Abstract—A Vehicular Ad-hoc NETwork (VANET) is a special type of Mobile Ad-hoc Network designed to provide communications among On-Board Units (OBUs) in nearby vehicles, and between OBUs in vehicles and Road-Side Units (RSUs) that are fixed equipment located on the road. Data packets have to be relayed hop by hop from a given OBU to a RSU or another OBU and vice-versa. This means that the mobile stations must accept to forward information for the benefit of other stations. However, these benefits would vanish if the mobile stations did not properly cooperate and forward packets for other stations. In this paper, we address this problem and propose mechanisms that encourage collaboration in packet forwarding.

Keywords-component: cooperation, rational, authentication multi-hop, hybrid VANETs, forwarding, payment, lottery

I. INTRODUCTION

The main goal of VANETs is to improve safety, efficiency, and comfort in everyday road travel. VANETs use systems that increase passenger safety by exchanging warning messages between vehicles. These safety-related applications are important components of Intelligent Transportation Systems (ITS), but its structure allows taking advantage of other services such as access to Internet and commercial advices too. Nevertheless this would suppose an important cost for operators to deploy all necessary infrastructures because it would consist in increasing the coverage by adding antennas. However, there is no need for any expensive infrastructure if nodes cooperation is used, because in this case the number of fixed antennas can be reduced while the coverage of the network can be increased. So, their main advantage is that there is no need for expensive infrastructure, but their major drawback is the comparatively complex networking management system and security protocols that are required.

The resulting ad hoc network offers several benefits, but requires the mobile nodes to collaborate in forwarding packets as described for ad-hoc networks in [1]. It is reasonable to assume that each node has the goal to maximize its own benefit by enjoying network services and at the same time by minimizing its contribution. It is clear that a node must be encouraged in some way to relay information for the benefit of other nodes. Some authors have made first approaches to the topic of cooperation in VANETs [2] [3] [4] [5]. Related to the proposal here described, Buttyan and Hubaux proposed in [6] and [7] the use of virtual credit in incentive schemes to stimulate packet forwarding. Also, Li et al. discussed some unique characteristics of incentive schemes for VANETs in [8] and proposed a receipt counting reward scheme that focuses on the incentive for spraying. However, the receipt counting scheme proposed there has a serious overspending problem. Based on the specific characteristics of VANETs, a more comprehensive weighted rewarding method is proposed in [9].

In this paper we mainly focus on the design of packet forwarding enforcement schemes for Inter-Vehicle Communication (IVC). We propose a solution based on appropriate rewarding of nodes and lottery mechanisms depending on the different types of packets or traffic to be sent. This paper is organized as follows. We introduce our system model in Section II and detail our model and goal in Section III. In Section IV we analyze how our solution impact leader nodes. Finally, we present our conclusions and future work in Section V.

II. SYSTEM MODEL

A. Assumptions

We assume that all communication is packet-based and we consider three different types of packets:

- Road Safety Packets: This type of packets provides information about some impending situation. For instance detecting traffic jams beforehand in order to avoid them.
- Internet Packets: This type of packets provides access to Internet.
- Advertising Packets: This type of packets provides information and advertising about shops, restaurants etc. that can be found in the geographical area coverage of the node.

We call group [10] to a set of vehicles that are located in a close geographical area. The group has to have a minimum of vehicles and is controlled by a node called “leader of the group”. All vehicles forming part of a group have a direct wireless connection (one-hop) with the leader and a shared secret key. The leader election is discussed at [10] where the leader becomes the first node sending the group creation request.

B. Cooperation Tools

According to the packet information, we encourage nodes to forward traffic for other nodes by remunerating or punishing them. In case of traffic information, if nodes decide not to relay this type of packets they will be punished by paying a fine. It is an obligation to warn drivers of
hazards on the road. However Road Safety Packets are beyond the scope of this paper.

