Routing Protocols for VANETs: An Approach based on Genetic Algorithms

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Abstract

Vehicular Ad Hoc Networks (VANETs) are self-configuring networks where the nodes are vehicles equipped with wireless communication technologies. In such networks, limitation of signal coverage and fast topology changes impose difficulties to the proper functioning of the routing protocols. Traditional Mobile Ad Hoc Networks (MANET) routing protocols lose their performance, when communicating between vehicles, compromising information exchange. Obviously, most applications critically rely on routing protocols. Thus, in this work, we propose a methodology for investigating the performance of well-established protocols for MANETs in the VANET arena and, at the same time, we introduce a routing protocol, called Genetic Network Protocol (G-NET). It is based in part on Dynamic Source Routing Protocol (DSR) and on the use of Genetic Algorithms (GAs) for maintenance and route optimization. As G-NET update routes periodically, this work investigates its performance compared to DSR and Ad Hoc on demand Distance Vector (AODV). For more realistic simulation of vehicle movement in urban environments, an analysis was performed by using the VanetMobiSim mobility generator and the Network Simulator (NS-3). Experiments were conducted with different number of vehicles and the results show that, despite the increased routing overhead with respect to DSR, G-NET is better than AODV and provides comparable data delivery rate to the other protocols in the analyzed scenarios.

Keywords: VANETs, Mobility Simulation, Routing Algorithms, AODV, DSR, Genetic Algorithms, Performance Evaluation.

1. Introduction

The study on VANETs is a current trend that is motivating the industrial and academic community in the search for solutions which allow to install wireless communications equipment in vehicles and/or on the banks of the automotive roads (streets, avenues, highways, etc.) to exchange information with acceptable reliability [1], [2]. Among the technological facilities, the use of Bluetooth or Universal Serial Bus (USB) so that drivers don't take hands off the wheel, is a constant reality in current vehicles. Another technology widely used in vehicles is the Global Positioning System (GPS), with maps that facilitate the life of the drivers, allowing them to locate fuel stations, service areas, shorter paths, position of traffic lights and even radars. However, these devices still can't automatically show if the roads are full because they are preconfigured and this feature requires an exchange of information in real time. For these reasons the academic community is concentrating its efforts in searching for mobile technologies that enable effectively the exchange of information between the vehicles. Thus, it would be possible to receive and pass information to other automobiles warning them about accidents, traffic jams and easy ways where they have passed, allowing other drivers to choose alternative paths through the messages received.

MANETs correspond to one of the leading technologies adopted to carry out these studies by presenting good results in sending and receiving messages with on-the-move antennas, as is the case for vehicles. From the union of this technology with automotive media emerged the term VANET, that consists of a MANET with motor vehicles. Ad hoc technology enables the equipment to send and receive information in unstructured environments, which is a vital feature for the effectiveness of networks between vehicles. The study on VANETs is on the rise with investments from several countries in conjunction with car manufacturers and partnerships with academic institutions as can be checked in [3]. Several authors [5], [6], [7], [8] have done comparisons between VANETs routing protocols. However, they adopt out-of-date tools or mobility models that fail to represent an environment of vehicular traffic accurately.

The VANETs can be characterized as a particular case of the ad hoc networks, usually differentiated by the great mobility of the nodes (vehicles) which compound them. Such networks characterize by being built anywhere, because they do not depend on the existence of a fixed structure [9], [10]. In the communication among vehicles there are problems that the MANETs are not able to solve. In this context, while in common mobile networks people dislocate in small spaces with their computers and normally there are fixed points which facilitate the constant communication, in vehicular networks the relatively elevated speed of the vehicles cause frequent and quick changes in the network topology [11]. Problems of disjointed nodes and disjointed paths also occur due to these changes in topology, provoking packet losses and reduction on the data delivery rate [14].

This paper proposes a routing protocol for VANETs, named G-NET, partly based on the DSR Protocol [15] and makes use of Genetic Algorithms (GAs) [16] for maintenance and route optimization. The G-NET not only keeps the reactive characteristic of the DSR, but also performs periodical updates on the routes taking as base the inapt search features present in GAs [18]. The G-NET operation is validated through simulations based on the network simulator NS –3 [19] and its performance is compared to the performances of DSR and AODV protocols [20].

The following sections of the present work include: Related work on Section 2. Section 3 presents the G-NET routing protocol and the details concerning the maintenance and route optimization by the genetic approach. The operation of the protocol and simulation environments are described in Section 4. The performance evaluation of the G-NET, based on simulations, is presented in Section 5. Finally, conclusions for this approach are drawn in Section 6.

