Routing Architecture for Vehicular Ad-Hoc Networks

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***Abstract*—The actual proposed routing protocols for VANETs(Vehicular Ad-hoc Networks) present different features for communication among hosts/vehicles considering the strong topology change, but most of these features are needed for routing in these specific networks. These routing protocols support vehicle traffic on a large scale, intense mobility of vehicles, connections without link breakage, etc. But as they are different protocols the routers (nodes) in these networks have to switch to a routing protocol in a certain moment, which is a problem. This paper presents a Routing Architecture for VANETs to face this problem. The most important technical features for routing in VANETs were grouped in the Routing Architecture. To validate the proposed architecture several existing protocols were unified in the architecture producing a new routing protocol for VANETs. The produced protocol is the Generic Vehicular Dynamic Source Routing (GVDSR). Simulations of the GVDSR protocol have been made on the Malaga city showing the contributions and advantages for routing performance. The proposed architecture and protocol were simulated in the Network Simulator 2 featuring better performance than the compared protocols.**

I. Introduction

Vehicular Ad-Hoc Networks are composed by vehicles capable of communication with other vehicles and infrastructured networks located at roadsides and streets conner. VANET is a practical example of mobile Ad-Hoc Network technology since it doesn't require a previously formed network to allow communication between vehicles. This system must be compatible with the DSRC (Dedicated Short Range Communications). DSRC enables communications between vehicles (V2V) and vehicles to infrastructure (V2I) and supports high transmission data rate (6-54 Mbps) on the radius of 1000 meters.

The most used standard for vehicular communications is the IEEE 802.11p WAVE (Wireless Access in the Vehicular Environment) architecture. The IEEE 802.11p WAVE standard [1][2] (finished in July 2010) defines the physical layer (PHY) and the media access control (MAC) for VANETs. The standard is based on wireless local networks standard (IEEE 802.11a), which operates on a near frequency band of the allocated for vehicular communications and works with a similar data rate.

The Vehicular Networks earned space on researches realized by the Industry and the Universities around the world[5], [4], [3]. Because VANETs offer a variety of applications that take into account, for example, the driver assistance, tourist information propagation, location of gas stations and automated toll collection. The VANETs can also be applied in the entertainment, which can be, for example, a system for video sharing between vehicles; and applications for the transit security, preventing accidents and congestions. Besides, there is the possibility of monitoring, in real time, the vehicles on the security industry, becoming a solution for kidnapping situations.

But in these networks there is a challenge of determine routes for packets forwarding in the vehicular networks due the high mobility of nodes in the network and instability of wireless links. VANETs' routing protocols for communication between nodes are classified as: topological, geographical, opportunists and dissemination of information. Topological protocols try to find the best path between any pair of nodes in the network. Typically, the best path is the one with lowest cost according to the used metrics. These protocols can be proactive, reactive and hybrid.

Position based routing (or geographical) is capable to provide more scalability in high mobility environments. In this approach, it's not necessary to keep information about the routes of each node in the network [7]. This type of routing assumes that elements present in the network have some location system like GPS, as Galileo [8]. Also exists the opportunists routing protocols, that considers scenarios with occurrence of services interruption and frequently node disconnection, similar to the problems faced by DTNs (Delay Tolerant Networks), fault tolerant networks [9]. Some approaches of this protocol can be found in [10] and [11]. The dissemination protocols spread the information to the several applications of vehicular networks [6], also providing services with the possible link breakage [12].

The existing protocols for VANETs try to increase the performance of the packets routing taking different characteristics into account. The most important features for VANETs are: carry large scales in the network on situations with high vehicles density to improve the routing performance [14]; support to the intense vehicle mobility, adapts quickly to the new topologies and enables a greater connection minimizing a possible link breakage [12]; adaptation system to the constantly position exchange of nodes in the network [16]; passivity [17] and dynamic [15][13]. Every single feature shown is found in different routing protocols for VANETs. The node will not switch the right routing protocol in a certain event, it is unpractical. And no else routing protocol have these features, very important for VANETs environments, integrated in one single routing protocol.

To face this problem, a Routing Architecture for Vehicular Communications is proposed in this paper. The main idea is to integrate the most important features for communications in VANETs in the proposed Routing Architecture. The proposal is scalar and modularized, with facilities on upgrading it with new technologies. Based on the architecture we introduce a new routing protocol called Generic Vehicular Dynamic Source Routing (GVDSR). The GVDSR protocol is a new routing strategy for VANETs that follows the proposed Routing Architecture. The GVDSR was implemented in the Network Simulator 2 [18], and it was compared to others protocols with the objective of operational validation. The results show the contributions and the advantages of the GVDSR protocol and of the Routing Architecture.

