Signal Processing and Renewable Energy
June 2019, (pp. 37-45)
ISSN: 2588-7327
eISSN: 2588-7335

A New method for Routing Optimization in Vehicular Ad Hoc Networks (VANETs)

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Received: 13-Dec-2018, Revised: 27-Dec-2018, Accepted: 30-Dec-2018.

Abstract

VANETs are a subset of MANETs in which vehicles are considered as network nodes. These networks have been created to communicate between vehicle and traffic control on the roads. VANETs have similar features to MANETs, and their main special property is the high-speed node mobility which makes a quick-change topology in the network. The rapid change of network topology is a major challenge in routing. One of the well-known routing protocols in VANETs is the AODV routing protocol. In this inquiry, nature-inspired algorithms such as GOA and GA are used to improve routing in VANETs to search the optimal configuration of the AODV routing protocol, and its impact on network evaluation criteria has been investigated. The rating measures applied in this research are the packet delivery ratio, end-to-end delays, and normalized routing load.

Keywords: VANETs, AODV routing protocol, nature-inspired algorithms.

1. INTRODUCTION

Vehicular ad hoc networks (VANETs) are wireless communication networks which employ infrastructure-less wireless technologies to create volatile networks among road users [1, 2]. Similar to many other new technologies, such as Nanoelectronics and Nanorobotics, which have been considered by many researchers [3-10], VANETs offer the possibility of improving the safety and efficiency of the road transports through the cooperative driving applications. VANETs are mainly characterized by their constraint such as highly variable topology and the Wi-Fi coverage limitations depending on the surrounding conditions. This, in concert with the absence of any central management entity, makes routing in VANETs critical and difficult labor. In the mentioned field, the research community has proposed many

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studies, creating new protocols or improving the existent ones [11-13]. One way to perform important improvements over routing protocols is to obtain the best form of the parameters which govern their performance; nevertheless, it is not easy to find such an optimal configuration in most protocols due to the vast number of possible feasible configurations. Thus, exact and enumerative methods are non-applicable to solve the underlying optimization problem because they critically require long execution times to do the lookup. In soft computing, metaheuristics have emerged as robust and flexible methods for tackling search and optimization problems. Metaheuristics have been used in many areas achieving a high degree of problem-solving efficacy. In VANETs, metaheuristics have been employed to find optimized protocol parameterizations, resulting important performance improvements [14, 15].

2. AODV ROUTING PROTOCOL

Routing protocols are essential for the proper packet exchange among the network nodes. In VANETs, the task of calculating the routing paths is yet harder because any central management entity does not exist, and the network suffers from frequent and rapid topology changes. Due to the fact that the methodology given in this article can be directly applied over any other protocol, we dispense with the QoS optimization in VANETs using the AODV routing protocol in this work. This section presents AODV, its QoS optimization problem and the related work.

A. *Ad hoc On-Demand Vector (AODV)*

Ad hoc On-Demand Vector (AODV) is a reactive routing protocol for ad hoc networks [16]. It defines the routes when a source node has packets to send, and it just maintains the routing paths which is currently in employment. AODV reduces the routing network load by utilizing a path discovery mechanism and by updating routing tables at each intermediate node in the route. The reduced routing overhead and the competitive QoS lead to its use in VANETs; thus, it is indicated that this optimization is a fruitful research line [17, 18]. The operation and performance of AODV are significantly influenced by the value of their control parameters. These parameters are principally five timers and six counters.

The parameter settings assign values to the counters, timers, and decision variables that govern the protocol performance; therefore, the behavior and the functioning of such protocols are extremely dependent on their configurations. Accordingly, we aspire to discover efficient AODV protocol configurations that is based on the network performance of the found parameterizations.

The efficient AODV routing problem in VANETs takes all feasible AODV as search space settings. The range of values assigned to the elements of the result vector are shown in Table 1. We addressed an optimization technique to fine-tune the solution vector to receive the best QoS. To evaluate the quality or fitness of the different AODV configurations (tentative solutions), we have defined a communication cost function for three of the most common QoS metrics which is used in this field [19, 20]:

1) Packet delivery ratio (PDR): the fraction of data packets originated by an application that is completely and correctly delivered.

2) Normalize routing load (NRL): the ratio of administrative routing packet transmissions to data packets delivered.

3) End-to-end delay (E2ED): the difference between the times a data packet is originated by an application and the time this packet is received at its destination; thus, an efficient AODV parameter setting for VANETs maximizes PDR and minimizes NRL and E2ED.

B. Related Work

Toutouh et *al.* proposed an approach "Intelligent OLSR Routing Protocol Optimization for VANETs" which is based on finding upgraded routes between the nodes to allow the relevant transfer of data specified in the case of OLSR protocol. As a result, the article deals with optimizing OLSR routing protocol. This process has been adjusted since it represents a chain of features that make it usable for extremely dynamic ad hoc network and for VANETs [1].

