A Technique to Mitigate the Broadcast Storm Problem in VANETs

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***Abstract*—Vehicular Ad Hoc Networks (VANETs) are networks formed by vehicles using the wireless medium as communication link for data transmission and reception. In this network, vehicles can transit on the roads with high speed and thus provide a high dynamism in its topology. This may cause the connectivity between vehicle lasts a short time. So, many applications in VANETs, which need to disseminate data traffic seek a fast and efficient diffusion mechanism. The forwarding broadcast mechanism is generally used to accomplish this task. However, a poorly elaborated mechanism for disseminating messages can flood the network with redundant data and increase the number of collisions due to disputes between vehicles for accessing the medium. These problems are usually known as broadcast storm problem. Thus, this paper proposes a probabilistic technique for mitigating the broadcast storm problem through a game from the Games Theory: The Volunteers Dilemma. In order to explore the equilibrium in the game and also evaluate the network technique performance some simulations using the Network Simulator 3 (NS3) were performed. The results showed that the technique presented a good delivery rate of packets and little loss of data with high vehicular densities. However, it was found that even without an overwhelming number of transmissions, a large amount of redundant information was noticed.**

Keywords*-*VANET; volunteers dilemma; routing protocol; broadcast storm;

I. INTRODUCTION

Vehicular networks known as VANETs are networks that show different characteristics from other wireless networks, such as, the Mobile Ad-hoc Networks (MANET) [1]. Both networks are wireless and self organized, in which their own nodes order and provide services. Although VANET is a special case of MANET, one of the main differences between them is their mobility patterns [2]. Since the key elements in a VANET are basically cars that communicate with each other through a wireless network, the direction and movement of the vehicles are usually limited by the dimensions of the way. Unlike VANETs, in MANETs the nodes can describe random trajectories. The main characteristics that distinguish VANETs from MANETs are found in [3].

In the environment of wireless vehicular networks, protocols that are designed to broadcast, transport, deliver or route messages from an application should be concerned with the special features that are in VANETs [3] [4]. Protocols originally designed for other types of networks generally have lower performance when applied in VANETs, since their characteristics and problems are different. Many applications in VANETs are designed to benefit all network elements, such as security applications in traffic to prevent collisions among vehicles [5]. Other applications in the same category which are supposed to send messages to all other nodes in the network use broadcast protocols. The use of a broadcast protocol in this case is a good strategy to disseminate data because the vehicles do not need to know an address and a route to a specific target [6]. However, the forwarding of messages following a broadcast protocol poorly prepared, with an excessive number of broadcasts, flood the network with duplicate messages and causes infinite loops of retransmissions. Since the network is wireless, vehicles share the same link and can compete for accessing the medium in a broadcast protocol for VANETs. This fact is especially true when a vehicle receives a specific packet and decides to relay it to other close vehicles. Recipient vehicles, which decide to relay the packet received in regular equal times cause huge amounts of collisions, consequently this makes the information transmitted by the packet maker vehicle is not passed on to further vehicles away from it. These problems are generally referred to as the broadcast storm problem [7] [8].

Thus, a smart mechanism that uses a technique to disseminate messages which are sent from the traffic generator vehicle and can be achieved by all neighbouring nodes is needed. In order to have the messages achieving vehicles out of the range of the transmitter vehicle, it is necessary that the intermediate vehicles forward these incoming messages. Since some protocols send messages only for management purposes, retransmitting these messages may cause a waste of processing, bandwidth, and a longer delay to access the medium controlled by the link layer protocols. Applications that require urgency, so that their messages reach the other nodes in the network would suffer a greater impact concerning a service break in the broadcast storm [7]. So, it is clear that the implementation of a broadcast mechanism poorly designed worsens the broadcast storm problem, overloading the network unnecessarily.

