Chapter 4
PHY/MAC Layer Design in Vehicular Ad Hoc Networks: Challenges, Standard Approaches, and Alternative Solutions

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ABSTRACT

Peculiarities of the vehicular environment make the design of the Physical (PHY) and Medium Access Control (MAC) layers for Vehicular Ad-hoc Networks (VANETs) very challenging. Technical solutions should carefully cope with (i) quickly changing network topologies caused by vehicles mobility, (ii) short connection lifetimes, (iii) multi-hop vehicle-to-vehicle communications, (iv) hostile environments for radio signal propagation, and (v) heterogeneous nature and quality requirements of various types of applications. The main aim of this chapter is to serve as an introduction for readers interested in vehicular network design, with a special focus on the MAC layer. It includes a detailed description of the major features and operating principles provided by PHY and MAC layers of the IEEE 802.11p and IEEE 1609 standard suites to support Wireless Access in Vehicular Environments (WAVE). The last part of the chapter contains a brief survey of some relevant MAC proposals in the scientific literature that try to cope with the challenges of vehicular networks. Most of them follow the contention-based channel access idea of the standard and propose extensions to the 802.11p MAC layer in order to achieve higher throughput and fairness; others capitalize on a centralized access to achieve deterministic service quality.

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1. INTRODUCTION

In the last few years, vehicular ad hoc networks (VANETs), which provide connectivity among vehicles and between vehicles and the roadside infrastructure, have aroused the increasing interest of the research community (Huang, 2010), (Olariu & Weigle, 2009), (Watfa, 2010). The reasons of such an interest come from the fact that VANETs can be considered as a viable solution for improving road safety and transport efficiency, and also as an enabling technology to provide value-added services to travelers on the road.

Past and ongoing research projects, supported by car manufacturers and electronic industries, governments and academia, have obtained allocation of frequency spectrum and are specifying standards, designing applications, and running field trials for VANETs (Papadimitratos et al., 2009).

Based on their targets, potential applications for VANETs can be arranged into the following classes: on-the-road safety, transport efficiency, and information/entertainment (infotainment) applications (Hossain et al., 2010).

Safety-related applications distribute information about hazards and obstacles on the road with the primary aim of limiting the risk of car accidents and making the driving more efficient and safe (Biswas et al., 2006). Due to their critical nature, these applications have real-time constraints, with a maximum allowed latency of 100 ms (CAMP, 2005); they typically rely on one-hop broadcasting and multi-hop vehicle-to-vehicle (V2V) or vehicle-to-roadside (V2R) communications.

Transport efficiency is pursued by traffic management applications that focus on optimizing flows of vehicles to reduce the travel time and avoid traffic jam situations (e.g., enhanced route guidance/navigation, traffic light optimal scheduling, lane merging assistance), or they focus on vehicle monitoring and urban sensing (e.g., pollution, forensic). These applications, by making the transportation systems more efficient, are also environmental friendly. In fact, by optimizing routes, gas emission can be reduced and fuel consumption can be decreased. Transport efficiency applications do not have stringent delay requirements; their quality gracefully degrades with the increase in packet loss and delay; and they can rely on V2R or V2V communications.

Also referred to as non-safety applications, comfort applications aim to provide the road traveler with information support and entertainment that makes the journey more pleasant (e.g., audio-video streaming, data download, information advertisements). Most of these applications rely on V2R communications; they often exploit the presence of roadside units acting as gateways towards the Internet.

The successful, reliable and efficient delivery of the aforementioned set of applications strongly relies on the design of a medium access control (MAC) layer able to cope with the challenges of the vehicular environment and with the various kinds of service requirements.

The main challenges for an effective and efficient MAC layer design for VANETs are summarized in the following list.

• Heterogeneous applications. VANETs have their own set of applications, specifically designed for the road environment, which mainly differ for the quality of service (QoS) requirements. On the one hand, safety-related applications have obvious real-time and reliability constraints, e.g., collision warnings must be timely distributed among all potentially involved vehicles. On the other hand, comfort/entertainment applications exhibit very different requirements, from the no special delivery requirements of information support applications (e.g., point of interest advertisements, map download, parking payment, automatic tolling service) to the guaranteed quality needs of entertainment applications (e.g., media streaming, voice...
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