This paper is organized as follows: Section II proposes the Routing Architecture; the GVDSR protocol is presented in Section III; the simulations are explained in Section IV and the results in Section V. The paper is concluded in Section VI.

II. Routing Architecture for Vehicular Ad-Hoc Networks

Many routing protocols for VANETs were studied and based on this we observed that these protocols focus in specifics features and presents limited solutions. Some of the most significant features necessary for VANETs routing protocols are described below:

- A VANET's protocol must be dynamic from the origin. The algorithm will be reactive, determining routes on-demand. [15].
- Must present also a good behavior in small scale situation, like in the streets where they have a lower vehicles traffic; and in large scale, where the vehicles traffic is bigger like found in the avenues [14].
- The protocol must recognizes the networks topology even with the constantly change of nodes position [16].
- And, to achieve routing performance, the protocol must provides a greater time connectivity between vehicle, for the packets routing can be done. And also presents mechanisms for link breakage situations between vehicles [12].

The presented characteristics are found in different routing protocols. The node will not switch to the right routing protocol for a certain event. These characteristic needs to be in one single protocol. To integrate these features in one routing strategy, an architecture was created to enable a new trend of routing protocols in VANETs. This new trend has to encompass most VANETs features in a modularized way. The architecture is shown in Figure 1. The Routing Architectures for VANETS presents the most significant features of the vehicular communication.

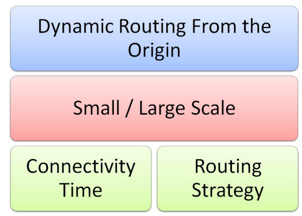

Fig. 1. Proposed Routing Architecture.

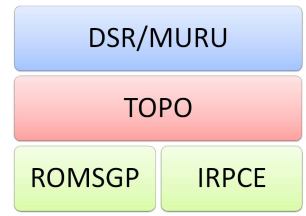

Fig. 2. Used algorithms in architecture's validation.

Figure 1 is the proposed architecture for VANETs. The routing protocols that will be developed based on architecture must follow it in the top-down methodology. The architecture contains three layers but four components, the components are: The Dynamic Routing, The Small—Large Scale, The Connectivity Time and The Routing Strategy. The principal component and the basis of any protocol developed based on the architecture is the Dynamic routing component. In this component, all the packets header are defined and the type of routing.

The Small—Large Scale component is a key element in the proposed architecture, because it differs the routing strategy in different situation. If the situation is a small scale of vehicles (characterized by the low density and velocity of nodes) the routing strategy attempted is the one in the dynamic routing component. If the situation is a large scale of vehicles (characterized by the high density and velocity of nodes) the routing strategy is the one in the routing strategy component. The design of this component is just adjust the parameters that characterize small or large scale of vehicles.

The Routing Strategy component enables a second methodology for routing. In this component is specified how the routing protocol will route packets in situation of large scale of vehicles. Every routing protocol for VANETs must have a mechanism for measurement of link strength. The routing overhead generated by requisition of routes is eliminated by the Connectivity Time component. This component must provide maximum time for transmission between the source and destination. Mechanisms of measurement of link strength or link breakage are advisable for this component.

III. Generic Vehicular Dynamic Source Routing

Instantiating the Routing Architecture, a new protocol was developed: The Generic Vehicular Dynamic Source Routing (GVDSR). The selected protocols which present techniques that composes the GVDSR are shown in Figure 2. These techniques can be replaced in every moment. The GVDSR protocol is an extension of the DSR (Dynamic Source Routing) protocol [22], but it is designed for Vehicular Communications incorporating the features of the other protocols founded in the GVDSR protocol stack, Figure 2. The protocols were chosen based in the specific steps of the Routing Architecture. Every component presents a feature and the chosen protocol face it. The used techniques in each component of the GVDSR's stack are explained in the next subsections.

A. The Dynamic Routing Component

To provide a dynamic routing from the origin the select protocol is the DSR (Dynamic Source Routing) with the strength link control from MURU [19]. The DSR sends broadcasts requests to find a route to the requested destination. The node that receives the requests do the same process until the destination node or an intermediate node which has a valid route to it respond. A response message, containing destination's location is then transmitted. When the source node receives the response with the path it starts to send information to the destination through the discovered path. But the DSR doesn't calculate the strength of the link on the path. The connection may be dropped for the link breakage and a new path request process is necessary. To eliminate this problem the MURU protocol calculates the strength of the link with the called EDD (Expected Disconnection Degree). The source can choices the shortest path with more link connection reliability.

