JAET

Journal homepage: http://jae-tech.com

Journal of Applied Engineering & Technology

ISSN : 2523-6032 ISSN-L : 2523-2924

Analysis of Greedy Strategies in Geographic Routing of VANETs

Amber Israr[1,*], Samina Muqeem[2], Muhammad Shafiq[1]

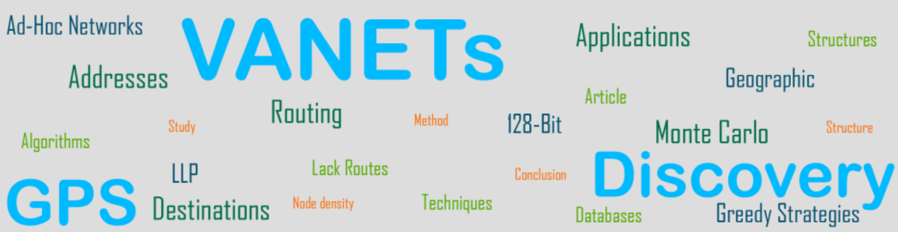
[1]Electronic Engineering Department, Sir Syed University of Engineering & Technology, Karachi 75300, Pakistan.
[2]Computer Engineering Department, Sir Syed University of Engineering & Technology, Karachi 75300, Pakistan.

*Corresponding Author

DOI: https://doi.org/10.55447/jaet.07.01.78

Abstract: The study and creation of networks that are independent of any pre-existing infrastructure has become highly popular in recent years. These networks fall under the category of Vehicular Ad-hoc Networks (VANETs), in which each car takes part in routing by sending data to other vehicles. However, geographic routing attracts VANETs networks because they lack route discovery and routing databases and the accessibility of low-cost GPS systems as well as the advent of the 128-bit address structure of IPv6 have enhanced the advantages of geographical routing over classical routing techniques. Additionally, the proposed algorithms based on greedy routing are the main method for the next hop selection in multi-hop communication for optimal and optimized solution in geographic routing. In this article, the study takes place with a number of hops per route and greedy algorithm selection success ratio in VANETs with source-to-destination pairs. A comparative study is taken out in which LLP affects node density, hop count, and transmission range. Monte Carlo simulations have been done with two important network parameters which are transmission range and node density. This study will be a guideline for the choice of greedy decisions to meet the objectives of network applications.

Graphical Abstract:



Keywords: VANETs, Mobile Ad Hoc networks, Node Density, Multi-Hop

1. Introduction

In recent years, new technology is introduced namely vehicular ad hoc network (VANET). It is communication between the two vehicles denoted by (V2V) [1]. Due to the rise of the Internet of Things and intelligent transport applications, VANET are growing in popularity. Trust mechanisms

*Corresponding author: *aisrar@ssuet.edu.pk*

are used in these networks to implement secure resource sharing functionalities. Peer-to-peer technologies are used by modern systems to span a wide operational area. Similarly, vehicle-to-infrastructure is denoted by (V2I). This technology provides an advantage in reducing travel time and gives a smarter way to make safer and more comfortably communication. It also enables the vehicles to share information via one or multi-hop communication [2]. Due to these reasons, it is considered the most important and favorable technology. Due to this, it is also used in many intelligent transport (IT) systems [3]. The success of this technology is higher due to its higher efficiency, comfort, and safety. Each application is designed to provide awareness in its aspect. For example, a comfort application is designed to give comfort to passengers [4-5].

1.1 Background and Related Study

There have previously been various attempts to address the problems with hop selection. A solution is offered by routing techniques for conventional ad hoc networks. In VANET, geographic routing is preferred because it can more accurately account for the geographic placements of vehicles [6]. Geographic routing is also named geometric and position routing. It is used to send a message to the node which passes through the different hops to attain position information. The message directly routes towards the position of the destination. [7]. Also, present nodes attain the other neighbor's location information. This information helps in choosing a neighbor and then hops to the node which is near the destination. For dynamic networks, geographic routing is much more attractive due to no routing tables [8]. Working against these networks like sensor networks results in higher costs due to procuring and the messages need bandwidth and higher energy [9].

In [10] the main tenacity of this research article is to support real-time traffic. The new approach is generated called fuzzy geographical routing which is based on the Greedy Perimeter Stateless Routing (GPSR). The three inputs which are taken into consideration are the delay, throughput, and size of the buffer. It outputs a singular relevant metric to list the next hop.

Another study [11] provides dynamic support in inter-vehicle communication. In this manuscript, a new routing algorithm is proposed called Link Connectivity analysis on Geographic Location (LCGL) for VANET. It is constructed due to link connectivity analysis based on geographical location. It is used to overcome the common issues of VANET routing. This strategy achieves the connectivity of links and the geographic location of nodes.

