Routing Challenges and Solutions in Vehicular Ad hoc Networks

1Samira Harrabi, 2 Ines Ben Jaafar and 3 Khaled Ghedira
1 ENSI University, Mannouba, Tunisia
2 ESCT University, Mannouba, Tunisia
3 ISG University, Tunis, Tunisia
E-mail: samira.harrabi@gmail.com, ines.benjaafar@gmail.com, khaled.ghedira@anpr.tn

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Abstract: Vehicular Ad-hoc Networks (VANETs) are known as a special type of Mobile Ad-hoc Networks (MANETs) specialized in vehicular communications. These networks are based on smart vehicles and base-stations, which share data by means of wireless communications. To route these information, a routing protocol is required. Since the VANETs have a particular network features as rapidly changeable topology, designing an efficient routing scheme is a very hard task. In this paper, we mainly focus on surveying new routing protocols dedicated to VANETs. We present unicast, multicast and broadcast protocols. The experimental results are discussed to evaluate the performance of the presented methods.

Key-words: Vehicular Ad-hoc networks, Routing, Unicasting, Multicasting, Broadcasting.

1. Introduction

In the 2000s, Mobile Ad Hoc Networks (MANETs) have been deployed in Intelligent Transport Systems (ITS) [1]. Specifically, they are used to ensure the inter-vehicle communication hence the appearance of Vehicular Ad hoc Networks (VANETs) [2]. The nodes in these networks are vehicles equipped with electronic and computer components (radars, cameras, sensors, scanners, etc.).

The VANETs networks aim to exchange data between vehicles or between infrastructure and vehicles. This exchange provides, firstly, road security [3] by transferring alert messages like congestion, accidents, work, etc. Secondly, it offers comfort services [3] for users such as Internet, looking for a parking spot, online games, etc. To route these data, a routing protocol is required.

Nevertheless, The VANETs networks are characterized by a very dynamic topology caused by the high mobility of vehicles [4]. These properties make MANETs routing protocols are mostly inadequate for this type of network [5].

In a highly dynamic environment, the link between vehicles may be interrupted frequently. However, the key differentiation between the VANETs and the MANETs makes the existing routing methods are very poor in vehicular communications [6].

In this investigation, the recent new results for the VANETs routing protocols are reviewed and compared.

The remained of this paper is structured as follows. Section 2 introduces of vehicular networks. It presents its applications, standards as well as the specific properties and the various challenges related to it. Section 3 reviews the designed routing protocols in VANETs. Section 5 concludes this paper and gives some possible future perspectives.
2. VANETs Networks

Vehicular networks represent a fast emerging class of the MANETs. The VANETs are self-organizing networks and distributed [2]. In the Fig. 1 it is built up by moving vehicles distinguished by a very high speed compared to other mobile nodes.

A moment ago, the VANETs have become an important field of research and its deployment is progress gradually.

2.1. VANETs Applications

The applications of the VANETs are significantly different from the traditional ones well-known from MANETs [3]. The most essential group of applications, which makes research studies on vehicular networks more and more popular, are those deals with driving safety. In fact, this kind of applications contain among others as route obstacles warning (unusual situations, accidents, etc.), driving assistance (changing of lane, slow-down decision, etc.), etc.

Another set of applications that become important as well as safety ones, are those related to the infotainment services. The mainly ones are related to advertising and distributing data about free parking spaces, the nearest Gasoline stations can as well be shared between vehicles. Evenly, several infotainment applications can be also available for users. Indeed, the time of arrival at the bus stations can be estimated on the basis of knowledge about traffic situations. Then, this information will be distributed to the waiting passengers.

The Fig. 2 summarizes the different applications of the VANETs.

2.2. VANETs Standards

United States (US) was developed the standard Dedicated Short Range Communications (DSRC) [7]. It represents a short to medium range communication service utilized for both Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I) communication.

In fact, the US Federal Communication Commission (FCC) puts 75 MHz of spectrum at 5.9 MHz for DSRC [8]. The spectrum of the standard DSRC has seven channels [3]. Every channel is 100 MHz. In 2003, American Society for Testing and Materials (ASTM) [9] sets ASTM-DSRC which was completely on the basis of 802.11 MAC layer and IEEE 802.11a physical layer [7]. The key problem of the IEEE 802.11a with Data Rate sets to 54 Mbps is it suffers from multiple overheads [10].

