Group Formation Through Cooperating Nodes in VANETs

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Abstract. Vehicular Ad Hoc Networks (VANETs) will play a vital role in the future road safety and comfort. The lack of centralized infrastructure and high node mobility and number of vehicles generate problems such as interrupting connections, difficult routing, security of communications and scalability. Groups are here proposed as a solution to avoid data collisions by decreasing the number of connections exchanged among vehicles. To reach this goal, nodes should cooperate with each other. They should form groups or join a group depending on their state. This paper provides a global vision of the life cycle of cooperative nodes that form groups and a description of how to deal with the information within a group. Simulation results show that the proposed scheme reduces the number of communications, avoiding data loss due to collisions.

Key words: cooperation, group, simulation.

1 Introduction

Cooperation between nodes is essential to create a communication network that would help to prevent accidents and to avoid traffic jams, which would save time, money, environment contamination and consumption of fuel reserves. The topology of the roads tends to create traffic jams, which produce the so-called hidden station problem that causes data loss due to collisions. The often used RTS/CTS mechanism is no longer feasible in road scenarios. In addition to this, reliability and not-delay are crucial for the efficiency of warning systems. Analyses show that the throughput of the WLAN broadcast scheme degrades rapidly with an increasing number of nodes. The use of groups allows optimizing communication in dense traffic situations.

Several general characteristics can be considered in wireless networks: authenticity, privacy, anonymity, cooperation, low delay, stability of communications, scalability, etc. [1] [3]. There are a few bibliographic references that propose the use of groups in VANETs. [2] describes clusters where the leader is the node in

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the middle with the lowest identifier. To maximize the advance of the relayed information and to avoid interferences [4] proposes clusters. None of these works define in detail the total life cycle of groups and present no reliable results that demonstrate the behavior of groups, which is the main objective of this work.

2 Group Stages

We distinguish among several stages in group management, corresponding to different situations of vehicles, depending on the route and on their status in each moment. The stages are: Detection, Election, Creation, Membership and Life of a group. There are a large number of highly volatile connections between vehicles in VANETs. For this reason it is necessary to define in detail the way in which vehicles must cooperate. The total life cycle of groups proposed in this paper is as follows. Initially all cooperating nodes start in the Group Detection stage. After this, each node can enter the Creation or the Election stage, depending on the circumstances. After Group Creation, one node will be the group leader, while after Group Election, the node would proceed to Group Membership stage.

Group Detection: This stage starts when the vehicle does not belong to any group. The node checks the number of neighbors and the number of leaders among them from time to time. If there is at least one neighbor that is leader of a group, the node proceeds to the Election stage, otherwise to the Creation stage. This stage does not generate any traffic of control due to the fact that all the necessary information is contained in the generated beacons.

Group Election: This stage starts when the vehicle has found, among its neighbors, at least one node that is leader of some group. If there is only one neighbor that is a group leader, the choice is automatic. Otherwise, if there are several leaders, the vehicle has to choose one of them to join it. $groupValue$ is a value that denotes a quantity used for the choice and $groupLeader(j)$ represents the j-th neighbor of the node that is leader of a group. If there are several leaders among its neighbors, the vehicle chooses one according to the $groupValue$ that depends on *Density* $A(j)$ of vehicles, *average quality of signal* $B(j)$ within the vehicles and *Time* $C(j)$ during which it has been *connected* to the leader. The analysis of simulations has determined that 8 is the best value for threshold of group formation, when there are 20 nodes in a close area, the number of lost packets grows up fast. The quality of signal in 100 meters is over 7/10. The time connected to the leader depends on the kind of road where the vehicle circulates. In simulations we used highways with 3 lines for each direction.

Group Creation: In this stage the vehicle is not close to any leader. It should check whether within their neighbors there are at least X nodes that do not belong to any group, plus a variable Y that indicates the number of vehicles that can turn off, separate or not join the new group that is being created. If the number of neighbors without group is lower than the minimum threshold required for group creation, the vehicle waits a period $time1$ and starts the Group Detection stage. Otherwise, if the number of neighbors is greater than the threshold $X+Y$, the vehicle begins a new Group Creation process. In order to do it, it multicasts a group creation request towards all neighbors with distance equal to 1. Nodes that receive this request respond accepting or rejecting the invitation. If the number of neighbors that accept the invitation is greater than the minimum threshold X, the new group leader sends to each node the secret key of the group encrypted with the public keys of each node. In this moment the new group is formed. Otherwise, the number Y of estimated vehicles is increased by adding the number of vehicles that did not accept the invitation.