The simulation results provide the v2v communication. It also provides routing protocols in the urban environment, particularly in packet delivery rate and average hops. Additionally, this scheme achieves a lower delay and higher throughput.

Similarly, in [12] the research article proposes a new forwarding improvement routing method is proposed for the Ad Hoc network. The dependable communication is calculated in the greedy forwarding phase. Formerly, the link quality is estimated according to relative displacement among the nodes and the maintenance time of the link. The distance between the first to the second node and the number of an opposite node gives a metric value. The forwarding mode is used for a while when a routing hole occurs.

In the GFS protocol, there is a lower number of hops, and it selects the shortest path. This routing protocol is simple and mountable as compared to other protocols. But the packet delivery can be failed due to the drawbacks of this protocol. These issues can be resolved to make this routing protocol works properly and efficiently. Many researchers used different strategies to increase the delivery rate of a packet. There are as follows:

- Complication
- Extended delay and path
- Communication overhead increase
- Trade-off among proficiency

- Single side efficiency

1.2 Organization of The Study

The manuscript is planned as follows. The introduction of this study is presented in section 1. The state of the art is defined in section 2. The problem definition is defined in section 3. Similarly, section 4 defines the mathematical model. The simulations are done in section 5. Section 6 presents the conclusion of this manuscript.

2. State of Art

This part of the manuscript discusses the recent trends in the field of geographical routing. The protocol used in geographical routing uses a single metric in the process. Due to this, they are not able to handle various problems like loss of link, holes in the network, and jamming. In [13] a protocol is proposed namely multi-metric geographical routing to solve the abovementioned issue. This study uses a multi-criteria decision-making method to address the boundaries and to accommodate many metrics analytically. Additionally, a scheme is proposed which helps in choosing the opposite next hop.

The results proved that this approach attains better performance than any other routing protocol. For data communication, different routing protocols are used. This communication will be unreliable due to different topologies and high mobility. This results in a loss of data and discontinuation in the link between the nodes. Geographical routing protocols are very efficient due to low overhead processes. In [14] Beaconless traffic-aware geographical routing protocol is developed for the density of traffic, direction, and distance of the next node which addresses the delay and discontinuation issues. The state of art protocols is considered for the simulation process.

In recent years, many researchers solve the different issues related to VANETS. The forwarding of information becomes a challenging task which is sometimes problematic. This problem [15] is solved by using an improved GPSR protocol. The selection of different stages is taken place in GPSR in greedy mode. In the intersection mode, the vehicle guidelines are expected to direct the next stage. The simulation results verify the effectiveness of the strategy used in this study to address various issues.

The most popular subclass of VANET is internet-connected vehicles which is an uprising form. In such types of networks, information sharing is done with the help of infrastructure or without infrastructure. The routing protocol plays an important role in data communication between vehicles. It also handles many characteristics like high mobility, discontinuation in links, and different topologies. About [16] the intersection gateway and connectivity-based routing protocol are presented for this subclass. This protocol uses traffic-aware routing which includes the density and direction of nodes. The simulation results verify that the proposed protocol attains better performance when compared to state of art routing protocols. This method is effective in terms of data delivery, delay, and throughput.

3. Problem Definition

This section of the manuscript defines the problem statement. The main issue and causes of routing decision failure are connectivity loss and link loss in greedy strategies. The number of hop counts is decreased due to the selection of border nodes between source to destination. The connectivity of the network is greatly affected by the parameter called link duration. This parameter depends upon the speed and the node's mobility pattern. This study observes the mobility metric change effect with its impact on the selection of forwarders in routing strategy's greedy part. In VANET the two main issues are to be considered. 1) Greedy forwarding protocol selection which is reliable in all scenarios without causing any issue in node density, hop count, and transmission range. 2) Neighbor location prediction in time which attains the node position information. The figure below describes the problem statement.