To decrease the overhead, a broadcast area is computed between the source and destination nodes. This mechanism avoids the messages being replicated in different directions out of the path between the communicating nodes. The broadcast area is defined by [19]:

$$Rectangle.X_{left} = min(source.X, destination.X) - L$$
$$Rectangle.X_{right} = max(source.X, destination.X) + L$$
$$Rectangle.Y_{up} = min(source.Y, destination.Y) - L$$
$$Rectangle.Y_{down} = max(source.Y, destination.Y) + L \quad (1)$$

By the equation 1, we can observe that the broadcast area is in the rectangular shape. The computed parameters are the coordinates of this rectangle. $Rectangle.X_{left}$ and $Rectangle.X_{right}$ represents the abscissa axis in the rectangle limits for the left and right side, respectively. $Rectangle.Y_{up}$ e $Rectangle.Y_{down}$ represents the ordinate axis in the rectangle limits for up and down, respectively. The functions $min()$ and $max()$ compute the minimum and maximum value of the parameters. The function parameters are de coordinates of the source and destination nodes. The L term means the quantity of blocks between source and destination nodes.

Another particularly feature of VANETs is the link strength measure of a path. The MURU algorithm proposes the link strength measure, to inform the source node when a path is safe for transmission, without the link breakage. The source node can selects alternatives paths preventing if the principal path is unsafe for transmission. The link strength computation is made by the Expected Disconnection Degree (EDD). This metric is computed in a T period. The path must have k nodes, which the link EDD n_{i-1}, n_i, $2 \geq i \geq k$, denoted by $EDD_{i-1,i}$ is computed for n_i according to the equation 2 [19]:

$$EDD_{i-1,i} = \alpha * |D(i-1,i) - D_0|^l + \beta * f(L(i), T(1,k)) + \gamma * g(M(i-1), M(i), T(1,k)) \quad (2)$$

and the terms α, β e γ are defined as tuning parameters, l is the propagation loss of a path in urban environments. D_0 is the correction factor, which is the hop distance that presents the lowest bit error rate for the link. D_0 can be computed as the distance which the bit error rate corresponding falls below a certain threshold on the propagation model. $D_{i,j}$ is the geographic distance of n_i and n_j; $L(i)$ is the actual localization of the n_i node; $M(i)$ is the motion information provided of n_i including the expected direction and velocity during the period T, and $T_{s,d}$ is the minor trajectory of the source node (n_s) to the destination node (n_d). The function $f(L(i), T_{s,d})$ returns 0 if n_i is in the lowest trajectory to the destiny for a period larger than T, and 1 otherwise. The function $g(L(i-1), M(i), T(1,k))$ returns 0 if n_{i-1} and n_i are in the transmission range of each one, in a period larger than T, and 1 otherwise.

Assuming that the source node n_0 tries to deliver packets toe the destination and there is no available path, the source node starts a route request and fulfils all the headers information of the created packet. The $EDD_{path}(0,i)$ is used to evaluate the path quality of n_0 to n_i. $EDD_{path}(0,i)$ is computed in the following manner [19]:

$$EDD_{path}(0,i) = \begin{cases} 0 & , i = 0 \\ EDD_{path}(0,i-1) + EDD_{path}(i-1,i) & , \quad else \end{cases} \quad (3)$$

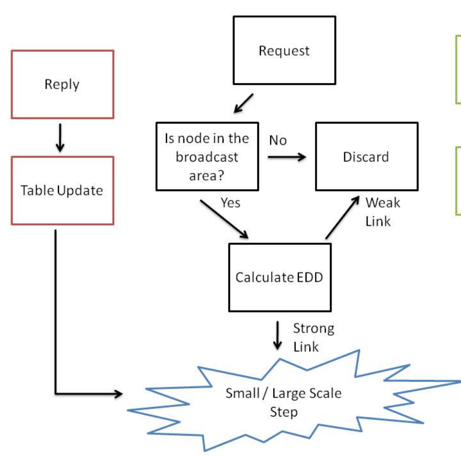

Fig. 3. The Dynamic Routing Step.