However, a Vehicular communication scenario requires a highly speed transmission data and fast communication because of its high changeable topology and mobility as well. Thence, ASTM group is renamed the standard DSRC to IEEE 802.11p Wireless Access in vehicular Environments (WAVE) [11]. This works on both MAC and physical layers. As is illustrated in Figure below, the WAVE is composed of Road Side Unit (RSU) and On-Board Unit (OBU) [12]. The Fig. 3 presents the architectures of WAVE and IEEE 1609.

2.3. VANETs Properties, Issues and Challenges

Even that the VANETs are one of the most promising applications of the MANETs, they have
special features as high mobility, network portioning and constrained topology. Indeed, the vehicular network concept raises lots of serious problems. The major important one is that related to the intermittent connectivity caused by high mobility of vehicles [4].

In fact, the highly dynamics of VANET nodes in conjunction with the utilization of short range communications provide the instability of the connectivity among the vehicles. This unreliable communication limits the above mentioned applications portfolio in the same manner as it is observed in other type of wireless networks.

Obviously, the quality of the communication differs in cities during traffic congestions where the networks may be dense and stable from the communication in highways where the networks are sparse and the topology is very dynamic [2].

In the Fig. 4, another problem is illustrated. This issue is related to the identification of the recipients and the way in which the data is propagated among them.

![Fig. 4. Mobility constraint in the VANETs.](image)

It has to be noted that the exceptional mobility pattern and quick variability of network topology imposes several challenges related to the deployment the VANETs. These challenges can be presented as follows [14]:

- **Network Management:** Since The VANET nodes are moving with a very high mobility, the network topology changes quickly. Consequently, using structures such as tree is not possible because it can’t be installed and maintained as fast as the topology modified.

- **Congestion and collision Control:** The unlimited size of network creates as well a challenge. In fact, in rural areas, the traffic load is low and it is high in urban environment. Hence, the network is congested and the collision occurs more in the network.

- **MAC Design:** Generally, the VANET utilizes the shared medium to communicate. Accordingly, the MAC design is the main issue. Numerous approaches have been proposed such as CSMA [15], TDMA [16], SDMA [17], etc. The standard IEEE 802.11 adopted the CSMA areas. Consequently, the partitions of the network occur frequently.

- **Security:** Seeing that the VANETs provide the route safety applications as warning message, security of this message have to be satisfied.

- **Routing:** In VANETs routing is one of the main challenge that need to be seriously investigated. Designing an efficient protocol for VANETs is very crucial. As we have discussed above, the VANETs possesses same properties as the highest mobility which causes the dynamics of network. These characteristics make routing decisions more challenging.

### 3. Routing in VANETs

Since a vehicular network is a particular version of MANETs, many researches studies have been conducted for using the traditional routing protocols [18-20]. However, various comparative studies have shown that the very high mobility of the vehicles makes the most of these methods unsuitable for the VANETs [6].

In this context, we have proved in [21] the limitation of MANETs protocols to ensure communication between nodes in vehicular scenarios.

In this section, we firstly focus on the current challenges related to the designed protocols for VANETs. We then compared their performance to test which protocol has better performance and which one suffers more in highway scenarios.

#### 3.1. An Overview of Designed Protocols for VANETs

In this study, we only investigated about different designed routing protocols for VANET. Furthermore, literature review also guides us to classify these routing algorithms into three categories which are: Unicast, Multicast/Geocast and Broadcast protocols.

The Fig. 5 presents this classification.

![Fig. 5. VANETs routing protocol.](image)

#### 3.1.1. Unicast Routing Protocols

Unicasting [22] is an essential technique for vehicle to create a source-to-destination routing in a VANETs as presented in the Fig. 6.
The most important purpose of unicast routing is to send data from a single source to a single destination by means of wireless multi-hop forwarding or carry-and-forward mechanisms.

In the first technique, the intermediate nodes in a routing route should transmit data as soon as possible from source to destination [23]. However, in the carry-and-forward technique, the source carries the transmitted data as long as possible to decrease the number of data packets [24]. Nevertheless, the packets delivery time which cost by carry-and-forward technique is generally longer than wireless multi-hop transmission technique.

The various unicast routing protocols are investigated as follows.

