Reliability and Quality of Service of an Optimized Protocol for Routing in VANETs

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***Abstract*—Vehicular Ad hoc NETworks (VANETs) are a special kind of Mobile Ad hoc NETworks (MANETs), which can provide scalable solutions for applications such as traffic safety, internet access, etc. To properly achieve this goal, these applications need an efficient routing protocol. Yet, contrary to the routing protocols designed for the MANETs, the routing protocols for the VANETs must take into account the highly dynamic topology caused by the fast mobility of the vehicles. Hence, improving the MANET routing protocol or designing a new one specific for the VANETs are the usual approaches to efficiently perform the routing protocol in a vehicular environment. In this context, we previously enhanced the Destination-Sequenced Distance-Vector Routing protocol(DSDV) based on the Particle Swarm Optimization (PSO) and the Multi-Agent System (MAS). This motivation for the PSO and MAS comes from the behaviors seen in very complicated problems, in particular routing. The main goal of this paper is to carry out a performance evaluation of the enhanced version in comparison to a well-known routing protocol which is the Intelligent Based Clustering Algorithm in VANET (IBCAV). The simulation results show that integrating both the MAS and the PSO is able to guarantee a certain level of quality of service in terms of loss packet, throughput and overhead.**

Keywords*–*VANET; MAS; PSO; Routing; Quality of service; Routing protocol.

I. INTRODUCTION

In recent years, the progresses in wireless mobile networks have permitted the emergence of a new type of networks, named Vehicular Ad hoc NETworks (VANETs). The VANETs arose from a special form of Mobile Ad hoc NETworks (MANETs) [1]. This particular kind of networks is developed as a main component of Intelligent Transportation Systems (ITS) in order to enhance driving, passengers safety and comfort [2].

The VANETs are formed by vehicles equipped with On Board Units (OBU), and a fixed infrastructure called Road Side Units (RSU). Both units have wireless communication abilities. In fact, the OBUs can communicate with each other as well as with the RSUs in an ad hoc way. Principally, as depicted in Figure 1, there are two types of communications modes in vehicular networks which are: Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I).

Although the VANETs have a lot of similarities with the MANETs as their low bandwidth, their short radio transmission range, and their omni-directional broadcast in most scenarios, they differ from ad hoc networks in numerous ways. Indeed, the vehicular networks are characterized by the rapid changes in communications links.

In addition, frequent disconnections between nodes can occur due to low density [3]. Therefore, designing an efficient protocol for routing in vehicular networks seems to be a key challenge created by the above properties [4][5]. Moreover, applying the MANETs routing protocols in vehicular environments is inefficient [6], since these approaches do not take the above-mentioned characteristics into account. Thus, modifying these methods or proposing new protocols specific for the VANETs are the usual solutions to efficiently resolve the routing challenge in the VANETs. Aiming to solve the routing problem in vehicular networks, we formerly enhanced in [7][8] the DSDV protocol based on the PSO and the MAS. The improved version is called *PSO-C-MADSDV*.

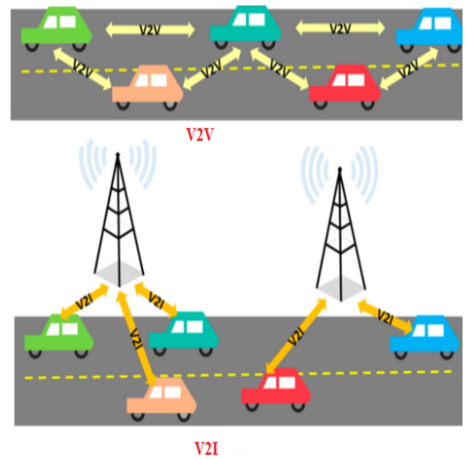

Figure 1. Communications mode in vehicular networks.