The Pseudo Code of the Strength link control utilized in this component of the GVDSR protocol is presented in the MURU procedure. Following DSR specification, the proposed algorithm has three phases: Request, Reply and Packet, as presented in Figure 3. When a node receives a request message it verifies if the source node is yet in the broadcast area to route

Procedure MURU(s,d,p) [19]

$n_i \leftarrow$ node i
$p_{req} \leftarrow$ the route request packet
$p_{rpl} \leftarrow$ the route reply packet
p $\leftarrow$ the data packet
if *n_i recieve p_{req} from n_{i-1}* **then**
  if *n_i is out of the broadcast are defined in Eq. 1* **then**
    Drop p_{req} and return
  if *n_{i-1} is closer to the destination* **then**
    Drop p_{req} and return
  //Assume n_s is the source
  Calculate $EDD(i-1,i)$ and $EDD_{path}(s,i)$ with Eqs. 2 and 3
  if *$\exists$ a $n_j \setminus j \neq i-1 \wedge EDD_{path}(s,j) < (EDD_{path}(s,i-1) + EDD(i-1,i)) \wedge n_j$ is closer to the destiny than n_i* **then**
    Drop p_{req} and return
  else
    if *$\exists$ a $n_k \setminus k \neq i-1 \wedge (EDD_{path}(s,k) + EDD(k,i)) < (EDD_{path}(s,i-1) + EDD(i-1,i))$* **then**
      Drop p_{req} and return
    else
      Update the routing table and let link (n_{i-1}, n_i) join the path
if *n_i recieve a p_{rpl}* **then**
  if *$n_i \neq n_s$* **then**
    Update the routing table
    send(p_{rpl})
if *n_i recieve p* **then**
  if *the next node is reachable* **then**
    send(p,next node)
  else
    Store p in a buffer
    Send a new p_{req} to the destination

the information. Reply is a phase to respond nodes with the destination path before update the routing table. And routing packets are possible when the next node of the path is known. If the next node is not available is necessary store the packet in a buffer until the next node is found.

B. The Small—Large Scale Component

Sometimes the information needs to traffic through the whole city to reach the desired destination. When a node starts the requests to find the destination path the process may create a bigger overhead and increase the path request time. Also when a path node is not available all the process will be started again. To lead this problems the TOPO algorithm was developed [14].

Figure 4 shows the process of Small—Large scale. If the destiny is in the antenna broadcast area of the source node, the algorithm switch to the principal routing strategy, which is the DSR/MURU algorithm. In this subsection we present the TOPO algorithm with the auxiliary procedures. These algorithms are shown in the TOPO, access and overlay procedures.

On TOPO procedure is verified if the destination node is in the broadcast area captured by the vehicle's antenna. If it is, the packet is transmitted to it. If it isn't, is verified if the source node is in an access area, if is, the small scale routing is made, else, the large scale routing is choice.

On access procedure, a neighbor's list is the reference for routing. Based in this list and verifying all the nodes that it

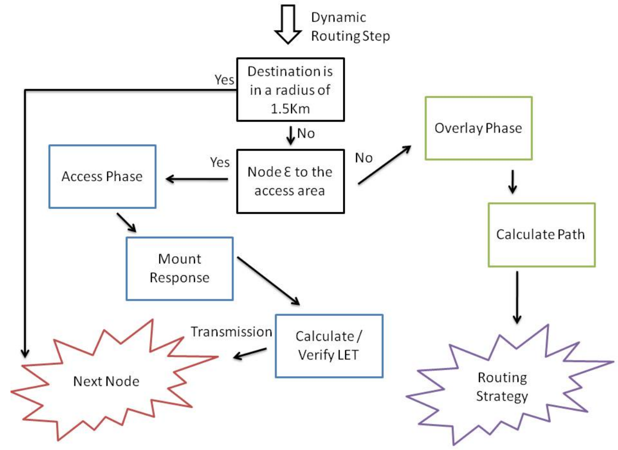

Fig. 4. The Small—Large Scale situation and The Connectivity Time Steps.

Procedure TOPO(s,d,p) [14]

// s = source node, d = destination node, p = packet
r $\leftarrow$ distance(s,d)
if *($r <$ 1.5Km) && (s,d $\in$ access)* **then**
  forward(s,d,p)
else
  if *s $\in$ access* **then**
    acess(s,d,p)
  else
    overlay(s,d,p)

has, the algorithm searches the destination and if it doesn't find the overlay routing is made. In the overlay phase, is used the cognitive routing presented by the IRPCE protocol. The routing phase that contains IRPCE is discussed in the Routing Strategy section. When a node is in an access area, the cognitive routing is made until the last hop in the overlay phase, and from this last hop, the routing is access until the destination.

