INTRODUCTION

Vehicular Ad hoc Networks (VANETs) play an important role in road safety by including vehicle cooperation and exchange of time-sensitive information, including location, speed, and acceleration, thus enhancing each vehicle awareness of its surroundings.

To make this paradigm a ubiquitous reality, IEEE has recently adopted the Dedicated Short-Range Communication (DSRC) radio technology under a new standard for vehicular networks, known as Wireless Access in Vehicular Environment (WAVE)/802.11p protocol (Jiang & Delgrossi, 2008). In fact, all vehicles in a near future are expected to incorporate the DSRC technology. Basically, DSRC (Kenney, 2011) operates at the 5.9 GHz band divided into seven 10 MHz channels (among which one channel, the control channel CCH, is reserved for system control and safety-related messages, and up to six channels, the service channels SCHs, are used to transmit non-safety data) with a 5 MHz guard band. DSRC utilizes the Orthogonal Frequency Division Multiplexing (OFDM) technique to support low latency wireless data communications among vehicles and between vehicles and infrastructure up to few hundred meters. Vehicles access the wireless medium using Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA or simply...
CSMA) together with the Enhanced Distribution Coordination Function (EDCF) to ensure Quality of Service (QoS) among emergency and routine safety messages. However, due to bad link qualities, transmission range degradation, and high collision probability in dense CSMA-based VANETs, the standard fails to ensure reliable and efficient broadcasting in those conditions, which is a requirement for safety-based applications.

Our objective in this work is to address these issues for the particular scenario of periodic safety-beacon transmissions within the CCH, with the use of techniques based on the Physical-Layer Network Coding (PNC) (Zhang, Liew, & Lam, 2006). More specifically, our goal is to provide fundamental elements of answer to the following questions:

• How to dynamically and efficiently schedule transmissions (in terms of time/bandwidth consumption) so that we approach the upper bound capacity of CSMA of possible transmissions within a time interval?
• How to take advantage of simultaneous transmissions (collisions) and relaying in PNC to improve the reliability and the packet reception rate (PRR) in VANETs?
• Given the mobility and the position of vehicles in the network, how to find a good (the best) relay at a given time so that the use of PNC is (quasi-) optimal, and the improvements targeted in the previous question are obtained?
• And, how to make cohabitation possible between the VPNC-based nodes and the CSMA-based nodes?

As a way to answer these questions, we propose a PNC-based MAC protocol for VANETs, which we refer to as the VPNC-MAC protocol or simply VPNC-MAC. VPNC-MAC is designed to operate under the WAVE standard, so that VPNC-MAC-based devices are compatible with WAVE-based devices. In addition, we define two priority modes in VPNC-MAC to facilitate the cohabitation between the CSMA nodes and the VPNC nodes while ensuring high PRR.

Our contribution in this paper is threefold:

• First, based on available position/speed information of nodes in a zone, we propose a simple technique where the node with the best coverage in terms of number of neighbours within the transmission range is chosen as the relay node for those nodes for a given time interval.
• Second, to efficiently schedule PNC-based transmissions while consuming as little as possible bandwidth during the setup phase, we incorporate in the VPNC-MAC setup phase a location-based Orthogonal Frequency Division Multiple Access (OFDMA) scheme.
• And finally, we make PNC transmissions effective in the VPNC-MAC session to ensure reliability and efficiency during the periodic safety-beacon exchange procedure. Furthermore, we define two priority modes to deal with the cohabitation of both the CSMA- based nodes and the VPNC-based nodes, and also with unpredictable events such as emergency broadcasts.

The remainder of the paper is organized as follows. The next section presents some related works. Then, the system model is described with the main assumptions considered in the section next. After, the VPNC-MAC protocol is detailed, and the theoretical analysis with some numerical results are developed in the sections that follow. Finally, the last section concludes this work while highlighting some future directions.

RELATED WORK

Reliable broadcasting is an important issue in VANETs. The probability of successful reception of a message by a receiver node strongly depends on many factors among which the presence of interferences in the communication range, the distance between the sender and the receiver, the quality of the communication links, and so on. For instance, for a given transmis-
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