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Geographical and maximum distance on-demand routing algorithm G-MDORA

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ABSTRACT

A vehicular ad hoc network (VANET) is an intelligent technology that allows efficient communication, secure data transmission, and traffic management. VANET allows vehicles in the network to communicate wirelessly with roadside units (RSUs) or between vehicles within a coverage area. The primary goal of adopting VANET is to reduce the frequency of accidents in specific urban regions drastically. It has a significant impact on passenger safety and the ability of drivers to drive safely in metropolitan areas. As the number of cars on the road grows, so does the number of accidents. As a result, a better traffic system is required to address this issue. VANET is a cutting-edge network that primarily delivers intelligent transportation system (ITS) services to end-users to facilitate data exchange and ensure safety. In this paper, we propose geographical and maximum distance on-demand routing algorithm (G-MDORA) that combines the advantages of geographic routing protocol (GRP) and MDORA protocol for Ad hoc routing between vehicle to vehicle (V2V). Our proposed model provides an idea that can be used to improve the performance of the GRP and MDORA protocol. Moreover, the performance of the G-MDORA, GRP, and MDORA protocol was compared in terms of end-to-end delay, communication overhead, throughput, and packet loss ratio.

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1. INTRODUCTION

A new wireless network known as vehicular ad hoc networks (VANETs), has emerged because of the growing number of automobiles equipped with wireless transceivers to communicate with other vehicles. To increase driver safety and provide a comfortable driving experience, messages for various purposes must be sent to vehicles via intervehicle communications [1]. VANETs are a type of mobile ad hoc network that allows cars to interact with one another and with fixed stations nearby. Vehicle traffic wastes a significant amount of time and fuel in prosperous countries. Because of the advancement of intelligent transportation systems, vehicles have become intelligent enough to adapt to dynamic changes in road traffic. Traffic-related concerns such as road accidents, and traffic bottlenecks, may be avoided by implementing an intelligent transportation system (ITS) that uses VANET. It might help with traffic control, road safety, and driver-to-passenger information exchange. The five VANET routing protocols are topology-based, position-based, broadcast-based, geo-cast-based, and cluster-based [2]. When the cars travel along the road, VANET solely uses the roadside topology. One may identify its exact location by interacting with other cars, avoiding wrecks and traffic congestion, and utilizing GPS to go in the right direction.

Vehicles that act as nodes should be equipped with powerful computers, communication systems, and sensors. To allow successful communication between different types of automobiles, the networks employ various routing protocols. To prevent numerous dangers that might jeopardize human life, routing protocols aid automobiles in travelling in the appropriate direction, gaining their optimal position, and employing the most efficient vehicle to vehicle (V2V) and vehicle to infrastructure (V2I) connections. Implementing proper routing protocols in the high mobility environment that is a feature of VANET [3] is always challenging since routing protocol performance degrades with network speed and scale. In a VANET, V2V communication provides a variety of advantages, such as a communication range of 100 to 300 meters, mobility, and multi-hop support, which is comparable to that of wireless sensor networks (WSN). WSNs commonly employ IEEE standard 802.15.4, which aims to provide the essential lower network layers for a wireless personal area network (WPAN) focused on low-cost, low-speed ubiquitous communication between devices. The basic design requires a 10-meter communication range and a transmission rate of 250 Kbit/s. V2V communication can also be accomplished using IEEE 802.15.4. The VANET safety application improves passenger safety by transmitting safety-relevant information such as emergency alerts and traffic conditions warnings via V2V communication. The IEEE 802.15.4 standard [4] can be used to send emergency warning messages between automobiles.