C. The Connectivity Time Component

The ROMSGP (Receive on Most Stable Group-Path) protocol proposed in [12] predicts the link breakage during the

Procedure access(s,d,p) [14]

if *p do not in overlay* **then**
  n $\leftarrow$ closer intersection
  while *neighbours list ! = NULL* **do**
    if *overlay node o $\in$ neighbours list* **then**
      forward(o,p)
    else
      the $\leftarrow$ forward(s,n,p)
  overlay(o,d,p) **else**
    RREP $\leftarrow$ forward(s,d,p)
    if *RREP == missing destination* **then**
      TOPO(actual node, new destiny, p)
    update the position information(d,s)

Procedure overlay(s,d,p) [14]

Calculate the path to d
if $d \in overlay$ **then**
  IRPCE(s,d,p)
else
  get the last intersection with id i in the path until d
  IRPCE(s,i,p)
  access(i,d,p)

transmission by a metric called LET (Link Expiration Time). The LET, with the help of a GPS, calculates the distance between the vehicles and through the car's direction verifies the link breakage probability. If the connection has a high probability to fall the protocol tries another route enabling the possibility of find another path if the link is not good enough to send information. This process increases the end-to-end delay but decreases the loss probability.

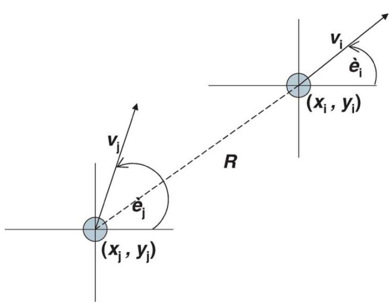

Fig. 5. Used parameters to compute LET [12]

To compute the LET, with the parameter in the Figure 5 we use this equation as in [12] :

$$LET = \frac{-(ab+cd)+\sqrt{(a^2+c^2)r^2-(ad-bc)^2}}{a^2+c^2} \tag{4}$$

where,

$$a = v_i \cos\theta_i - v_j \cos\theta_j$$

$$b = x_i - x_j$$

$$c = v_i \sin\theta_i - v_j \sin\theta_j$$

$$d = y_i - y_j$$

that, considering the two vehicles i and j, r is the range of the antenna, v_i and v_j are the vehicles velocity, (x_i, y_i) e (x_j, y_j) are the Cartesian plane coordinates and θ_i e θ_j are the angular velocities. All the parameters are shown in Figure 5.

D. The Routing Strategy Component

For forward packets in the overlay phase, the selected protocol is the IRPCE (Intelligent Routing Protocol for City Environments), proposed in [16]. The greedy method in the TOPO algorithm presents a large overhead in the network to route information among access areas. To provide a lower end-to-end delay and decrease the overhead IRPCE protocol shows a method to move information in a better way.

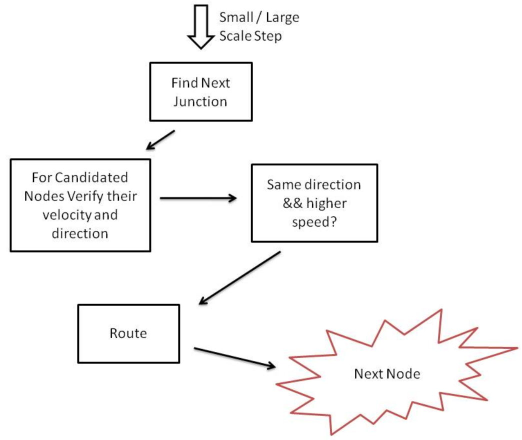

Fig. 6. The Routing Strategy Step.

Figure 6 shows how the IRPCE method route packets in the large scale situation and how it is integrated in the proposed architecture. The algorithm finds the junctions to the destination in different paths and route the packet to the node that has the same direction and highest velocity. This information about the nodes are obtained in the packets and to provide the best effort routing. The Pseudo Code of the technique used in this component is shown in the IRPCE procedure.