2. Related Work and Routing Protocols

2.1 Related work

Analyzing the literature, one can see that a high number of routing protocols have been proposed by the community. The majority is implemented for MANETs in order to increase bandwidth performance and throughputs, and/or lowering end-to-end delays, packet overheads, energy consumption and others. The authors show that each protocols have their own advantages and disadvantages under certain traffic selection and network conditions.

A lot of simulated approaches were carried out for demostrate the performance of several routing protocol. In 0 is proposed one of the most widely known routing algorithms, called DSR, which is classified as on-demand algorithm and it has route discovery and route maintenance phases. The AODV routing protocol was developed as a work based on DSDV (Destination-Sequenced Distance-Vector) routing algorithm [22]. AODV aims to reduce the number of broadcast messages forwarded throughout the network by discovering routes on-demand instead of keeping the route information. Both algorithms, AODV and DSR will be better discused in Section 2.2. In [23] the authors proposed Temporally-Ordered Routing Algorithm (TORA), an adaptive and scalable routing algorithm based on the concept of link reversal. It finds multiple routes from a source to a destination in a highly dynamic mobile networking environment. In [12], the authors evaluate the performance of the delay-tolerant of Vehicle-Assisted Data Delivery (VADD) protocols in a road network with a grid layout, normalized from the [4]. The evaluation is based on a maximum of 210 vehicles, however, only 15 traffic sources are available to send packets to two stationary sites. Similarly, in [13] has been evaluated the performance of the landmark overlays for urban vehicular routing environments (LOUVRE) in a small road topology, derived from the [4]. In contrast to [12], the authors employ realistic mobility using VanetMobiSim for 100 vehicles. In [17] is evaluated an algorithm called Static-Node-Assisted Adaptive Data Dissemination (SADV) on a slightly larger grid topology than VADD and LOUVRE, where vehicles take random trip until the end of the simulation. In contrast to VADD, vehicles generate packets to random destinations, nevertheless the total packet generation rate in the map is constrained to 10 packets per second.

In [24] the authors analyze the performance of DSR and AODV. Although both DSR and AODV use on demand route discovery, they have different routing mechanics. The authors show that for application oriented metrics such as delay and throughput, DSR outperforms AODV when the numbers of nodes are reduced. AODV outperforms DSR when the number of nodes is very large. In [25] the effects of various mobility models on the performance of DSR and AODV are presented. Four mobility scenarios are presented: Group Mobility, Freeway, Random Waypoint and Manhattan models. Performance comparison has also been conducted across varying node densities and number of hops. The results illustrate that the performance of routing protocols varies according to different mobility models, node densities and length of data paths. In [26] the performance comparison between routing protocols like AODV, DSDV and a variation of DSDV, is presented. The authors use network metrics, called packet delivery ratio, end-to-end delay, and routing overhead. In [27] a set of different routing protocols as AODV, TORA, DSDV and DSR are compared. It is shown through simulation results that DSR generates less routing load than AODV. AODV decreases performance from end-to-end delay while TORA has very high routing overhead. The better performance of DSR is because it exploits caching and maintains multiple routes to the destinations. A comparison between AODV, DSR and Link State, protocols for two different traffic classes is done in [28]. This denote that AODV and DSR perform very well when the network load is soft or moderate and if the traffic load is increased then simple Link State outperforms the reactive protocols.

Due to the VANETs characteristics, several approaches have been proposed to work well with this kind of network. In relation to solutions presented by the scientific community, normally the researchers are introducing some modifications into all layers, including transport layer protocols. The available routing protocols in vehicular communication networks are extensively based on two categories, position-based and topology-based routing. In position-based routing protocols, each vehicle contains a GPS receiver or other positioning device, where the nodes (vehicle) know their real positions, directions, and others relevant informations. The destination node is known by use of location services [29], [30]. The path maintenance is irrelevant [31], [32], as each node has to memorize its one-hop neighbors through beaconing. Topology-based routing techniques can be reactive (on-demand), proactive (table driven), and hybrid. On-demand routing protocols, for instance DSR [15], AODV [33] maintain only those routing paths that are currently in use. Otherwise, table-driven routing protocols, for instance OLSR [34] [35], maintain all the available paths in the network topology.

