Performance Evaluation for a Unicast Vehicular Delay Tolerant Routing Protocol Networks

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Abstract
Vehicular Ad hoc Networks are considered as special kind of Mobile Ad Hoc Networks. VANETs are a new emerging recently developed, advanced technology that allows a wide set of applications related to providing more safety on roads, more convenience for passengers, self-driven vehicles, and intelligent transportation systems (ITS). Delay Tolerant Networks (DTN) are networks that allow communication in the event of connection problems, such as delays, intermittent connections, high error rates, and so on. Moreover, these are used in areas that may not have end-to-end connectivity. The expansion from DTN to VANET resulted in Vehicle Delay Tolerant Networks (VDTN). In this approach, a vehicle stores and carries a message in its buffer, and when the opportunity arises, it forwards the message to another node. Carry-store-forward mechanisms, packets in VDTNs can be delivered to the destination without clear connection between the transmitter and the receiver. The primary goals of routing protocols in VDTNs is to maximize the probability of delivery ratio to the destination node, while minimizing the total end-to-end delay. DTNs are used in a variety of operating environments, including those that are subject to failures and interruptions, and those with high delay, such as vehicle ad hoc networks (VANETs). This paper discusses DTN routing protocols belonging to unicast delay tolerant position based. The comparison was implemented using the NS2 simulator. Simulation of the three DTN routing protocols GeOpps, GeoSpray, and MaxProp is recorded, and the results are presented.
Keywords: *VANETs, Position Based Routing, DTN.*

I. INTRODUCTION

Vehicular Ad hoc Networks (VANETs) are derived from the Mobile Ad Hoc Networks (MANETs). VANETs are established especially for car-to-car communication (C2C) between moving vehicles and/or Road Side Units (RSUs). As stated above, VANETs allow set of applications related to providing more safety on roads, more convenience for passengers, self-driven vehicles, and intelligent transportation systems (ITS) [1-2].

Geographic routing protocols are considered to be more suitable for highly dynamic environments, such as VANET. These protocols are commonly categorized into DTN and non-DTN [3]. VDTN protocols are specifically designed to handle network partitioning and disconnections mainly caused by frequent mobility and sparse topology [4]. Hence, packet delivery ratio in VDTN is more important than delay, as these networks are characterized by inadequate transmission opportunities and irregular connectivity.

As the direct connection with a node in VDTN may not be possible because of the restricted transmission range of Road Side Units (RSUs), vehicles may be considered as an intermediate node to relay packets [5].

Automobile industry is currently motivated by the requirements of self-driven vehicles. Thus, there is a dire need for the exchange of information between such self-driven vehicles to enhance the safety, security and convenience of drivers and passengers alike [3-5].

So far, we have three types of communication in VANETs; namely the Vehicle to Vehicle (V2V) communication (i.e., the communication in between the self-driven vehicles themselves), vehicle to Road Side infrastructure (V2I) and Road Side Infrastructure to Road Side Infrastructure (I2I).

As earlier established, routing in Vehicular Ad hoc Networks involves several challenges in light of the specific features of this network, such as the high mobility of vehicles, the topological dynamic changes and the highly segregated network. Such features are commonly regarded as challenging in light of our pursuit to achieving reliable, non-stop and seamless way of communication in respect of moving vehicles.

In unicast routing protocols, transmission of data is triggered from one source to one destination. It is the basic unit protocol in ad hoc networks, upon which other types of protocols are based. Subdivisions are further made from Unicast routing protocols according to topology, position, cluster and hybrid protocols [5].

In position-based routing protocols, all vehicles can recognize their own locations and the geographic locations

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of their neighboring vehicle through position-pointing devices, such as Global Position System (GPS). A GPS device does not develop any routing table nor exchange any information related to the status of link with the neighboring vehicles. It rather provides the information used in making routing decisions. This type of routing provides better performance because it is needless to create and maintain an overall route path from the source vehicle to the destination vehicle. The position-based routing protocols may be further categorized into non-delay tolerant network (non-DTN) routing protocols, delay tolerant network (DTN) routing protocols, and hybrid routing protocols.

This paper focuses on DTN position based routing protocols in VANET environment and offers a detailed review of GeOpps, GeoSpray and MaxProp routing protocols.

The rest of the paper is divided into the following sections. Vehicular Ad hoc Networks are illustrated in section II. Section III discusses the issues related to routing protocols in VANETs. Section IV introduces VANETs unicast position based routing protocols. Section V records the simulation results. Finally, Section VI contains discussions.

