VANET: Performance Comparison of BNGF Method in Different Vehicular Traffic Scenarios

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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. A lot of research work around the world is being conducted to design the routing protocols for VANETs. In this paper, we examine the significance Greedy Forwarding with Border Node based approach for VANETs to optimize path length between vehicles in different traffic scenarios. This protocol is called Border Node Greedy Forwarding (BNGF) since it uses border nodes with Greedy Forwarding. We categorize BNGF as BNGF-H for highway and BNGF-C for city traffic scenarios. We have simulated this protocol using NS-2 simulator and calculated the performance in terms of end-to-end delay and packet delivery ratio. We compare both the methods for highway and city traffic scenarios. The result clearly show that the end-to-end delay for BNGF-C is significantly lower and packet delivery ratio is higher than BNGF-H.**

Keywords: MANET; VANET; DSRC; Routing Protocols; Greedy Forwarding; BNGF.

I. INTRODUCTION

Vehicular ad hoc networks (VANETs) [1] are a special class of mobile ad hoc wireless networks (MANETs). It is currently attracting the extensive attention of research in the field of wireless networking as well as automotive industries. VANETs [2] will provide safer and well-organized road in future by communicating information in timely manner to drivers and concerned authorities. VANETs use short range wireless communication. IEEE 802.11p [3] [4] (modified version of IEEE 802.11a standard protocol) is wireless communication protocol specially designed for vehicular ad hoc networks (VANETs) to support safety and non-safety applications. The mobility of nodes in VANETs is very high and it exhibits stronger challenges to researchers. The topology of these networks dynamically changes over time. It causes frequent network partition and makes communication more difficult.

Mobile Ad-hoc Networks (MANETs) [5] refer to self-organizing wireless networks consisting of mobile nodes capable to establish communication among them without any fixed infrastructure. Every node in this network acts as router and forwards the message hop by hop. Due to its nature i.e. infrastructure-free environments MANETs can be deployed in emergency rescue, military, airports, sports stadiums, campus, and disaster management. Due to this broad applications area of MANETs researchers paying more attentions in the development of such networks.

To facilitate communication within a network, a routing protocol is used to find reliable and efficient routes between nodes so that message delivered between them in timely manner. Routing is responsible for selecting and maintaining routes and forwarding packets along the selected routes. Since the network topology in the VANETs is frequently changing, finding and maintaining routes is very challenging task in VANET.

In this paper, we propose a novel position-based routing protocol for VANETs called Border-Node Greedy Forwarding (BNGF) protocol. This routing scheme uses the concepts of border-node of the sender's communication range to minimize the number of hops between source and destination in different vehicular traffic scenarios.

The rest of this paper is organized as follows. Section II describes the basic of Dedicated Short Range Communication. Characteristics of VANET are presented in section III. In section IV, routing strategies for VANET is described. The design of proposed routing protocol will be presented in section V. Section VI presents the simulation result and performance analysis of the proposed protocol. Finally, we conclude this paper in section VII.

II DEDICATED SHORT RANGE COMMUNICATION (DSRC) BASICIS

VANETs are based on short-range wireless communications. In 1999, the Federal Communication Commission (FCC) allocated a frequency spectrum for vehicle to vehicle and vehicle to roadside wireless communication. The commission then established the Dedicated Short Range Communications (DSRC) service in 2003. DSRC is a communication service that uses the 5.850-5.925GHz frequency band (5.9 GHz band) for the use of public safety and private applications [6]. DSRC radio technology is able to provide architecture for mobile nodes within a vehicular communication range to communicate each other and with the roadside equipment. The DSRC spectrum is divided into seven channels each with 10 MHz frequency band. Channel 178 is control channel which is specific for safety applications and therefore is high priority channel. The rest are service channels which can be used for safety as well as non-safety applications (see figure 1) [7]

[8]. There has been increasing academic and scientific interest in DSRC research is last one decade.
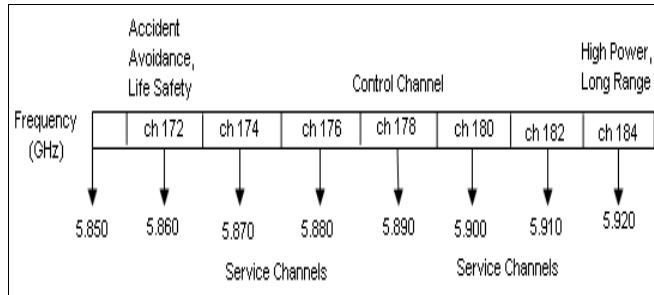

Figure: 1. DSRC Channel Management

III. UNIQUECHARACTERISTICS OF VANET

VANET have some important characteristics such as nodes forming the networks are vehicles, restricted vehicle movements on the road, highly mobility of vehicles and rapid change in topology, and time-varying vehicle density. We are discussing some unique characteristics [9] that differentiate VANETs form other networks.