The other parts of this paper are organized as follows: Section 2 will show how routing protocols can be classified in VANETs. Section 3 focuses on main broadcast protocols that worked as a stimulus for formulating probabilistic broadcast protocol in this work. Section 4 shows the modeling of the Volunteer's Dilemma [21] game in order to produce a broadcast protocol for VANETs. In Section 5, the results

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of experiments between two probabilistic protocols will be shown: the first comes from Quantal Response Equilibrium (QRE) [22] (proposed in this work) and the second comes from the Nash equilibrium [18]. Finally, Section 6 will discuss the conclusions and future work.

II. CLASSIFICATION OF ROUTING PROTOCOLS IN VANETs

Most routing protocols in the literature proposed for VANETs [6] [9] focus on more specific characteristics, making these protocols become quite limited. Thus, for a routing protocol it has a higher efficiency, some main features must be considered.

In [10], the essential features that one routing protocol must have are shown, some of them are the most important: the protocol must be dynamic, and acting reactively creating routes on demand. Another important feature is that the routing protocol must be scalable in such a way that the routing protocol must show good performance in scenarios with low and high quantity of vehicles. In order to achieve a better performance, a protocol should have mechanisms to know the network topology, even after the vehicles change their positions. Many times, it facilitates developing solutions to situations of broken connections. And lastly, a good feature for routing protocols is to provide a larger time of connectivity between vehicles. This latter feature is important for routing because it provides the required time to complete the calculation of routes taken by the protocol.

Through several researches on routing on wireless vehicular wireless networks, many protocols have been reported in scientific communities. However, it is difficult to find protocols that suit the different situations and scenarios. Many routing protocols in VANETs are designed in order to troubleshoot specific networks, thus these protocols may have similar properties and features. Not only by the protocols features, there are several ways to classify the routing protocols in VANETs. One can classify them by the techniques used, routing information, service quality, routing algorithms and others [9].

Some authors tend to classify routing protocols following a common genre. Works, such as [11], [12], and [13], classify protocols based on the use of techniques and particular characteristics in five classes: position, grouping, geocast routing, topology, and broadcast. However, other authors prefer to classify them in relation to their routing strategies, it means proactive or reactive [14]. In other scientific papers, the authors classify protocols regarding the information contained in the packet based on topology or geographic information [15].

Deepening the classification of protocols based on the strategies of transmissions, Lin [16] presents some of the main mechanisms for disseminating data in VANETs as well as main protocols in their category in the literature. In his work, he classifies routing protocols for disseminating information into three major groups: Unicast, Multicast, Geocast, and lastly, Broadcast.

Similar to Lin [16], Panichpapiboon and Pattara-Atikom [6] also classify the protocols regarding the main techniques for disseminating information on VANETs. However, the attention is directed to the broadcast protocols. In his work, the classification of broadcast protocols are done basically in two main categories: Multi-hop and Single-hop Broadcast.

Fig. 1 shows clearly the protocols broadcasts classification made by [6]. The figure also shows the main techniques used by the protocols. Some of these protocols are presented in the next section.

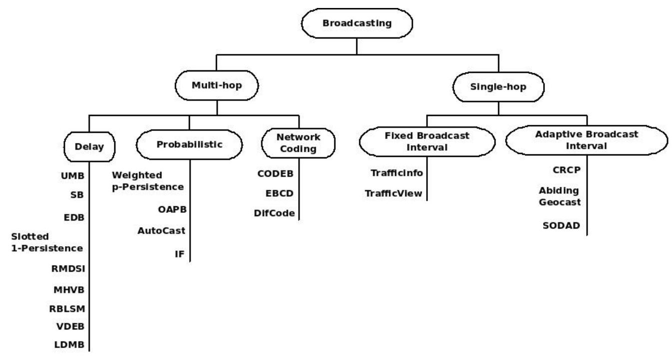

Figure. 1. Classification of broadcasts protocols in VANETs. Adapted from [6].

III. BROADCAST PROTOCOLS

Here, after some protocols presented in [6] will be shown, their main features will be discussed. The focus remains in some protocols which use techniques based on timers and probability, since parts of their approaches worked as inspiration for the development of this work.