With Internet packets, when an initiator node A wants to communicate with Internet, it has to set up an end-to-end session with a RSU. In order to set up a session, node A generates a request message and broadcasts it. Each intermediate node in a group receiving the request, authenticate itself including a pseudonymous authentication [11] in the packet, and sends it to the leader of it group. The leader checks the traffic information, puts its pseudonymous authentication in the packet and looks for a forwarding node in the group. When the request arrives to the RSU, it returns a session setup reply and sends a session setup confirmation message towards node A. The session becomes active on the one hand for the RSU when it sends the confirmation messages and on the other hand for the vehicles when they receive a valid confirmation message. The goal of using pseudonymous authentication is to sign messages in order to the operator knows the identity of cooperative nodes and rewards them without the other relay nodes can discover it.

Dissemination of commercial advertisements via car-to-car communication is the third mentioned use of this type of network. In this case the provider sends out commercial ads, and nearby receiving vehicles start to disseminate them to other vehicles while they are moving by using leader groups. These ads are forwarded for a certain period of time and distance from source provider. Inspired by a micro-payment scheme [12], each payment for a forwarding service can be thought as a lottery ticket. Upon receiving it, both the payee and the winner node can determine whether it is a winning ticket or not. The payee will not only pay to the node with the winning ticket but also to the node that received the forwarded packet. This scheme permits providers to determine beforehand the amount of reward they offer, what is an advantage because otherwise it might have a serious overspending problem.

III. OUR MODEL

Our protocol uses two different schemes depending on the type of packets that are being relayed on. In both cases it uses the idea of groups that was introduced in section II where nodes driving at a similar speed in the same direction, join together in the same group. This idea of groups permits to reduce the number of packets in the network because the leader is in charge of making decisions about the packets that reach its group. This prevents from having multiple retransmissions of the same packet. Now we analyze in detail how our model behaves for the two types of studied packets:

A. Internet Packets

We assume that this service has been contracted in advance with an Internet operator. Consequently, we assume that there is some user who has contracted a service, an operator that offers this service and a set of groups of vehicles that carry out the connection between the source and the destination. Nodes responsible for packets retransmission might decide not to transmit Internet packets. In this situation the operator must use some cooperation mechanism in order to provide the service to their customers. In this paper, we propose that the payment is a valuable resource for nodes, such as for example petrol. In order to obtain this valuable resource that is petrol, the nodes will be motivated to cooperate. Each intermediate node should be encouraged to retransmit those packets that allow the connection between the clients and the operator. The cost of this retransmission should be covered by the operator to which the user pays for this service. In order to perform this connection there are two different types of packets, those responsible for establishing the session between client and operator, and the individual data packets:

**Establishing session Packets:** As we have seen in section II, when a node A wants to connect to Internet, it has to find a route to a RSU that provides this service. When the node has no direct connection with a RSU, it will have to find a route through one or more groups of vehicles. Inside each group, the packet may arrive through any node belonging to the group, who it will relay to the group leader. The leader will establish a route from its group to the RSU by using some node from its group. The group leader has knowledge of the group structure, so it can determine the node inside the group that must send this packet to reach a base station or another group closer to the next hop towards the destination.

**Data Packets:** Once the connection is established, data packets are retransmitted without having to go through the leader node. In this way, the leader will not have to receive all these data packets and can focus on its actions as leader. The operator must distinguish between session packets and data packets because the number of data packets is much larger. Therefore, it may not be profitable for the operator to pay an amount that depends on the number of necessary packets. To solve this problem we propose that the nodes retransmitting data packets must be paid a reward $r$ significantly less than one $(0 < r << 1)$ for every transmitted packet. A node can estimate the number of data packets that can relay before losing the connection with a base station or another group of nodes. Call $n$ to this number of packets and $r$ to the reward for broadcasting each one of these packets. Therefore in a basic scheme such a node would obtain as total reward $T$:

$$T = r n$$

The operator will know who has broadcast packets because as we explained in Section II, the packets are signed by pseudonyms.