A. Self-Organization

VANET is self-organizing and adaptive network. Thus a network in VANET may formed or deformed automatically anywhere at any time. The nodes in the network transmit packets with or without the need of a fixed infrastructure.

B. Highly Dynamic Network Topology

The speed and selection of route defines the dynamic topology of VANET. Roads limit the vehicular network topology to actually one dimension; the road direction. If we assume two vehicles moving away from each other with a speed of 50 km/h (13.88m/s) and if the packet transmission range is about 200m, then the link between these two vehicles will last for only 7.20 seconds (200m/27.77ms^{-1}). This defines the VANET has highly dynamic network topology.

C. Unpredictability

Due to highly node movement and dynamic topology, there is high degree of change in the number and distribution of the nodes in the network at given time instant. Vehicular nodes are usually controlled by pre-built highway, roads and streets. Therefore for the given street map and speed, the future position of the vehicle can be predicted.

D. Infinite Energy Supply

In VANETs vehicular nodes have plenty of energy and computing power, since nodes are vehicles instead of small handheld devices. Thus vehicular nodes can provide continuous power to their computing and communication devices. As a result, routing protocols do not have to account for methodologies that try to prolog the battery life.

IV. ROUTING STRATEGIES FOR VANETs

Short duration of communication link between nodes, high vehicles mobility, unpredictable node density, rapid change in topology, and less path redundancy make routing in VANETs relatively challenging. Routing is the important factor for the success of VANET applications since it must efficiently handle rapid network topology changes conditions. Here we discuss the three main category of routing protocols.

A. Ad hoc Routing

Most of the ad hoc routing protocols such as DSDV (Destination Sequenced Distance Vector) [10], AODV (Ad hoc On demand Distance Vector) [11], and DSR (Distance Source Routing) [12] etc are designed for general purpose mobile ad hoc networks and they do not maintain routes between nodes unless they are needed. Since the operational principles of VANET and MANET are almost same except the high dynamic topology and frequent networking disconnection due to fast vehicles movement. Therefore some well-known ad hoc routing protocols such as AODV and DSR are partially used in VANETs. In [9], authors evaluated AODV and showed that AODV is unable to quickly find, maintain, and update long routes in VANET. Real world experiment shows packets are extremely lost due to route failure under AODV and it is impossible for a TCP connection to stop its three-way handshake to establish a connection. Thus to meet the VANET challenges, these ad hoc routing protocols need to be modified.

B. Hybrid Routing

Ad-hoc routing (proactive and reactive) have their own advantages and drawbacks. The hybrid routing makes use of node position information and information on the paths from the source to destination. The hybrid protocols propose to proactively set up routes to the nodes inside a given zone, while letting the process of obtaining routes outside the zone operate on-demand. Thus the communications pattern in MANET/VANET will likely involve nearby nodes. The Terminode Routing (TMNR) and Zone-based hierarchical link state Routing Protocol (ZRP) are hybrid protocols that combine both reactive and proactive approaches.

C. Position-based Routing

Position is one of the most important data for vehicles. In VANET each vehicle wishes to know its own position as well as its other neighbor vehicle's position. A routing protocol using position information in known as the position based routing. Position based routing algorithms need the information about the physical location of participating vehicles be available. This position can be obtained by periodically transmitted control messages or beacons to the direct neighbors. A sender can request the position of a receiver by means of a location service. In VANETs, route is composed of several pair of vehicles (communication links) connected to each other from the source vehicle to the destination vehicle. If we know the current information of vehicles involved in the routes, we can predict their positions in the near future to predict the link between each pair of vehicles in the path. Various approaches have been recommended to improve the throughput and the efficiency of position based protocols [9] [13] [14] in highways or rural areas and city or urban areas for linear and non-linear topology network. Recently, some position based routing protocols such as MFR, GEDIR, Compass Routing, and PNR specific to VANETs have been proposed.