2.2 Routing protocols considered

2.2.1 Ad Hoc On-Demand Distance Vector Protocol (AODV)

AODV [44], [33] is a distance vector routing protocol that operates reactively to reduce overhead finding routes only on demand. When a route to a given destination does not exist, a route request (RREQ) message is added by the source and by the intermediate nodes where there is no previous routes in their table. Once the RREQ message reaches the destination or an intermediate node, the node responds by unicasting a route reply (RREP) message back to the neighbor from which it first received the RREQ message. As the RREP message is forwarded back along the reverse path, nodes along this path set up forwarding entries in their routing tables, pointing to the node from which they received RREP message. AODV uses sequence numbers created by the destination for every route entry to avoid routing loops. Routes with the greatest sequence number are preferred in selecting routes from the source to the destination.

2.2.2 Dynamic Source Routing Protocol (DSR)

Dynamic Source Routing (DSR) is a routing protocol for wireless mesh networks [45]. It is similar to AODV in that it forms a route on-demand when a transmitting computer requests one. Furthermore, it uses source routing instead of relying on the routing table at each intermediate device [45]. Determining source routes requires accumulating the address of each device between the source and destination along the route discovery. The accumulated path information is cached by nodes processing the route discovery packets. The learned paths are used to route packets. To accomplish source routing, the routed packets contain the address of each device the packet will traverse. This may result in high overhead for long paths or large addresses, like IPv6 0. To avoid using source routing, DSR optionally defines a flow id option that allows packets to be forwarded on a hop-by-hop basis. This protocol is truly based on source routing whereby all the routing information is maintained (continually updated) at mobile nodes. It has only two major phases which are Route Discovery and Route Maintenance [46]. Route Reply would only be generated if the message has reached the intended destination node (route record which is initially contained in Route Request would be inserted into the Route Reply). To return the Route Reply, the destination node must have a route to the source node. If the route is in the Destination Node's route cache, the route would be used. Otherwise, the node will reverse the route based on the route record in the Route Reply message header (symmetric links). In the event of fatal transmission, the Route Maintenance Phase is initiated whereby the Route Error packets are generated at a node. The erroneous hop will be removed from the node's route cache, all routes containing the hop are truncated at that point. Again, the route discovery phase is initiated to determine the most suitable route.

The characteristics of on-demand routing protocols approach motivated us to focus on proactive routing for our proposed routing protocol for VANETs. Thus we propose a routing protocol that seeks to optimize performance metrics through the genetic approach. Our approach explores the characteristics of genetic algorithms, reacting to changes in the environment, and proposing new (and possibly better) routes by use of genetic operators. The protocol was envisioned to work well for different types of VANET applications and ensure user connectivity.

3. G-NET: Routing Based on Genetic Algorithms

Based on the premise, which defends that the use of bio-inspired algorithms may help solving several problems in communications, and in routing protocols specifically, the present paper proposes the routing protocol for VANETs, named G-NET (Genetic Network Protocol). The G-NET was developed based on the DSR with maintenance and route optimization based on GAs. Genetic algorithms are a kind of bio-inspired algorithms which allow problems to be solved in changing environments. Nevertheless, it is verified that the GAs are able to find solutions sufficiently feasible in these kinds of environments as observed in [18].

The proposal is based on a “source routing” protocol, because this kind of protocol stores the whole route from the origin until destination. Thus, the intermediate nodes of the route must be known in such a way that they make the application of genetic algorithms possible, differently from the “hop-by-hop” routing protocols which know only the next hop of the route. Therefore, due to the fact it is a “source routing” protocol, the DSR protocol was chosen as the starting point for the development of the G-NET.

As in any other protocol optimization project, there is a tradeoff between performance gains and implementation costs. In G-NET, the need for additional mechanisms to maintenance and route optimization entails an increase in implementation complexity.

3.1 Genetic Algorithm for route optimization

The genetic algorithm is a populational-based metaheuristic for combinatorial optimization. In GAs, a population is a group of individuals (possible solutions) and each individual is represented by a chromosome. Individuals in a population are combined (through crossover) and modified (by mutation) to produce a new generation of solutions. When the solutions are combined, the attributes (genes) of the better quality solutions have a bigger probability to be passed over the next generation. This process is repeated over generations, improving the quality of the new population's solutions throughout the time [36].

Individuals chosen to match via crossover are called "parents", consequently the generated solutions are called "children" or "offsprings". In the G-NET protocol, the objective of the population evolution is to improve the quality of routing, in the sense of reducing the latency of the routes and at the same time producing a range of different routes, with possible gains in case of route breaking. We notice that, the search for the optimal routing belongs to the category of optimization problems with highly multimodal search space, in this case it is more important to search for a feasible solution in practical time than the optimal absolute solution.