Group Membership: Once the group is formed, the leader must periodically validate that the group continues being useful. Otherwise, it would be necessary to change the leader or to end the group. When the node loses any contact with the leader of the group for certain time, the node stops to belong to its group and begins the Group Detection stage.

Group Life: The leader of a group periodically checks that the group is still useful. If group size falls below a certain threshold, the leader checks whether it has a number of neighbors greater or equal to D (group formation threshold) and waits for $time2$ instead of ending the group in order to avoid introducing group management traffic when the vehicle is in a dense traffic situation. If the leader is not in a dense traffic situation, it begins a leader change or a group ending process. First, the leader asks about the neighborhood density in order to know if the number of neighbors of the same group or without any group near is bigger than X. It also finds out which of its neighbors has more neighbors. After this, it sends a leader change signal to all its neighbors. The new leader will begin a Group Creation stage. In the absence of any neighbor exceeding the threshold, the leader sends a multicast group ending signal to all its neighbors.

3 Simulation Analysis

In order to make a comparative study, NS-2 simulations of node cooperation network that and without groups formation using the same topology has been implemented. The parameters used for the simulation of the shown results are the following: Total number of vehicles: 80, number of vehicles with OBUs: 80, number of lanes for each direction: 3 and 3, simulation time: 100 seconds, moment when retransmissions begins: 40 seconds, retransmission period: 10 seconds, distance relay nodes: 75 meters, routing protocol: DSDV, distance traveled before the traffic jam happens: 800 meters.

Thanks to the analysis of the output files of the NS-2 simulations, we can obtain information about the number of packets generated or lost in the whole network, the number of formed groups, which nodes are the leaders of the groups, which nodes generate packets and which nodes forward them, etc. A complete comparative study among the models was done. Fig. 1 show measures obtained respectively in networks with groups and without them. The conclusion we got is that the number of generated packages is always inferior when groups are used, what shows that groups and cooperation imply an improvement of the original schemes without groups. Therefore, cooperation and group tools, suppose a

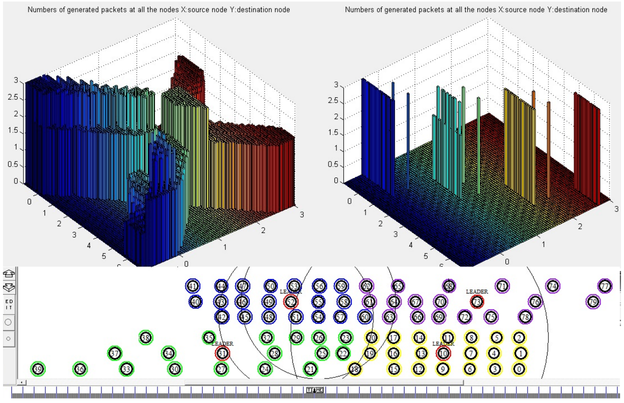

Fig. 1. Number of generated packets

useful defence for the problem of overhead and collisions that can present the network during the node lifetime.

4 Conclusions

In this paper the use of cooperating nodes which form groups has been proposed as a solution to decrease the number of communications in VANETs under dense traffic conditions when the overhead of transmitted data causes a considerable drop in communication quality. In particular, a complete description of the total life cycle for group management in VANETs is provided, which includes differentiation among possible vehicle states: from the initial state when it does not belong to any group, to the choice of an existent group to join it, the creation of a new group, and the end of a group. This paper also shows how to proceed with group communications. A complete analysis has been done through simulations using the open source traffic simulator SUMO and network simulator NS-2. Such simulations allow the analysis of the operations at each stage, of the reduction in communications, and of the optimal threshold values. A more detailed analysis of the schemes is not displayed for lack of space.

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