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CISTER-TR-190616

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Abstract

Vehicular networks are a core component in Intelligent Transportation Systems (ITS) enabling communication among vehicles for collaborative applications. One example of such an application that may bring benefits in reducing travel time, fuel consumption and improving safety is platooning. This application coordinates a group of vehicles that travel together, doing automatic control of inter-distances and speeds [1]. A critical part of this application is the vehicle-to-vehicle (V2V) communication highlighting the importance of improving the channel quality. Existing ITS standards, namely WAVE (USA) and ITS-G5 (Europe), use IEEE 802.11p DSRC (Dedicated Short-Range Communication) [2] that relies on CSMA/CA distributed access arbitration. Despite the Collision Avoidance attribute collisions can still occur and the channel quality can degrade significantly in dense traffic environments.

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I. Introduction and related work

[1]Vehicular networks are a core component in Intelligent Transportation Systems (ITS) enabling communication among vehicles for collaborative applications. One example of such an application that may bring benefits in reducing travel time, fuel consumption and improving safety is platooning. This application coordinates a group of vehicles that travel together, doing automatic control of inter-distances and speeds [1]. A critical part of this application is the vehicle-to-vehicle (V2V) communication highlighting the importance of improving the channel quality. Existing ITS standards, namely WAVE (USA) and ITS-G5 (Europe), use IEEE 802.11p DSRC (Dedicated Short-Range Communication) [2] that relies on CSMA/CA distributed access arbitration. Despite the *Collision Avoidance* attribute collisions can still occur and the channel quality can degrade significantly in dense traffic environments.

The related literature includes several enhanced MAC protocols that were proposed for vehicular networks aiming at improving channel quality [3]. For applicability reasons we are interested in overlay protocols that can operate directly on top of IEEE 802.11p. And for the same reason we further confine our study to TDMA-based protocols that reorganize transmissions in time, in a more efficient manner than the original protocol does. In particular, we consider two works, that of Segata etal [4], which protocol we will refer to as *Plexe-slotted*, and that of Aslam etal [5] that proposed RA-TDMAp. Both protocols build on top of CSMA/CA and are tailored for platooning by considering the requirements of the formation control and the reliability of communications under different traffic conditions. Moreover, we use the original IEEE 802.11p as a base line, referred to as CSMA/CA. The three protocols are used transparently by the platooning application that is running on top. We use the Plexe platoon simulator [6] that runs on OMNeT++ to carry out our study. This work-in-progress report ends with a few words on the on-going work.

II. TDMA-based Overlay Protocols

According to the original IEEE802.11p protocol, every vehicle transmits a beacon, independently and periodically, e.g. every $100ms$, containing diverse information among which the vehicle position and kinematic sate that is used by the platooning application [1][6]. The CSMA/CA arbitration of the IEEE802.11p protocol does not require any synchronization among the vehicles, making the protocol very flexible to deploy and use. Potential collisions are reduced using carrier sensing and random back-off intervals. However, synchronizing the beacons of several vehicles allows avoiding or further reducing potential collisions, e.g., transmitting in order or in exclusive cyclic time slots, i.e., a TDMA fashion. Keeping the underlying CSMA/CA mechanism has the additional advantage of tolerating potential collisions that could arise due to disturbances in synchronization making the system more robust in general. Globally synchronizing transmissions of all vehicles is impossible thus, synchronization is normally done within groups of vehicles, only. The approach of the two following protocols is to synchronize transmissions within the platoons, only, keeping different platoons independent.

A. Plexe-slotted

This protocol, described in [4], divides the beacon period T_{tup} in N equal intervals, where N is the number of vehicles in the platoon. Then, the transmissions in the platoon take place in a cycle starting by the leader, which transmits with high power to reach all platoon members, followed by all the $N-1$ followers in order, separated by an interval of T_{tup}/N and transmitting with reduced power. The followers just reach the neighbor followers and propagate information down the platoon in a multi-hop fashion. The more vehicles in the platoon the more vehicles will be synchronized and the more effective will the collisions reduction be. Nevertheless, it is possible that other platoons or vehicles transmit with similar period and in phase, creating frequent collisions until clock drifts separate their transmissions in time.

B. RA-TDMAp

This protocol, described in [5], is rather similar to the previous one with two major differences. First, the transmissions cycle rotates in the other way, from the last vehicle to the leader, also with T_{tup}/N separation. This allows gathering information in the leader from all followers in just one cycle (one beacon period). Moreover, every cycle all nodes measure

[1]This work was partially funded by the Portuguese Government through FCT grant UID/EEA/50008/2013.

