentioned protocols the packet delivery rate is lower than the proposed protocol, because in this category of protocols, due to the high speed of vehicles and changing network topology, the information (location, etc.) may not be accurate when sending the data packet, or Have expired. This will lead to wrong decisions and eventually lead to incorrect routing. The proposed protocol has a better packet delivery rate. Because in the proposed method, a data packet is sent at the very beginning with no beacon messages.

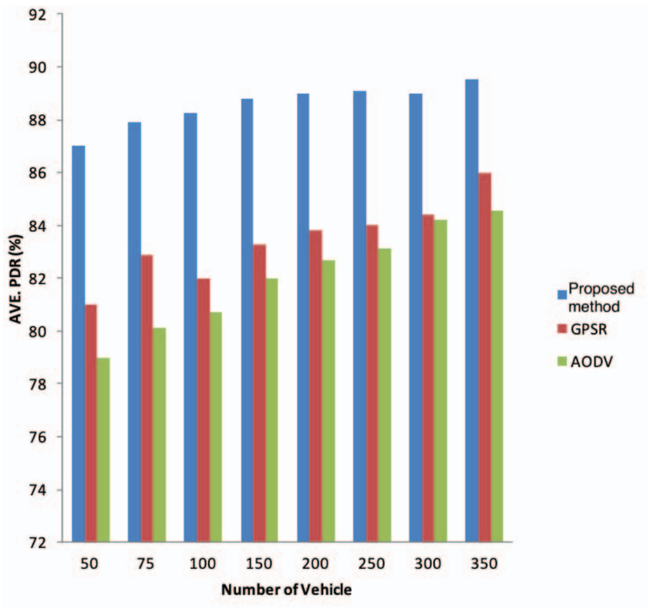

Fig.5 PDR with respect to number of nodes

End-to-end delay for a packet sent by node i (source node) and successfully reached destination as shown in Fig.6. The proposed method has less end to end delay than the other protocols, and the reason for this is the choice of routes and less number of hops so the route length is reduced compared to the other methods and the packet arrives at the destination faster than the other protocols, thus reducing latency.

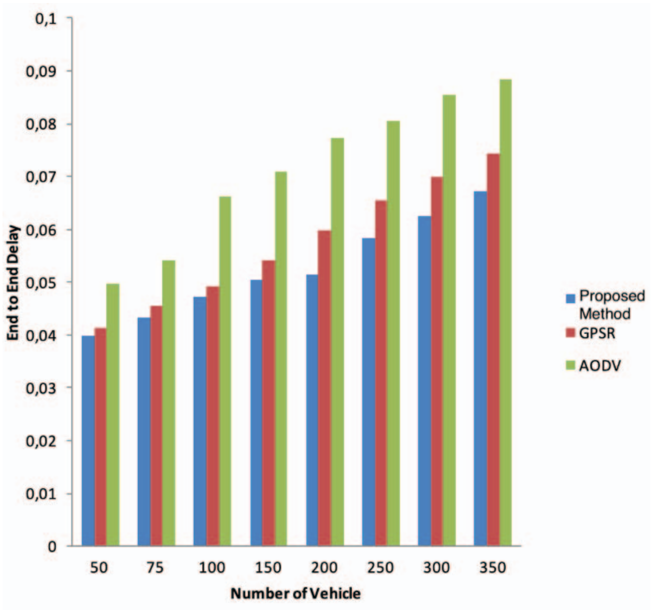

Fig.6 End to end delay with respect to number of nodes

Fig.7 shows the control overhead comparison of the proposed method with the mentioned protocols. Control overhead is always one of the most important and basic criteria for routing in wireless networks. Fig.7 shows that the proposed method has the lowest average control overhead compared to the studied protocols. As mentioned in the previous section, the reason for this is not using beacon messages in the process of routing and sending direct packets.

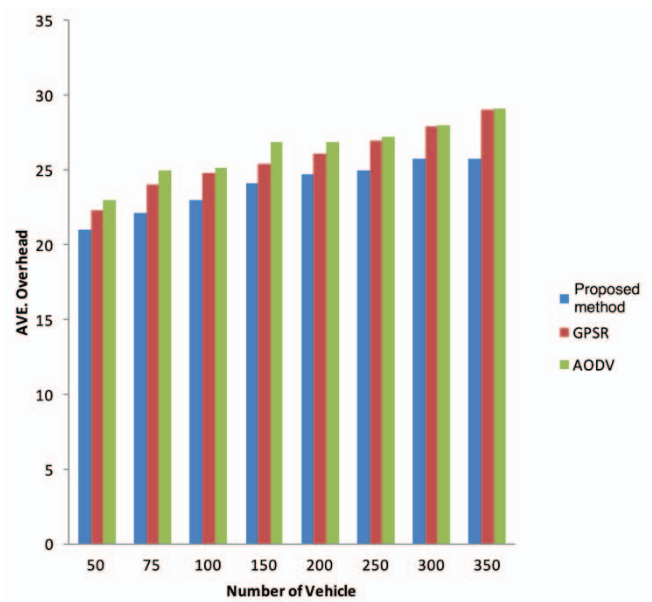

Fig.7 Overhead with respect to number of nodes

V. CONCLUSION AND FUTURE WORK

In this paper, a geographical routing algorithm without the use of beacon messages is presented based on the progress to the destination and with a three-step hand-shaking mechanism for selecting and sending messages. In VANETs, due to the dynamics of the network and the changing location of vehicles at any moment, a routing algorithm must be used that guarantees high packet transmission rates and low latency. As discussed in this work, there are many algorithms that ensure interconnection between nodes, but these protocols are usually designed on the assumption that vehicles are uniformly sharing their position and information using beacon messages and neighboring nodes update their information using these messages and this will reduce packet delivery ratio and increase delay. The results show the better performance of the proposed method in terms of packet delivery rate, control overhead and end-to-end delay in the network compared to the mentioned protocol (AODV, GPSR).