II. VEHICULAR AD HOC NETWORKS

Vehicular Ad hoc Networks (VANETs) can be classified as a subcategory of Mobile Ad Hoc Networks (MANETs) that interact between the moving vehicles, on one hand, and the nearest fixed Road Side Units (RSUs), on the other. VANET is a high-end emerging technology, extensively used as means to provide more safety on roads and more convenience for passengers. It also serves the self-driven vehicles and the intelligent transportation systems (ITS) [1, 3].

Efficient routing protocols help make roads safer by rapidly disseminating information about the road conditions and traffic among the participating vehicles, within a very short period.

VANETs also enable both automated city and highway applications, where the vehicles can voyage without receiving any assistance from drivers; such applications were once fantasies yet have become realistic and the demand for them has risen. VANETs have some specific, unique challenging features, such as high mobility of vehicles, the varying density of vehicles based on time, highly segregated network, the frequent disconnections and the topological dynamic changes. [6] It is a challenge to build strong networks between vehicles and ensure continuous, secure, and reliable communication paths among the neighboring vehicles in motion [5].

The Federal Communications Commission (FCC) has assigned a spectrum 75MHz within 5.9 GHz band for vehicle-to-vehicle (V2V) and vehicle-to-roadside (V2I) communication, known as dedicated short-range communication (DSRC). In parallel, the Institute of Electrical and Electronics Engineers (IEEE) is in the process of developing a standard for wireless access in vehicular environments (WAVE), which is known as the IEEE 1609 family, implying an architecture and a complementary, standardized set of services and interfaces that jointly allow security for both vehicle-to vehicle (V2V) and vehicle to infrastructure (V2I) wireless communication [6]. The basic components of VANET are shown in figure 1.

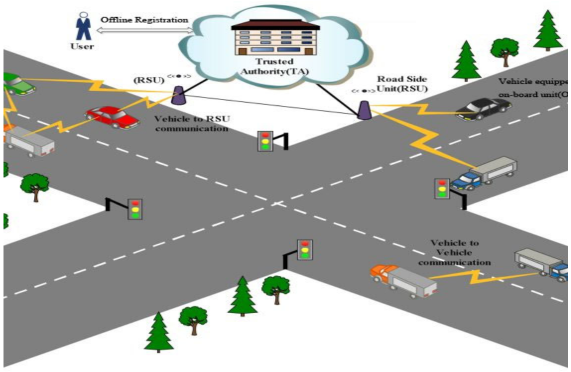

Figure 1 Vehicular Ad hoc Networks.

III. VANETS ROUTING PROTOCOLS

Achieving a reliable and fast routing in VANETs is the challenge we face, considering the unique specific nature and features of such network, such as dynamically changing topology, high mobility of vehicles and highly partitioned network. In view of fast-moving vehicles, it is quite challenging to ensure reliable, uninterrupted and seamless communication [7]. Several external factors such as road topology, and internal factors such as vehicle mobility, do control the performance of VANETs routing protocols, which means that we are in a dire need for a highly adaptive approach to deal with the dynamic circumstances that can only be achieved by selecting the best routing strategies and use of appropriate transmission and mobility models.

1. UNICAST ROUTING PROTOCOLS

Unicast Routing Protocols are commonly used for the transmission of data packets from one vehicle source to one vehicle destination only. Those protocols are specifically beneficial as they support both the personalized and commercial applications alike, such as multimedia access and internet connectivity.

2. BROADCAST ROUTING PROTOCOLS

One of the routing protocols most used by VANET, especially in the safety-related applications. Among the remarkable techniques used with broadcast routing protocols is flooding. However, blind flooding creates a broadcast storm problem, which means that the channel capacity is overloaded, leading to channel congestion and ultimately affecting the reliability of communication. Therefore, broadcast protocols are suitable only for a network with a limited number of vehicles [7-8].

3. MULTICAST/GEOCAST ROUTING PROTOCOLS

Multicast routing allows for the transmission of messages from one source to a group of target destination vehicles. An example of location-based multicast routing is Geocast routing protocol, aiming to deliver information from only one source vehicle to all other vehicles within a specified geographical region, called a Zone of Relevance (ZOR) [9].