As in VANETs the vehicles represent high mobility and high speed nodes, the variation of nodes (genes) are able to make individuals (routes) that were considered more adequate in a certain moment can be considered inadequate a few seconds later. This way, even though there are many generations, the route latency can be optimal; however, a few seconds later, the same route (individual) may have its latency elevated due to the displacement of the mobile nodes. In this case, it is possible to produce a migration of individuals from a previous generation to an immediately posterior generation, in order to take advantage of the best past routes as part of the next population throughout the time, as illustrated in [18], [37].

3.1.1 Codification of chromosomes

The first challenge in using GAs is defining how the chromosomes will represent the possible problem solutions. Normally the problems are codified in bits which represent genes and bits chains represent chromosomes. In the G-NET case, each complete route from an origin to a destination represents a possible solution (chromosome) and its latency determines the quality of the route. Thus, to represent the routes into chromosomes, each node of the network is considered a gene and the group of nodes of a complete route represents the chromosome.

3.1.2 Fitness function

GAs need the value of a fitness function for each member of the population, which must be a nonnegative value. The fitness function provides for each individual a measure of how well adapted to the environment it is; in other words, in a maximization problem the bigger the value, the bigger are the chances of the individual to survive in the environment and reproduce itself, passing part of its genetic material to further generations. In this process, individuals with high adequacy will have a high probability of being selected and consequently, higher chances of survival [48].

In G-NET, a route is considered good if it presents low latency. As individuals represent the routes, low latency identifies better adapted individuals to the environment. However, in order to achieve uniformity with the operation of the genetic algorithm, in this work, the inverse of the latency (normalized with respect to the set of routes to the same destination) is used and the fitness function is defined by Equation 1 below:

$$F_{id} = \frac{\frac{1}{L_{id}}}{\sum_{j} \frac{1}{L_{jd}}} \tag{1}$$

where L_{id} is the latency of route *i* for the destination *d*. It is important to note that, in G-NET, the population size is equal to the length of the set of routes to a given destination.

3.1.3 Individuals' selection

In this study, the selection method through "tournament" was applied. Individuals of the initial population are selected as parents so that they can generate offsprings (as possible better solutions). According to [48], the stochastic tournament method consists in extracting randomly a pair of individuals, but only the individual with the best fitness is selected to match. We note that there is no consensus about the best and fairest selection method. This way, depending on the scenario and the study field, a certain kind of selection may be suitable or not. For this reason we considered the tournament method for being of low complexity.

3.1.4 Crossover

In G-NET, the "one point crossover" is considered, i.e., a commum point among two chromosomes (parents) is identified and the genes are inverted from this crossover point in order to produce offsprings. The crossover operation is performed periodically, with 100% probability, based on the exchange of especial control packets (see Section 3.2). However, in G-NET occurs some problems which differ from classical crossovers:

- The first one consists in the variable size of the routes. In this case, there is not a way to determine the quantity of genes in an individual because there might be routes with several intermediate nodes or no intermediate node (when the origin and the destination are direct neighbors). This way, the routes are only treated by the GA if there are at least two routes with the minimum of one intermediate node between the origin and the destination.
- Another problem is that the origin and the destination nodes can never change their positions. Thus, in case a route has only one intermediate node, only this node is converted in gene and this way there will be a chromosome with only one gene.
- Due to the different length of the routes, the crossover point must be common for both routes. In this context, the smallest individual (with lower number of genes) must be identified and the crossover point is randomly selected in an interval which varies from the first gene until the length of the smallest individual. For example, if the smallest individual has three genes the crossover point varies from one to three, as observed in **Fig. 1** (where each gene corresponds to three digits).