Procedure IRPCE(s,d,p) [16]

for *For all candidate junctions 'i'* **do**
  $N_i \leftarrow$ the next candidate junction
  C $\leftarrow$ is the actual junction
  $D_n \leftarrow$ the curvimetry distance between the candidate junction N_i and the destination node
  $D_c \leftarrow$ the curvimetry distance between the actual node C and the destination node
  $D_p = D_n/D_c$ // Determines the proximity of the candidate junction for the destination node

IV. Simulation Model

The GVDSR was implemented in the Network Simulator 2 (NS2) [18]. The main objective for implementing the GVDSR is the functional validation of the protocol and the architecture. The chosen scenarios are totally contextualized with VANETs considered real scenarios. In the scenario one was used the urban perimeter traffic model of the Malaga City (Andaluzia, Spain), Fig. 7. Cars can vary their velocity between five to 30 m/s, appropriate range for the mobility standards in vehicular scenarios. The number of nodes/vehicles in this scenario is 30 since 20 are communicating nodes. Others information for the scenario 1 are presented in the Table I.

Fig. 7. Urban Perimeter of the Malaga City - Spain.

Fig. 8. Highway Perimeter of the Malaga City - Spain.

The scenario 2 presents the same basic characteristics of the scenario 1. But in the scenario 2, the perimeter of the Malaga city is on a road zone. Others information for the scenario 2 are presented in the Table I. The NS2 traces for both scenarios were obtained at [25], exists some tools that can generate new traces for perimeters of any city in [26]. The GVDSR protocol was compared with other protocols: AODV (Ad-Hoc On-Demand Distance Vector) [23] and DSDV (Destination Sequenced Distance Vector) [24].

The metrics for comparison are: Packet Delivery Ratio, Application Throughput, Delay, Percentage of Dropped Packets and Total Packets. These metrics were calculated as following:

- Packet Delivery Ratio: percentage of the total received packets under the total of the send packets (1). This metric shows the completeness and correctness of routing protocols. These mechanism are important because the VANETs scenarios are characterized by high level of loss.
- Application Throughput: is the data rate per second delivered to the destination application (2). This metric show how the routing protocol utilizes the maximum available bandwidth in the network. The high mobility and velocity helps to decrease this rate, but the routing protocol must adjust itself for a higher throughput.
- Delay: calculated as the difference between the time of arrival of the packet and the time of sending the packet (3). This metric shows the average time a packets takes to reach its destination.
- Dropped packets: percentage of loss in the amount of produced packets. This metrics shows the amount of loss produced in the network with a routing protocol. The total of packets is the sum of produced packets and routing packets. This metric shows the routing overhead of each routing protocol and a trade-off between the packet delivery ratio and the routing overhead, the benefits and disadvantages of having a higher metric than the other.

The simulation configuration is shown in Table I. The intention of the simulations is the functional validation of the Routing Architecture and the GVDSR protocol. For all values of speed, on each scenario and each protocol it was executed 50 trials, changing the seed of each execution presenting 90% of reliability.

Simulation in VANETs scenarios is difficult for many reasons. First, is very difficult to reproduce results of the specific routing protocol for VANETs because there is no draft or standard, and it's a challenge reproduce results only with conference or journal papers. Second, the simulation for VANETs are founded in different simulators, there is no specialized framework or benchmarking for simulation. And finally, the IEEE standard for vehicular communications utilized in VANETs was finished in July 2010, which is very recent. So the simulation model, presented in this section, was developed based on the existing approaches found in the literature [20] [21].

TABLE I
EXPERIMENTS PARAMETERS

Parameter	Value
Number of nodes	30
Velocity	5 - 30 m/s
Number of communicating nodes	20
Simulation Area	1000 m x 1000 m
Transceivers	IEE 802.11 standard
Propagation Model	Two Ray Ground
Antennas	Omnidirectional
Routing Protocols	AODV/DSDV/GVDSR
Queue	Priority Queue
Traffic Protocol	TCP
Application Protocol	FTP
Simulation Time	900 s

V. RESULTS

According to the evaluated topologies is possible to identify different behaviors of the evaluated algorithms depending of the selected scenario. For the first topology, which represents the scenario of the urban perimeter of the city of Malaga, the results are present in Figure 9. With respect to packet delivery rate (Figure 9 (a)), an equivalence among the algorithms evaluated algorithms can be found, indicating that due to the reduced number of vehicles as well as the low level of mobility found in urban environments, there were no representative differences in the results.

Regarding the delay, Figure 9 (b), and the amount of discarded packets, Figure 9 (d), we can see some differences according to the used routing technique. For the delay, the techniques that are based on routing tables instead of creating a list of jumps obtained better results. With respect to dropping packets, AODV showed the best results, since the level of node mobility is relatively low, but when they happen it has updated routes more efficiently than DSDV and GVDSR.