4. CLUSTER-BASED ROUTING PROTOCOLS

In a vehicular ad hoc network, clustering means the virtual partitioning of the dynamic vehicles into several sets. Here, we have a set of vehicles known as clusters, and for each cluster there is a cluster-head. Cluster-heads are assigned several responsibilities; channel assignment for cluster members, spreading of inter-cluster traffic, scheduling of intra-cluster traffic, and including routing cluster members. In this protocol, Cluster members take no part in routing [10].

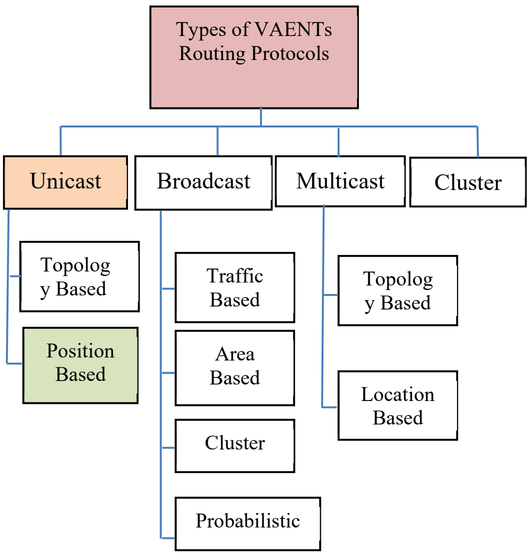

Figure 2 Types of VANETs Routing Protocols.

IV. UNICAST POSITION-BASED ROUTING PROTOCOLS

The most prominent of all VANETs protocols are the Unicast Routing Protocols in ad hoc environment, upon which other types of protocols are based. There are a number of subcategories that derive from the Unicast Routing Protocols, based on topology, position, cluster-based and hybrid protocols [11-14].

Topology-based routing protocols proved to be infeasible in VANETs due to the overheads related to the discovery and maintenance of routes in the presence of moving vehicles. Vehicle mobility is one of the most important factors affecting the VANET environment, as it leads to the frequent network partitioning and route disconnection, which in itself entails a re-calculation of propagation paths according to the new topology data.

In position-based protocols, the routing decisions are highly dependent on the geographic position of the vehicles, which demands no establishment or maintenance of routes, but rather requires location services to determine the position of the destination. Simple Location Services (SLS), Reactive Location Services (RLS), DREAM Location Services (DLS) and Global Position System (GPS) are some of the commonly used location services [4]. In this protocol, data are transmitted, regardless of the digital map to the one-hop neighbor, being the closest to the position of the destination vehicle. So, beacon (Hello) packets with the vehicle position information and other vehicle identification parameters shall be frequently sent by each and every vehicle. Position-based protocols are suitable for VANETs and are better than topology-based routing protocols, since they offer a higher delivery ratio in a highly mobile environment [12]. Therefore, they have the advantages of providing minimum delay in establishing the route path and achieve good scalability, as well.

Greedy forwarding, contention-based forwarding, opportunistic forwarding, trajectory-based forwarding and hybrid forwarding are examples of forwarding routing mechanisms used by position-based routing protocols. Position-based approaches are further classified into a delay-tolerant network, and a hybrid network.

In position-based routing protocols, with the use of through position-pointing devices such as GPS, all vehicles know their own positions and their neighboring vehicle geographic locations. A GPS device does not create a routing table and does not exchange connection status information with neighboring vehicles, but instead provides the information that is used in routing decisions. This type of route provides better performance because it is not necessary to create and maintain a total route path from the source vehicle to the destination vehicle. The position-based routing protocols may be further classified into non-delay tolerant network (non-DTN) routing protocols, delay tolerant network (DTN) routing protocols, and hybrid routing protocols [13-16].

Figure 3 illustrates the Classification of position based routing protocols. In this paper, our focus is on the DTN routing protocols.DTNs are used in a variety of operating environments, including those that are subject to outages and interruptions and those with high delay, such as vehicular ad-hoc networks (VANETs).

Due to the limited transmission range of a RSU, remote vehicles may not be able to connect directly to the RSU and therefore must rely on intermediary vehicles to forward packets. During the message relay process, complete end-to-end paths may not exist in highly segmented VANETs. Therefore, the intermediate vehicles must use buffer to store and forward messages opportunistically.

Through buffer, carry and forward, the message can finally be delivered to the destination, even if there is no end-to-end connection between the source and the destination at all. The main objective of routing protocols in DTN is to maximize the probability of delivery ratio to the destination while minimizing the end-to-end delay. In addition, vehicle traffic models are significant for DTN routing in vehicle networks because the performance of DTN routing protocols is closely related to population and mobility models of the network. In dynamic network environments, an adaptive framework and VDTN routing protocols are necessary to detect an appropriate next-hop forwarder node from neighbor on the path towards the destination. This selection should be made in such a way that increases data delivery probability with reduction in delay time and balancing of the network overhead.