For our future work, first we will examine this protocol in real urban scenarios with roads and junction. we can use some new approaches to improve this protocol too. One noteworthy approach is using data mining and incorporating the past data in the protocol to be able to choose the best rout. Here we mention several practical suggestions to increase packet delivery rate:

- Retrieve past routes when there is no node ahead to select as the next relay node.
- We can take into account the cars moving in the opposite direction, when selecting the next node in such a way that they can provide a better result in cases where cars going in the same direction cannot be good choices.

REFERENCES

[1] Yousefi, S., Altman, E., El-Azouzi, R., Fathy M., (2008). Analytical model for connection in temporary vehicle networks., IEEE deals in automotive technology;57 (6): 3341-56.

[2] Qureshi, KN., Abdullah, H., (2013) Topology based protocol for VANET and their comparison with MANET., Journal of Theoretical and Applied Information Technology;58 (3): 707-15.

[3] Qureshi, KN., Abdullah, AH., Lloret, J., (2016). Road Perception-Based Geographic Routing Protocol for Temporary Vehicle Networks., International Journal of Distributed Sensor Networks;12 (2): 2617480.

[4] Qureshi, KN., Abdullah, AH., Lloret, J., Altameem, A., (2016). Aware Road Routing Strategies for Vehicle Temporary Networks: Specifications and Comparisons, International Journal Distributed sensor networks;12 (3): 1605734.

[5] Saleet, H., Langar, R., Naik, K., Boutaba, R., Nayak, A., Goel, N., (2011). Intersection-based geographical routing protocol for VANETs: a proposal and analysis., IEEE Transactions on Vehicular Technology;60(9):4560-74.

[6] Chen, YS., Lin, YW., Pan, CY., (2011). DIR: diagonal-intersection-based routing protocol for vehicular ad hoc networks., Telecommunication systems., 2011 Apr 1;46(4):299-316.

[7] Ghafoor, KZ., Bakar, KA., Lloret, J., Khokhar, RH., Lee, KC., (2013). Intelligent beaconless geographical forwarding for urban vehicular environments., Wireless networks., 2013 Apr 1;19(3):345-62.

[8] Y. Ko and Vaidya, N.H. (2000). GeoTORA: a protocol for geocasting in mobile ad hoc networks, *Proceedings 2000 International Conference on Network Protocols*.

[9] Gallego-Tercero, L.R., Menchaca-Mendez, R., Rivero-Angeles, M.E. and Menchaca-Mendez, R. (2020). Efficient Time-Stable Geocast Routing in Delay-Tolerant Vehicular Ad-Hoc Networks, *IEEE Access*, *8*, 171034–171048.

[10] B. C. Seet, G. Liu, B.S.L.C.H.F.K.J.W. and Lee, K.K. (2004). A-STAR: A mobile Ad Hoc routing strategy for metropolis vehicular communications, *Lect. Notes Comput. Sci. (including Subser. Lect. Notes Artif. Intell. Lect. Notes Bioinformatics)*.

[11] O. Senouci, Z. Aliouat and S. Harous, (2021). "Geo-SID: A new Geocast Safety Information Dissemination protocol in VANET for urban areas," *2021 2nd International Conference on Computation, Automation and Knowledge Management (ICCAKM)*, 2021, pp. 287-292,

[12] Kaiwartya, Omprakash and Sushil Kumar. (2015). "Cache agent-based geocasting in VANETs." *Int. J. Inf. Commun. Technol.* 7: 562-584.

[13] Celes, Clayson et al. (2013). “GeoSPIN: An Approach for Geocast Routing Based on SPatial INformation in VANETs.” *2013 IEEE 78th Vehicular Technology Conference (VTC Fall)*: 1-6.

[14] Rosário, Denis & Zhao, Zhongliang & Santos, Aldri & Braun, Torsten & Cerqueira, Eduardo. (2014). A Beaconless Opportunistic Routing Based on a Cross-Layer Approach for Efficient Video Dissemination in Mobile Multimedia IoT Applications. Computer Communications. 45. 21–31.

[15] M. Heissenbüttel, T. Braun, T. Bernoulli, M. Wälchli, (2004). BLR: beacon-less routing algorithm for mobile ad hoc networks, Comput. Commun. 27 (11) (2004) 1076–1086.

[16] Gong, Jiayu & Xu, Cheng-Zhong & Holle, James. (2007). Predictive Directional Greedy Routing in Vehicular Ad hoc Networks. 2-2. 10.1109/ICDCSW

[17] Perkins, Charles, Elizabeth Belding-Royer, and Samir Das. (2003). "Ad hoc on-demand distance vector (AODV) routing.".

[18] Karp, Brad, and Hsiang-Tsung Kung. (2000). "GPSR: Greedy perimeter stateless routing for wireless networks." *Proceedings of the 6th annual international conference on Mobile computing and networking*.