The remainder of this paper is structured as follows. The Section II underlines and describes the challenge in routing for the VANETs. Besides, it proves the limitation of applying the MANETs protocols for vehicular scenarios. The Section III presents some related works that deal with routing in vehicular networks. Also, it sums our proposed PSO-C-MADSDV routing method. Finally, in Section IV, we present the simulations results obtained regarding packets losses, throughput and overhead. There is a comparison between the PSO-C-MADSDV and the IBCAV protocols. At last, the section V gives conclusions and future works that may arise.

II. ISSUES OF ROUTING IN VANETS

Routing is defined as the task of forwarding a data packet from a source node to its destination. Sometimes, this process requires multi-hop forwarding nodes. To this end, finding the

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routes to deliver the packets to their destination is the role and the responsibility of routing protocols. In general, an efficient routing protocol is one that is able to forward packets with a short rate of dropped packets and provide a minimal amount of the overhead.

Unlike the routing protocols designed for the MANETs, the routing protocols for the VANETs must principally take into consideration the highly dynamic topology [9]. Consequently, applying traditional MANET routing protocols in vehicular networks is inefficient. Hence, modifying or improving the MANET protocols is the usual requirement to resolve expeditiously the routing challenge in the VANETs. In fact, to better understand this challenge brought by the VANETs, it is necessary first to analyse the specific features of these networks.

The VANETs are a very dynamic environment since they are formed with vehicles that join and leave the network all the time. Even though they have many similarities with the MANETs, like their short radio transmission range and their low bandwidth, they possess some particular characteristics making them different from the ad hoc networks in several aspects.

Actually, the VANETs are characterized firstly by their quick changes in network topology. Secondly, the link between vehicles may be interrupted frequently mainly because of the low density of vehicles. Finally, out of the networking aspects, the different applications that are expected to run over the VANET make it a unique environment. Also, they pose interesting questions related to the protocol design. Consequently, in the literature there are different ways to address the routing challenges in the VANETs.

III. RELATED WORK

Recently, numerous studies reported in the literature have dealt with routing in the VANETs. As discussed above, the specific characteristics make routing a big challenge that requires to be solved in the vehicular environments. Indeed, the MANETs protocols have proved that their performance is poor in the VANETs [10][11].

The key problem with these routing methods ((Ad hoc On-demand Distance Vector (AODV)[12], Dynamic Source Routing(DSR)[13], etc.) in VANETs scenarios is the route instability. In fact, due to the high mobility of vehicles, the paths that have been established as fixed succession nodes, can be interrupted frequently. As a result, this interruption increases overhead, minimizes the rate of delivery ratios, and growths as well the delays of transmission data.

As illustrated in Figure 2, when the vehicle V1 moves out of the transmission range of the source node, the path (Vs, V1, Vd) created at time t will be broken at the instant t+Dt. To solve this problem, an alternative solution is given by the geographical routing protocols (e.g., Greedy Perimeter Stateless Routing (GPSR)[14]). This category does not establish routes, but it utilizes the geographical position of the destination node and its neighbor to deliver data.

Differently from the node-centric routing, the geographical routing approaches have the advantage that any mobile node ensuring progress to the given destination can be applied to forward data.

Thus, in Figure 3, to deliver data to the destination node Vd, the node V2 can be used instead of the node V1. Even with a better route stability, the geographical routing methods

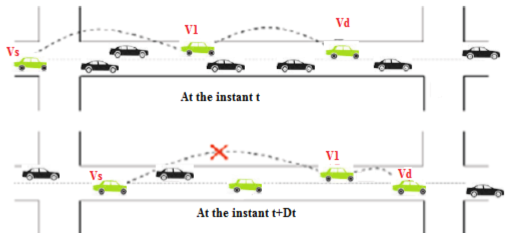

Figure 2. Mobility problem in VANETs.

do not perform well in scale scenarios [10][15]. In this case, their main problem is that many times are needed to look for a next hop (i.e., a node closer to the destination than the current node).