In the throughput, Figure 9 (c), the GVDSR presents the best application throughput for the urban perimeter scenario. The integrated mechanisms of GVDSR?s protocols benefit the route discovery mechanism. Once a route is discovered, the application packets can be sent to the destiny more efficiently, since routing errors are more difficult to happens because of the links control executed by the Connectivity Time Component. DSDV reached an intermediate result and AODV was the worst of all, what is expected to an on-demand protocol in a constant transmission scenario.

Figure 9 (e) presents the total traffic of the network, indicating the participation of application and routing traffic on it. As indicated, the amount of packets created and transmitted

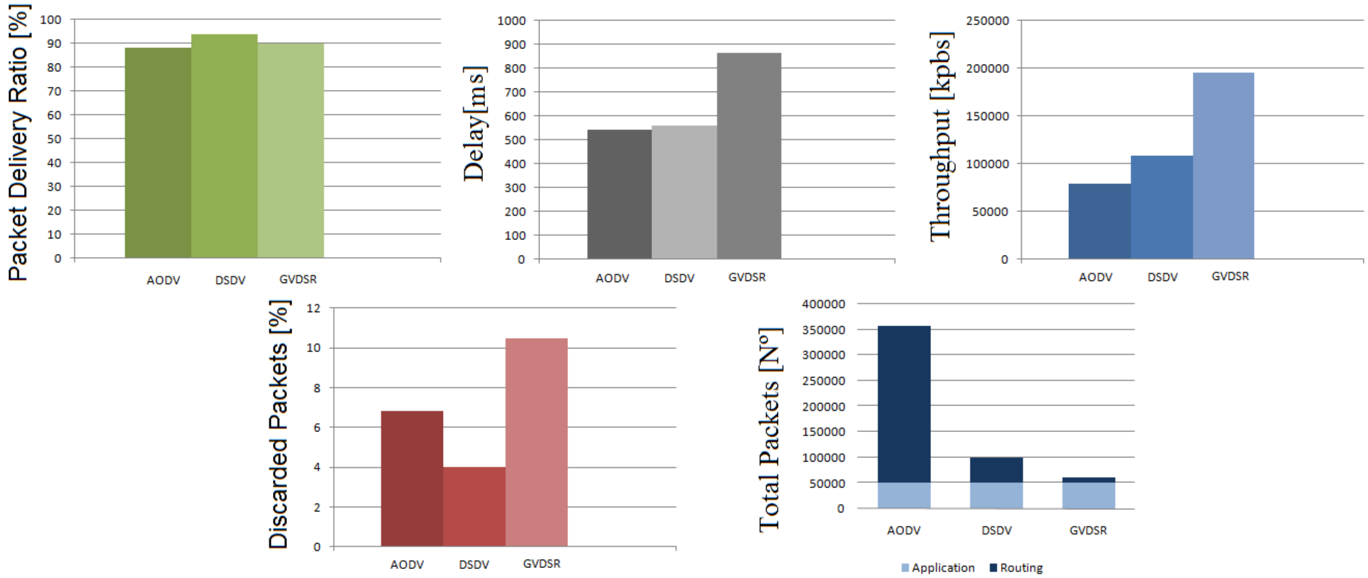

Fig. 9. Graphs for the Urban perimeter of the Malaga city.

by the application was equivalent to all three evaluated protocols. However, routing overhead presents completely different results. As expected, GVDSR presents the lowest overhead because of the better routing messages dissemination control of the Small-Large Scale Component and the lower number of route requests to re-establish connections when them fail, obtained by Connectivity Time Component. DSDV needed more routing tables than GVDSR but, as it uses a proactive routing, communication fails had no influence in its routing overhead. AODV presented the worst results of the evaluated protocols, since the scenario used an application which is constantly transmitting information among many nodes, obligating the protocol to broadcast many informations to maintain the routes valid, substantially increasing the routing overhead.

In the second scenario, which considers the topology of the city of Malaga in a stretch of highway, we find results completely different with that observed initially. In this scenario, all evaluated metrics presented better results than in first scenario. In all evaluated metrics all protocols led to more approximate results, since none of the protocols have been overloaded during their operation. Nevertheless, protocols presented the same general behaviors of the first scenario: DSDV obtained the higher packet delivery and the lower packets discard; AODV had the lower delay; and GVDSR presents the best results for throughput and routing overhead.