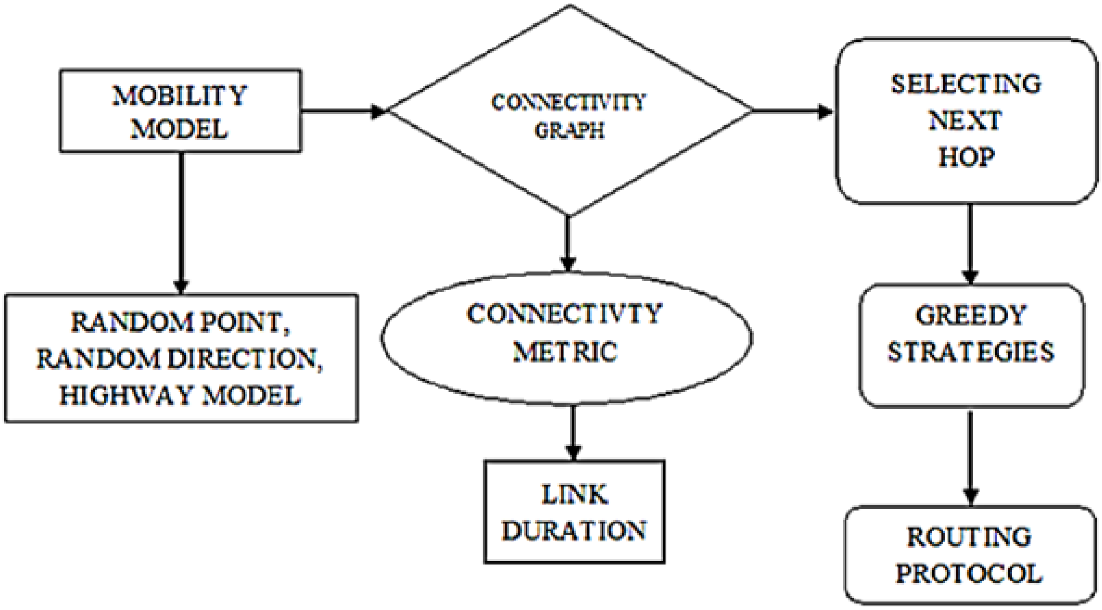


Fig. 1 - Problem Statement Flow Chart

4. Proposed Framework

VANETs are very hard to deal with in terms of routing, because of their dynamically changed topology rate, high mobility, and frequent link disconnections [17]. Research trends of the last decade show that the Arrival of IPv6 has a 128-bit address structure and the availability of cheap GPS systems had attracted researchers engrossed in routing techniques for Ad Hoc networks to work on geometric routing techniques [18]. Recent research shows that geographic routing will be the preferred solution for routing issues of Ad Hoc networks in near future [19].

Geographic routing was developed for wired and radio packet networks also called geometric and position routing [20]. The three assumptions on which this network works is, the node is conscious of its location, the node knows its neighbor with location and the location of the destination is known. The basic idea in geographic routing protocols is that the node's decision for data packet transmission towards another node entirely depends upon the ending point and its neighbors' position.

The neighbors within their transmission range are picked as the next hop neighbors in forwarding decisions. [21]. Geographic routing adjusts greedy techniques as forwarding techniques. In this, the mobile node decides to hop toward the neighboring node to the destination according to its distance [22]. The following two equations are used to calculate the location and distance,

The prediction of the location of neighbor x on the st line is given as:

$$|x't| = st.\frac{st}{|st|} \tag{1}$$

$|x't|$ denotes the distance to the destination.

$$|yt| = |st| - |xt| \tag{2}$$

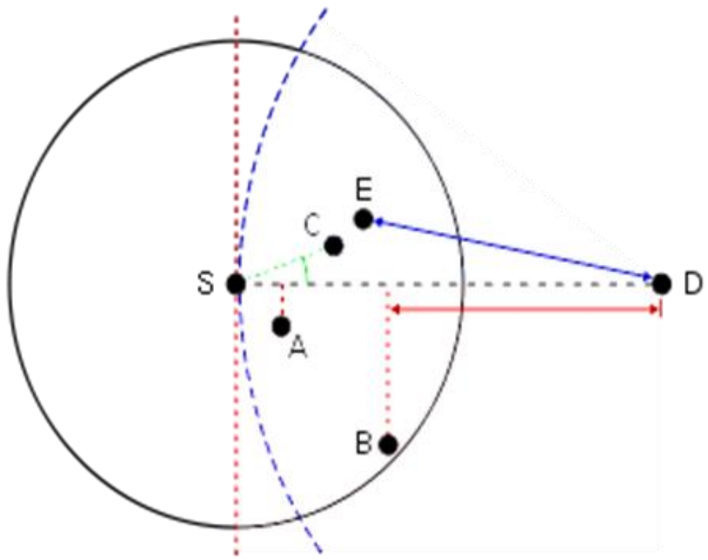


Fig. 2 - Progress and Advance

Figure 2 shows the geometrical techniques used for the next-hop selection in forwarding, where S presents the source node that can find a relay node for further forwarding a message to the destination, D presents the destination, A shows the Nearest with Forwarding Progress (NFP), B denotes the Most Forwarding progress within Radius (MFR), C is the compass routing, and E presents Greedy. Any two nodes x and y can directly communicate with each other if and only if they are in the communication range of each other. In contrast with static networks; an increase in node density, and the mean of link up and link down increases in mobile Ad Hoc networks because of the speed and frequent topology change of the network. One of the most basic geographic routing strategies is the MFP. The forwarding progress idea is the main key to MFP standards. In the destination direction, a packet is forwarded to a neighbor with the longest likely hop. The hop count is concentrated in this strategy due to the jumping of a packet through nodes to reach the destination. The performance objective is the main tool on which the hop count depends [23]. If the neighboring node is the projection on the line, the link must be linking the source and destination nodes.
Thus, the space between projection and source is called progress. MFP is a strategy including minimum weight routing. In this routing protocol, fewer hop paths are chosen. The progress is controlled from the current node to the destination in Most forward within the transmission range strategy. Due to some drawbacks, this strategy is not vastly used in VANETs. The progress is restricted to forward direction in MFP.