MFR (Most Forward within Radius) [15] [16] is a well-known method for finding a route in a network by utilizing position information of nodes. The neighbor with the greatest progress on the straight line is chosen as next hop for sending packets further. Therefore MFR forwards the packet to the node that is closest to the destination node in an attempt to minimize the number of hops. A GEDIR (GEographic DIstance Routing) [15] is a loop free location based routing algorithm. It is the variant of greedy routing. In GEDIR, a source node forwards packets to its neighbor node that is closest to the destination node.

A DIrectional Routing (DIR) [17] (referred as the Compass Routing) is based on the greedy forwarding method in which the source node uses the position information of the destination to calculate its direction. Then the message is forwarded to the nearest neighbor having direction closest to the line drawn between source and destination. Thus a message is forwarded to a neighbor such that the angle between the source and the selected node is minimized.

PNR (Position and Neighborhood based Routing) [18] is a new position-based routing which is used to improve the performance of the network by using full flooding techniques initiated by all nodes throughout the network. In PNR each node in the network can determine its own position using a GPS system and position of other nodes determined through flooding. PNR scheme assigns a "Neighbors Expiry Time" as a time period, if a node does not receive any HELLO message from a neighbor node during "Neighbor Expiry Time", it assumes the communication link is lost. This scheme is suitable for large size network in which, if a node travels longer than a given distance, it sends out a flooding message with its new position.

In PNR scheme the whole network is divided into neighborhoods for the purpose of optimizing flooding by considering the network size and the size of the specified neighborhood. Thus the new PNR scheme reduces the overheads caused by position update messages.

V. PROPOSED WORK

A. Assumptions

The BNGF protocol design is based on the following assumptions [19],

- Border nodes for forwarding packets
- Hello (beacon) control message for next-hop neighbors
- Vehicles are equipped with GPS receiver, electronic digital maps and sensors
- Communication between vehicles using wireless ad hoc network
- No other communication infrastructure
- Maximum forwarding distance mar vary
- Forwarding direction towards destination
- Message based communication
- No battery power issues

B. Procedure of Border Node Selection

A node in the network has a set of one-hop nodes within its transmission range. These one-hop nodes are called neighbor nodes. The one-hop neighboring nodes are divided into two groups - interior nodes and border nodes. A border node [19] [20] [21] is defined as a peripheral node, whose distance from the central node is exactly R_o, which is equal to the maximum transmission range R of the central node. Therefore, the border node lies furthest away from the central node within its transmission range (see figure 2).

(a)   (b)
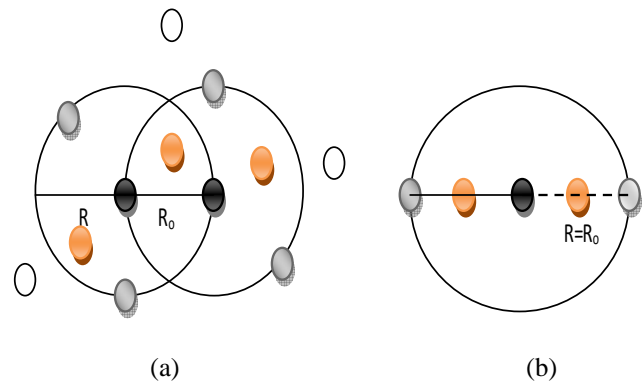
⬤ = Source Node, ◖ = Border Node, 🟠 = Interior Node, ○ = Outer Node, R = Radius of Circle, Ro = Max Transmission Range

Figure: 2. Border Node Architecture

C. Border Node Greedy Forwarding Method (BNGF)

Procedure of our proposed selection method is described in this section. Next-hop forwarding method like greedy forwarding scheme (see figure 3) for linear network does not support well in highly mobile ad hoc network such as vehicular ad hoc network. Therefore, other position based protocols such as MFR, GEDIR, Compass routing, etc. have been used for VANET to improve its performance for non-linear network in a high vehicular density environment.

These protocols can be further improvement by utilizing farthest one-hop node in a dense and highly mobile network. In this paper, we propose a routing protocol that uses Border-Nodes that is closest to destination. We call this protocol Border-Node Greedy Forwarding (BNGF).
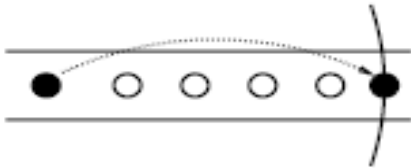

Figure: 3. Greedy Forwarding

The BNGF utilizes the border-node to avoid using interior nodes within the transmission range for further transmitting the packet. This method selects the border-node as a next-hop node for forwarding packet from source to destination. In this method, a packet is sent to the border-node that is closer to destination in both linear (highway) and non-linear (city) highly dynamic network.