3.1.1.1. Vehicle-Assisted Data Delivery Routing Protocol (VADD)

The routing protocol VADD is proposed by Zhao et al. [25]. It adopted the technique of carry-and-forward for data delivery from a mobile vehicle to a static destination node. The mainly important aim is to choose a forwarding route with the least packet delivery time.

To maintain the smallest data transmission delay, the VADD sends the data packets via wireless channels as much as possible. In fact, if the packet must be carried via roads, the path that has the highest speed value is selected firstly. The protocol VADD supposes that the vehicles are equipped with pre-loaded digital maps. Consequently, the traffic density and vehicle speed on paths are provided at diverse times of the day.

Fig. 7 presents that the source vehicle Vs attempts to transmit a packet to static destination Vd. The possible intersections zones are I1, I2, I3 and I4. The VADD considers that the I1, I2 and I3 as forwarded intersections to join the destination vehicle Vd. However, the intersection I4 has the highest vehicle density that is why it is not selected during the identification of the possible roads task.

3.1.1.2. Connectivity-aware Routing Protocol (CAR)

Several papers [26, 27] are considered that the limitation of the VADD is related to the static destination. For this, in [28] Naumov et al. proposed the connectivity-aware routing protocol (CAR) to overcome the drawback of the static vehicle.

The contribution of the CAR is to establish a routing route from source to destination by setting the anchor points at intermediate intersections zones.

The protocol CAR transmits the searching packets to discover the destination vehicle. Each packet sender archives its identification Id, the number of hop, and the total number of neighbors in searching packets. Upon receiving the searching packets, the destination selects a routing path having the smallest delivery time and replies it to the source vehicle.

While the destination forwards the reply packet to the source, the intersections passed through by this packet are considered as the anchor point and the path is created. Then, the data packets are transmitted through the set of anchor points toward the destination. The Fig. 8 illustrates the concept of the protocol CAR.
3.1.1.3. Diagonal-Intersection- Based Routing Protocol (DIR)

In [29], the authors proposed a diagonal-intersection-based routing protocol (DIR). The purpose of this method is to create a series of diagonal intersections between the source and destination vehicles. This contribution depicts the main difference the CAR and the DIR protocols.

As shown in the Fig. 9, the source vehicle Vs transmits the data packet toward the first diagonal intersection, then the second diagonal intersection, and so on, up to the last one. Finally, the packet arrives to the destination vehicle. To get a pair of neighboring diagonal intersections, two or more disjoint sub-roads exist between them. The sub-path with the lowest data packet delay is dynamically chosen to send the data packets.

The advantage of the DIR protocol is the fewest number of the anchors compared to the CAR protocol [30].

3.1.1.4. Greedy Perimeter Coordinator Routing Protocol (GPCR)

In [31], the authors developed the greedy perimeter coordinator routing (GPCR). It is based on the position for routing in VANETs. Compared to the previous schemes, the GPCR is well appropriate for highly dynamic scenarios as the communication between vehicles on the highway environment.

The protocol GPCR manages the intersections by a constrained greedy forwarding task. In addition, it adjusts the routing route by the healing strategy which is on the basis of the topology of streets as well as the intersections. Fig. 10 depicts that the vehicle Vs tries to forward packets to vehicle Vd. The node Ha is initially chosen as first hop. Then, the vehicle Hb is selected as the next hop and the created path is Hc → Hd → He.

Once the vehicle receives the packets, it checks that the destination Dv is not figured in this path. Consequently, the vehicle Hb re-routes the packets to Hf → Hg → Hh. From the vehicle Hh the packets are well received by destination Dv.

The previous unicast routing protocols are compared and presented in Table 1.

3.1.2. Multicast Routing Protocols

Multicasting [32] is known as a routing operation where a single vehicle in a group initiates delivery of data and all other members in a group receive it by multi-hop communication as illustrated in the Fig. 11.

![Fig. 9. The DIR protocol.](image)

![Fig. 10. Strategy in GPCR.](image)

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**Table 1.** Comparison between unicast routing protocol.