The first protocol presented is the Weighted p-Persistence [7]. It is a probabilistic protocol. Protocols based on this category are characterized for deciding forwarding the received information by a probability p. In the weighted p-Persistence protocol, when a vehicle receives a packet via broadcast for the first time, it bases the need of rebroadcasting on the distance between the packet source node and it. The distance between them can be obtained through the receivers position and the transmitters position that is inserted into the sent packet. When a vehicle receives a broadcast packet it takes the decision to rebroadcast information with the probability (1).

$$p = \frac{D_{ij}}{R} \qquad (1)$$

in which D_{ij} is the distance between the receiver i and the transmitter j, and R is the transmission range. The great advantage of using this approach is that it gives a certain priority to the vehicles near the radius edge R, what may provide greater achievement of packets transmitted on the network. However, this obtained probability does not consider the number of vehicles in the network. When the network shows a high density of vehicles, there may be a large number of vehicles with a high probability of forwarding and thus rise to a large number of retransmissions. The second protocol is called Irresponsible Forwarding (IF) [17], and it is also a probabilistic protocol. Similarly to the protocol Weighted

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p-Persistence [7], the forwarding probability is built on the distance between the transmitter and the receiver. Although it also considers the density of vehicles. Thus, when a vehicle receives a broadcast packet, it decides to relay the information with the probability (2).

$$p = e^{-\frac{\rho_s \ (z-d)}{c}} \quad (2)$$

in which ρ_s is the vehicular density, z is the transmission range and d is the distance between the transmitter and the receiver vehicle. The parameter c is a coefficient with value greater or equal to one which is set to regulate the curve of the probability function. The main idea inserted in the formula is the fact that vehicles further from the transmitter have a higher probability of relaying information compared to vehicles which are closer to the transmitter.

The third protocol is the Slotted 1-Persistence Broadcast [7]. This protocol is based on timing. These protocols are characterized by retransmitting the information to other vehicles in the network after waiting a given time. It is expected that the waiting time set in the vehicles is different so that the vehicles far from transmitter are prioritized, it is, the closest vehicles to the edge in the transmission range will have a much shorter waiting time than other vehicles that are located closer to the transmitter.

So, the protocol Slotted 1-Persistence Broadcast uses a strategy using sectors to prioritize the vehicles waiting time concerning the distance. The transmission range of a vehicle is divided into sectors of times in which sectors more distant from the transmitter have a shorter waiting time than the ones closer to the transmitter. Thus, when a vehicle receives a broadcast packet, it computes its waiting time defined by the sector time following (3).

$$T_{S_{ij}} = S_{ij} * \tau \quad (3)$$

where τ is the propagation time of a jump between vehicles and the average waiting time for accessing the medium. And S_{ij} is the number of the sector defined by the distance between the transmitter and receiver. The sector number is calculated following (4).

$$S_{ij} = N_s \left(1 - \left\lceil \frac{min(D_{ij},\ R)}{R} \right\rceil \right) \quad (4)$$

where D_{ij} is the distance between the transmitter i and the receiver j, R is the transmission range, and N_s is the total number of sectors previously defined. The number of sectors must be wisely chosen since as the network becomes denser, there is the possibility that many nodes in the same sector have the same waiting time. This makes they transmit at the same time resulting in several collisions between packets.

Finally, a probabilistic protocol derived from Game Theory [18] [19] stands out over. This work worked as the main inspiration for the design of the protocol proposed in this work. In [20], a model using the symmetric game based on Volunteer's Dilemma is made [21] in order to mitigate the broadcast storm problem. In this work, we calculated the probability of a player volunteer derived from the Nash equilibrium [18] [19] with aiming to make the decision of transmitting a broadcast message by a vehicle in the network. The probabilistic protocol also incorporates some other strategies, such as the use of sectors and timers adopted by the Slotted 1-Persistence Broadcast protocol to prioritize the waiting time for transmission of a packet by a receiving vehicle over the distance from the source vehicle.

