Computers and Electrical Engineering 000 (2017) 1–23

Contents lists available at ScienceDirect

Computers and Electrical Engineering

journal homepage: www.elsevier.com/locate/compeleceng

Survey of medium access control schemes for inter-vehicle communications☆

Nasser Torabi, Behrouz Shahgholi Ghahfarokhi*

Department of Information Technology Engineering, Faculty of Computer Engineering, University of Isfahan, Isfahan, Iran

ARTICLE INFO

Article history:
Received 7 June 2016
Revised 21 February 2017
Accepted 22 February 2017
Available online xxx

Keywords:
Vehicular Ad hoc Networks (VANETs)
Medium Access Control (MAC) schemes
Quality of Service (QoS)
Vehicle-to-Vehicle (V2V) communications
Inter-Vehicle Communications (IVC)

ABSTRACT

Currently, Vehicular Ad-hoc Networks (VANETs) are attracting a lot of attention due to their favorable applications. VANETs are the key to providing safety and efficiency on the roads. The vehicles can communicate with other vehicles to inform the ongoing status of the traffic flow or critical situations like accidents. However, this would entail a reliable and efficient Medium Access Control (MAC) protocol. Due to the high speed of the nodes, the frequent changes in network topology, and particularly the lack of an infrastructure, the design of the MAC for vehicular communications turns into a more challenging task. A lot of research works has been conducted to overwhelm the vehicular MAC problems regarding Quality of Service (QoS) requirements of both safety and non-safety applications covering both Vehicle-to-Infrastructure (V2I) and Vehicle-to-Vehicle (V2V) communications. Recently, a significant number of MAC schemes has been proposed for V2V communications. In this paper, for future studies to be more effective, the outstanding proposed V2V MAC schemes are intended to come under review. Moreover, V2V MAC design approaches are discussed and a qualitative comparison is provided. A novel classification of V2V MAC schemes is then presented, and the characteristics of these schemes along with their strengths and weaknesses are studied. Finally, a comparative summary is given and some open challenges regarding the design of V2V MAC schemes are discussed.

1. Introduction

Vehicular Ad hoc Networks (VANETs) are primarily designed to help improve safety on roads and management of traffic flow [1]. They can also be used to provide infotainment services such as Internet access, video streaming, social networking, etc. VANETs are a special type of Mobile Ad hoc Networks (MANETs) with their own specific characteristics such as frequently changing network topology, unstable links, variable density of vehicles, and the large scale network. Mobile nodes in VANETs or vehicles are characterized by their distinctive and unique features such as variety in type, high mobility, high speed, and road-constrained movements. VANETs, generally, consist of vehicles equipped with On-Board Units (OBUs) and stationary access points referred to as Road-Side Units (RSUs). The presence or absence of RSUs in vehicular communications builds up two distinguished types of communications namely Vehicle-to-Infrastructure (V2I) and Vehicle-to-Vehicle (V2V) communications, respectively. The latter is also known as Inter-Vehicle Communications (IVC).

Considering the natural characteristics of VANETs and concerning the differences between the wide range of safety and non-safety applications in term of QoS requirements, it is a vital characteristic for a MAC scheme to provide appropriate

☆ Reviews processed and recommended for publication to the Editor-in-Chief by Associate Editor Dr. M. H. Rehmani.

* Corresponding author.
E-mail addresses: n.torabi@eng.ui.ac.ir (N. Torabi), shahgholi@eng.ui.ac.ir (B.S. Ghahfarokhi).

http://dx.doi.org/10.1016/j.compeleceng.2017.02.022
0045-7906/

Please cite this article as: N. Torabi, B.S. Ghahfarokhi, Survey of medium access control schemes for inter-vehicle communications, Computers and Electrical Engineering (2017), http://dx.doi.org/10.1016/j.compeleceng.2017.02.022