<table>
<thead>
<tr>
<th>Protocol</th>
<th>Transmission method</th>
<th>Recovery method</th>
<th>Maintenance of the routing path</th>
<th>Digital map</th>
</tr>
</thead>
<tbody>
<tr>
<td>VADD</td>
<td>Wireless multi-hop forwarding</td>
<td>Carry-and-forward</td>
<td>Active</td>
<td>Yes</td>
</tr>
<tr>
<td>CAR</td>
<td>Wireless multi-hop forwarding</td>
<td>Anchors points</td>
<td>Active</td>
<td>Yes</td>
</tr>
<tr>
<td>DIR</td>
<td>Wireless multi-hop forwarding</td>
<td>Anchors points</td>
<td>Active</td>
<td>Yes</td>
</tr>
<tr>
<td>GPCR</td>
<td>Wireless multi-hop forwarding</td>
<td>Carry-and-forward</td>
<td>Passive</td>
<td>No</td>
</tr>
</tbody>
</table>
The receivers may form a specific geographic area. In this case, we talk about geocasting technique. One of the most important challenges is how to develop an efficient multicast/geocast protocols with the highly changeable topology of the VANETs networks.

In this section, we review some of the existing protocols for VANETs as follows.

### 3.1.2.1. Multicast Protocol in Ad Hoc Networks Inter-Vehicle Geocast (IVG)

In [33], Bachir et al. proposed the inter-vehicle geocast protocol (IVG). The IVG is a multicast method utilized to inform all the vehicles in a highway if any risk as an accident is happened. The danger area is specified in terms of both positioning of vehicles and driving direction. The vehicles figured in this area form a multicast cluster.

Using the position, speed, and driving direction of the vehicles, the multicast group is determined temporarily and dynamically. In order to overcome the network fragmentation, the protocol IVG protocol uses periodic broadcasts for sending messages to multicast members. The maximum value of speed is the parameter used to calculate the period of the re-broadcast.

In addition, the IVG minimizes the hops number of forwarding packet by means of the deferring time. In fact, the vehicle with the farthest distance to the source waits for fewer deferring time in order to broadcast again.

The Fig. 12 illustrates an example for the protocol IVG. The vehicle VA detects a routing problem. Consequently, it delivers a notification to all nodes in the risk area. The multicast group is formed by the vehicles VB, VC, and VD since they are figured in the risk danger. However, the vehicle VC is the next hop of VA because it is the farthest node from VA.

### 3.1.2.2. Distributed Robust Geocast Multicast Routing Protocol (DRG)

In [34], Joshi et al. developed a distributed robust geocast protocol (DRG) to ensure the communication between vehicles. The main goal of the DRG is to send packets to vehicles figured in a particular static geographic area. A vehicle should receive or ignore packets depended only on its current position in such geographic region. This area defined as zone of relevance (ZOR) when the vehicles located in it should receive the geocast packets.

In order to improve the reliability of receiving the geocast messages, the zone of forwarding (ZOF) is specified in [35] as the geographic zone where the vehicles should forward the messages to other vehicles figured in the ZOR. Usually, the ZOF encircles the ZOR to guarantee that the geocast packets may be forwarded to the vehicles in zone of relevance.

In order to surmount the fragmentation of the network, the protocol DRG uses a periodic re-transmission strategy. As it is shown in Fig. 13, this problem is overcome using the ZOF (vehicles VG and VF).

### 3.1.2.3. Robust Vehicular Routing (ROVER)

The ROust Vehicular Routing (ROVER) [36] is a geographical multicast protocol where only control packets are diffused in the network. However, the data packets are unicasted. The key purpose of the protocol
ROVER is to deliver a message to all other vehicles within a particular ZOR. The ZOR is determined as a rectangle defined by its corner coordinates.

A message is defined by the triplet \([A, M, Z]\) where \(A\) indicates a specified application, \(M\) is a message and \(Z\) defines the identity of a zone.

Upon receiving a message, the vehicle executes this packet only if it is within the ZOR. It also defines a ZOF where the source vehicle are located as well as the ZOR. To achieve the routing task, all the vehicles in the ZOF are utilized.

The protocol ROVER uses a reactive path discovery process within a ZOR which started with sending a Zone Route Request (ZRREQ) [36]. The vehicle that receives the ZRREQ transmits a Zone Reply Request (ZRREQ) (Fig. 14). This transmission is scheduled after a backoff time. Usually, the message is retransmitted at the expiry of the backoff time. Nevertheless, it creates a lot of redundant messages in the network. Consequently, the data transfer delay is high.

