JWSN ***2016***, *4*, 1-0019

Journal of Wireless Sensor Networks
ISSN: 2001-6417
www.wsn-journal.com

Review

A Review of IEEE 802.11p (WAVE) Multi-Channel MAC Schemes

Mohammad Pasha[1,]* and Khaleel Ur Rahman Khan[2]
[1]ITD, MJCET; muhammed.pasha@gmail.com
[2] CSED, ACE; khleelrkhan@gmail.com

*****Author to whom correspondence should be addressed; E-Mail: muhammed.pasha@gmail.com;
Tel.: +919-700-464-925;

Received: 23rd May 2016 / Accepted: 27th August 2016/ Published: 28th August 2016

Abstract: In recent years governments, automobile manufacturers and academia are working together to develop vehicular ad hoc network (VANET) based communication technologies. In VANETs there are multiple channels i.e., control channel (CCH) and service channels (SCHS), to provide public road safety and other comforts while driving vehicle. Based on standard draft IEEE 802.11p and IEEE 1609.4, this paper presents a review of the various proposals for multichannel medium access control (MAC) schemes, which can dynamically adjust the length ratio between CCH and SCHs. Authors compare IEEE 802.11p with other similar fields to gain better knowledge of the subject. Finally, open issues and challenges are presented.

Keywords: IEEE 802.11p, IEEE 1609.4, Vehicular Ad Hoc Networks, Dedicated short range communication, Wireless access in vehicular environments, multi channel MAC;

1 Introduction

WAVE standardization process of IEEE 802.11p began from the allocation of the dedicated short range communications (DSRC) spectrum band in the United States In 1999, U.S. Federal communication commission allocated 75MHz of DSRC at 5.9GHz exclusively to be used for vehicle-to-vehicle and vehicle-to-infrastructure communications. The primary goal is to enable public safety applications that can save lives and improve traffic conditions. DSRC spectrum is structured into seven 10MHz channels in figure 1. Channel 178 is restricted to control channel (CCH) [1], which is used for safety applications. Two channels at the end are reserved for special use and the rest are service channels [1] available for both safety and non safety usage.

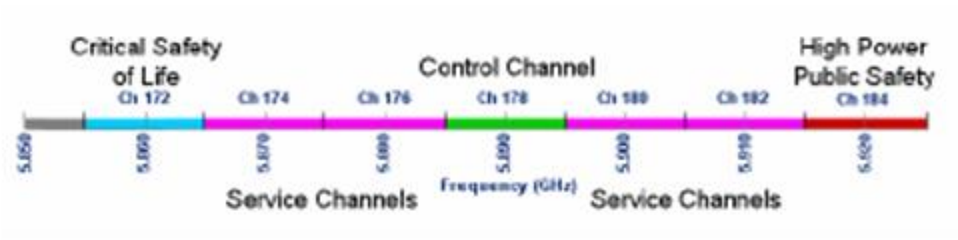

Figure 1. DSRC spectrum band and channels in the U.S. from [1]

Wireless Access in Vehicular Environment imposes a set of new requirements on the communications system that led to the introduction of the WAVE operating mode and of the WAVE BSS in IEEE 802.11p. While the IEEE 802.11p standardization process is moving closer to pass a letter ballot in the general IEEE 802.11 working group, there are also industry efforts in implementing and field testing such radios. Prototype IEEE 802.11p radios have been developed by the Vehicle Infrastructure Integration Consortium (VII-C) in 2007 both for on-board and roadside units. Likewise, interoperable radios are being built by the Crash Avoidance Metric Partnership (CAMP) for collision avoidance and vehicle-to-vehicle safety applications. It should be noted that while IEEE 802.11p describes how the communications take place over each individual channel of the DSRC spectrum, a complete communications system for WAVE needs to include support for multi -channel operations, security, and other upper layer operations. These are addressed by the IEEE 1609 trial-use standards, which are expected to be substantially updated in the near future.

1.1. DSRC multi channel approach

As shown in Figure 2, IEEE 1609.4 describes a concept of channel intervals in which time is divided into alternating Control Channel (CCH) and Service Channel (SCH) intervals. The general concept calls for each interval to be 50ms long. A pair of a CCH and SCH intervals forms a Sync interval. There are ten Sync intervals per second. This is motivated by a desire to map Sync intervals to the generally assumed 10Hz vehicle safety messaging rate. The start of a CCH interval is aligned with the start of a Coordinated Universal Time (UTC) second or multiples of 100ms thereafter.