These changes occur due to large differences in the pattern of mobility, speed and dispersion of vehicles. Even road environments having a degree of mobility much higher than urban environment and also vehicles with higher speed and more distant from other vehicles, "relative" mobility among the nodes is lower than in urban scenario. Nodes have closer speeds and are more similar directions what makes possible keeping a better quality of communication.

VI. Conclusion

This paper proposes a Routing Architecture for VANETs scenarios. The Routing Architecture collects the most relevant features of the VANETs, enabling a best effort routing according to the instantiated protocols stack. For validation of the Routing Architecture was design an appropriated protocol stack with many techniques of many protocols for improvement of performance of VANETs, generating a new routing protocol called GVDSR. The GVDSR have premises for dynamic routing, handle situations of small/large scale, support for link breakage and a greedy routing strategy for routing information in large scale situations.

GVDSR was evaluated considering two real scenarios to validate the proposed Architecture. These experiments varied the speed of the vehicles, the mobility pattern and the topology. Compared to AODV and DSDV, The GVDSR presented better performance and stability, indicating the benefits of using the Routing Architecture for the design of VANETs protocols.

The strength of the proposal is the mechanism that integrates the most important features of VANETs in one single architecture, enabling a design of a routing protocol that treats all these characteristics. And present greater performance with the compared protocols, regarding the most important metrics for VANETs: the Packet Delivery Ratio, the Throughput and the Routing Overhead. The weakness of the proposed architecture is that it was not compared to specific routing protocol for VANETs, but the paper describes the difficult of simulating routing protocols in this specific environment.

The design of a traffic model and the evaluation of the Routing Architecture on it, a stochastic model correlating the random variables are required for the mathematical validation and the evaluation of multimedia transmission on VANETs scenarios are some examples of possible future works that can be done.

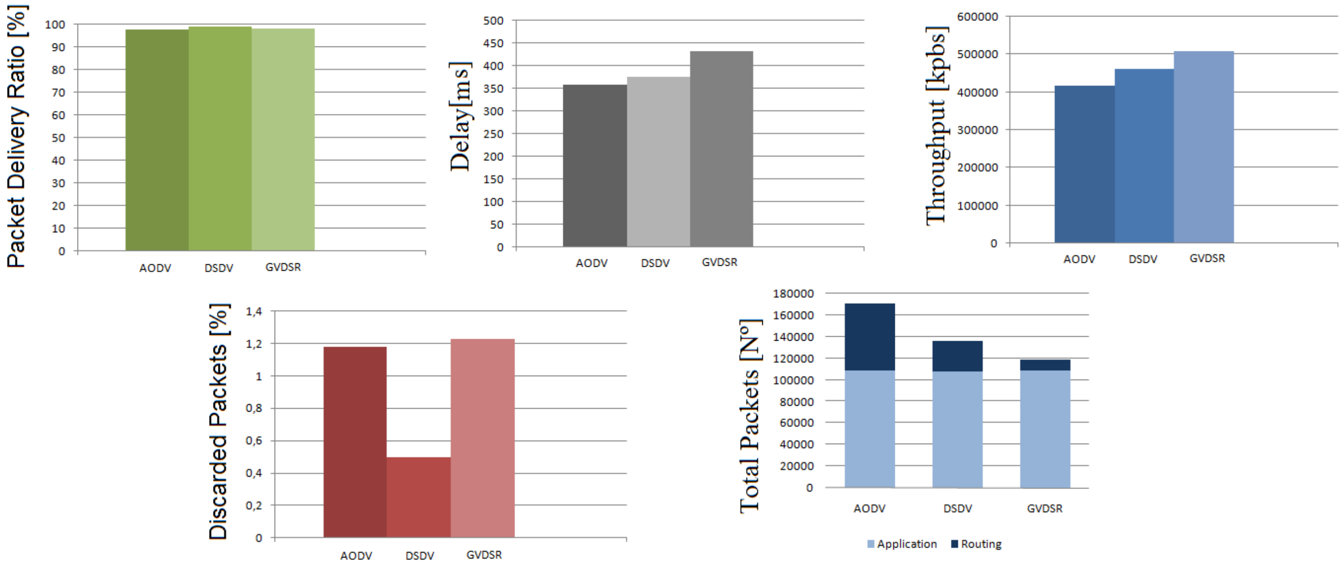

Fig. 10. Graphs for the Highway perimeter of the Malaga city.

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