![Fig. 14. The concept of ROVER protocol.](image)

3.1.2.4. Distant Node Based Multicast Routing Protocol (DBMR)

The protocol Distant Node Based Multicast Routing Protocol (DBMR) is proposed in [37]. It includes both the unicast and multicast behavior. On one hand, the multicast performance of the protocol DBMR provides an effective utilization of the available bandwidth. On the other hand, the DBMR presents the unicast behavior when the destination vehicle is within the radio communication range of the current forwarding node.

The protocol DBMR uses a threshold to choose the vehicles which will be receiving the data packet of the multicast. It splits it is operation into two different phases which are neighbor-group creation and multicast step and the phase of distant node selection.

During the process of neighbor-list collection, a set of neighbor-list collected. Then, the neighbor vehicles use this list to select the distant node. When, the list is ready, the threshold is utilized to choose a multicast group and to classify the updated one-hop neighbors to receive the multicast data packet.

However, with low density of vehicles, the process of the neighbor-list collection is a very critical. It requires to be updated frequently. The multicast group selection is illustrated in Fig. 15.

The aim objective the second step is to select the distant node. This vehicle is chosen based on diverse conditions. Firstly, as shown in the above figure, if the multicast cluster is empty, the source vehicle doesn’t transmit enough messages and carries the data packet. However, if there is just a single member in the multicast group, automatically, it will be chosen as a distant vehicle.

![Fig. 15. Selecting a multicasting group condition in DBMR.](image)

Finally, if a multiple group creates, every vehicle of the group engages two timers called \(T_i\) and \(T_j\). After the multicast data packets are completely received by the vehicles, the first timer is utilized to predict the time of when the phase of selecting the distant node will launch. Yet, the timer \(T_j\) is used to choose the re-multicast time. All the vehicles members of the multicast group have the same \(T_i\).

The previous Multicast routing protocols are compared and presented in Table 2.
### Table 2. Comparison between Multicast routing protocol.

<table>
<thead>
<tr>
<th>Protocol</th>
<th>Forwarding strategy</th>
<th>Region based</th>
<th>Destination location method</th>
<th>Forwarding decision</th>
</tr>
</thead>
<tbody>
<tr>
<td>IVG</td>
<td>Defer time</td>
<td>Yes</td>
<td>Specified method</td>
<td>Multi-hop</td>
</tr>
<tr>
<td>DRG</td>
<td>Distance-based backoff time scheme</td>
<td>Yes</td>
<td>Specified method</td>
<td>Multi-hop</td>
</tr>
<tr>
<td>ROVER</td>
<td>Routing Discovery and data transfer</td>
<td>Yes</td>
<td>Specified method</td>
<td>Multi-hop</td>
</tr>
<tr>
<td>DBMR</td>
<td>multicast group selection and distant node</td>
<td>No</td>
<td>Specified method</td>
<td>1-hop</td>
</tr>
</tbody>
</table>

### 3.1.3. Broadcast Routing Protocols

In vehicular networks, broadcasting technique [38] is frequently utilized to make communication between vehicles. It is defined as the routing operation where a node delivers a message to all others vehicles beyond the transmission range. It is based on multi-hops transmission method.

As presented in Fig. 16, the broadcast forwards a message to every vehicle in the network, usually using flooding. This strategy guarantees the delivery of the packet. However, the vehicles receive a multiple copy of this packet, which takes up a large part of the bandwidth. Broadcasting is more efficient for scenarios with least density number of vehicles [38].

![Fig. 16. Broadcast in VANETs.](image)

Several of existing broadcast routing protocols in VANETs are reviewed in this section as follows.

#### 3.1.3.1. A Border node Based Routing Protocol (BBR)

Mingliu Zhang et al. proposed in [39] a Border node Based Routing protocol (BBR). It is a hybrid method designed for partially connected sparse VANET clusters. The BBR utilizes a domain function where mobility and location information is unavailable. It can support the fragmentation of the network caused by high vehicle mobility.

The key purpose of the method BBR is to reduce flooding of packets [39]. To achieve this goal, it uses two individual functional units which are: a neighbor discovery algorithm, and a border node selection algorithm. While, the first scheme is based on a periodic beacon messages to advertise the existence of vehicles, a border nodes are chosen using broadcast messages.