This paper aims to propose a geographical and maximum distance on-demand routing algorithm (G-MDORA) algorithm that combines the advantages of geographic routing protocol (GRP) and MDORA protocol and implement these protocols in the urban environment designed by MATLAB. In addition, G-MDORA, GRP, and MDORA protocol performance were compared using four metrics (throughput, packet loss ratio, end-to-end delay, and communication overhead). The rest of this paper is organized as: section 2 introduces ad hoc networks categories. Section 3 gives VANET Architecture. Section 4 shows routing protocols. Section 5 describes the proposed algorithm. Section 6 outlines performance evaluation, while section 7 summarizes this work through a conclusion.

2. AD HOC NETWORKS CATEGORIES

This section presents the categories of ad hoc networks, as the ad hoc network is divided into three categories: Wireless mesh network (WMN), mobile ad-hoc network (MANET), and WSN. In addition, the MANET network is divided into three sections: VANET, intelligent vehicular ad hoc networks (InVANETs), and internet-based mobile ad hoc network (IMANET). The ad hoc network categories are shown in Figure 1.

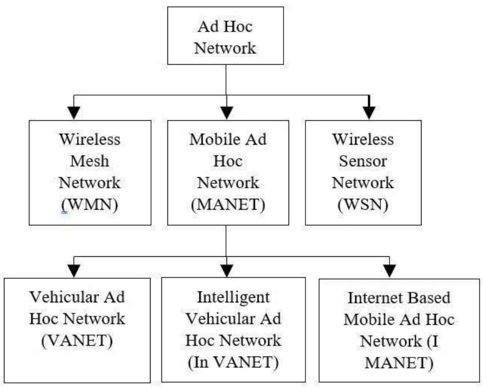

Figure 1. Ad hoc networks categories [5]

2.1. Wireless mesh network

WMN are gateways, routers, and radio nodes that communicate with one other. In addition, any node within its communication range is aware of all other nodes. As a result, the whole network is linked together, and numerous pathways exist between them. Destination and source messages are also sent between the source, destination, and gateways using mesh routers [6].

2.2. Wireless sensor networks

This network consists of a collection of static sensor nodes scattered around an area to monitor physical or environmental characteristics such as temperature. The sensor nodes then collaborate to monitor and transmit data to the base station, often positioned far away from the monitored location. Using sensor networks, medical, industrial, and military applications are all possible [5], [6].

2.3. Mobile ad hoc networks

MANETs are wirelessly linked mobile devices that form an infrastructure-free network. As a result, mobile devices have complete freedom of movement. When mobile nodes move from one site to another, the MANET connection changes often. The most challenging aspect of MANETs is equipping each mobile node with the technologies required to gather and retain the data required to route messages. MANET nodes must also act as routers, passing messages from other nodes onto other nodes. The MANET category is separated into three subcategories, as shown in Figure 1 [6], [7]: VANET, InVANETs, and IMANET.

2.3.1. Vehicular ad-hoc networks

VANETs are a specific type of MANET [8]. The network topology of a VANET can change more frequently than in a MANET. The roadside infrastructure and the vehicle itself are the two structures that make up the VANET. From search and rescue to road mapping and disaster monitoring, VANETs may be used in various military and civilian applications [9]. VANETs may be modelled as moveable nodes that operate in a road-like topology with permanent roadside infrastructure. VANETs are a networking design that faces a unique set of problems, like MANETs. V2I and V2V communication are the two most essential aspects of VANET communication, as shown in Figure 2. As a result of the frequent change in location, which is represented by mobility, the wireless link between every two nodes may be damaged by disconnection [10]. As can be observed from the above, VANET topologies vary often, central communication and all-time connectivity become a severe barrier for VANET-based multi VANET task planning, and the distance between nodes is more significant than in MANET, all of which are attributable to VANETs' mobility. As a result of all these variables, utilizing a high gain antenna to accomplish long-range transmission, reduce hop count, and enhance latency performance is becoming increasingly popular. When compared to MANET [10], [11], VANET's power allows it to undertake real-time activities, such as a live video feed, that demand a high data rate and a large amount of bandwidth [6].