1. BNGF in Highway (BNGF-H)

The BNGF-H protocol is designed for sending messages from one node to other node by using unicast forwarding. This is likely to be an appropriate method for routing in highway VANETs by considering routes over vehicles driving on the straight line in the same direction. VANET in highway can be characterized as partially connected network with low node density and high node mobility. Therefore designing of routing protocols for highway VANET scenarios is challenging. This method is well suited for vehicle to vehicle communications in rural and remote areas highways. In BNGF-H an ideal node to forward a packet would be the node located at the border of the communication range of the source node. The border node is selected based on direct one-hop neighbor information using unicast forwarding.

Figure: 4. Highway Traffic Scenario

Highway scenario (see figure 4) may have single or multiple lane, uni or bi-directional way. Destination is a moving vehicle, located ahead or behind of the source vehicle in the same lane . This method is more suitable for highway or rural traffic environment where nodes are evenly distributed on the straight line within the transmission range in the networks. In figure (5), node A is the border node of the communication range of source node S. Source node S selects node A as the next-hop node for forwarding packet further because node A is the farthest node (border node) within its transmission range. When node A receives the message, it uses the same method to selects the next-hop border node and forward the packet further. In this way, finally node B is selected as a next-hop border node for forwarding packets to destination.
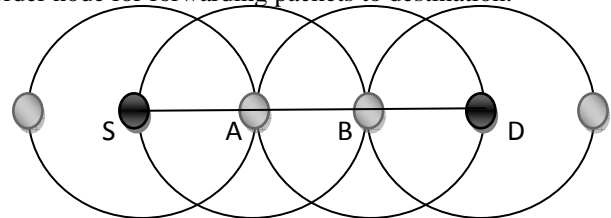
Figure: 5.   BNGF-H Forwarding Method

Although it is not necessary (less probability) that nodes on the border of the transmission range of each forwarding node will be available all the time during packet transmission from source to destination. If such situation comes, this BNGF-H method will give better performance than other greedy forwarding method as the number of hops from the source to destination will be minimized.

2. BNGF in City Scenario (BNGH-C)

Generally city scenario consists of several vertical and horizontal streets as well as many crossings and junctions. The traffic density is very high in city scenario for VANET due to a potentially large-scale network. VANET in city scenario has several characteristics such as signal reception is more difficult due to radio obstacles, scalability is very high due very open network environment, neighboring network density always changes depending upon the time and area. Due to these distinctive characteristics the design of routing is very challenging in city vehicular scenario. Despite the challenges above, city VANET has many advantages like vehicles utilizes the full use of Global Positioning System (GPS) receiver and city digital maps without having resource limitations which can be used to make better routing decisions. The goal of routing protocol in city scenario is to avoid collisions caused by hidden vehicles and sending message in all directions. The packet should be delivered with high successful rate.
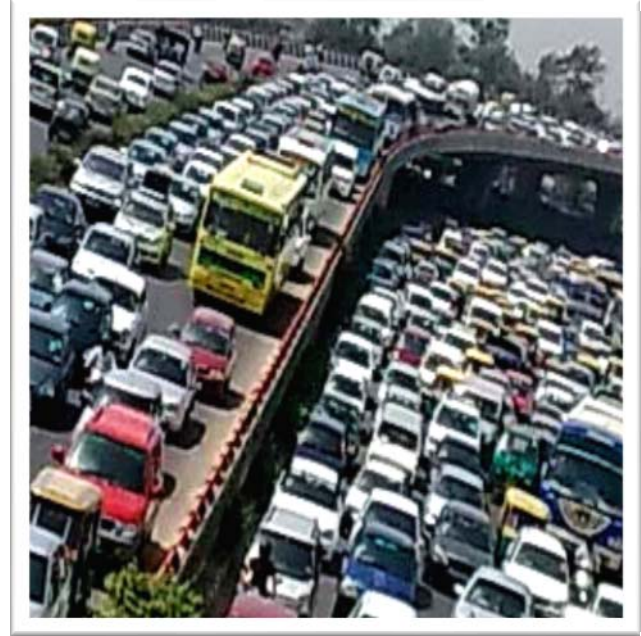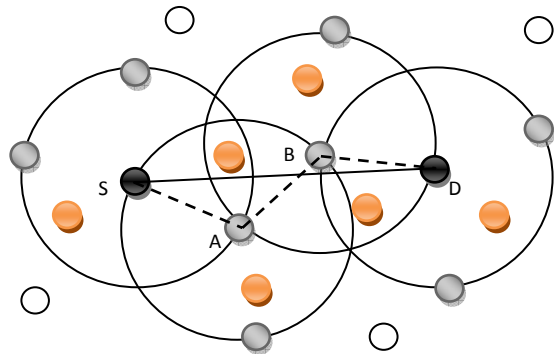