Due to this, the looping issue is not overcome, and the packet moves far from the destination [24]. The researchers proposed NFP method due to the abovementioned drawbacks and issues. This strategy depends upon distance-based approaches. The next hop is selected by the source node based on the shortest distance from the source. Thus, the message sent to the node is the bordering neighbor. It is also called forward progress near the destination node. The main advantage of this strategy is that it remains on the chosen path all the time and reduces energy and bandwidth. This routing protocol strategy depends upon the stability factor. One more routing method is named Random progress forward (RFP) in which the packets are forwarded to the destination with equal probability with all the adjacent nodes [25]. The Greedy Forwarding Scheme (GFS) is a Cartesian routing policy that depends upon geographic routing. It is also called cartesian routing. By using all nodes' location information, the packets are forwarded to the destination node. The next neighbor for the hop is selected on the basis that the node is near the destination and beyond it. GFS always chooses the neighboring node that is closest to the destination.

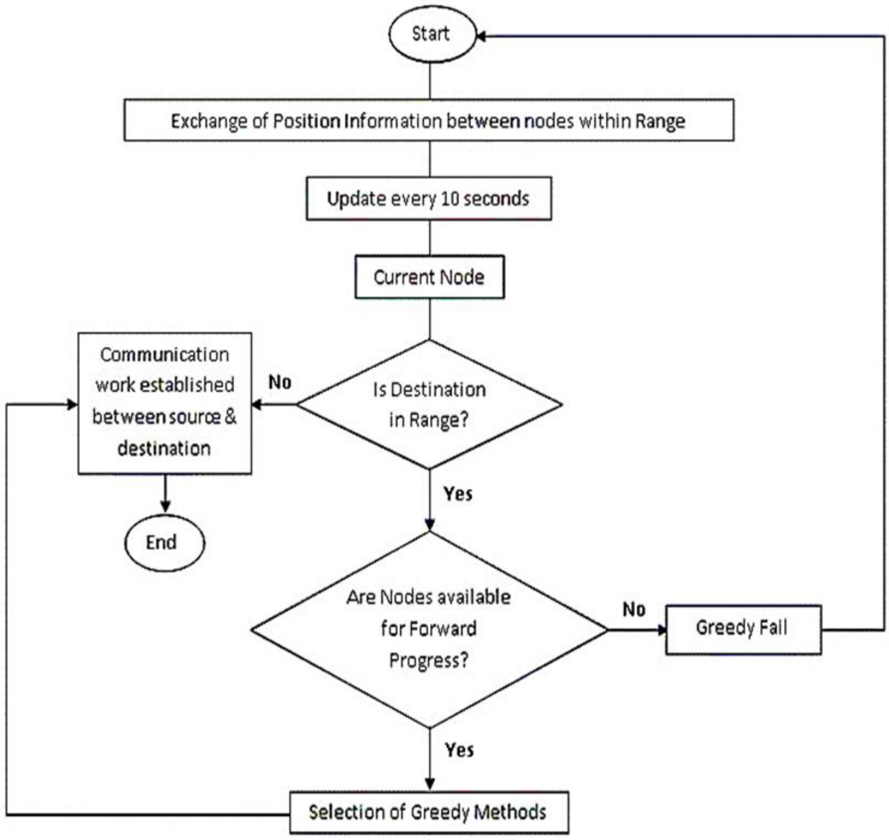


Fig. 3 - Greedy Methods Selection Flow Chart

Figure 3 presents the flowchart of the system. First, there is an exchange of position information between nodes within the range which is updated every 10 seconds. Afterward, the strategy checks whether the destination is in range. If yes, then the algorithm further checks if there are nodes available for forwarding progress. If nodes for forwarding progress are not available, then it is considered a Greedy failure and the algorithm starts again. Otherwise, the algorithm selects the appropriate Greedy method and establishes the link between the source node and the destination node. If, however, the destination is not in range, the algorithm establishes a communication link between the source and the destination. Types of greedy methods available are the shortest distance from the destination, NFP, most forwarding progress, and random forwarding progress.