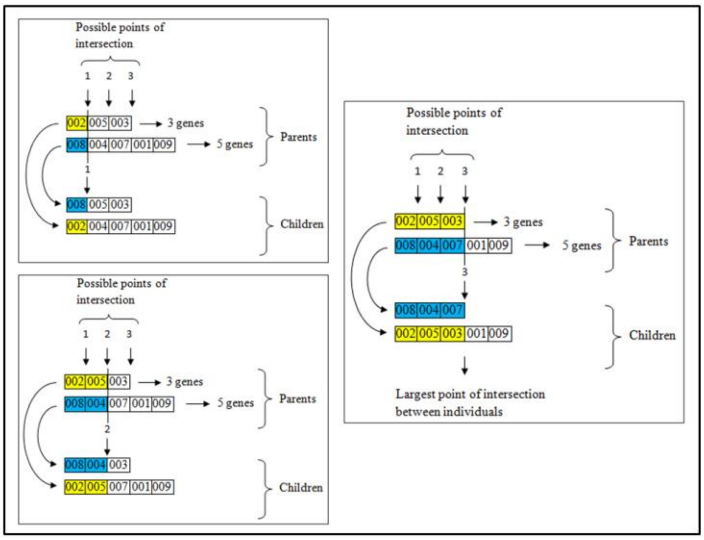

Fig. 1. Example of Crossover

3.1.5 Mutation

In G-NET, the mutation operation is used with the aim of maintaining alternative routes in the route cache. The mutation is performed in some parents and offsprings. All the genes present in the population can be used in the mutation process. The last parent of each pair (selected for crossover) and the first obtained offspring suffer mutation. A random gene from those individuals is chosen and this gene is replaced by another gene from the population.

3.1.6 Routes repairing

During the crossover and the mutation, there might appear equal genes in a offspring. For that reason, on both the crossover and the mutation, an inspection is made to confirm there are not equal genes in the same individual (which would bring loops in the produced route). Due to this, in case there are still repeated genes, only the first gene is kept in the generated individual.

3.2 Functioning of the G-NET protocol

G-NET is a distributed protocol configured in each node in the network. It makes use of control packets (*G-NET_REQUEST* and *GNET_RESPONSE*) besides data packets (*DATA_PACKET*) for its correct functioning. The control packets have as a purpose to allow the calculus of the latency of the routes (individuals in the population). Each node of the network executes the G-NET, and according to its location in the route (source, destination or relay) specific actions are taken. The most important protocol tasks are associated to the sources; the tasks associated with destination and relay are very simple.

Fig. 2 presents a diagram in modular structure which describes the functioning of the G-NET protocol.

Basically, each node in the network executes a predetermined action according to the received packet. If a node is the source of data packets, the G-NET verifies if there is a route for the destination. In case there are routes in the routing table (*route cache*) it chooses the best route, sends the packet (*next hop*) and increases a transmitted packets counter - *Nt(dest)*. In case there is not a route for the destination, the G-NET starts a process of route discovery. In the process of route discovery, the G-NET removes the packet of the transmission queue, finds routes with the same process as DSR, updates the routing table and replaces the packet in the transmission queue. When *Nt(dest)* exceed a pre-determined number of packets, *Np*, for the desired destination, a maintenance process and route optimization (based on the control packets transmission) is activated.

In case the received packet came from another node, the G-NET verifies if the nodes is the destination or if it is an intermediate node. If it is an intermediate node (relay), it just sends the packet to the next hop. On the other hand, the G-NET verifies the packet kind to take its decision, as explained below:

1) *DATA_PACKET*: If the destination node receives a data packet, it just extracts the received message.

2) *GNET_REQUEST*: Here, the destination sends back a *GNET_RESPONSE* packet following the inverse route.