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delays affecting the transmissions of their neighbors, caused by the CSMA/CA mechanism or other sources, and report such delays to the leader that, in turn, delays the next cycle correspondingly. This allows the platoon to shift the phase of its cycle, avoid the periodic transmissions of other platoons or vehicles that caused the delays in the previous cycle.

III. Varying the Platoon Size

An initial comparison between these protocols was already presented in [5] but it was limited to platoons of fixed size. Here we will show further comparisons, namely how the protocols compare when the platoon size N varies from 2 to 16 vehicles. We consider two particular metrics that were proposed in [6], the rate of collisions and the ratio of medium accesses in which the medium was busy. We considered a fixed number of 16 platoons and we used a Cooperative Adaptive Cruise Control (CACC) platoon controller with a target inter-vehicle distance of $5m$. We used the PHY and MAC models of IEEE 802.11p with the simulation parameters in Table I. Then we ran the simulation for 30s of simulated time in the Plexe/ Veins/ Sumo/ OMNeT++ simulation framework [6].

TABLE I
PHY and MAC parameters

Parameter	Values
PHY/MAC model	IEEE 802.11p/1609.4 only (CCH)
Channel	5.89 GHz
Bitrate	6 Mbit/s
MSDU size	200B
Leader's Tx power	100mW
Follwer's Tx power	1mW

Figures 1 and 2 show 2^{nd} order fitting curves superimposed on the measurement points for the average rate of collisions and the average busy time ratio, respectively. We can see that Plexe-slotted performs close to CSMA/CA while RA-TDMAp shows a visible reduction in both metrics as the platoon size grows. This is a confirmation of the effectiveness of RA-TDMAp that allows platoons to escape from the interference of each other adjusting the phase of their cycles.

IV. Work-in-Progress

This work-in-progress paper showed preliminary results from a broader comparison between TDMA-based overlay MAC protocols for vehicular networks. More studies are in progress, namely addressing scenarios with constant number of vehicles but variable organization in platoons, variation of the referred metrics with vehicles density and speed and finally comparing with other related protocols such as token-based [7].

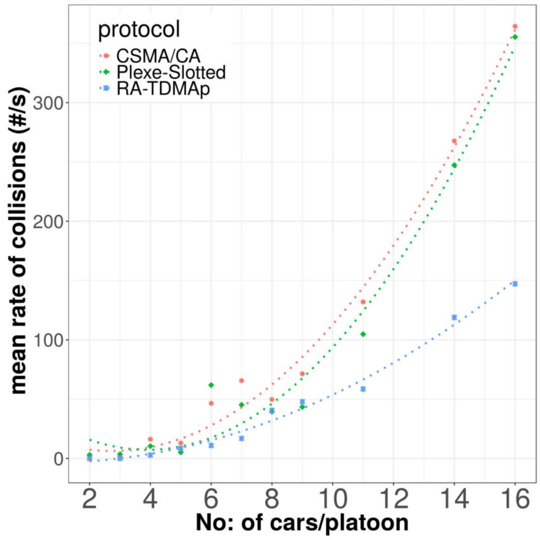

Fig. 1. Collisions for given scenarios, no: cars/platoon

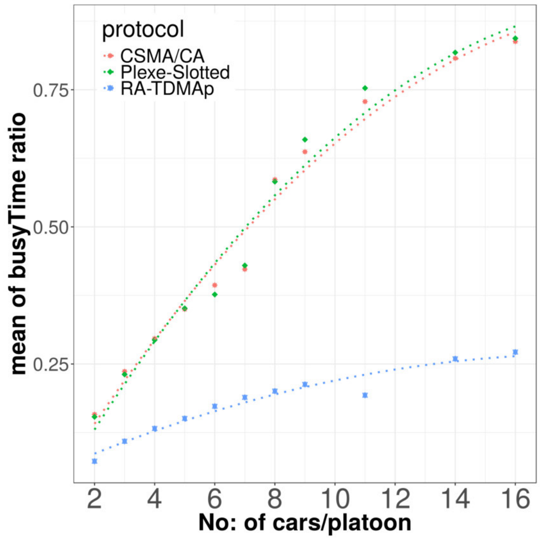

Fig. 2. Busy time ratio for given scenarios, no: cars/platoon

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