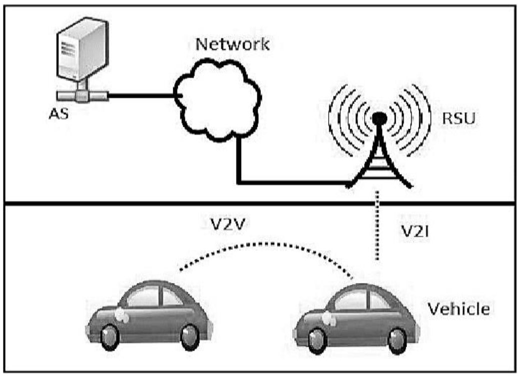

Figure 2. Vehicular ad-hoc networks [12]

2.3.2. Intelligent vehicular ad-hoc networks

Intelligent techniques to employ VANETS and combine numerous ad-hoc network technologies such as Wi-Fi IEEE 802.11 and Zigbee are defined in this area. As a result, cars may communicate more accurately, effectively, and simply. In vehicular Ad-hoc networks, many wireless technologies can be used, including dedicated short-range communications (DSRC), a form of Wi-Fi [6].

2.3.3. Internet-based mobile ad hoc networks

IMANET is one of the subcategories of the MANET network. IMANET is made up of two parts. The first part is an ad hoc network that connects mobile nodes. The second part is gateway nodes that may convey messages to or from the first component because standard ad hoc network routing algorithms cannot be utilized directly on the IMANET [13].

3. VANET ARCHITECTURE

Wireless access in vehicular environment (WAVE) is a wireless communication system that allows vehicles to communicate with one other and with a roadside unit (RSU). This mode of communication allows safety apps to increase road safety, create a comfortable driving experience, and give drivers and passengers a wide range of information [14]. The phrases "provider" and "user" denote two distinct entities. A provider provides the services while a user uses them. RSUs and OBUs can function as either providers or users depending on their roles in the network [15]. An RSU, application unit (AU), and on-board unit (OBU) are the three primary components of a system [16]. Figure 3 shows the architecture of the VANET.

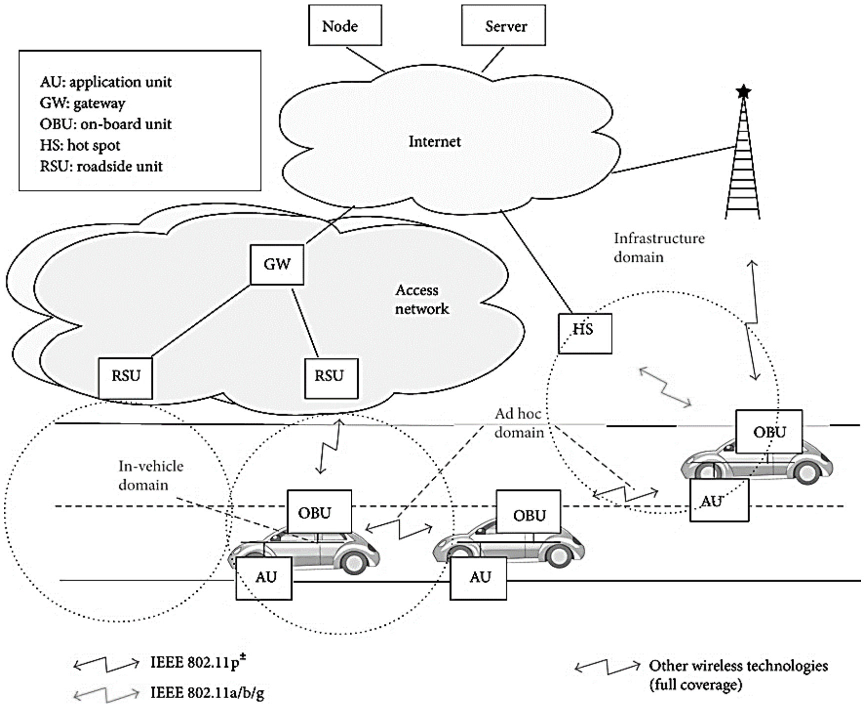

Figure 3. VANET Architecture [12]