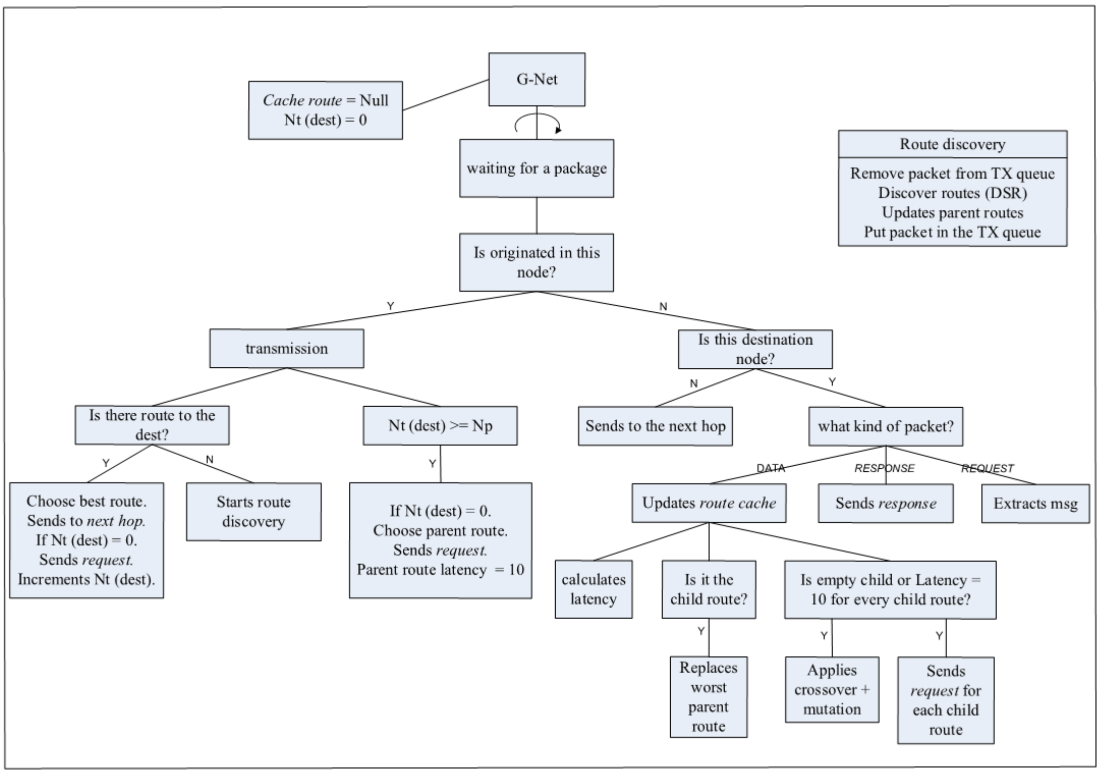

Fig. 2. Diagram of the G-NET functioning.

3) *GNET_RESPONSE*: In this case, the node updates the "route cache", it calculates the latency (based on the elapsed time between the sending of the *GNET_REQUEST* and reception of the *GNET_RESPONSE*) and updates the fitness. Possessing the fitness for the several individuals (parents), the genetic algorithm produces (through crossover and mutation) new routes (offsprings). A *GNET_RESPONSE* is sent to determine the offspring routes' latency. At the same time occurs the substitution of the worst routes.

It can also be observed that in case it is not possible to calculate the latency of a offspring route, this route is considered non-existent or unreachable. In this case, it remains in the "route cache" until it is discarded by the expiration route time.

4. Simulation Environments

The computational simulations allow one to perform network performance tests before implementing the technologies in a real environment. For this reason, the academic and scientific communities often use high performance simulation tools in their research. To perform VANET experiments, three kinds of tools can be used: network simulators, vehicle mobility generators and VANET simulators. However, only two forms of simulation are possible, one integrating mobility generators with network simulators, and the other using only the VANET simulators. VANET simulators tend to produce good results. However, as usually these tools are developed as closed technology private software, the scientific community prefers to use network simulators that are integrated to mobility generators, due to the advantage of that being qualified as free open source software, in most cases. This allows the user to have more autonomy to perform the studies, and, overall, these tools working all together usually achieve results as good as or even better than the VANET simulators, depending on the conditions in which they are tested. In addition, authors in 0,[41] claim that VANET simulators need still more extensions and contributions to be widely used by the scientific community.

4.1 VanetMobiSim

VanetMobiSim mobility simulator is a set of extensions to CanuMobiSim (Communication in Ad Hoc Networks for Ubiquitous Mobility Simulator), which corresponds to a exible structure to model the user mobility [39]. VanetMobiSim extension introduces new models of realistic car movement at both macroscopic and microscopic levels. At a macroscopic level, the VanetMobiSim can import maps from TIGER (Topologically Integrated Geographic Encoding and Referencing Geodatabases) geographic database [4], or one can randomly generate them using Voronoi lattices. In addition, it provides support for roads with multiple lanes, separate directional flows, differentiated speed restrictions and traffic signals at intersections. At a microscopic level, VanetMobiSim implements new mobility models, providing a realistic interaction for both V2V (Vehicle-to-Vehicle) as for V2I (Vehicle-to-Infrastructure) communications. According to these models, vehicles regulate their speed depending on the nearby cars, cross each other and act according to the presence of traffic signals at intersections [42]. VanetMobiSim allows one to view the movements of vehicles in simulation time. In order to enjoy the realistic motion of vehicles in VanetMobisim, in this work intelligent mobility models known as IDM IM (Intelligent Driving Model with Intersection Management) and the IDM LC (Intelligent Driving Model with Lane Changing) were chosen. The model of overtaking (MOBIL) [43] that interacts with IDM IM to manage changes lanes, vehicle braking and acceleration was also adopted. During the simulation, VanetMobiSim sends the motion data to an output file. This file contains the ID of each vehicle (node id), the starting position, the elapsed time of the entire simulation, the vehicles positions during their displacement, as well as their speed for each change in position over time. This output file is known as trace of mobility in the VanetMobiSim and is essential to import via NS-3.