IV. VOLUNTEERS DILEMMA AS A BROADCAST PROTOCOL

Taking as a model the Volunteer's Dilemma [21] game using its symmetric version, it is possible to adapt it to the VANETs scenario in which a given vehicle in the network to which the network receives a broadcast message and decides to retransmit it to the others based on the probability of volunteering modeled by the game. Creating an algorithm for such purpose can be explored using the parameters involved in the game.

Let N be the number of vehicles participating in the game and all of them have a set of pure strategies, it means, each vehicle chooses to transmit or not transmit the received message. The decision of not broadcasting a message taking into account the fact that at least one vehicle has already made that decision, provides the greatest payoff B. The vehicle which decides to broadcast the message will pay a cost C and thus result in a payoff $B - C$. And in the case any vehicle does not decide to relay the message a minimum payoff of M will be shown. The representation of game in the regular way is shown in Table 1.

TABLE I
NORMAL FORM OF THE GAME.

	AT LEAST ONE FORWARD	ALL QUIET
FORWARD	$B - C$	$B - C$
QUIET	B	M

With the model presented by Goeree et al. [22], to insert noisy behavior and aversion to unequal gains for QRE equilibrium, it is possible to define a probability p of a vehicle to forward the incoming message to its neighbors following (5).

$$p = \frac{exp(\lambda \pi_v)}{exp(\lambda \pi_v) + exp(\lambda \pi_n)} \quad (5)$$

where $\pi_v = B - C - \alpha(1-p)C$ and $\pi_n = B(1-(1-p)^{N-1}) + M(1-p)^{N-1}$ with the precision parameter λ and aversion parameter α estimated through experiments. It is assumed that the cost C and the benefits B, M are properly defined.

As the game is the symmetric Volunteer's Dilemma, then the relationship C/B for vehicles belonging to the game should be similar. However, it is necessary to give a priority to the vehicles further away from the transmitter so that the message has a longer range with the vehicles in the network. Thus, a strategy using sectors similar to the one addressed by

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Wisitpongphan et al. [7] and Roberto et al. [20] was adopted to prioritize the vehicle through space.

The transmission range R of the transmitter vehicle is divided in an amount N_{sect} denominated number of sectors. The numbering of the sector S happens in descending order tank into consideration the message transmitter, ie the sector most distant from the transmitter has value $S = 1$ and is labeled S_1, the second sector from the transmitter is labeled S_2 and so on until the nearest transmitter sector S_N. Each sector also limits some area to which vehicles may be passing. Thus, the length of the sector is defined as S_{len} and can be easily found using the transmission range R divided by the number of sectors N_{sect}. It can be formally defined as shown in (6).

$$S_{len} = R/N_{sect} \tag{6}$$

Since every vehicle in the network is transmitting and receiving ad messages (beacon messages) stating their mobility pattern, any vehicle that receives a broadcast message has the necessary information obtained to calculate the distance between it and the transmitter. That distance will be called the D_{tr}, which can be interpreted as the distance from a transmitter t from a receiver r. So, a vehicle can discover in which sector S_i it is compared to the transmitter performing the following computing (7).

$$S_i = \lfloor (N_{sect} + 1) \; - \; (D_{tr}/r) \rfloor \tag{7}$$

The modeling of costs and benefits is highly related to the transmission range of the vehicle and in which sector they are located. Thus, for a vehicle having a transmission range R equal to 1000 meters and the number of sectors N_{sect} equal to 5, vehicles located in the most distant sector from the transmitter will have benefits equal to 1000. Vehicles located in the second most distant sector from the transmitter will have their benefits equal to 800 because it is the result of a proportional reduction in the size of the length of the sector. The same idea is applied to the second most distant sector from the transmitter and so on until the closest section to the transmitter. So, a vehicle will know its benefit B_i through the sector it is in relation to the transmitter. That is, it will know its benefit calculating (8).