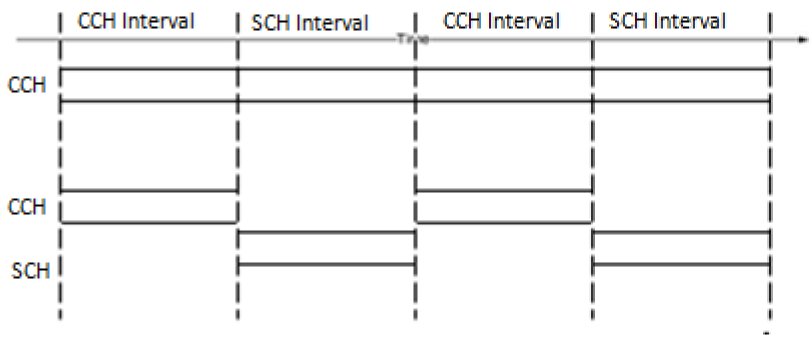

Figure 2. Channel intervals and continuous/alternating channel access from [3]

While this paper describes concerns from vehicle safety communications' point of view, Wang and Hassan examined the issue from the other direction and questioned what channel capacity could be left for non-safety applications [2]. Prior to the formulation of IEEE 1609.4 in its current form, there have been proposals of alternative approaches for DSRC multi-channel operations. Mak *et al.*

described a design in which a road side unit coordinates multi-channel operations for vehicles around its coverage. This proposed approach is still based on time division oriented channel switching. While IEEE 1609.4 is currently being updated and revised, this paper is intended to contribute to the technical discussions, and to bring attention to the most relevant and critical issues.

2. Performance analysis of MAC protocol with multiple channels

In multi channel MAC, 75MHz bandwidth at 5.850-5925GHz frequency band is divided into 10MHz frequency channels. One of the seven frequency channels is assigned as the control channel (CCH). CCH is a public channel for providing safety messages and exchanging control packets. The other six channels are service channels (SCHs), mainly assigned for non-safety applications such as infotainment or commercial applications to make ITS technology more cost effective. It is assumed that the standard of each OBU is equipped with single radio (i.e., wireless transceiver) and RSU is equipped with multi-radio. So that all vehicles can listen to safety packet, the channel time is divided into synchronization intervals (SI) with a fixed length of 100ms, consisting of a CCH interval (CCHI) and a SCH interval (SCHI) of default length equal to 50ms (see Figure 3). Radio can transmit packet over only one channel at a time, therefore, it has to continuously switch betAuthorsen CCH and SCHs every 50ms. In order not to miss safety packets during the CCHI, all OBUs' radio are tuned to the CCH and transmit/receive control packet, event-driven emergency packets and RFS packet. During SCHI, all OBUs are tuned their radio to their assigned SCH for non-safety communication. EDCA MAC protocols are recommended for CCH and SCH but no specific designs are mentioned in the standards.