Accordingly, since in the VANETs the vehicle movements are more constrained on roads rather than a geographical region [10], the wrong road routes that do not lead to the destination can be selected. In addition, packets can be transferred to dead ends providing unnecessary and extra traffic overhead in the network as well as longer delays for packets.

Instead of routing data on the dotted route, geographical forwarding delivers data to V1 and V2, following the shortest geographical route from Vs to Vd on a dead path, as shown in Figure 3.

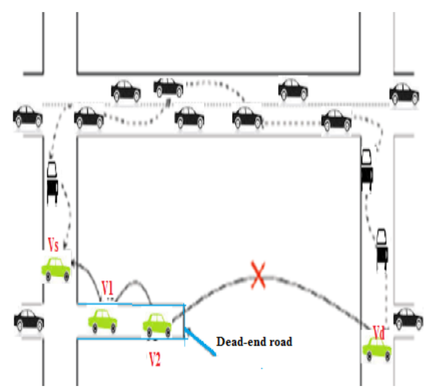

Figure 3. Drawback of geographical forwarding approach.

To address this limitation, numerous road-based routing protocols [10][11][15][16] have been proposed. These methods forward packets based on the shortest road path between the source node and destination. However, [10][16] did not take into account the vehicular traffic flow.

As demonstrated in Figure 3, it is possible that the paths segments on the shortest roads are empty or have network fragmentations. To alleviate this issue, other routing approaches were given in [15][17][18][19]. The purpose of these projects was to use some historical data concerning average daily/hourly vehicular traffic flows.

Unfortunately, this data was not an accurate indicator of the actual road traffic conditions, as events such as road constructions or traffic redirection were not rare. In order to solve the routing challenge in the VANETs, other studies were published [20][21][22][23]. The idea of those related works was to improve the MANETs protocols to make them suitable in a vehicular environment. In this context, we focused in

[7][8] on enhancing the DSDV protocol.

In fact, during the process of designing and deploying a VANET, various questions must be answered that pertain to protocol performance and usefulness. For instance, when designing a routing protocol, a key question is: How can we integrate the VANETs features (road topology, real-time road traffic flow, presence of building, etc.) for better performance? What is the best way to integrate them? All these questions and many more require knowledge of the topological characteristics of the VANET, which are addressed in [7].

The responses have been given based on a multi-agent system approach. A MAS is composed of a collection of autonomous software agents which are capable of completing desired goals cooperatively. The basic attributes of an agent that are considered typical are autonomy, learning and cooperation [24]. These properties imply that agents are capable of executing independently from any other control and possibly asynchronously, discover relevant knowledge from the environment and other agents that may help in attaining the desired goals, and work cooperatively and competitively with other agents. In addition, when performing message routing, a key question is: Which are the highest-quality vehicles? The forwarding process would lead to an optimal communication cost with a minimal number of rebroadcasts so as to reduce latency and packet loss.

Particle Swarm Optimization (PSO) [25] is a stochastic optimization technique, inspired by the idea of a flock of birds moving towards a final goal through cooperation as well as independent exploration. The underlying phenomenon of PSO is that knowledge is optimized by social interaction in the population. The PSO searches for the optimal solutions by updating the velocity and the position of each particle.

Motivated by the performance of the PSO algorithm, in [8], our published research work mainly concentrated on optimizing the routing quality of service. Therefore, we have made an attempt to enhance the routing performance in terms of throughput, packet loss and overhead based on the clustering approach [26]. This technique helps the protocol to minimize the messages count and to increase the network connectivity. It also makes the communication more secure and more stable.

Nevertheless, the previous paper did not compare the PSO-C- MADSDV to any routing protocol specifically designed for the VANETs to see which manner (modifying the traditional methods or proposing new protocols) is the most efficient to deal with the routing issue.

IV. STUDY AND PERFORMANCE COMPARISON

In this section, we investigate the routing protocols for the VANETs. To evaluate the performance of our proposed approach and to demonstrate the usefulness of the agent technology, as well as the PSO algorithm, we chose to compare our method with the Clustering Algorithm in the VANET (IBCAV) [27].