On the other hand, the number of establishing session packets is less than the number of data packets, but the reward should be the same. It is impossible to connect the source and the destination node without establishing a session. Therefore, the reward for establishing session packets for leader nodes should be a value $T_L$ greater than $r$ ($T_L > r$). In section IV we will explain in detail the value of $T_L$ and how it affects the group leaders.
B. Ads Packets

For this type of packets the ad provider sends out commercial ads and sends them to all vehicles that are in its scope. In this case the number of generated packets is relatively higher than Internet packets because the aim of such packets is to provide advertising to as many vehicles as possible. Although the number of generated packets is larger than with Internet packets, thanks to the idea of groups, the leader manages to relay them in an orderly manner. The leader will receive the packet and will be responsible for broadcasting it within its group. The result is that no nodes will receive the same packet many times from its neighbors because if a leader receives a packet that had previously received, it will not relay it again to its group. Moreover, the leader will seek a route within its group to a neighbor group through one of the members of its group nodes. Hence it achieves in reducing both the number of retransmissions between groups and the number of retransmissions inside the group.

Our model proposes a kind of lottery in which each node will have a probability $\text{Prob}$ of being winner. We denote by $V$ the current node, $V_{i}$ the child nodes to that $V$ broadcasts the ads packet, and $\text{rec}_{V_{i}}$ the receipts that the children nodes $V_{i}$ send to $V$. Each ad $Q$ provider generates a packet $P_{O}$. The packet contains a unique identifier PackID, the ad information and a hash code $C$ computed randomly with a certain size. We denote the concatenation operator by $\mid$:

$$P_{O} = [\text{PackID} \mid \text{AdInformation} \mid C]$$

When a node $V$ receives the packet, it checks the information. If $V$ decides to participate in the forwarding, it sends the message to other nodes and waits for $\text{rec}_{V_{i}}$. Then the node $V$ computes for each child node $\text{rec}_{V_{i}}$ a hash on PackID, $\text{NodeID}_{V}$ and $\text{rec}_{V_{i}}$, and checks the result against $C$.

$$\text{hash (PackID |NodeID}_{V}\text{|rec}_{V_{i}}) = C \quad (2)$$

If the equality (2) fulfills in one of these verifications, then the node $V$ is a winner. We denote by $\text{Prob}_{b}$ the probability that a hash on PackID concatenated with $\text{NodeID}_{V}$ and the receipts $\text{rec}_{V_{i}}$ that child nodes send to a relaying node collides with a value $C$.

$$\text{Prob}_{b}(V) = \text{Prob} [\text{hash (PackID |nodeID}_{V}\text{|rec}_{V_{i}}) = C] \quad (3)$$

It is assumed that a node can receive only one reward, the probability of a relaying node winning a prize $\text{Prob}_{r}$ in forwarding packets to $N_{i}$ nodes, where it received the packet from a number of nodes $N_{j}$, could be defined as:

$$\text{Prob}_{r}(V) = (N_{c} + N_{f}) \cdot \text{Prob}_{b} \quad (4)$$

As we explained above and showed in (2) a node can get a reward if it computes the hash of the packet with the receipts from some of its children and gets a winning code. Furthermore a node can also get a reward if it sends the winner receipt to it father. This last case is represented by $N_{f}$ in (4). Therefore a node can transmit packets or receipts to get an award. Hence, the greater the number of retransmissions is, the greater probability of winning. In this way nodes are motivated to cooperate. Moreover, this mechanism will motivate child nodes to send the receipts to node $V$. Then, as we explained previously, if the father earns a reward with its child recipient, the father will make its child receives a share of the total reward.

However, if we analyze the probability function in (4), we find that when a node gets a winner receipt, it will not broadcast more packets since the previous function restricts a only one reward for winner. This behavior would not be desirable since the objective is to motivate relaying all packets. To solve this problem we reconsider the probability as follows, where we denote $V_{i}$ both the $N_{i}$ child nodes and the $N_{j}$ father nodes of $V$:

$$\text{Prob}_{h}(V) = \left( N_{c} + N_{f} \right) \cdot \text{Prob}_{b} - \sum_{i,j=1}^{N_{c}} \text{Prob}_{h}(V_{i} \cap V_{j}) + \sum_{i,j=1}^{N_{f}} \text{Prob}_{h}(V_{i} \cap V_{j} \cap V_{k}) - \ldots$$