5. Simulation Results

This section shows the computational simulations of success ratio & hop count against node density and transmission. The simulations take place on the MATLAB program. The data sets are arranged in two methods that are 1) Variable transmission range with constant node density and 2) Variable node density with constant transmission range. Functions for strategies are as follows:

- Straight distance from an existing node
- Straight distance from the endpoint
- Random & most froward progress

The input of these functions is transmission range & node density while the output of these functions is success ratio & hop count. The values are used in plotting graphs and deposited in arrays. The following observations are made from the graphs that are as follows.

- Increasing the transmission range reduces the hop count.

- Increasing the transmission range increases the success ratio.
- Increasing node density does not affect much hop count and success ratio.

The graph between transmission range & average hop count may be seen in the image below. In this example, assume that the node density is a constant value, with a constant value of 40 per 100 m2 of a network. The chart shows that the transmission range ranges from 15 to 35 m during brief time periods. The graphs demonstrate an increase in hop count in SDFCN with increasing transmission range. In RFP, the hop count changes at 30 meters, leaps to a specific figure, and then stays the same. Like this, the hop count in MFP continues to fluctuate. In SDFD, a decrease in hop count caused by an increase in transmission range indicates that the hop count is steady.

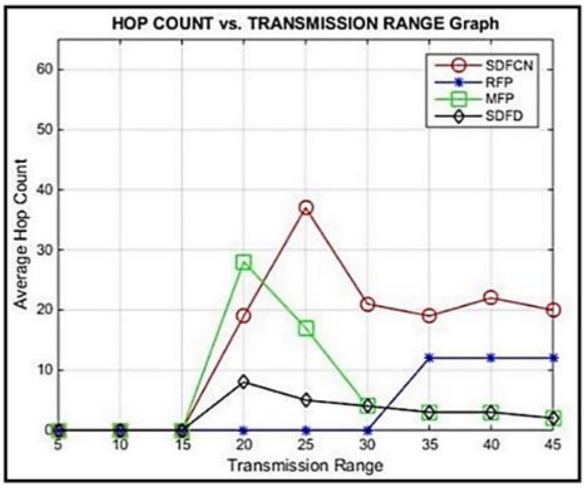


Fig. 4 - Transmission Range vs Average hop count graph assuming constant node density

The graph between the transmission range & success ratio may be seen in the image below. Think of the node density in this scenario as a constant number, with a constant value of 40 per 100 m2 of a network. The chart shows that the transmission range ranges from 20 to 45 m in brief time intervals. The graphs demonstrate that the success ratio in SDFCN grows as the transmission range does. The broadcast range expansion in RFP results in a lower success ratio impression. Similar to this, the success ratio in MFP improves as the transmission range grows. Last but not least, an SDFD transmission range expansion leads to a likely success ratio and stabilization.

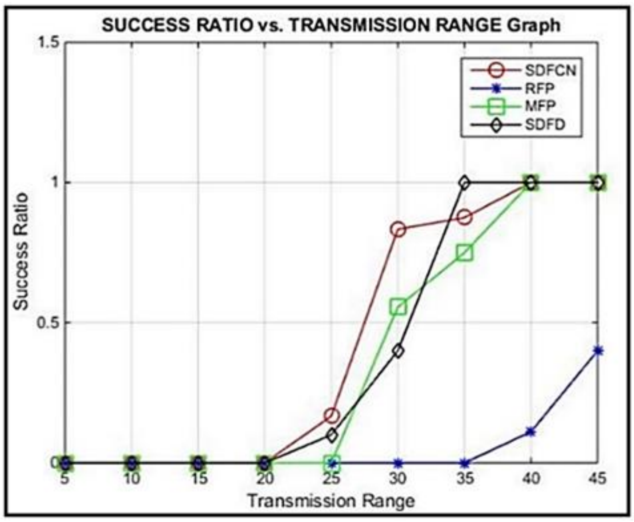


Fig. 5 - Transmission Range Relation vs Success Ratio graph constant node density

The graph between node density and average hop count is displayed as follows. Within 100 m2 of the network, consider transmission range as a constant value with a constant value of 25. The image shows how the node density changes quickly, going from 20 to 65 nodes in a short amount of time. The graphs demonstrate that while maintaining a constant node density, SDFCN exhibits unpredictable and random behavior. At a particular point in RFP, the node density shifts and fluctuates between high and low node density levels. In MFP, the node density and hop count both stay constant. The node density and hop count lastly remain constant and exhibit more stability in SDFD.