The IBCAV seeks to enhance the routing performance in the VANETs by employing inter-layered methods, as well as the awareness of the network traffic flow. It combines several factors using a smart method on the basis of an artificial neural network. The clustering technique was also applied. In fact, the cluster size, speed and density of vehicles are the metrics taken to form a cluster. For a header selection, the IBCAV combines the factors utilizing the Genetic Algorithm (GA)[28].

The selected protocols were evaluated through simulation using some performance metrics. Hence, in this part, we first present the used metrics. Second, we analyze the obtained results.

A. Analyzed Metrics

In a highly mobile environment as the VANETs, characterized by frequent topology changes, the major routing problem is the breaking of links, which can cause packet loss. The metrics used to assess the performance are the following:

- **Rate of dropped packet**: It presents the number of the data packets having failed to reach the destination.
- **Throughput**: It sums the data packets produced by each source node, counted by kbit/s.
- **Routing overhead**: This metric is utilized to measure the effectiveness of the routing protocol. Indeed, it is determined as the total number of additional routing packets per the number of unique data packets received at destinations. Moreover, this parameter counts the extra traffic produced by the protocol for successfully transmitted packets.

B. Simulation Results

This section makes an attempt to evaluate the performance of the PCO-C-MADSDV and the IBCAV over low, medium and high density with a node mobility speed of 30m/s. The evaluation is done using the DARS simulator (Dynamic Ad-Hoc Routing Simulator)[29]and the JADE framework [30]. The simulation parameters are listed in Table 1.

TABLE I. simulation parameters.

Parameter	*value*
Transmission rate	54Mbps.
Simulation time	50s.
Playground Dimensions	1300m x 700m.
Routing protocols	PSO-C-MADSDV and IBCAV.
Transmission range	150m.
Number of nodes	30.
Mobility Model	Random Waypoint Model[31]
MAC layer	8012.11p

We first present the obtained results in terms of dropped packet rate. After that, we analyze the performance of both routing methods in terms of throughput. Finally, we demonstrate the impact of nodes density on previous protocols according to the routing overhead.

- **Rate of dropped packet**: The graph in Figure 4 demonstrates the obtained results regarding the average of packet loss ratio. As it can be seen, the number of dropped packets in both approaches with low density (10 to 20) is nearly the same and slightly goes up with the increase in vehicles density. However, in medium and high density the IBCAV protocol drops much more packets compared to the PSO-C-MADSDV.
  For example, at 30 vehicles, the IBCAV suffers a loss of 8.12%, whereas our approach suffers a loss of 5.2%.
  In addition, the best behavior of the PSO-C-MADSDV is more noticeable when the number of vehicles grows to reach 50 nodes. In this scenario, the IBCAV protocol drops about 21% of the delivered packets while the PSO-C- MADSDV is more efficient and loses 17%.

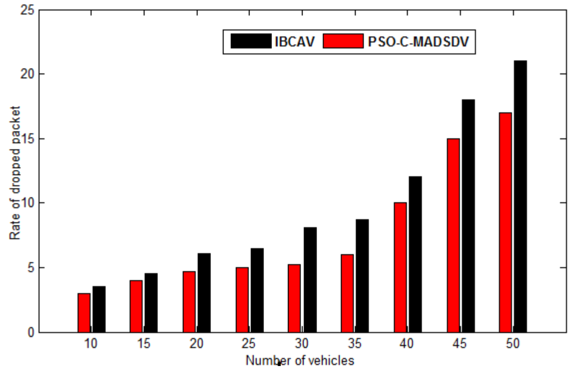

Figure 4. Analysis of dropped packet rate.