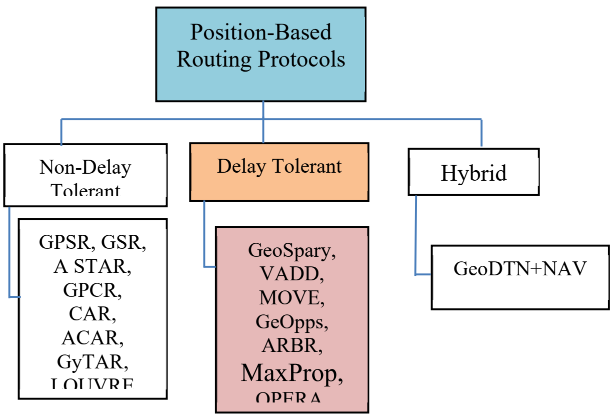

Figure 3 Classification of Position-Based Routing Protocols.

V. DELAY Tolerant Network (DTN)

Delay Tolerant Network (DTN) is a network approach that uses a carry and forward strategy related to heterogeneous networks to overcome the frequent disconnections of network nodes. DTN protocols store the packet information and then forward it later when an opportunity arises in case a vehicle cannot contact other vehicles.

The Delay Tolerance Network (DTN) uses a carry-and-forward strategy to overcome frequent disconnections of network nodes. In the carry-and-forward strategy, when a node cannot contact other nodes, it stores the packet and the transfer is done based on some metrics from the neighboring nodes.

Vehicle-Assisted Data Delivery (VADD) [17] is based on the idea of the carry-forward approach, using the predictable mobility of vehicles. The main problem is to select a route for forwarding the path with minimal packet delivery delay, using information about traffic patterns and road layout.

MOtion VEctor routing algorithm (MOVE) [18] was proposed for specialized sparse scenarios for vehicle-to-infrastructure (V2I). The MOVE algorithm uses knowledge of the velocities and paths of neighboring vehicles to predict which vehicle is actually moving closest to a RSU destination. This algorithm assumes a network with lower density, in which infrequent opportunistic routing decisions must be made in a predictive manner. It is assumed that each vehicle knows its own direction and position, and the destination (RSU) is assumed to be a fixed location, which is known globally. The current vehicular source node finds the closest distance between the current source and the destination along its path. The MOVE algorithm uses two main messages HELLO and RESPONSE for the carry-and-forward approach. The vehicle node regularly sends a hello beacon. The RESPONSE message sent by neighboring nodes enables the current vehicle to create the short route to the location along the path of the neighboring vehicle. Then, the current source vehicle decides to forward the message while establishing the current distance of each vehicle from destination.

Geographic Opportunistic Routing (GeOpps) [19] is considered as a new type of delay-tolerant routing algorithm that uses the information available from the navigation system to route a data packet to a specific geographic location. This allows the selection of vehicles to carry the information closer to the final destination of the packets. The node with the minimum arrival time is selected to forward packets. GeOpps delivery rate depends on mobility patterns and road topology, but not on vehicle density.

Geographical Spray in the VDTN (GeoSpray) protocol [20] uses the principles of single copy and single path GeoOpps to carry out a multiple copy, multiple path routing approach.

Adaptive Road-Based Routing (ARBR) assumes that each vehicle must know its geographical position and direction through a global positioning system (GPS) and is equipped with digital maps to select which road portion or which intersection [21] is to be taken. The ARBR protocol uses two mechanisms to increase delivery ratio and reduce end-to-end delay:

a) Find a high-quality route for forwarding between the route requesting vehicle and the packet forwarding vehicle, along with the discovered route.
b) The stability of the routes is secured by updating the route in the header of the road response packet through intermediate nodes.

MaxProp [22] is used for sparse networks with limited transmission possibilities. It is based on prioritizing both the list of packets transmitted to other peers and the list of packets to be dropped. It operates in three basic stages; neighbor discovery stage, data transfer stage and storage management stage.