$$B_i = ((N_{sect} \; - \; S_i) \; + 1) \; S_{len} \tag{8}$$

To avoid the likelihood that at least one vehicle transmits the received message be reduced to zero due to cost and benefit have very similar values, resulting in a cost benefit close to 1, this cost is modeled as a function of the least benefit. That benefit is provided by the closest sector from the transmitter. The cost obtained is considered the same for all sectors. Then, the cost C can be set following (9).

$$C = B_{min} \; q \tag{9}$$

where B_{min} is the lowest benefit provided by the nearest sector from the transmitter and $0 < q < 1$ is a reduction factor of the lowest benefit. For example, if the lowest benefit achieved B_{min} is equals 200 and the factor q is equal to 0.5, then the modeled cost for all sectors will be equal to $C = 200 * 0.5 = 100$. In this work, the value of M is modeled with zero. Fig. 2 illustrates a scenario in VANETs in which nodes in the network use the sector approach to model the costs and benefits of the Volunteers Dilemma game. The algorithm resulting from the proposed modeling Volunteer's Dilemma game is defined in Algorithm 1.

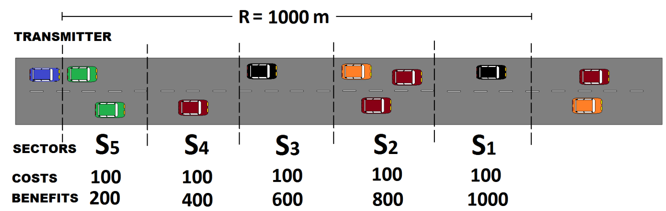

Figure. 2. Modeling of costs and benefits.

In: Packet received by broadcast
if *(The packet was received earlier)* **then**
  Discard packet;
else
  $S_{len} = R/N_{sect}$;
  $S_i = \lfloor (N_{sect} + 1) \; - \; (D_{tr}/r) \rfloor$;
  $B_i = ((N_{sect} \; - \; S_i) \; + 1) \; S_{len}$;
  $C = B_{min} \; q$;
  $\pi_v = B \; - \; C \; - \; \alpha(1 - p)C$;
  $\pi_n = B(1 - (1 - p)^{N-1}) \; + \; M(1 - p)^{N-1}$;
  $p = \frac{exp(\lambda \pi_v)}{exp(\lambda \pi_v) + exp(\lambda \pi_n)}$;
  n_{rand} = RAND(0, 1) ;
  if *($n_{rand} \leq p$)* **then**
    Forward packet;
Out: Transmission, or not, of packet received..

Algorithm 1: Proposed algorithm for broadcast forward.

In order to perform the calculations required for the probabilistic decision of retransmitting a packet received via broadcast, one vehicle must know some information of its neighbors. However, this decision is not made cooperatively but individually. Thus, a message exchange mechanism between neighbors becomes essential as a tool for the capture and dissemination of information in the neighborhood. For this reason, a management mobility mechanism was created as a separate module inspired by [23] and is also used by [20] in their work.

So, the game starts in each sector whenever a vehicle performs the spread of a packet via broadcast and vehicles located within sectors limited by the transmission range must make the decision to retransmit information for the other vehicles in the network or not. The game ends when all vehicles have taken their decisions.

Thus, the algorithm is applied when a vehicle in a sector receives a packet as input. If a packet is identified as received then it is discarded. Otherwise, if it was received for the first time, then the receiver vehicle uses the information as the basis of its neighborhood table to calculate the values of the expected payoff of volunteer π_v and of not volunteering π_n to be applied in the formula of probability p. The number of players in a sector is obtained using the mobility management module. Considering the parameters λ and α estimated [22], involving the game parameters, the vehicle transmits the packet with probability p.

V. RESULTS

The experiment of this work is a freeway scenario with two lanes where vehicles move with constant speeds in the same direction. (topology similar to Fig. 3). The transmitter vehicle is sending packets every second in the simulation time. When the receiver receives a message from the source message vehicle or coming from a relay, the implemented algorithm runs and decision to forward the message is taken.