To sum up, for all scenarios, the PSO-C-MADSDV outperforms the IBCAV protocol. This is thanks to the PSO algorithm which converges quickly to the best and optimal solution. As a consequence, the probability of producing path breakages decreases. This increase is also guaranteed by the benefits of the agent paradigm, more particularly the autonomy that makes it possible to establish a link despite the topological change.

- **Throughput** : Figure 5 depicts the corresponding throughput obtained for both IBCAV and PSO-C-MADSDV protocols. From the plotted results, we can observe that the PSO-C-MADSDV achieves greater throughput compared to the IBCAV scheme, especially with high-density scenarios.

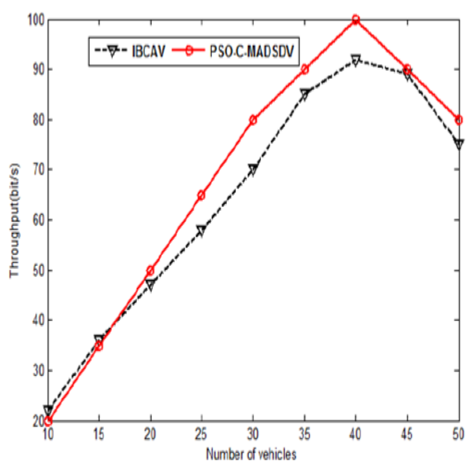

Figure 5. Analysis of throughput.

The main reason for this behavior is that the PSO-C-MADSDV does not require extra time to look for the paths. Whereas, for the IBCAV, there is some spent time in which the protocol does not forward packets. Consequently, the throughput declines.

- **Routing overhead**: Considering the obtained results indicated in Figure 6, we can see that the IBCAV protocol produces the highest rate of routing traffic into the network compared to the PSO-C- MADSDV. This observation is valid for all density levels.

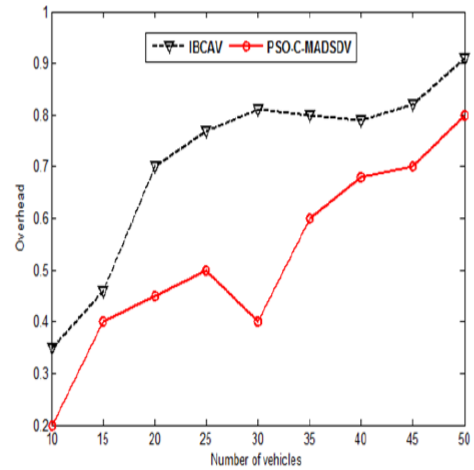

Figure 6. Analysis of overhead.

The reason for this superiority is the cluster technique used by the PSO-C- MADSDV, which can it more stable against the link failure compared to the IBCAV. This makes it more efficient as it avoids sending unnecessary packets.

V. Conclusion and Future Work

Thanks to the advances in wireless technology, it is possible to form a network using vehicles, called VANET. It is a particular class of the MANET. Nevertheless, the high dynamic nature of the vehicular network, caused by the high speed of vehicles, makes it different from the MANET and various challenges arise, especially the routing issue. Therefore, to solve this problem, it is essential to design a new protocol taking the mobility model into account or to improve the MANETs routing protocols to suit the VANETs nature.

In this paper, an attempt has been made to provide a comparative analysis of two routing protocols, which are the PSO-C-MADSDV and the IBCAV. The first one is an enhanced version of the traditional MANETs protocol, whereas the IBCAV is a specific routing scheme designed for the VANET. The key aim of our comparative study is to identify the way that has a better performance, taking place in highly mobile environment of the VANET.

For the simulation results, we can observe that our proposed PSO-C-MADSDV approach outperforms the IBCAV in terms of throughput, packet drop and routing overhead. Hence, considering the obtained results, we can conclude that the designed protocols for routing in the VANETs need to be improved to adapt well in some real-time scenarios.

As a future plan, we envision to evaluate the PSO-C-MADSDV in different scenarios (i.e., city, urban, rural, etc.) to test the impact of varying the communication environment on its performance.

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