5. Performance Analysis

In order to analyze the G-NET performance, it is important to compare its behavior in relation to other known protocols. In this study a comparison with the AODV was carried out for two main reasons: for being an ad hoc protocol widely employed in studies in mobile environments and the DSR, because it has served as a basis for the creation of the G-NET. The AODV is a reactive protocol which reduces the routing overload because it only sends broadcast packets to discover of routes when a node intends to send data [38]. The DSR has the characteristic of being source routing and tends to present positive results in relation to the routing overload [4][8].

5.1 Data Traffic and Metrics

Two traffic generation strategies were considered, both using On/Off sources with constant bit rate (CBR) and UDP protocol. In the first strategy a traffic similar to that used in [47] was considered. In this case, during the whole simulation, each node will be sending data to a random destination for a time chosen between 40 and 60 seconds. After that, it will not send for a time chosen between 0 and 5 seconds. After this pause period, it will pick another destination randomly and repeat the process until the simulation ends. In the second case it was considered a continuous traffic in which each vehicle chooses a random destination and sends data, without pause, during all the simulation time.

For the protocol analysis, an environment was configured as observed in **Table 1** (based on Ref [7]). In the simulations two performance indicators were considered: the Average Delivery Rate (ADR) and the Routing Overload (RO) in function of the number of vehicles in the simulated environment. The ADR is defined as being the number of packets successfully received at the destinations per number of packets sent by the data traffic sources. This metric tells how good was the protocol in the task of successfully transmitting data end-to-end. The RO is defined as being the number of routing packets (protocol messages) per number of data packets successfully received at the destinations. This metric tells about the extra traffic generated by the routing protocol in order to successfully deliver data packets.

Table 1. Summary of the parameters employed in the simulations.

Simulation Parameters	
Simulation area	1000m x 1000m
Communication range	250 m
Propagation model	Nakagami (m = 1)
Mobility model	VanetMobiSim (IDM/LC)
Application	CBR
Transport Protocol	UDP
MAC and PHY	802.11p
Packet size	512 bytes
Transmission Rate	4 packets/second
Interface queue	20 packets
Number of vehicles	25, 50, 75, 100 vehicles
Maximum speed of the vehicles	60 km/h
Routing Protocols	AODV, DSR and G-NET
Confidence Interval	95%

5.2 Analysis of Results

The results of the computational simulations, considering the three routing protocols, are analyzed in the following paragraphs. We performed packet-level simulations, using the NS-3 package, to check the network-layer metrics. The graphs show the average for each metric, considering 15 independent simulations with different initial seeds, and confidence interval of 95%. In these simulations we considered the population size equal to 8 individuals.

The behavior of the Average Delivery Rate (ADR) is presented in Fig. 3, with and without pause in CBR traffic, respectively. packets. On this figure, G-NET-10 (20) refers to Np = 10 (20) packets. It can be observed that G-NET and DSR present an ADR visibly superior to the AODV and both G-NET-10 and G-NET-20 continues with superior rates than DSR with 50, 75, 100 vehicles, in this scenario. The ADR remains approximately constant as the number of nodes increase for all protocols (except for 25 vehicles). The increase of the number of packets delivered results in an increase of the number of lost packets, and the metrics remains stable.

We note that, with 25 vehicles all protocols present an average delivery rate close to 100%. One of the reasons for this behavior is the lower number of vehicles relative to the size of the environment; it is probable that most part of the communication occurs with the few nodes which are nearby. It happens mainly because the antenna transmission range allows more direct connections among the vehicles, reducing the number of intermediate nodes.

In G-NET, as the number of vehicles increases, there is a trend for a bigger number of intermediate nodes, enabling the existence of more reliable routes. Thus, the G-NET can take advantage of the genetic mechanism. In addition, the crossover of chromosomes can make better use of these additional nodes and, by this reason, improves the performance of the Average Delivery Rate. Furthermore, the DSR may also obtain the best route, but this is not certain. In this case, the G-NET becomes more efficient, since the goal of the algorithm is always finding the best route.