Each vehicle has a transmission range of approximately one kilometer following the Nakagami propagation model, the radius is divided into five sectors and therefore the size of each sector is 200 meters. Thus, in order to evaluate the performance of probabilistic techniques in more realistic scenarios in which network connectivity depends on the distance between the vehicles, a modeling was performed where the inter vehicle spacing was exponentially distributed. All experiments were done using the NS3 [24] to evaluate the game performance in the network. The simulations were performed with the following vehicular densities: 10 (vehicles/km), 15 (vehicles/km), 30 (vehicles/km), 45 (vehicles/km) and 60 (vehicles/km).

The simulation parameter values were chosen according to levels of vehicular traffic (light, moderate and heavy) [7] and also induces behavior as the probability of a vehicle forward data, since the amount of vehicles in a sector and the cost-benefit determine these probabilities [21] [22]. The parameters were heavily influenced by the works of [7] and [20]. All simulation results were obtained with confidence level equal to 0.95 for the confidence interval of each of the averages of data obtained through measurements presented below.

For the result analysis, the probabilistic technique based on Nash equilibrium of the symmetric game based on the volunteers dilemma simply Nash Equilibrium [21], was call. This technique is similar to [20], as shown in Section 3. In addition, the technique based on the probabilistic balance QRE, also from the same game, called the QRE equilibrium [22].

Another observation to be made concerns the forwarding probability for each routing technique. Fig. 3 shows the behavior of the probability of retransmission in each sector to the Nash equilibrium and each density discussed previously. Eg vehicular density equals to 10 vehicles/km corresponds to the same vehicular density of 2 vehicles/sector since the radius is partitioned into 5 sectors and each sector has 200 meters. Similarly, Fig. 4 shows the behavior of the probability of retransmission in each sector for QRE equilibrium.

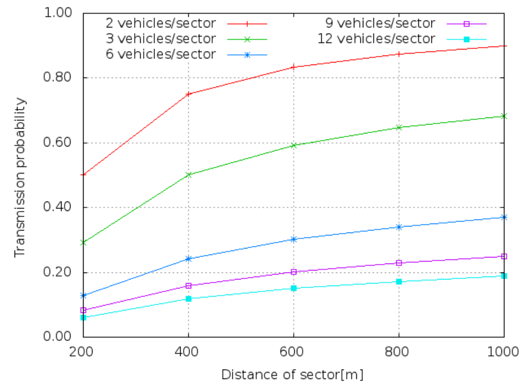

Figure. 3. Probability of retransmission of packets in each sector to Nash equilibrium.

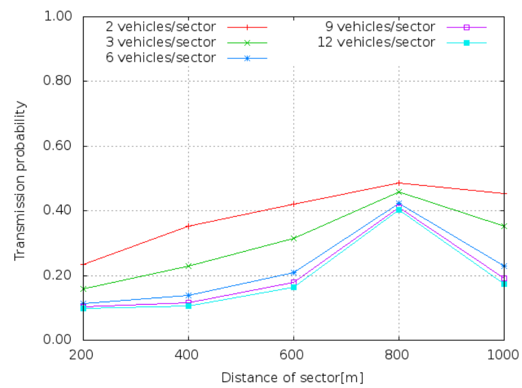

Figure. 4. Probability of retransmission of packets in each sector to QRE equilibrium.

Standard packet delivery rate: The expected analysis of this metric concerning both techniques is that the delivery rate increases as the vehicular density also increases. That is exactly what happens in the graphs shown in Fig. 5. In high vehicles densities, the ones which are located closer to the transmitter have a great chance to receive the data transmitted.

The graphs also show that the Nash equilibrium has a packet delivery rate greater than QRE equilibrium for lighter and moderate vehicular traffic. This is explained by the fact that the probability of routing in the Nash equilibrium is relatively high for small groups, thus more retransmissions are performed. However, when the number of players increases, the probability of volunteer decreases considerably. In the QRE equilibrium, the probability behavior of volunteering does not decrease a lot compared to the Nash equilibrium. Thus, for large groups, the probability of forward in the QRE equilibrium becomes higher than in the Nash equilibrium and therefore a larger amount of packets will be sent and received successfully.