Object Pursuing based on Efficient Routing Algorithm (OPERA) works in sparse situations and it is applicable to both moving and fixed destinations [23]. Optimization of decision making at intersections is based on the connectivity and feasibility metrics. By exploiting the related metrics, next road is selected to forward the packet in order to minimize the overall delay. Position-based Directional Vehicular Routing (PDVR) ensures that the packets can be sent to the destination in an efficient and stable route. It selects the next-hop from the vehicles travelling in the same direction as the forwarding vehicle based on their angular direction of relative destination.

Object Pursuing based on Efficient Routing Algorithm (OPERA) works in sparse cases and can be used for both moving vehicles and fixed destination (RSU) [23]. The optimization of decision making at intersections is based on feasibility and connectivity metrics. By taking advantage of the associated metrics, to minimize the overall delay, the next street is selected to forward the packet. Position-based Directional Vehicular Routing (PDVR) ensures that the packets can be forwarded to the destination in an efficient and stable manner. Based on its angular direction of relative destination, it selects the next-hop from the vehicles travelling in the same direction towards the destination as the forwarding vehicle.

1. Geographical Opportunistic Routing (GeOpps)

GeOpps is a geographic routing that can be considered as one of the most promising methodologies for efficient routing, which take into account location information of the moving vehicle. GeOpps routing for vehicular networks aims to improve the performance of single copy routing protocol in VDTNs [28]. It uses the vehicle's geographic location to opportunistically route the geographic bundle to the final destination. Therefore, the vehicle traveling to or near the bundle's destination becomes the next bundle carrier. The next point that a vehicle will transport the bundle to is called the next point and is used in computing Minimum Estimated Time of Delivery (METD) as follows:

METD = time to nearest point + (remaining distance / average speed).

Advantages	Disadvantages
To find a vehicle driving towards to or near the destination GeOpps needs few encounters.	It does not provide a method to optimally calculate these parameters
Performance shows that GeOpps has a high delivery ratio.	GeOpps provides only single copy and single Path.
The delivery ratio of GeOpps depends on the mobility patterns and the road topology, but is not dependent on high the density of vehicles	Privacy is an issue because navigation information is disclosed to the network.

Table 3 Advantages and Disadvantages of GeOpps [13]

2. GeoSpray (Geographical Spray in VDTN).

GeoSpray Protocol [20] uses the principles of single-copy, single-path of GeOpps routing protocol to implement a multi-copy, multipath bundle routing approach. GeoSpray also merges a hybrid policy between multiple and single copy routing protocols. It distributes a limited number of bundles copies to the network nodes by controlling the node spraying.

Routing schemes that use multiple copies are noticed for their low bundle delivery delay, high delivery ratios, and high overheads caused by duplicated copies. Therefore, GeoSpray depends on the repetition approach of the spray-and-wait protocol to reduce the number of copies [7]. Initially, it uses a multiple copy scheme that distributes limited copies of the packets to utilize diverse paths. It later switches to a single-copy forwarding scheme. GeoSpray deletes delivered packets from vehicles storage by propagating the delivery information. As a result, GeoSpray protocol achieves a better delivery ratio and better resource utilization than GeOpps protocol at the expense of high replication overhead.

3. MaxProp (Maximum Priority) Routing

The MaxProp routing protocol is based on a carry-store-forward mechanism, which is typically used in a DTN environment. In MaxProp, when two nodes communicate, they exchange packets in a specific order. If the node is currently in contact with the destination node of some packets, these packets are transmitted first. Secondly, the routing information, which includes the estimated probability of meeting any node, is exchanged. The probability calculation is based on the number of encounters between two nodes. At the end, a confirmation of the data provided is sent.

In addition, MaxProp has also established a mechanism to manipulate old data within the network. In MaxProp, each packet stores a list called hop list, which list the nodes that the packet already traversed. This hop list allows each node to recognize the age of packets. The packets with lower hop list values are considered new packets, and therefore assigned a higher priority, as explained in Table 4. Packets with the highest priority are transmitted first and the remaining packets are transmitted later. On the other hand, each node can decide either to send or drop the packets, which have the lowest priority according to its buffer status.

Packets towards the encounter node	High Priority
Routing information based on historical data	
Acknowledgements of delivered data	
Packets with a short hop list	
Other packets	Low Priority

Table 4: Priority of Packet in MaxProp.