3.1. Roadside unit

RSUs are wave devices often mounted along the side of the road or in specialized locations, such as near crossroads and parking lots [17]. The gadget links to the internet and may thus be used to avoid mishaps and deliver security information to the user. Only authenticated users have access to information. As for tactics, we deploy pseudonyms, mix zones, ad hoc anonymity, and silence times [18]. They are, for example, located at high-vehicle-density junctions and parking lots.

3.2. Application unit

An AU is a device fitted within the vehicle that communicates with the OBU using the application given by the supplier. The AU might be operated on a regular device, such as a personal digital assistant (PDA) that runs web services [14] and safety apps. The OBU is wired or wirelessly linked to the application units. It provides OBU with Internet access so that data may be transferred and received [15].

3.3. On-board unit

OBU is a piece of hardware that is put in every vehicle. OBUs are WAVE devices commonly installed on automobiles and exchange data with RSUs or other OBUs. The transceiver is connected to a radio frequency aerial and a CPU, like a router [19]. It not only transmits information but also relays it to other OBUs. It assists AU in the form of service programs [20]. Several wireless communication protocols may be offered [18].

4. ROUTING PROTOCOLS

In VANET and MANET research, routing protocols are a hot topic [21], [22]. Most MANET routing protocols were designed with random architecture and immobile or low-speed nodes. On the other hand, vehicles follow a predefined path on highway lanes and can go at a very high speed. As a result, VANET applications employ MANET routing protocols as the routing approach is not precise. Position, topology, broadcast, multicast or geocast, and cluster-based routing protocols are the five types of VANET routing protocols. The focus of this research is on position-based routing methods.

4.1. Greedy perimeter stateless routing (GPSR)

GPSR protocol [23]-[25] is a position-based routing protocol; the algorithm determines the next node to retransmit the packet based on the position of the nodes as well as the destination. A node GPSR operates in greedy mode by default, forwarding packets to the nearest neighbour. Neighbourhood discovery is accomplished by the periodic broadcast of Beacon messages, including the node's address and position (x, y).

4.2. Geographic source routing (GSR)

Based on geographical location and information about road structure, the GSR protocol [23], [26] constructs knowledge suited for the urban context. According to the protocol GSR, a source vehicle aiming to transfer a data packet to a destination vehicle uses geographical information from a road map to identify the shortest routing path to reach this destination vehicle. It is worth noting that the routing path in question is determined in its whole, for example, by employing the Djikstra approach. The vehicle source selects a set of junctions from the predicted routing path to transit to the destination vehicle for the data packet. This series of junctions comprises a set of defined geographical locations for data packet transmission. The authors recommend employing a greedy technique to get signals from one junction to the next.

4.3. Greedy perimeter coordinator routing (GPCR)

The GPCR methodology [23], [27] is a cross between the GPSR and road mapping protocols. According to the authors, each node can detect if it is in an intersection, at which point it acquires coordinator status. As a result, messages are greedily delivered along the road, with coordinator nodes taking precedence. This shows that to prevent blocking radios, a node coordinator (a node at an intersection) is preferred over a non-coordinator node when picking the next relay node, even if it is not the closest to the target.

4.4. Anchor-based street and traffic-aware routing (ASTAR)

A-STAR is a routing protocol based on the geographic location of the vehicular environment in the metropolitan area [23], [28]. It identifies an anchor path with a good connection for packet forwarding using the information on city bus routes. The ASTAR protocol is like the GSR in that it uses an approach-based routing anchor to represent street characteristics. Unlike GSR, though, it determines "anchor pathways" based on traffic. Each roadway is given a weight based on its capacity (large or small street).