Yussof *et al.* proposed a Genetic oriented routing, which is employed to determine the minimal path. In the computer networks, shortest path routing is widely practiced. Genetic oriented routing has been placed to be more scalable and intensively applied in network topologies. In this paper, the purpose is to reduce the computation time of the genetic algorithm for working

Table1. ***Set of AODV parameter.***

Parameter	Type	Range
HELLO_INTERVAL	R	**[1.0, 20.0]**
ACTIVE_ROUTE_TIMEOUT	R	**[1.0, 20.0]**
MY_ROUTE_TIMEOUT	R	**[1.0, 40.0]**
NODE_TRAVERSAL_TIME	R	**[1.0, 40.0]**
MAX_RREQ_TIMEOUT	R	**[1.0,100.0]**
NET_DIAMETER	Z	**[3, 100]**
ALLOWED_HELLO_LOSS	Z	**[0, 20]**
REQ_RETRIES	Z	**[0, 20]**
TTL_START	Z	**[1, 40]**
TTL_INCREMENT	Z	**[1, 20]**
TTL_THRESHOLD	Z	**[1, 60]**

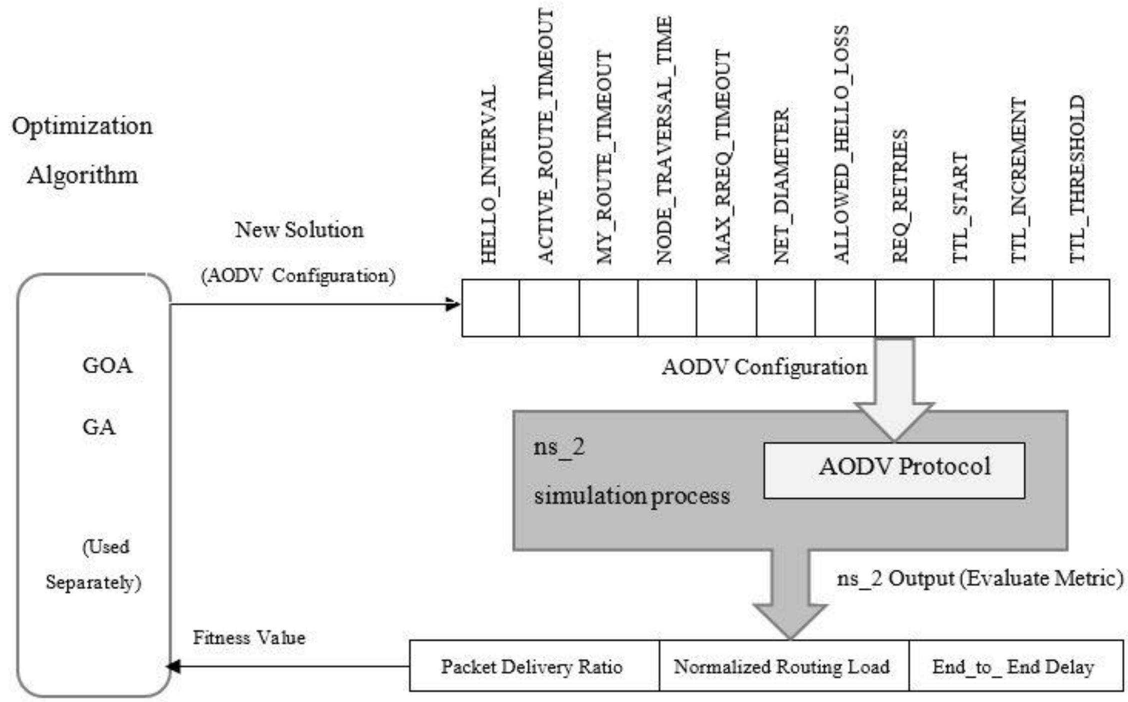

Fig. 1. Optimization framework.

out the problem of shortest path routing [2].

Raghay *et al.* proposed an approach "A Genetic Algorithm for Management of Data Stream in VANET" for handling the data flow. The genetic algorithm is applied to find the sufficient number of vehicles to generate knowledge from information accumulated by the population. Dissimilar types of data can be exchanged in the context of VANETs, especially to alert drivers the significant occurrences or possibly life threatening events. As a consequence, during their travel, the vehicles are flooded by information provided by others. The relevant data are then employed locally to inform or alert the driver [11].

3. OPTIMIZATION FRAMEWORK

As previously remarked, the optimization strategy used to obtain automatically efficient AODV parameter configurations is carried out by coupling two different levels:

1) An optimization procedure and 2) A simulation phase. The optimization lock is brought out by metaheuristic method, i.e. GA and GOA. These two methods were conceived to obtain optimal results in continuous search spaces, which is the case in this constitution. We use a simulation process for putting a quantitative quality value (fitness) to the AODV performance of computing configurations in communication cost. This process is run out by the $NS-2$ network simulator widely used to simulate VANETs accurately [12]. For this paper, $NS-2$ has been modified to interact automatically with the optimization process

with the aim of taking out new routing parameters, opening the way for similar future research. As Fig. 1 illustrates, when the used metaheuristic requires the valuation of a solution, it conjures up the simulation procedure of the tentative AODV configuration over the defined VANET scenario. Then, $NS-2$ is started and evaluates the VANET under the conditions defined by the AODV routing parameters and generated by the optimization algorithm. Later on the simulation, $NS-2$ returns global information about the PDR, the NRL, and the E2ED of the whole mobile vehicular network scenario. This data is applied in turn to compute the communication cost (*comm_cost*) function as follows:

$$\text{fitness} = \text{w}_1 \cdot (-\text{PDR}) + \text{w}_2 \cdot \text{NRL} + \text{w}_3 \cdot \text{E2ED} \quad (1)$$

The communication cost function, addressed in this paper, represents the fitness function of the optimization problem addressed in this paper. To improve the QoS, the objective here consists of maximizing the PDR and minimizing both NRL and E2ED. As shown in Eq. (1), we applied an aggregate minimizing function, and for this reason, PDR was formulated with a negative sign [13]. In this equation, factors *w1*, *w2*, and *w*3 were used to consider the influence of each metric on the resultant fitness value. These values, being *w*1 = 0.5, *w*2 = 0.2, and *w*3 = 0.3.

4. EXPERIMENTS

We have used the Network Simulator (*NS*-2) to simulate VANET. The VANET instance defined in this paper contains 50 cars moving through an area of 670×670 m^2, and their speed fluctuates between 10 km/h and 50 km/h. Table 2 summarizes the principal features of the network which is used in our VANETs simulations.

Table 2. ***Main parameters defined for the NS − 2 simulation.***

Parameter	Value
Simulation time	180 s
Simulation area	670×670 m^2
Number of vehicles	50
Vehicle speed	10-50 km/h
PHY/MAC protocols	IEEE 802.11b
Routing protocol	AODV
Transport protocol	UDP

A. Result

In this segment, we compare the resultant AODV configurations for selected QoS indicators (*PDR*, *NRL*, and *E2ED*). We can see the AODV parameter settings in Table 3, considered for comparison in this analysis. This Table shows the best AODV configurations which are obtained by each of the two aforementioned metaheuristics algorithms : GOA and GA.

The simulation results of our VANET scenario with these AODV configurations are shown in Table 4.

Our notices are mentioned as follows:

By examining the PDR indicator, we can effectively report that the PDR which is obtained by GOA is 100% and 96.86% for

Table 3. ***The best solutions for AODV parameter in optimization algorithms.***

	Optimized configurations	
Parameters	**GOA**	**GA**
HELLO_INT	2.4609	4.7441
ACTIVE_R_T	1.2092	3.0593
MY_R_T	2.7523	6.0749
NODE_T_T	1.0466	3.2764
MAX_R_T	15.8698	17.3790
NET_D	5	17
ALLOWED_H_L	3	5
REQ_R	2	4
TTL_S	4	6
TTL_I	3	4
TTL_T	7	11

Table 4. ***QoS comparisons of considered AODV configurations.***

	Optimized configurations	
Metric	**GOA**	**GA**
PDR(%)	100	96.86
NRL(%)	0.21	0.51
E2ED(ms)	11.41	10.13

its counterpart GA. Since a low PDR directly implies a higher packet loss, this topic has an important role in highly dynamic VANETs, which takes in the AODV protocol to generate additional administrative packets with an impingement in the network congestion.

Touching on the NRL, we notice that the NRL obtained by GOA is 0.21% and the GA achieve the intended NRL 0.51%. GOA has optimized AODV configuration and showed better routing loads than the GA. Bringing down the routing load is important since this

Table 5. ***Fitness results.***

	Optimized configurations	
	GOA	**GA**
Fitness	-0.496	-0.480

is a way to cut down the possibility of network failures related to the congestion problem in VANETs [14].

In terms of the E2ED, we can get that GA obtains the best result (10.13 ms), and this time in GOA increases to 11.41 ms. Evidently, the low routing load has experimented in these configurations, limited the routing management operations; therefore, the average E2ED is worse than the other configurations with high routing load.

In parliamentary law to examine the performance of the optimized AODV configurations, the fitness function is taken out to compare the best-found configurations by each algorithm (GOA and GA).

The fitness results presented in table 5 demonstrate that significant advances are accomplished when using the GOA (fitness=-0.496) over the GA (fitness=-0.480).

Our aim in this paper is minimizing a fitness function, and the result in Table 5 confirmed that GOA provides the best AODV configuration to GA.

5. CONCLUSION

In this paper, we have addressed the optimal parameter which tunes the AODV routing protocol to be used in VANETs by employing an automatic optimization tool. For this purpose, we have set an optimization scheme based on coupling optimization algorithms (GOA and GA) and the $NS-2$ network simulator. For the performance of the optimization techniques employed in this paper, GOA provides the best AODV configuration to GA. This feature obtains as a result of higher capability of fitness in GOA than GA. As a subject of the further work, we can analyze the evaluation of the fitness function by using several VANET simulations simultaneously, and the diligence of other optimization algorithms to the problem tackled here.

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