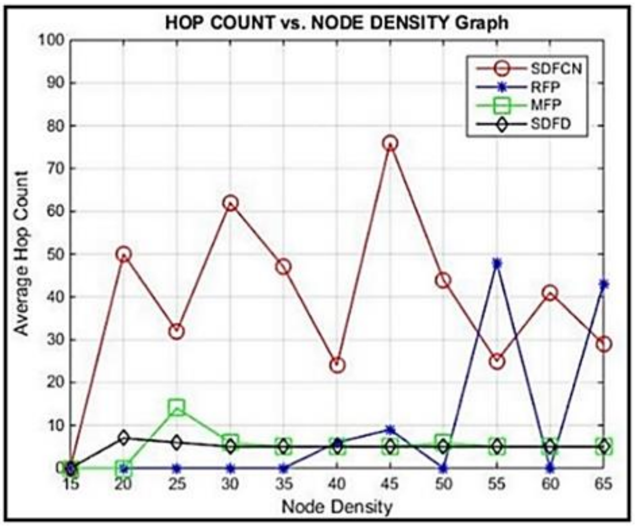


Fig. 6 - Node Density vs Hop Count graph with constant transmission range

The graph between node density and success ratio is displayed as follows. Take the constant value of 25 for the transmission range to be within 100 m2 of the network in this example. The image shows how the node density changes quickly, going from 15 to 65 nodes in a short amount of time. The graphs demonstrate that in SDFCN, the success ratio performs consistently and stays within acceptable bounds.

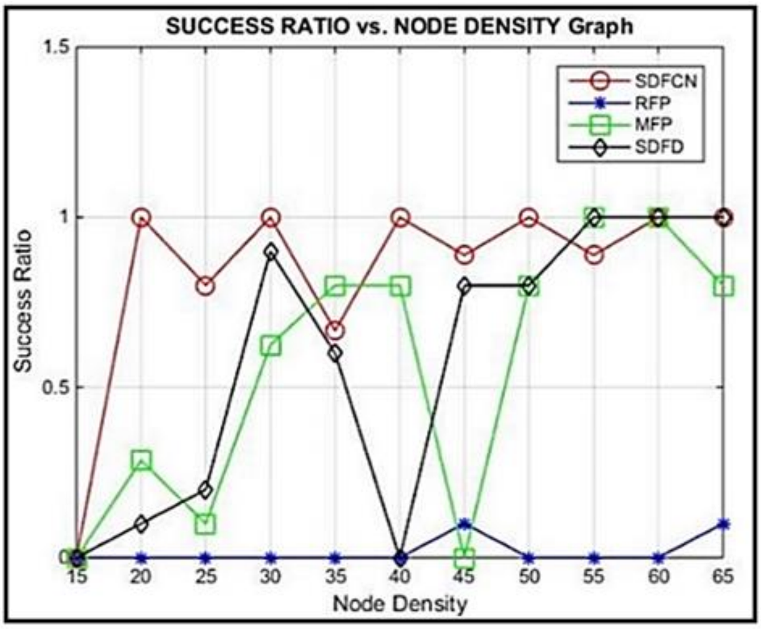


Fig. 7 - Node Density Relation vs Success Ratio with constant transmission range

For each node density value in RFP, the success ratio stays at a lower value. Similar to this, for various node density numbers in MFP, the success ratio continues to be unpredictable. Last but not least, in SDFD, the success ratio reaches a consistent rise at >40 and stays variable at 40.

5.1 Analysis

Based on techniques of geographic routing protocols the analysis is finished. Some greedy methods are the basic tool to perform calculations based on geometry. In greedy forwarding strategies, a single route is used to send message packets among the adjoining nodes. A single path to the destination is used in most forwarding range strategies (MFRS) and greedy forwarding strategies (GFS). The nearest forwarding progress (NFP) uses the same strategies and route. The shortest path from source to destination is called the best path which is chosen by greedy methods. Assume the path from source to destination is a direct path i.e., shortest path based on these results. The network nodes attain the position information with complete data set. Due to transforming network circumstances and limited resources, these assumptions failed in real-time implementations.

Thus, it's not required to route all packets through an optimal route. The optimal path-choosing probability is reflected in the medium. In routing protocols, the next neighbor node decision is founded on hop count. It is known as a good parameter in all routing protocols. The other advantages of greedy strategies geometric based are that the design is simple, and it provides a low traffic overhead. The message packet loss is due to the failure of a single node. Thus, robustness is considered to be medium in greedy strategies. There is no memory parameter involved that is there is no data or record of node values through which the packet passes. The delivery rate of the message is low in small network areas and high in huge network areas. There is no guarantee that the message packet reaches its destination in any network as there is a lot of packet loss caused. The hop count is the key parameter for decision-making. The number of hops between any two connecting nodes is directly proportional to the square root of the populace of nodes in the network, neglecting the speed of the nodes.

The difference between NFP & MFR is that one works on progress-based standards and the other on a distance-based standard. But both strategies choose the neighbor hop from the nearest node and do not deliver loop freedom. In GFS regressive node is not selected, avoids the loop system, and uses the positive progress technique. In GFS & MFR the transmission range is fixed in a network. The advanced strategies used in geographic routing protocols are the non-geometric-based greedy forwarding techniques. They use some other parameters also with the hop count as the deciding factor to lessen the problems that were present in the latter routing protocol.