Standard packet loss rate: In Fig. 6, the graphs show that the QRE equilibrium performance was worse than the Nash equilibrium in the first three densities. This happens because the probability of forwarding in the Nash Equilibrium is greater than the equilibrium QRE. It can also be noted that

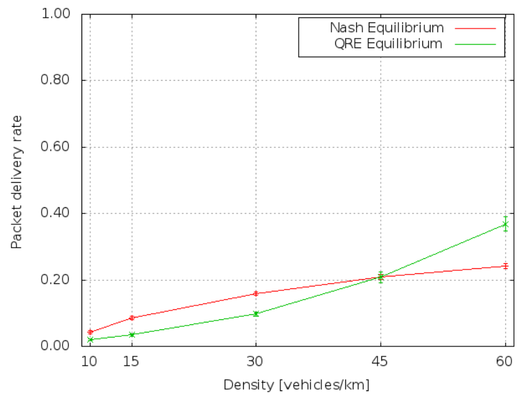

Figure. 5. Standard rate packet delivery.

the further away from the transmitter, the signal information becomes weaker, getting to a point in which the network device will no longer be able to receive the message. In larger networks, there is a greater tendency for this to happen and thus resulting in a higher packet loss. Another factor that influences the rate of packet loss is the amount of collisions during the broadcast storm.

With vehicular density equal to 45 vehicles/km, both techniques presented performances quite similar. But in a heavy vehicles traffic it can be noticed a reversal in performance techniques. As previously explained and reassured in the results from the rate of delivered packets, the probability of routing in QRE equilibrium remains higher than the Nash Equilibrium groups with lots of players. Thus, the packet transmitted by the source message vehicle has a great chance to reach the destination and few packets are lost in the network.

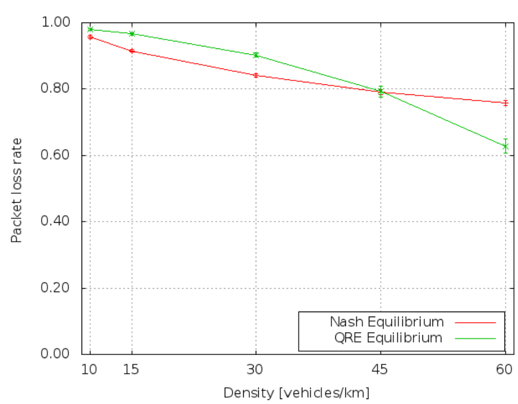

Figure. 6. Standard packet loss rate.

Number of duplicate packets: The greater the number of message retransmissions in the network it is expected a greater number of duplicate messages. The graphs in Fig. 7 shows the results obtained from both techniques to prove this fact. As we can see, the Nash equilibrium got better results than the QRE equilibrium in the following densities: 10 vehicles/km, 15 vehicles/km and 30 vehicles/km.

With a density of 45 vehicles/km there was a slight difference in the techniques performance where it was from there that the QRE equilibrium proved to be the worst. It may be noted that for the higher density, the number of duplicated packets in QRE equilibrium was slightly more than twice than at the Nash Equilibrium. A greater difference in the values shown from that point is justified because the vehicles are closer to each other. As the transmission range vehicle can cover a large number of neighboring vehicles any relay performed by any of these vehicles in high density networks will result in large amount of duplicate information.

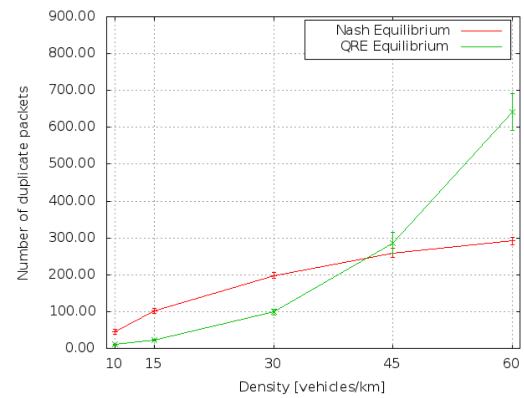

Figure. 7. Number of duplicate packets.