The border vehicle is a node that must save the received broadcast messages and forward it. When, set of vehicles receives the same message, only the selected border nodes keep and re-broadcast it. On the basis of one-hop neighbor information as well as the received broadcast messages, the border vehicle decision is discretely made.

The border node selection process is on the basis of the least common neighbors. It adopts the idea that the vehicles at the border of transmission range should have the less common neighbor nodes with the broadcast source compared to those that are nearer to the source node.

As illustrated in Fig. 17, the transmission range, denoted R, is delimited by a circle. For example, suppose that the vehicle S is the broadcast source. The vehicles at the border of the R as P and C when compared to those nodes adjacent to S like A, B and D have less common neighbors with the source S. Consequently, both P and C can be considered as the border nodes.

![Fig. 17. Border node selection process in BBR](image)

#### 3.1.3.2. Urban Multihop Broadcast Protocol (UMB)

In order to overcome the packet collision as well as the interference problems frequently occurs during
the distribution of messages in multi-hop broadcast; the Urban Multihop Broadcast Protocol (UMB) is developed [40]. In the UMB, the sender node chooses the furthest vehicle in the broadcast direction to forward and acknowledge the packet. It is much more efficient where the packet loads is higher and the number of the vehicles is higher too.

The UMB routing scheme is based on two steps which are Directional Broadcast and Intersection Broadcast. In the first phase, the sender vehicle tries to find the furthest node in the broadcast direction [40]. Since the vehicles change their topology rapidly, this selection is achieved without knowing the identification or the position of sender neighbors.

However, the second step is designed to solve the problem of dissemination data caused by different obstacles as tall buildings that can disturb the communication between vehicles in same transmission range. For this, the protocol UMB treats this problem by installing repeaters at intersections points since the repeaters have the best line of sight to the other path segments.

As illustrated in Fig. 18, the vehicle A utilizes the directional broadcast to join the node B. According to the presented example, the node A is not in the transmission range of the repeater C as the vehicle B. Therefore, once C receives a message, it begins a directional broadcasts to both north and south directions. As the repeater D is in the transmission range of C, it also forwards the packet to D based on the IEEE 802.11 protocol.

A packet can be transmitted from one intersection to the other if there are sufficient vehicles in the path segment attaching these two intersections.

3.1.3.3. Distributed Vehicular Broadcast Protocol (DV-CAST)

In [41], the authors proposed a distributed vehicular broadcast protocol (DV-CAST) for routing in VANETs. The DV-CAST is a multi-hop broadcast method. It presents three traffic scenarios for a vehicular broadcasting. The first one is the dense traffic scenario. While the second is sparse traffic scenario, the last scenario is related to the regular traffic.

The DV-CAST is more suitable for the first two scenarios. It minimizes overhead generated by the broadcasting technique. Every vehicle supervises the states of neighboring nodes all the time to make the decisions of broadcasting. In case of reception of a new broadcast packet, a vehicle Vi tests firstly whether nodes exist behind. If it is true, the broadcast suppression scheme is adopted to send the broadcast message. If not, the vehicle Vi forwards the broadcast message using the traffic flow in the opposite direction and it overhears for an instance of time to make sure that the message is successfully broadcasted[41].

In the Fig. 19, the vehicle source Vs initiates the broadcasting process. It forwards a broadcast message group1 to group2. Despite the fact that the groups 1, 2, and 3 are dense, the two clusters 1 and 2 meets the problem of temporary fragmentation of the network. In fact, the first group cannot directly transmit packets to the group 2. Consequently, the vehicle VA is not able to send packets to group 3 which is figured in the opposite direction. Then, the vehicle VB sends packets to group 2. According to the figure below, is can observe that, the mentioned routing problem is as well considered in the broadcasting design.

The above cited broadcast based routing protocols are compared and presented in Table 3.

3.2. Performance Evaluation

In this section, we compare the various routing classification on the basis of simulation results. Aiming at this purpose, we select from each routing categories one protocol.
As a result, we evaluated using OMNET++ [42] and MATLAB [43] the performance of the ROVER, GPCR and DV-CAST protocols.

In this section, we firstly present the used performance metrics. Then, we analysis and compare the obtained simulation results.