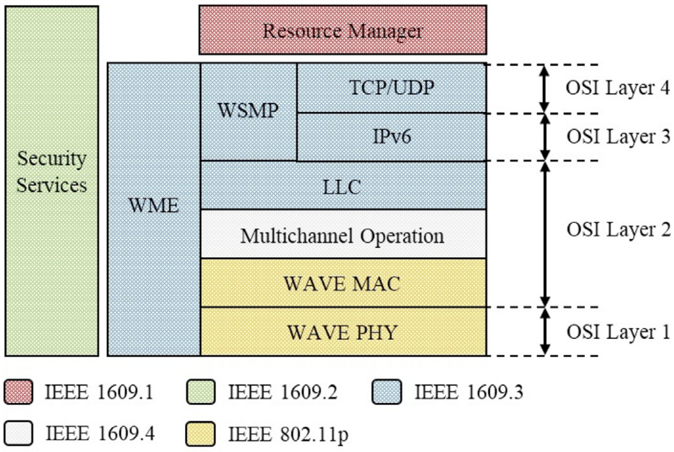

Fig. 1. The IEEE WAVE protocol stack and its comparison to OSI reference model.

levels of QoS for each type of applications. Therefore, the design of a fast, reliable, scalable, efficient and fair MAC protocol is a challenging issue. The MAC protocol should be fast enough to offer predictable access delay and should be sufficiently reliable against the instability of links. It needs to be flexible enough to share bandwidth between growing numbers of vehicles in a way that leads to fair channel access. Also, the MAC protocol should cope with channel access issues like the hidden node problem which strongly affects its efficiency.

On the other hand, given the advantages of employing V2V-based VANETs against V2I-based, discussed in [2], there is a great tendency among researchers for studying V2V MAC schemes. In the literature, there exist a plethora of MAC protocols that have been proposed to cover V2V communications [3–19]. Correspondingly, several papers have surveyed V2V MAC solutions.

In [1], authors go through multi-channel MAC protocols. They distinguish between channel coordination and channel allocation methods and discuss some issues and challenges. Authors in [20] survey MAC solutions that are not compatible with the IEEE 802.11p or the IEEE 1609.4 standards. The authors of [21] classify the MAC protocols for VANETs into three different categories: channel partitioning, random access, and taking turns. Although their categorization is straightforward, it does not cover all VANET-specific MAC schemes. A similar survey of MAC schemes for VANETs has been addressed in [22] where the authors categorize the protocols into three categories: time-based, DSRC-based, and directional antenna-based. However, their classification does not cover all types of MAC protocols. In [23,24], multi-channel MAC protocols have been surveyed. Authors in [25] go through a wide range of recently proposed Time Division Multiple Access (TDMA)-based MAC protocols for VANETs and divide them into three categories including protocols operating in a fully distributed manner, protocols operating on cluster-based topology, and protocols operating on centralized topology.

With respect to the aforementioned surveys, the main contribution of this out-of-the-box study is to present a novel inclusive classification of V2V MAC design strategies in an attempt to cover all types of design approaches. Moreover, the paper focuses on detailed characteristics of the recently proposed V2V MAC schemes and discusses their strengths and weaknesses. The paper is organized as follows. Section 2 provides a summarized background of MAC layer and its standardization in VANETs. Section 3 gives a classification of the V2V MAC design approaches. Section 4 reviews the details, advantages, and limitations of the recently proposed V2V MAC schemes. Section 5 presents a comparative summary of reviewed schemes. Section 6 discusses some open challenges focusing on drawbacks of the existing V2V MAC schemes. Finally, Section 7 concludes the paper.

2. Background

Following, we take a look at the standardization efforts in VANETs and then we review several QoS and security aspects in VANETs. In the last section, we briefly discuss the MAC schemes in ad-hoc networks.

2.1. Standardization efforts for VANETs

The standardization of VANETs is still under research and discussion. The IEEE in the US and the ETSI in EU are two main leaders supporting the VANETs standardization process, each with separate but fairly similar protocol architectures. The IEEE protocol stack which is known as WAVE is depicted in Fig. 1. The WAVE protocol stack includes a set of standards, including IEEE 1609.1/.2/.3/.4, and IEEE 802.11p, defining several functionalities similar to Open Systems Interconnection (OSI) model, but with some additional specifications and extensions. A management plane, termed as WAVE Management Entity (WME) is also superimposed to the data plane of WAVE suit to facilitate management services throughout the stack layers.