- ARP has got many standards of the GFS but has some advanced characteristics as well. It includes the memorization data of previous neighbors and loop freedom is also applied in this protocol. The header of a message packet contains memorization data. An angle-based progress technique is introduced in this protocol which performs well in tiny networks also due to avoiding local neighbors.
- MAGF also has got many standards of the GFS except the deciding factor. It is an advanced standard so the nodes have higher mobility in it. Only positive forwarding is used which makes it loop-free as well. The traffic overhead is reduced. However, the next-hop neighbor selection is quite similar to the GFS protocol.
- NADV chooses neighboring nodes based on the best path between the advance and link costs. Here also, only positive forwarding is used which makes it loop-free. According to researchers, the hop count is reduced of a packet from the source node to the destination. It also increases the delivery rate of packets.

- GBR has got many standards of the GFS but has some advanced characteristics as well. The route stability parameter is an increased decision factor in this. This can increase the delivery rate. Also, a secondary recovery scheme is used in it that guarantees the message reaches its destination. It is a free loop strategy because message packets are just forwarded in a positive direction. The GBR performs well compared to GFS based on control overhead, packet delivery rate, and route lifetime parameters.

6. Conclusion

The need for networks that function using wireless mobile systems is growing in the modern time. Such networks are in need because they provide more beneficial advantages than a wired system. Also, it can be applied to areas where no wired systems are used. That's why the mobile nodes attain the facility of availability at any time & anywhere. In everyday life, the best example is rescue operations in which nodes are mobile and move randomly. This type of routing is not easy to handle. So, the conclusion is that the protocol used must be reliable and the design must be efficient. Most forwarding range strategies (MFRS) and greedy forwarding methods employ a single route to the destination (GFS). The same methods and path are taken by the closest forwarding progress (NFP). The optimum path, which is determined using greedy approaches, is the one that leads directly from point A to point B. Based on these findings, presume that the route between source and destination is a direct one, or the shortest one. The network nodes get positional data along with the whole data collection. These presumptions were not verified in real-time implementations because of changing network conditions and scarce resources. In this work, source-to-destination pairings are used in VANETs with several hops per route and a greedy algorithm selection success ratio. The effects of LLP on node density, hop count, and transmission range are examined in comparative research. Transmission range and node density, two crucial network factors, have been used in Monte Carlo simulations. This research will serve as a guide for choosing greedy actions to achieve the goals of network applications.

Acknowledgment

The author would like to thanks the Sir Syed University of Engineering and Technology for supporting in carrying this research work.

References

[1]. Tyagi, Amit Kumar, and Niladhuri Sreenath. "Intelligent Transportation System Based on Internet of Things (IoT)-Based Cloud Applications." In Intelligent Transportation Systems: Theory and Practice, pp. 283-304. Singapore: Springer Nature Singapore, 2022.

[2]. Soni, Mukesh, Brajendra Singh Rajput, Tejas Patel, and Nilesh Parmar. "Lightweight vehicle-to-infrastructure message verification method for VANET." In Data Science and Intelligent Applications: Proceedings of ICDSIA 2020, pp. 451-456. Springer Singapore, 2021.

[3]. Zalte, S. S., V. R. Ghorpade, and Rajanish K. Kamat. "Synergizing Blockchain, IoT, and AI with VANET for Intelligent Transport Solutions." Emerging Computing Paradigms: Principles, Advances and Applications (2022): 193-210.

[4]. Al-Turjman, Fadi, and Joel Poncha Lemayian. "Intelligence, security, and vehicular sensor networks in internet of things (IoT)-enabled smart-cities: an overview." Computers & Electrical Engineering 87 (2020): 106776.

[5]. Hartwich, Franziska, Matthias Beggiato, and Josef F. Krems. "Driving comfort, enjoyment and acceptance of automated driving–effects of drivers' age and driving style familiarity." Ergonomics 61, no. 8 (2018): 1017-1032.

[6]. Zhang, Hang, Xi Wang, Parisa Memarmoshrefi, and Dieter Hogrefe. "A survey of ant colony optimization based routing protocols for mobile ad hoc networks." IEEE access 5 (2017): 24139-24161.

[7]. Boussoufa-Lahlah, Souaad, Fouzi Semchedine, and Louiza Bouallouche-Medjkoune. "Geographic routing protocols for Vehicular Ad hoc NETworks (VANETs): A survey." Vehicular Communications 11 (2018): 20-31.