Link load: Finally, we have the average results from the load link shown in Fig. 8. These results strengthen what other metrics showed. The greater the amount of information transmitted by a given vehicle, the greater the amount of information received by receiver vehicles. The routing probability in both techniques also shows the same pattern.

In the lower densities of 10 vehicles/km, 15 vehicles/km and 30 vehicles/km the values were very small because losses may have happened. But this can be explained because the receiving vehicles are usually away from the transmitter vehicle and thus, for vehicles outside the range of the transmitter, the arrival of packets generated by the source depends on retransmissions carried out by vehicles within the transmission range.

Similarly to what happened with the other previous metrics, with density equal to 45 vehicles/km the performance of both techniques were very similar, mainly motivated by the behavior of their quite similar probabilities. And for the density of 60 vehicles/km QRE equilibrium keeps the routing probability greater than the Nash equilibrium and thus it gave a higher amount of transmissions and thus receptions. The analysis of the number of duplicated packets proves what was said and evaluated the load link results.

VI. CONCLUSION

In this work, a modeling of the game Volunteer's Dilemma was carried out, particularly the symmetric version, and this idea was based on Game Theory in a totally different environment, such as the vehicular networks. With the main objective

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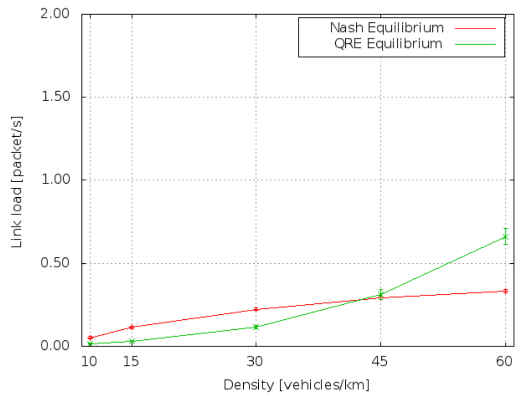

Figure. 8. Link load.

to mitigate the effect of broadcast storm in VANETs, a proposed probabilistic technique based on the QRE equilibrium was made.

From the results we can see the behavior and the characteristics involved in the game of volunteers dilemma. Particularly, we observed the effect of probability to volunteer in a Nash equilibrium stemmed from mixed strategies and the probability of volunteering in QRE equilibrium with additional parameter of aversion. As expected, the results strengthened the concepts in both equilibrium involved, since the parameters to setting the routing probability QRE equilibrium contribute to this probability decrease more slightly than in the Nash equilibrium.

The probability impact of a player volunteer using the probability stemmed from the QRE equilibrium provides some positive contributions. For example, when vehicular density is high, a delivery and loss rate becomes more satisfactory than in low densities. But a side effect in the same situation in a network with high vehicular density is that it can generate a higher rate of redundant information in the network.

Thus, the proposal in this work proved to be a very interesting and satisfying technique to spread information via broadcast in VANETs in order to mitigate the broadcast storm problem. In order to be a technique to be applied in a more robust dissemination protocol, some improvements can be made. A further study to reduce the packet loss rate caused by collisions can be made. In this sense, the use of timers can be inserted to prevent simultaneous transmissions. Another improvement that can be exploited is through modeling costs and benefits, verifying the ideal values in their modeling for each scenario. It is also possible to run some simulations with costs and benefits asymmetrically in order to prioritize vehicles further from the transmitter. Another way to prioritize vehicles can be made by exploiting the quality and strength of the signal coverage area of the transmitter vehicle. Thus, with this change, a greater amount of scenarios could be tested and compared with some protocols in literature in order to assess its efficiency and viability.

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