In this case, a node can win the lottery for each packet it relays. So, nodes can win more than once with the same packet. On the other hand, nodes can also win the lottery by every receipt they return to their parent node. Similar to the previous case, nodes could win the lottery by one or more receipts. Hence, the problem that once a node wins the award, it ceases to retransmit the same packet is solved. Then if a node wins a prize, this does not mean that it cannot win another prize. An important aspect of using a hash function is that it may map two or more keys to the same hash value. It is called a collision. However, for the advertiser it is desirable to minimize the occurrence of such collisions. This means that the hash function must map the keys to the hash values as evenly as possible. However, the expression (5) can be considered equivalent to (4) if the hash function minimize the probability of collisions. So the advertiser should set this value and the reward to motivate nodes to participate in the broadcast, making it attractive enough.

IV. ANALYZING THE LEADER PROBLEM

It is not difficult to assume that no node wants to be leader because the number of packets they have to handle is greater than any other node belonging to the group. However, if we analyze the mechanisms used for the different types of packets we will conclude that in both cases being leader provides greater reward than being a single node in the group.

A. Internet Packets

As we discussed in section III when a session is established, the leader is in charge of finding the best route
among the nodes of its group and the base station. Once this connection is established, the leader node is not longer part of this communication. However, if the leader decides not to establish the connection session, the communication would be impossible. So, the total reward received by the leader L for broadcasting and calculating the best route for Internet packets will be \( T_L \). This reward is the same than the reward of being a relay node (1) even when the amount of packets broadcast by a leader for establishing an Internet connection is much smaller than any relay node of their group. Hence the leader will be motivated to cooperate and it will want to be leader.

**B. Ads Packets**

As we explained in section III this model is a lottery where the ad provider must commit to provide a fixed total reward \( T \). The vehicles that participate in the forwarding and receive a winner packet will get a share of the total reward. According to the group structure introduced in section II, a leader \( L \) will receive all ad packets in its group. Hence, it will have a bigger probability to receive a \( \text{rec}_v \) that produce a hash collision with \( C \), so that it could be a winner node. The probability of a leader \( L \) to win a prize \( \text{Prob}_L(L) \) in a group consisting of \( G \) nodes, which receive the packet from one node of the group, could be defined as:

\[
\text{Prob}_L(L) = G \cdot \text{Prob}_b
\]

(6)

In (6) it is include both what then leader can earn per receipt from their children \( (G-N_i) \) and from its \( N_i \) fathers. However, again the above formula implies that the leader can only win a prize per packet, which would not be correct. In that case, if the leader receives a winner receipt, it will broadcast no more packets to their neighboring nodes. To solve this problem again we should consider the probability of the union.

\[
\text{Prob}_L(L) = \text{Prob}_b \left( \bigcup_{i=1}^{G} V_i \right)
\]

(7)

Therefore, as we explained above, if the hash function minimizes the probability collisions, the expression (7) can be considered asymptotically equivalent to (6). It provides an incentive for leader to propagate ad packets, because the higher the number of retransmissions, the greater the probability of winning a reward. As leader, the packets are broadcast to all of member of its group, the model promotes that nodes prefer to be leaders, and consequently this mechanism motivates the nodes to become leaders and cooperate.

**V. CONCLUSION**

In this paper we present some ideas for security cooperation mechanisms and we consider two different cooperation tools. The basic objective of the proposed tools is ensuring communication by using incentive and payment schemes based on lottery and reward. These mechanisms foster cooperation for the packet forwarding service in vehicular ad hoc networks. We have designed metrics for contribution according to the characteristics of VANETs and to parameters that are important both for the source node and for enforcing cooperation among nodes.

Since this is a work in progress, many open questions exist such as the simulation of the new approach using Network Simulator NS2 on different scenarios and network conditions so that nodes will have different transmission ranges, like in the real world. Another open question is the analysis of how can data associated to traffic and weather conditions can be used in order to improve the efficiency of the proposal.

**VI. REFERENCES**