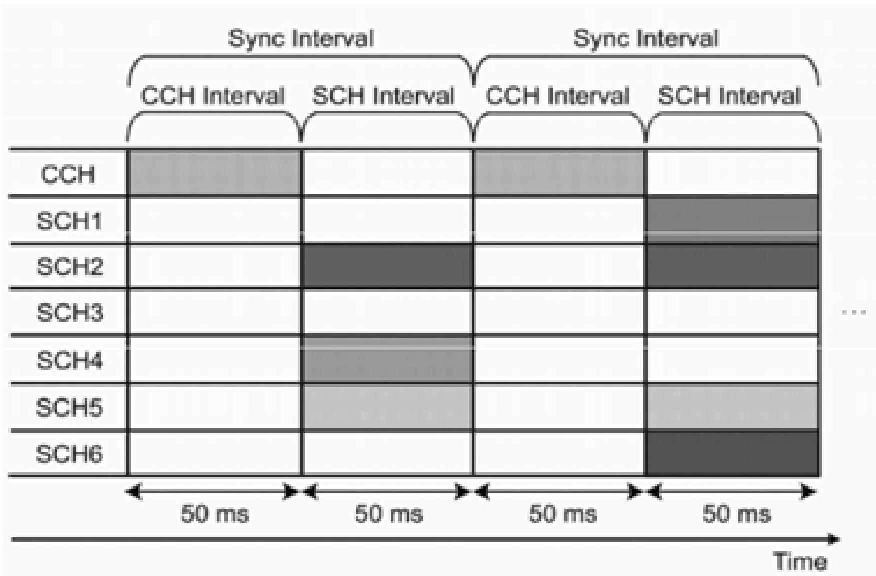

Figure 3. CCHI and SCHI from [2]

For Intelligent Transportation System (ITS), MAC protocol is proposed which is of multi-channel based on reservation by DCF on CCH for IEEE 802.11p/1609.4 WAVE, and give an novel analytic modeling of Authors proposed MAC and obtain the probability of successful delivery and HOL delay of RFS packet in terms of system parameters. Authors on-going research is on the analysis of MAC protocol in case that DCF is replaced by EDCA, which is more a realistic system.

3. Performance evaluation of IEEE 802.11p WAVE communication standard

The MAC layer of WAVE is equivalent to the IEEE 802.11e Enhanced Distributed Channel Access (EDCA) Quality of Service (QoS) extension [3]. Application messages are divided into different ACs, where AC0 has the lowest priority and AC3 the highest priority. Inside the MAC layer a packet queue exists for each AC. During the selection of a packet for transmission the four ACs content internally. The selected packet then contends for the channel externally using its required selected contention parameters. The contention parameters used for the CCH are shown in Table. 1. To calculate CWmin and CWmax the values aCWmin = 15 and aCWmax = 1023 are to be used.

	Queue-1	Queue-2	Queue-3	Queue-4
Priority	Highest	-	-	Lowest
AIFS	58 μs	58 μs	71 μs	123 μs
CWmin	3	7	15	15
CWmax	511	1023	1023	1023

Table 1. EDCA parameters for the CCH

In this work Authors have analyzed the capabilities of the standard, to give an overview of the capabilities and the limitations of the technology. The defined parameter set for the EDCA used in WAVE is capable of prioritizing messages, however, with increasing number of nodes sending AC3 especially, the collision probability increases significantly. Since collisions are detected *after* a transmission if at all, a high collision probability results in many dead times; times where the channel is blocked but no useful data is exchanged. Due to the continuous switching between CCH and SCH, which also use different packet queues, the collisions have an even worse impact. Messages for the CCH queue up further during the SCH intervals, resulting in longer queues and a higher end-to-end delay. Especially in dense scenarios or in case of filled MAC queues the technology can not ensure time critical message dissemination (e.g. collision warnings). Authors suggest integrating a re-evaluation mechanism for messages, similar to the concept presented in [10], to continuously reduce the number of high priority messages and prevent long message queues. In addition, the use of different EDCA parameters could mitigate the high collision probability.

4. Cognitive MAC protocol for multi channel wireless networks

The cognitive MAC (C-MAC) protocol is a distributed multi-channel wireless networks. C-MAC operates over multiple channels, and hence it is able to effectively deal with other available resources. One of the key concepts in C-MAC is the use of a dynamic and totally distributed RC which is used to support multicast and broadcast. Analytically, C-MAC has been evaluated through simulations and is implemented in a real hardware prototype. Performance results are favorable. Authors believe that C-MAC is a novel in many respects and opens up new research directions for MAC protocols in cognitive multi channel wireless networks.

5. A cooperative Scheme for Service Channel Reservation in IEEE 802.11p

The WAVE standard suggests that the WAVE management (WME) in each wireless station keeps track of SCHs which are in use by nearby WAVE devices. The objective is that, when it is called for a particular task, the wireless device can choose the least congested SCH for its WBSS setup. The standard does not specify how to select the SCH; it only suggests measuring the congestion level of SCHs by monitoring WSAs received on the CCH from providers. By doing so, a wireless node can potentially know about the status of the SCHs reserved by providers at one hop distance. CRaSCH (Cooperative Reservation of SCH), a gossip-based reservation mechanism relies on co-operation among nearby providers. WAVE providers, through properly modified WSA frames, exchange information about the *perceived* SCH reservation status, instead of only advertising their own SCH as suggested in the standard. Specifically, Authors propose two incremental approaches:

- *Proactive Gossiping:* every provider advertises in enhanced WSA frames about the information of its own SCH and the SCHs reserved by nearby providers whose WSAs have been heard.
- *Reactive Gossiping:* besides spreading out the perceived SCH status information every provider also explicitly reacts to a detected SCH-overlapping event (when hearing two or more providers reserving the same service channel) by sending a collision warning frame, which triggers the SCH change by one (or more) providers.

