Vehicular Wireless Media Network (VWMN) – A Distributed Broadband MAC for Inter-Vehicle Communications

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ABSTRACT
The allocation of 75MHz spectrum in the 5.9GHz band for Dedicate Short Range Communications (DSRC) in North America makes it possible to deliver high data rate multimedia applications via vehicle-to-roadside and even vehicle-to-vehicle wireless links. However, Medium Access Control (MAC) protocols mostly studied for DSRC systems are designed for safety relevant applications and insufficient for high data rate multimedia applications. In this work we propose a novel MAC solution, namely Vehicular Wireless Media Network (VWMN), based on a distributed beaconing scheme. The VWMN MAC is designed to support both time critical safety relevant applications and high data rate multimedia applications in Vehicular Ad hoc Networks (VANETs), especially with multiple channels and in multi-hop scenarios. The most challenging issues faced by Inter-Vehicle Communications (IVC), i.e. synchronization and dynamic topology control, are discussed as well based on the VWMN MAC with proposed solutions.

Categories and Subject Descriptors
C.2.1 [**Network Architecture and Design**]: *Wireless communication*

General Terms
Algorithm, Design, Performance, Reliability

Keywords
Ad-Hoc, Beaconing, Distributed, MAC, VANET

1. INTRODUCTION
Research on vehicular communication got a major boost since the allocation of 75MHz Intelligent Transport System (ITS) spectrum at 5.9GHz in the US. According to the standard, the available spectrum is divided into seven 10MHz channels used for control and services. The IEEE 802.11 based WLAN techniques are commonly accepted for Medium Access Control (MAC) and physical layers (PHYs) for vehicular communications. However, designed for the time and reliability critical applications, the IEEE 802.11 MAC and most of other MAC protocols being studied for vehicular communications are inefficient for high data rate media type applications in a high mobility vehicular environment. The sufficient bandwidth and growing demands on applications require more sophisticate MAC protocols for inter-vehicle communications.

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2. Requirements and challenges for VANET MAC protocol design
Both the safety relevant and the high-data rate media type applications should be supported efficiently by the MAC protocol, while the safety relevant applications are always serviced with the highest priority. Multi-channel and multi-hop operations are required for increasing the system spectrum efficiency and communication range. Comparing with asynchronous MAC protocols, a synchronized MAC scheme is more preferred regarding the channel access efficiency. Besides, the mobility conditions varying from a traffic jam scenario to a sparse traffic highway scenario challenge the network topology management, which should also be addressed during the MAC protocol design.

3. VWMN MAC description
Within the context of the WILLWARN (Wireless Local Danger Warning) application of the European Research project PREVENT [1], this work proposes a distributed, synchronized and reservation based VWMN MAC with support for both safety relevant and media type applications. To enable such a MAC protocol, a distributed beaconing scheme is employed for time synchronization, channel access coordination and network topology management.

3.1.1 Superframe structure
To enable the synchronized channel access and beaconing scheme, VWMN uses a synchronized superframe structure, which consists of a fixed number of equal length channel time slots. The whole superframe is further divided into two sub-periods, namely Beacon Period (BP) and Data Period (DP), for beacon transmission and data exchanging, respectively.

3.1.2 *Beaconing*

Every VWMN enabled vehicle station has to find a unique beacon slot to transmit its beacon in the BP of every superframe. It is also mandatory for every vehicle station to listen to the whole BP for the beacons from all its neighbors. Every beacon carries the information of MAC ID, GPS information, BP length, BP occupancy bit map and channel resource occupancy information in the current superframe.

Through the distributed beaconing scheme each vehicle station can learn the neighborhood topology, i.e., who are its neighbors and neighbors' neighbors, as well as the reserved channel usage situation of the current superframe, as shown in Figure 1. Besides, a beacon collision resolution scheme is employed for detecting and resolving the possible beacon collision.

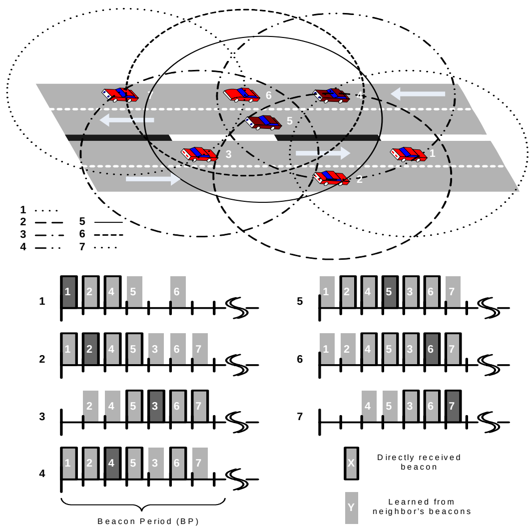

Figure 1. Using beaconing algorithm in a highway scenario with 7 vehicle stations and the beacon period structure of each station

3.1.3 *Channel access methods*

Based on the distributed beaconing scheme, two kinds of channel access methods are defined in VWMN MAC, namely Enhanced Distributed Channel Access (EDCA) and the reservation based Distributed Resource Reservation Protocol (DRRP), for contention based and contention-free channel accesses respectively. EDCA is exactly the same as in IEEE 802.11e standard, while DRRP uses the distributed beaconing scheme to make channel resource reservation based on the synchronized superframe structure [2]. In general, the contention based EDCA is suitable for the asynchronous ordinary traffic and the reservation based DRRP is designed for media type applications.

4. Performance analyses of the VWMN MAC

The proposed MAC protocol is efficient for supporting both the safety relevant and media type services. For safety relevant applications, the beacons can be used for disseminating the warning message within the neighborhood. Besides, special channel resources are reserved in the system wide for the safety relevant applications, in case the transmitter is temporarily involved in a beacon collision. Both methods can give the highest priority to the safety relevant application. For high data rate media type services, DRRP is able to provide efficient channel accesses, especially in multi-hop and multi-channel scenarios.

5. Challenges and proposed solutions

The most challenging issues, which have been foreseen for the proposed MAC protocol, are synchronization and topology control in a high mobility environment. For the synchronization problem, techniques like training sequence in OFDM can provide the link level synchronization; timing information carried by beacon frames can be used for synchronizing vehicles in an independent VANET; and to achieve synchronization among several independent VANETs the GPS clock information can be employed. The impact introduced by the mobility on the network topology is represented as the beacon collision probability in the proposed MAC protocol. To solve the problem, on the one hand, multiple beacon periods in one superframe are used to separate vehicles with high relative speed among each other. On the other hand, we can use the transmission power control to limit the number of vehicles in the radio range and consequently reduce the beacon collision probability.

6. Conclusion and Outlook

In this work, we present the distributed, synchronized and beaconing based VWMN MAC for inter-vehicle and vehicle-to-roadside communications. In addition to the time critical danger warning application, the VWMN MAC is able to support the high data rate media type applications, especially in multi-hop and multi-channel scenarios. Synchronization and dynamical topology control, as the most challenging problems for VANETs, are studied based on the VWMN MAC.

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8. REFERENCES

[1] PREVENT: Preventive and active safety; 6th Framework program integrated project http://www.prevent-ip.org/

[2] Hiertz, G. R., Zang, Y., Habetha, J. and Sirin, H. Multiband OFDM Alliance – The next generation of Wireless Personal Area Networks. *Proceedings of the IEEE Sarnoff Symposium 2005*, Princeton, New Jersey, U.S., Apr. 2005.