VI. SIMULATION RESULTS AND DISCUSSIONS

Simulation Parameters	
Network Simulator	NS-2 version 2.34
Simulation Time	300 seconds
Map Size	2000 m x 1500 m
Mobility Model	M-Grid
Vehicle's Speed	20 ,40, 60, 80 km
Number of Vehicles	100-300
MAC Protocol	802.11 DCF
Channel Capacity	2 Mbps
Trans. Range	250 m
Traffic Model	15 CBR connections
Packet Sending Rate	4 packets / second
Data Packet Size	128 bytes
Channel Type	Wireless channel
Antenna Model	Omni directional

Table 5 Simulation Parameters

We have studied the routing protocols: GeOpps GeoSpray, and MaxProp, which are unicast DTN position-based protocols. Figure 4 shows node density versus package delivery ratio. The graphic clearly shows that the MaxProp protocol has a much better delivery ratio than GeOpps and GeoSpray routing protocols. This is because MaxProp is a guided routing protocol that looks for possible paths to destinations by selecting the relay nodes, which improves the percentage of delivery ratio. The packet delivery ratio of the GeOpps routing protocol was low compared to the other protocols, especially when the number of nodes is low. That is due to the fact that GeOpps routing protocol provide only single copy and single path. The GeoSpray protocol provides multiple copies of multi-paths, which results in a better performance than in GeOpps. In addition, it is clear from the graph that the average packets delivery ratio improves as the node density increases. This is because when the density of nodes has increased, the number of reliable routing paths from the source to the destination has increased.

The nodes density versus the End-to-End delay is shown in figure 5. As can be seen in Figure 5, the MaxProp routing protocol performs worse compared to the GeOpps and GeoSpray routing protocols, especially when the nodes density is low due to the complexity of its buffer handling. The results also show that the overall performance of the routing protocols improves as node density increases due to the availability of node on the connected path. Figure 5 also illustrates that GeOpps routing protocol achieves lower

End-to-End delay compared to GeoSpray and MaxProp, especially when the nodes density is low. Results from figure 4 and figure 5 reflect that there always exists a trade-off between delivery ratio, end-to-end delay, and network resource usage, while applying different approaches in the vehicular networks.

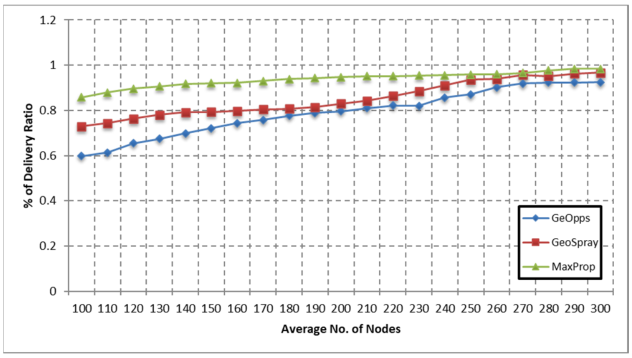

Figure 4 Node Density Vs % of Delivery Ratio.

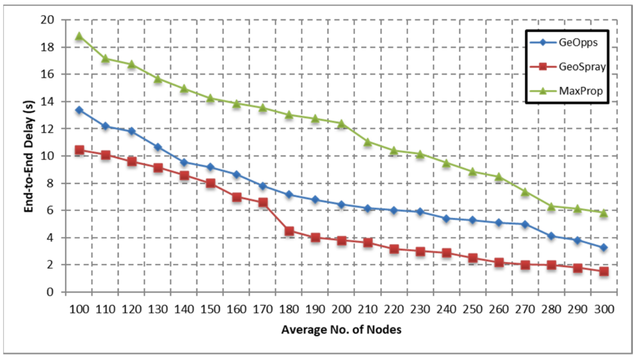

Figure 5 Node Density Vs End-to-End Delay.

VII. CONCLUSION

Performance measurements VANETs routing protocols depends on many factors such as the mobility of vehicular, vehicular density, rapid topological changes and other driving environment. Performance metrics also depend on the appropriate use of mobility model and propagation model. The routing protocol of VANETs should perform well in both heavy and light traffic, both in the city and on highways. In this paper, protocols belonging to unicast non-delay tolerant position-based are discussed. We have conducted our comparison on the NS2 simulator. Simulation of DTN routing protocols GeOpps, GeoSpray, and MaxProp is carried out and the results are presented. According to simulation, results show the outperformance of MaxProp in delivery ratio than other protocols but it leads to more average delay due to buffer processing algorithm and priority calculation.

Simulation results show that there always exists a differentiation between delivery ratio, total end-to-end delay, and network resource usage, while applying different approaches in the vehicular networks.

In the next research paper, we will try to determine the performance difference between delay tolerant network (DTN) routing protocols and Non-DTN routing protocols.

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