4.5. Geographic routing protocol (GRP)

The GRP is a proactive routing protocol based on location. Each mobile node in GRP is helped by a GPS, which is used to find and label the node's location, and quadrants are used to optimize flooding. The flooding position is updated when a node travels and crosses the neighbourhood. Nodes will broadcast a 'HELLO' protocol to identify their neighbours and their location. On the other hand, route locking allows a node to return a packet to the previous node if it is unable to transmit it to the next node. GRP divides a network into many quadrants to prevent route flooding. The entire world is divided into quadrants from lat, long (-90, -180) to lat, long (+90, +180). After the network's first 'flooding,' each node knows the beginning position of every other accessible node. When a node moves a longer distance than the user requested or crossed a quadrant, routing flooding occurs. Reference points in various fixed coordinate systems are also utilized in addition to absolute geographic coordinates supplied by the GPS [29], [30].

4.6. MDORA

MDORA [31], [32] is also a type of position-based routing protocol. Designed for VANETs, this protocol works on the principle of creating paths between vehicles on-demand only. Using traffic data, this protocol creates a graph between the source vehicle and its neighbours. Based on the maximum distance from the transmitting vehicle to the destination vehicle and sufficient communication lifetime to transfer the packet, the suitable path is determined to route the data. An MDORA protocol goes through two phases: the discovery and creation of the path and the second is the data transfer.

5. PROPOSED ALGORITHM

The vehicular ad hoc network allocated in the urban environment is considered for the proposed algorithm. This algorithm was proposed by integrating the features of the MDORA protocol with the GRP protocol, where the broadcast of 'Hello' messages was reduced by dividing the network into quarters. The following sections will explain the mechanism of action of the proposed algorithm.

5.1. The method of dividing the network in this protocol

The entire network is divided into quarters to minimize hello message messages. A specific value can determine the quarter's size by the scale of the network structure. All quarters are organized hierarchically.

Each quarter with a higher level is divided into four smaller quarters. This paper has divided the network into three levels, as described in Figure 4. Using hierarchical quarters, the suggested algorithm selects the following vehicle when the package is directed.

a. First, the entire network is divided into parts A and B (level 1).
b. After that, each quarter of A and B is divided into four low levels (Aa, Ab, Ac, and Ad), B is divided into (Ba, Bb, Bc, and Bd) respectively (level 2).
c. Aa is also divided into four more minor levels (level 3) (Aa1, Aa2, Aa3, and Aa4). AB, AC, and AD are also divided. Each of them to four quarters.

5.2. Hello message

The hello message contains information (vehicle speed, vehicle ID, vehicle address, and message type), as shown in Table 1. Vehicles broadcast a hello message to neighbor vehicles in two cases. The first case is when the vehicle moves a longer distance from the pre-selected distance. The second case is when the vehicle exceeds the quarter limits, it will send hello message until it tells its adjacent vehicles of its current location. Each vehicle inside the network retains the neighbour table; even when the vehicles receive hello message, it will save the information in the table. Illustrative examples about hello message:

a. If a vehicle moves from a quarter of Aa1 to a quarter of Aa2, the hello message is populated within the Aa quarter, as shown in Figure 4.
b. If the vehicle moves from Aa quarter to Ab quarter, the hello messages only flooded A quarter of the entire network as described in Figure 4. This will avoid sending an unnecessary hello messages message and use it to save network resources.