Figure: 6. City Traffic Scenarios

Figure: 7. BNGF-C Forwarding Method.

City traffic scenario (see figure 6) consists plenty of vehicles, lot of vertical and horizontal roads, and omni-directional way. Destination is a moving vehicle, located in any directions at any point of the source vehicle. Road Side Unit (RSU) is available along the roadway to relay the message in all directions. In BNGF-C, the source node tries to select the furthest node (border node) in the direction of the destination for forwarding packet from source to destination. This method is more suitable for city or urban traffic environment where nodes are distributed unevenly within the transmission range in the network.

In figure (7), node S and D are source and destination nodes. Source node S selects the border node A as the next-hop node that is closest to the destination node D for forwarding packet further. When node A receives the packet, it uses the same procedure to select next-hop border node. In this way, finally node B is selected as a next border node for forwarding packets to destination.

VI. SIMULATION RESULTS AND PERFORMANCE ANALYSIS

To evaluate the performance of BNGF protocol as BNGF-H and BNGF-C, it is implemented using NS-2 simulator and simulations are conducted. We compare BNGF-H with BNGF-C position based routing protocol in vehicular environment. Based on the simulation parameters given below, we simulate the protocol with a variable transmission range from 200m to 1000m. We consider highway traffic scenario where vehicles are moving on the straight line and a city traffic scenario where vehicles are moving in every direction.

The IEEE 802.11 DCF (Distributed Coordinated Function) is used as the MAC protocol. We use a 2000m x 2000m square area for simulation. Network size is represented by the number of vehicles. The speed of vehicles varies from 30-50 km/h.

TABLE 1. SIMULATION SETUP

Parameter	Values
Simulation area	2000m * 2000m
Simulation time	200s
No. of Vehicles	30, 50, 70, 90, 110
Vehicle's Speed	30 – 50 Km/h
Transmission Range	200m - 1000m
No. of Packet Senders	30
Packet Size	512bytes
CBR (packets/sec)	0.1, 0.2, 0.4, 0.6, 0.9,1
Vehicle Hello Interval	0.20, 0.40, 0.80
MAC Protocol	IEEE 802.11, DCF

The traffic density is not uniform and it depends on the number of vehicles chosen in the given area. Among all the vehicles, 30 pairs of source-destination are chosen randomly to send packets. The packet transmission density can be adjusted by setting different CBR rates with a packet size of 512 bytes. A simulation runs for 200 seconds and we have taken average of 10 simulation runs.

A. End to End Delay

This is the average delay between source and destination node for all successfully delivered data packets. In figure 8, the end-to-end delay for BNGF-C is significantly lowers than BNGF-H. Further, BNGF-C has comparatively small end-to-end delay when number of vehicles becomes more. Therefore from this figure, we can observe that BNGF-C outperform BNGF-H in terms of end-to-end delay.
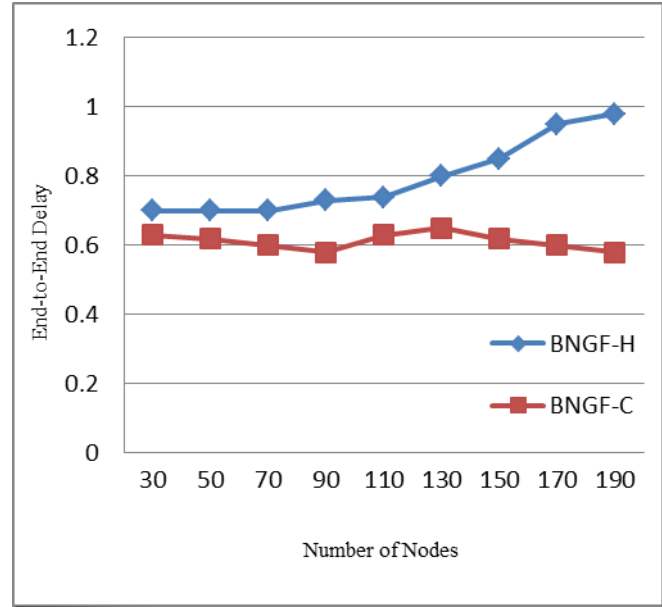

