Applying Cooperation for Delay Tolerant Vehicular Networks

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Abstract—**This paper proposes a Cooperative ARQ protocol to be used in delay-tolerant vehicular networks. The proposed scheme has been implemented and evaluated through an experimental testbed, showing that packet losses in transmissions from an access point to cars can be reduced to the half without any cost as long as cooperation takes place on areas where connectivity with access points is not present. In these areas, cars in a platoon recover from other cars packets that they have failed to receive from the access point.**

***Index Terms*— Automatic repeat request, Cooperative systems, Network reliability, Delay Tolerant Networks, Vehicular Ad-hoc Networks.**

I. Introduction

Vehicular Ad-hoc NETworks (VANETs) are a particular case of MANETs in which nodes are vehicles that move following specific patterns (i.e. roads). Important application of VANETS are: *Transportation-related applications,* such as cooperative forward collision warning, extended electronic brake lights, road-condition warnings or alternative route warnings; and *Convenience and Personalized applications* including Internet access, hot-spots access, gaming, sharing files or P2P services.

VANETs support both car-to-car and car-to-road communication. In this paper we focus on delay-tolerant applications, in which cars download information from Access Points (APs) placed on the road. However we will use car-to-car communication in order to improve the performance of the information transfer.

VANETs are networks characterized by intermittent connectivity and rapid changes in their topology. In contrast with other ad-hoc networks, these networks also have a very specific mobility patterns. In the scenario considered, and due to the high nodes speed, vehicles accessing an AP have few seconds to download information in an environment with high losses. Measurements of UDP and TCP transmissions of vehicles in a highway passing in front of an AP moving at different speeds report losses on the order of 50-60% depending on the nominal sending rate and vehicle speed; see [1]. In ranges of around 250 meters, throughput reaches approximately 4Mb/s, while at larges distances (e.g. 400 meters) the throughput drops to around 1 Mb/s.

In this harsh environment, innovative communication techniques are needed. We believe that *cooperative techniques* (extensively studied for other kinds of wireless networks; see for instance [2], [3], [4] or [5]) can be beneficial in order to improve the performance of this type of networks and applications. The main objective of this paper is to test this hypothesis.

The main contributions of our work are the following: we propose a variation of the Cooperative ARQ (C-ARQ) scheme to be used in vehicular networks where cars download delay-tolerant information from APs on the road, suffering an intermittent connectivity. Cooperation among cars is established in the dark areas, where connectivity with the APs is lost. During the cooperation phase, cars exchange signaling and data packets, requesting the retransmission of lost frames to other cars in the platoon. To evaluate the proposal, we have built an experimental prototype based on IEEE 802.11 technology, which runs in a real urban environment.

The main outcome of our research is, firstly, that the proposed protocol can effectively reduce the packet losses of transmissions from access points to cars in a platoon. As a side result, we have found that the relative position of the cars can have a great impact on the opportunities for cooperation (i.e. if two cars are close enough while receiving data, they will have similar reception conditions, thus reducing the opportunities for cooperation). In any case, we have demonstrated, with a prototype that uses a very simple implementation of the mechanism, that an almost optimal performance can be achieved in the sense that, given the packet receptions on each car in the platoon, each car is able to recover all the packets it has lost from the access point from the other cars provided that they have them. The experimental results give promising improvements to take into account for future research on the field.

Note that an important conclusion that can be derived from these results is that the mechanism can effectively reduce the number of access points that a car needs to access for, for example, downloading a certain file. Moreover, this loss reduction can be used also to increase de transmission rate of the APs, while keeping a reasonably loss rate.

II. A Cooperative ARQ for Delay-Tolerant Vehicular Networks

In this section we introduce a novel Cooperative ARQ scheme that allows nodes of an 802.11-based delay-tolerant vehicular network to work cooperatively in order to increase the delivery rate of all of them in packets received from a fixed AP.

Consider Figure 1 in which vehicles want to download information from the Internet through APs distributed along a road. Due to the harsh conditions produced in VANETs, the losses produced in such environment are high. Reference [1] reports experiments on a highway in which vehicles passing in front of an AP moving at different speeds have losses on the order of 50-60% depending on the nominal sending rate and vehicle speed.

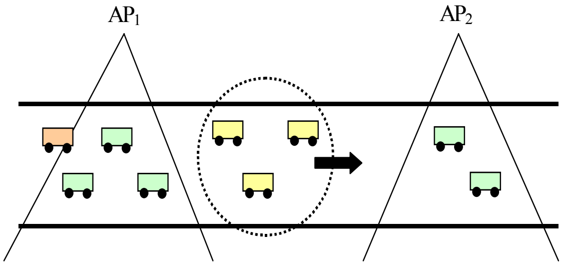

Figure 1. Network Scenario

We propose a scheme to decrease this high level of packet losses which uses the so-called *Cooperative ARQ* protocol. The proposed scheme should be provided with adequate signaling and mechanisms for association, authentication, data transmission and data retransmission request, etc. We will be mainly focused, however, on the aspect of the potential performance improvements.

We have not considered security issues and the association with the AP has been made very simple: the AP is continually transmitting numbered packets addressed to each car in the experiment and a vehicular node is considered associated with the AP in the moment it receives a packet from the AP (it enters into the coverage area). Note that in this case the AP has no knowledge about the association status of the cars, or whether they are or not on the coverage area, which simplifies the implementation greatly.

Nodes entering the coverage area of the AP will request information blocks to be downloaded and the AP will transmit them to the vehicular nodes. In our prototype, the exact request mechanism is not implemented, and this phase starts with the reception of the first packet from the AP and finishes when no packets have been received for a given time period (5 seconds in our case).

While in this phase, vehicular nodes receive data from the AP (that in our experiments is always transmitting data no matter whether cars are in the coverage area or not). Each car receives its data but also buffers the packets addressed to other cars in the platoon that consider it as cooperator. The cooperation relationship is established through the exchange of HELLO messages sent periodically by the vehicular nodes.

In the considered scenario, data flow is always from the AP to the vehicular nodes, and no retransmissions or acknowledgements are used. We avoid retransmissions, at the hope that other cars in the platoon (i.e. cooperators) will receive packets incorrectly received by the destination and will help it in the Cooperative-ARQ phase, without the need of wasting the useful time in coverage with the AP in retransmissions. In this way the channel can be used by the AP to transmit as much new data addressed to the cars as possible, thus reducing the downloading time and increasing the effective data rate.

When the cars leave the AP range, they enter into the Cooperative-ARQ phase. In our prototype this phase starts when the timeout from the last received packet from the AP expires (5 seconds in the current implementation). At this point, every node checks which packets it has failed to receive correctly from the AP (from the first it has received to the last) and starts to request them to other vehicular nodes (i.e. to its cooperators), in an attempt to recover all packets from the first to the last received from the AP.

III. CONCLUSIONS AND FURTHER WORK

This work has presented a novel mechanism to be used in delay-tolerant vehicular networks based on a *Cooperative ARQ* protocol. An important issue on these kinds of networks is that vehicles accessing an AP have few seconds to download in a harsh environment with high level of losses. The main objective of the proposed scheme is to reduce these packet losses.

We have built a real implementation and an experimental testbed in an urban scenario and have tested the performance of the proposed protocol. We have checked how the *Cooperative ARQ* protocol can effectively reduce the number of access points that a car needs to access for, for example, downloading a certain file.

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