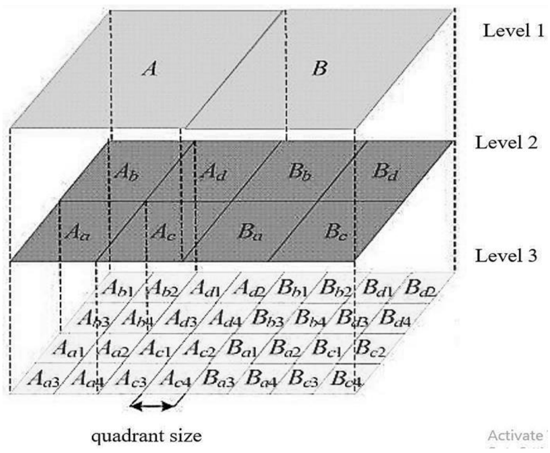

Figure 4. Hierarchical network

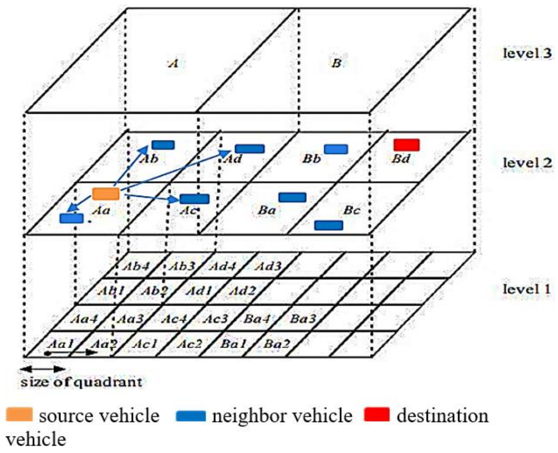

Figure 5. Calculate the distance factor

Table 1. Hello message information

Vehicle velocity	Identification_vehicle	Vehicle _address	Message _type
Vehicle_v	ID_vehicle	Vehicle_add	M_type

5.3. The stage of path establishing and transferring packets

To transfer the packet from the source vehicle or (current vehicle) to a destination vehicle. The appropriate path is detected, and the best next-hop through the distance factor account between the destination vehicle and neighbour vehicles adjacent to the source vehicle within A quarter (Aa, Ab, Ac, and Ad) as shown in Figure 5. the distance is calculated according to the (1). After calculating the distance, the distance table is created, and the distance of the vehicles is stored and arranged from the least distance to the highest distance, as shown in Table 2. The Ad vehicle is selected for the least distance (closest) to the destination vehicle.

$$Dist = \frac{Dist^2\,(S,D) + Dist^2\,(S,n) - Dist^2(n,D)}{2 \times Dist^2(S,D)} \tag{1}$$

where:

$$Dist\ (S, D) = \sqrt{(x_{Dx} - X_{Sx})^2 + (y_{Dy} - y_{Sy})^2} \quad (2)$$

$$Dist\ (S, n) = \sqrt{(x_{nx} - X_{Sx})^2 + (y_{ny} - y_{Sy})^2} \quad (3)$$

$$Dist\ (n, D) = \sqrt{(x_{Dx} - X_{nx})^2 + (y_{Dy} - y_{ny})^2} \quad (4)$$

Table 2. Distance table and ascending distance

Quarter	Meter (m)	Quarter	Meter (m)
Aa	200	Ad	50
Ab	150	Ac	100
Ac	100	Ab	150
Ad	50	Aa	200

Then, the communication lifetime factor (CLTF) is calculated (the time of expiration of the connection between vehicles) for vehicles in the distance table to ensure that the vehicles survive inside the communication range. The CLTF, is calculated in the (5).

$$CLT = \frac{-(ab+ac) + \sqrt{(a^2)r^2 - (ac-ab)^2}}{a^2} \quad (5)$$

Where: $a = vi - vj$, $b = xi - xj$, and $c = yi - yj$

In addition, the factor is defined (CLT _Threshold) and is known as (the minimum time required for the data transfer process is 0.001 msec). This factor is used to assess the communication lifetime for the next jump vehicle. (CLT_Threshold) furthermore, the CLTF result is compared. If CLTF is less than (CLT_Threshold) will be removed from the distance table. The second vehicle (Ac) is selected from the distance table, and the previous steps are calculated from CLTF → etc. While if CLTF is larger and equal to CLT_Threshold, the current vehicle will transfer the packet to the Ad vehicle. The packet contains the following information (the required packet to be transferred to the destination, vehicle ID, neighbour ID (the vehicle ID that sent the packet), and destination address) as shown in Table 3. Compared to the vehicle ID that received the Ad_ID packet and the destination ID (D_ID) and wondered if identical identifiers would end the algorithm because it is a destination vehicle. If the identifiers do not match, the vehicle Ad that received the packet will recalculate the distance factor and repeat all previous steps until the packet reaches the destination vehicle.