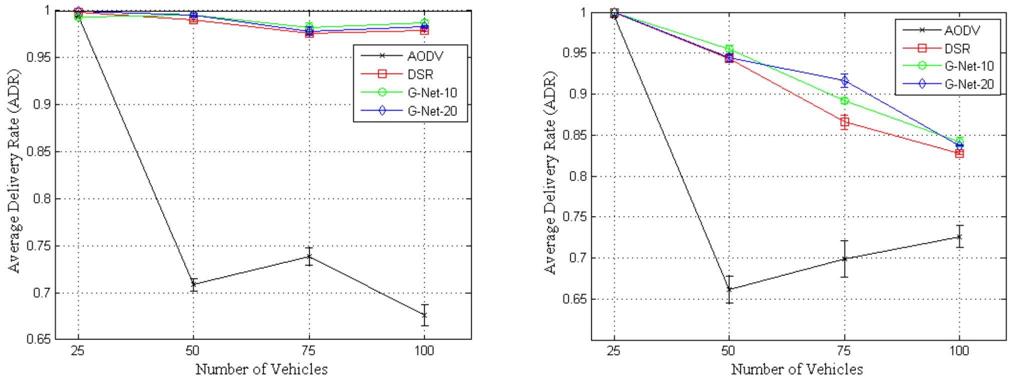

Fig. 3. Graphic of ADR results with (first graph) and without (second graph) pause in CBR traffic.

Fig. 4 presents the performance of the protocols, in terms of Routing Overload (RO) versus the number of vehicles, in order to reveal the impact of routing packtes. The increase of the number of vehicles results in an increase of the routing overhead. It can be observed, as expected, that G-NET-10 presents an overload slightly superior to G-NET-20, because its more frequently updates. Besides, it can be perceived that both G-NET-10 and G-NET-20 have kept the routing overload lower than the AODV, even performing periodic updates. It is very important that the routing overhead of a protocol be as small as possible. So in order to make a routing algorithm useful and scalable the amount of control traffic exchanged in the network must be kept small.

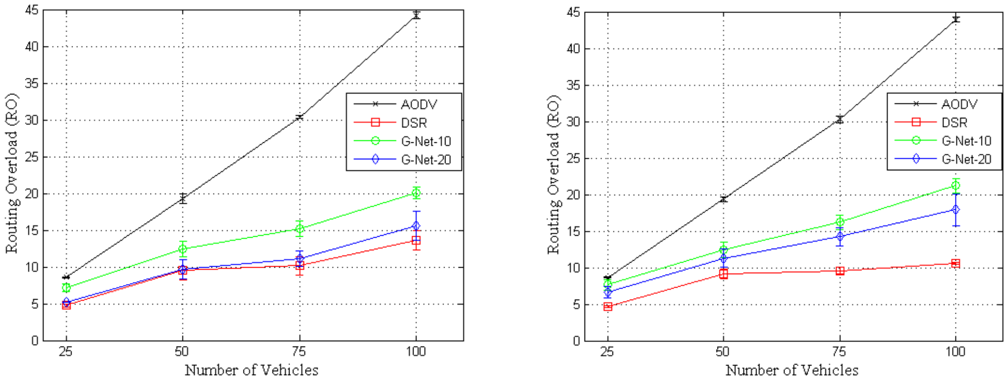

Fig. 4. Graphic of RO results with (first graph) and without (second graph) pause in CBR traffic.

6. Conclusion

In this paper, we have presented a research study on VANETs, providing a comparison between AODV, DSR, and an alternative new routing protocol for VANETs, called G-NET, on a typical urban environment. The experiments were performed with the NS-3 network simulator and the VanetMobiSim mobility generator, demonstrating their importance and how they can be used for VANET simulations, encouraging the scientific community to use these tools. We have studied the protocols' behavior through experiments taking into account a set of network metrics.

The G-NET makes use of genetic algorithms for maintenance and route optimization. The protocol was simulated in order to analyze its average delivery rate and routing overload in relation to the AODV and the DSR protocols. The G-NET route updating system, with periodic sending of control packets, generated an increase of the RO when comparing to the DSR. However, relatively to the overload, even with the increase, the G-NET was always superior to the AODV in the analyzed scenario and, in some cases, it was observed an RO noticeably inferior to the AODV and just a little over the DSR, depending on the number of vehicles. Regarding the ADR, the G-NET has proved to be equivalent to the DSR and superior to the AODV.

As a matter of further work, we intend to test new selection methods and genetic operators, evaluate new metrics (average delay and throughput), and to perform simulations with more protocols and different scenarios.

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