[8]. Awan, Khalid M., Nadeem Ashraf, Muhammad Qaiser Saleem, Osama E. Sheta, Kashif Naseer Qureshi, Asim Zeb, Khalid Haseeb, and Ali Safaa Sadiq. "A priority-based congestion-avoidance routing protocol using IoT-based heterogeneous medical sensors for energy efficiency in healthcare wireless body area networks." International Journal of Distributed Sensor Networks 15, no. 6 (2019): 1550147719853980.

[9]. Lakshmanaprabu, S. K., K. Shankar, S. Sheeba Rani, Enas Abdulhay, N. Arunkumar, Gustavo Ramirez, and J. Uthayakumar. "An effect of big data technology with ant colony optimization based routing in vehicular ad hoc networks: Towards smart cities." Journal of cleaner production 217 (2019): 584-593.

[10]. Zaimi, Imane, Abdelali Boushaba, Zineb Squalli Houssaini, and Mohammed Oumsis. "A fuzzy geographical routing approach to support real-time multimedia transmission for vehicular ad hoc networks." Wireless Networks 25, no. 3 (2019): 1289-1311.

[11]. Zeng, Qingwei, Yuliang Tang, Zhuyue Yu, and Weihong Xu. "A geographical routing protocol based on link connectivity analysis for urban VANETs." Journal of Internet Technology 21, no. 1 (2020): 41-49.

[12]. Zhang, De-Gan, Peng-Zhen Zhao, Yu-ya Cui, Lu Chen, Ting Zhang, and Hao Wu. "A new method of mobile ad hoc network routing based on greed forwarding improvement strategy." IEEE Access 7 (2019): 158514-158524.

[13]. Kim, Beom-Su, Sana Ullah, Kyong Hoon Kim, BongSoo Roh, Jae-Hyun Ham, and Ki-Il Kim. "An enhanced geographical routing protocol based on multi-criteria decision making method in mobile ad-hoc networks." Ad Hoc Networks 103 (2020): 102157.

[14]. [Din, Sadia, Kashif Naseer Qureshi, M. Sheheryar Afsar, Joel JPC Rodrigues, Awais Ahmad, and Gyu Sang Choi. "Beaconless traffic-aware geographical routing protocol for intelligent transportation system." IEEE Access 8 (2020): 187671-187686.]

[15]. [Mahmoud, Marwan, and Mahmoud Ahmad Al-Khasawneh. "Greedy Intersection-Mode Routing Strategy Protocol for Vehicular Networks." Complexity 2020 (2020).]

[16]. [Qureshi, Kashif Naseer, Muhammad Ahmed, Gwanggil Jeon, and Francesco Piccialli. "An Enhanced Multi-Hop Intersection-Based Geographical Routing Protocol for the Internet of Connected Vehicles Network." IEEE Transactions on Intelligent Transportation Systems (2021).]

[17]. Akhtar, Nabeel, Sinem Coleri Ergen, and Oznur Ozkasap. "Vehicle mobility and communication channel models for realistic and efficient highway VANET simulation." IEEE Transactions on Vehicular Technology 64, no. 1 (2014): 248-262.

[18]. Rajesh, M., and J. M. Gnanasekar. "Path observation based physical routing protocol for wireless ad hoc networks." Wireless Personal Communications 97, no. 1 (2017): 1267-1289.

[19]. Alzamzami, Ohoud, and Imad Mahgoub. "Link utility aware geographic routing for urban VANETs using two-hop neighbor information." Ad Hoc Networks 106 (2020): 102213.

[20]. Karp, Brad Nelson. Geographic routing for wireless networks. Cambridge, MA: Harvard University, 2000.

[21]. Carofiglio, Giovanna, Massimo Gallo, and Luca Muscariello. "Optimal multipath congestion control and request forwarding in information-centric networks: Protocol design and experimentation." Computer Networks 110 (2016): 104-117.

[22]. Xiang, Xiaojing, Xin Wang, and Zehua Zhou. "Self-adaptive ondemand geographic routing for mobile ad hoc networks." IEEE Transactions on Mobile Computing 11, no. 9 (2011): 1572-1586.

[23]. Farooq, Muhammad Junaid, Hesham ElSawy, Quanyan Zhu, and Mohamed-Slim Alouini. "Optimizing mission critical data dissemination in massive IoT networks." In 2017 15th International Symposium on Modeling and Optimization in Mobile, Ad Hoc, and Wireless Networks (WiOpt), pp. 1-6. IEEE, 2017.

[24]. Farooq, Muhammad Omer, Cormac J. Sreenan, Kenneth N. Brown, and Thomas Kunz. "Design and analysis of RPL objective functions for multi-gateway ad-hoc low-power and lossy networks." Ad Hoc Networks 65 (2017): 78-90.

[25]. Al-Turjman, Fadi. "A cognitive routing protocol for bio-inspired networking in the Internet of nano-things (IoNT)." Mobile Networks and Applications 25, no. 5 (2020): 1929-1943.