Table 3. Packet information

Destination address	Destination identification	Neighbour identification	Packet
D_add	D_ID	Neig_ID	Packet

6. EVALUATION PERFORMANCES

6.1. Simulation parameters

In this study, we created a realistic urban environment of intersections and bidirectional roads, the simulation environment was designed, and MATLAB programmed the protocols. Figure 6 shows the simulation environment in which the protocols were applied. This work will be investigated by three metrics, end-to-end delay, packet delivery ratio, and communication overhead. Table 4 shows the simulation parameters.

Table 4. Simulation parameter

Parameter	Value
Protocols	GRP, MDORA, GMDORA
Simulation area	1 km × 1 km
Number of vehicles	70
Number of lanes	2 Bidirectional
Velocity	(40–80) km/hr
Position generator	Random every time

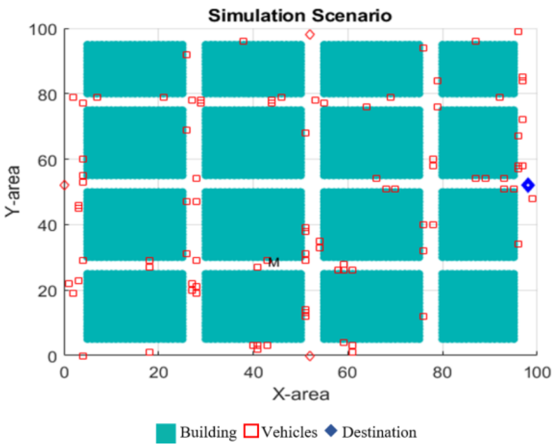

Figure 6. Simulation environment

6.2. Studied metrics

End-to-end delay: Latency refers to the time it takes for a packet to travel from one start point. If data in a packet is significantly delayed beyond the allowed value, it becomes unusable for the application [33], [34]. In (6), $E2E$ is calculated:

$$E2E = \frac{Time\ of\ transmission\ packet}{\sum Number\ of\ received\ packets} \tag{6}$$

Communication overhead is the proportion of additional routing packets to packets delivered successfully at destinations. This measure depicts the network's saturation level. The lower the OH value, the better the protocol's performance [35]. In (7), overhead is calculated:

$$OH = \frac{Total\ number\ of\ overhead\ messages}{Total\ transmitted\ data\ packets} \tag{7}$$

Throughput: the flow rate is the quantity of data successfully received to the destination in each time unit. When choosing a routing protocol for vehicular ad hoc networks [33]. In (8), throughput is calculated:

$$Throughput = \frac{\sum Size\ Packages\ received}{(Time\ Reception - Time\ Sending)} \tag{8}$$

The packet loss ratio is the proportion of packets lost during data transmission divided by the number of broadcast packets [36], [37]. In (9), overhead is calculated:

$$Packet\ loss\ ratio = \frac{(Total\ Packet\ Transmitted\ –Total\ Packet\ Delivered)}{Total\ Packet\ Transmitted} \tag{9}$$

6.3. Results and discussion

This section presents simulation results for each performance metric as described in the previous section using MATLAB software. The simulation data values are summarized in Table 5 regarding throughput, delay, and packet loss ratio. Figure 7 presents the result of the end-to-end delay (E2E) for the MDORA, GRP, and G-MDORA protocol. The G-MDORA protocol has the lowest average delay, which depicts a better performance compared to the MDORA and GRP protocols. This is due to the short path and few hops that the packet travels from the source vehicle to the interface vehicle.