Figure: 8. End-to-End Delay

This improved performance of BNGF as BNGF-H and BNGF-C in different traffic scenarios can easily be explained by understanding the significance of using border nodes in our protocol as next hop forwarding node. Therefore, in BNGF-C, the time taken to deliver the packet from source to destination (end-to-end delay) is reduced. Further, in BNGF-C as the node density increases, the probability of presence of border node increases as compared to BNGF-H. This gives higher rate of successful deliveries and reduction in number of retransmission. This improves the end-to-end delay that is evident from the figure as the end-to-end delay for BNGF-C grows slowly as the number of nodes increases.

B. Packet Delivery Ratio

Packet delivery ratio is the ratio of the packets that successfully reach the destination.

$$\text{Packet delivery ratio (Pdr)} = \frac{\text{Total number of packets delivered}}{\text{Total number of packets transfered}} \times 100$$

Here we compare the performance of BNGF-H and BNGF-C in terms of packet delivery ratio. From the figure 9, we can see how packet delivery is affected by the packet transmission density and vehicular traffic density. In case of low vehicle density, very few vehicles will be available within the transmission range for next-hop selection along a particular path.
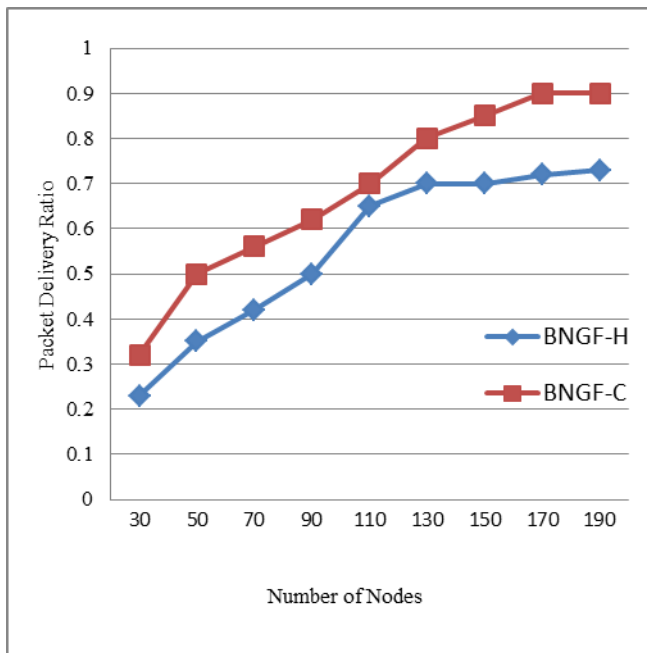

Figure: 9. Packet Delivery Ratio

When the vehicle density is more, the connectivity is much better. In this case all routing methods achieves better delivery ratio, since more vehicles can be met to forwards packets. In BNGF, a node will forward packet to the next-hop border node of its transmission range which is moving towards the destination. The packet delivery ratio is directly proportional to the vehicle density. As shown in figure 8, BNGF-C outperforms BNGF-H in terms of packet delivery ratio when the vehicle density is high.

VII. CONCLUSION AND FUTURE WORKS

In this work, we have investigated routing aspects of VANETs. We have characterized the VANET and previous studies on position based routing in VANETs. By using the unique characteristics of VANET, we have proposed a new Border Node Greedy Forwarding method (BNGF). BNGF protocol is designed to find robust paths to forward packet with minimum delay. Furthermore, we have categorized the BNGF as BNGF-H and BNGF-C for two different traffic scenarios highway and city for VANETs.

Our simulation result have shown BNGF-C outperform BNGF-H in terms of end-to-end delay, packet delivery ratio. As for future works, we are currently working on routing protocols to select best path for real time vehicular ad hoc networks in different vehicular traffic scenarios. VANETs needs more research which could lead to further improvements in vehicular ad hoc routing.

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