### 3.2.1. Performance Parameters

To compare the above mentioned routing protocols, we utilized two performance metrics. The first parameter is the Packet Delivery Ratio (PDR) which defined as the average number of delivered packets to the best destination. The second metric is the Packet Delivery Time (PDT).

The PDT represents the average time from where the first message leaves the source until joining the destinations. It is defined by the below expression:

\[
PDT = TT + PT
\]

where TT is the transmission time and PT is the propagation time.

### 3.2.2. Simulation Results

The results discussed here are obtained by varying the number of vehicles.

#### 3.2.2.1. Packet Delivery Ratio (PDR)

According to the results presented in the Fig. 20, the protocol ROVER delivers successfully more packets when compared to the both DV-CAST and GPCR protocols. It maintains its efficiency for almost all routing scenarios; low, medium and high vehicle density. This is due to its route discovery strategy.

We can notice also that the protocol GPCR outperforms the DV-CAST where the number of vehicles is in the interval [5, 20] nodes. However, this performance does not kept when the vehicles passes 25 nodes. In this case, broadcasting strategy is much more powerful than the GPCR protocol.

To sum up, according to the Fig 20, it is clear that the multicasting routing operation is more reliable and efficient than both unicasting and broadcasting.

#### 3.2.2.2. Packet Delivery Time (PDT)

The impact of varying the vehicle density on the performance of the previous protocols in terms of packet delivery time is illustrated in the Fig. 21.

It is shown that the protocol ROVER has the worst behavior. In all scenarios, it has the longest delay. The reason for this bad result is that the ROVER requires sending the beacon message to find the routing path before sending the packet data.

#### 3.2.3. Results Summary

In the previous section, an analytical study was done to evaluate and compare the different routing protocols categories in vehicular networks. Based on the obtained results, we can conclude that no one of the above discusses methods is effective all the time and for whatever degree of vehicles traffic densities.
For example, multicasting is an effective routing operation since it drops the least number of packets. However, it suffers more in terms of packet delivery time.

In the Tables below (Tables 4 and 5), a numerical comparison between the evaluated protocols is presented. The different values are picked up for highest and lowest number of vehicles.

Table 4. A numerical comparison in terms of PDR.

<table>
<thead>
<tr>
<th>Protocol</th>
<th>Number of vehicles is 5</th>
<th>Number of vehicles is 45</th>
</tr>
</thead>
<tbody>
<tr>
<td>DV-CAST</td>
<td>3 %</td>
<td>5.5 %</td>
</tr>
<tr>
<td>ROVER</td>
<td>8.21 %</td>
<td>7.6 %</td>
</tr>
<tr>
<td>GPCR</td>
<td>8 %</td>
<td>4.1 %</td>
</tr>
</tbody>
</table>

Table 5. A numerical comparison in terms of PDT.

<table>
<thead>
<tr>
<th>Protocol</th>
<th>Number of vehicles is 5</th>
<th>Number of vehicles is 45</th>
</tr>
</thead>
<tbody>
<tr>
<td>DV-CAST</td>
<td>0.5</td>
<td>0.6</td>
</tr>
<tr>
<td>ROVER</td>
<td>2</td>
<td>4.5</td>
</tr>
<tr>
<td>GPCR</td>
<td>1.12</td>
<td>4.3</td>
</tr>
</tbody>
</table>

4. Conclusion

In this paper, we have introduced the vehicular ad-hoc networks (VANETs) which are a particular application of the mobile ad-hoc networks (MANETs). The very changeable topology caused by the high mobility of VANET nodes is the major difference between the two types of mobile networks. Consequently, the traditional MANETs routing protocols are unsuitable for VANETs.

In order to solve the routing challenges in the vehicular networks, a numerous protocols are developed specially for VANETs. These methods are divided into three categories which are Unicast-based, Multicast-based and Broadcast- based protocols.

In this paper, we have reviewed the designed protocols to compare their performance and to check which category is more suitable for VANETs in terms of packet delivery ratio and packet delivery time.

The performance evaluation is done to evaluate ROVER, DV-CAST, and GPCR protocols. The simulation results were proved that ROVER is more reliable in terms of PDR and DV-CAST is much more efficient in terms of PDT.

Designing an efficient routing protocol for VANETs with low communication cost in terms of PDT and PDR may be treated in our future researcher outline.

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