Figure 8 shows the comparison between MDORA, GRP, and G-MDORA protocols regarding communication overhead. The comparison showed that the G-MDORA protocol has the lowest communication overhead rate than the MDORA and GRP protocols because the packet in G-MDORA is delivered to the destination in the least possible number of control messages (hello messages). Thus, the percentage of communication overhead is lower in G-MDORA.

Table 5 presents the comparison results between MDORA, GRP, and G-MDORA protocols in terms of throughput. The comparison shows that the G-MDORA protocol has the highest throughput rate than the MDORA and GRP protocols. This is because the probability of packet success for a particular link is strongly affected by the quality. In the G-MDORA protocol, the link with the highest connection probability is selected to forward packets, resulting in higher link quality per hop and higher packet delivery rates than MDORA and GRP. Therefore, the productivity of G-MDORA is the highest.

Table 5 presents the packet loss ratio for the MDORA, GRP, and G-MDORA protocol. We notice that the packet loss rate in the G-MDORA protocol is less than in the MDORA and GRP protocols. In the G-MDORA protocol, the best path is chosen to route the packet from the source vehicle to the interface vehicle. Therefore, the G-MDORA protocol shows lower packet loss than MDORA and GRP.

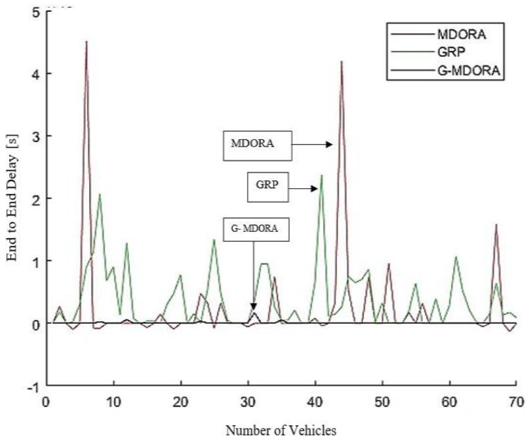

Figure 7. E2E Delay

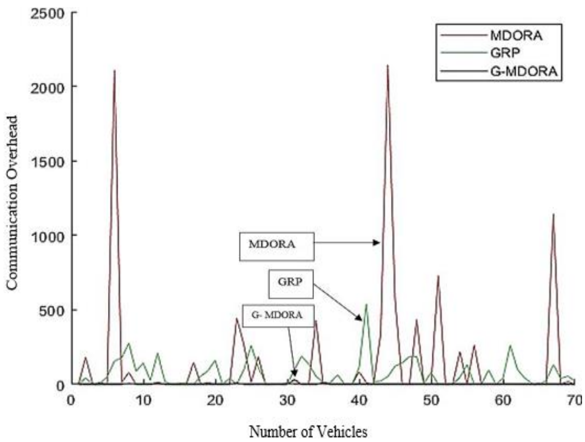

Figure 8. Communication overhead

Table 5. Comparative analysis of packet loss ratio, throughput, and delay

Header	MDORA	GRP	G-MDORA
Packet loss ratio	95.729	15308	29.286
Throughput	0.89945	0.89992	0.98911
Delay	2137.6	3730.6	92.226

7. CONCLUSION

In this work, a simulation-based analysis was performed to analyse the performance of a VANET system using various routing protocols. In this paper, we propose a G-MDORA algorithm that combines the advantages of GRP and MDORA routing protocols for Ad hoc routing between V2V. Our proposed model provides an idea that can be used to improve the performance of the GRP and MDORA protocol. The results show that the performance of VANET is improved by adopting the G-MDORA protocol compared to GRP and MDORA in terms of high throughput, low packet loss ratio, reduced E2E delay, and reduced communication overhead. The proposed protocol and simulated results may serve as guidelines for designing modern traffic control mechanisms that track safety implementation, faster data packet propagation, and the intermittent connection problem in VANETs.

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