Thus, the proposed scheme targets vehicle-to-infrastructure and vehicle-to-vehicle communications, where nodes, either roadside or on-board units, acting as WAVE providers choose a service channel for their initialized WBSS.

6. A Dedicated Multi channel MAC Protocol (DMMAC)

DMMAC is specially used to provide collision-free and delay-bounded transmissions for safety applications under various traffic conditions. DMMAC is based on a hybrid channel access that exploits both the advantages of TDMA and CSMA. The essential part of this protocol is named as adaptive broadcasting. The two issues have not been addressed in most of the existing multi-channel MAC designs and all vehicles are equipped with a single half-duplex radio transceiver. DMMAC is similar to WAVE MAC and the channel access time is equally divided into Sync Intervals, and each Sync Interval consists of a CCH Interval (CCHI) and an SCH Interval (SCHI) of the same length. The CCHI is further divided into an (i.) Adaptive Broadcast Frame (ABF) which contain Basic Channel (BCH) for collision-free delivery of the safety message and number of time slots contained in the ABF is called the ABF Length (ABFL). (ii.) Contention-based Reservation Period (CRP) which uses CSMA as its channel access scheme and reserve the resources on SCHs for non-safety applications. The length of the CRP depends on the ABFL of the vehicle due to the fixed length of CCHI.

7. Novel MAC protocol

The proposed MAC protocol, VMESH is especially designed for single control channel and multiple service channels. Under unsaturated load conditions when traffic load is heavy VMESH protocol outperforms the WAVE protocol, this is one of the main advantage. VMESH is based on Wireless local danger warning (WILLWARN) application of European research PREVET [9]. In this protocol new attributes are introduced

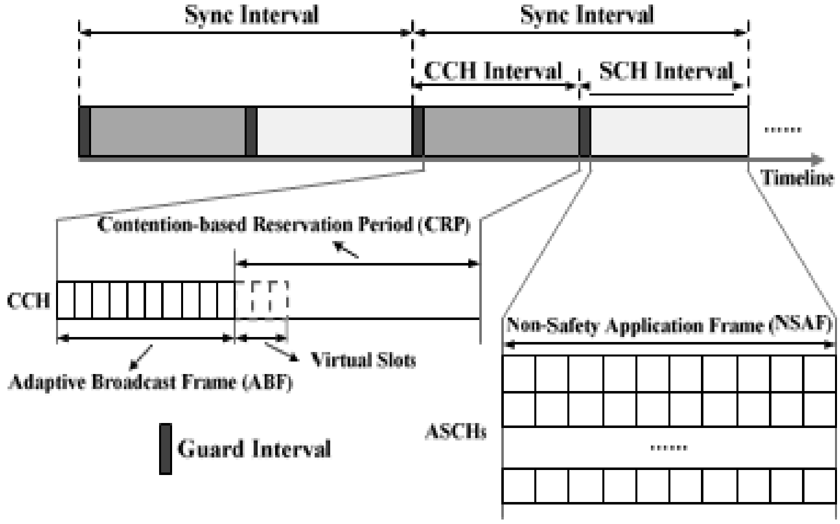

Figure 4. Architecture of DMMAC from [8]

i. VMESH super-frame: It contains multiple 1609 synchronization channels. The other form is the beginning of the each UTC and it has ten consecutive synchronization intervals (figure 5)

ii. CCH interval: CCH interval is divided into two parts, i.e., Beacon period (BP) and the safety period (SP). BP is designed for synchronized distributed beaconing protocol, in which each device uses a unique beacon in BP and is then transmitted in every CCH interval which is ruled by Reservation-ALOHA protocol. In SP, safety applications are reserved which uses enhanced distributed channel access rules.

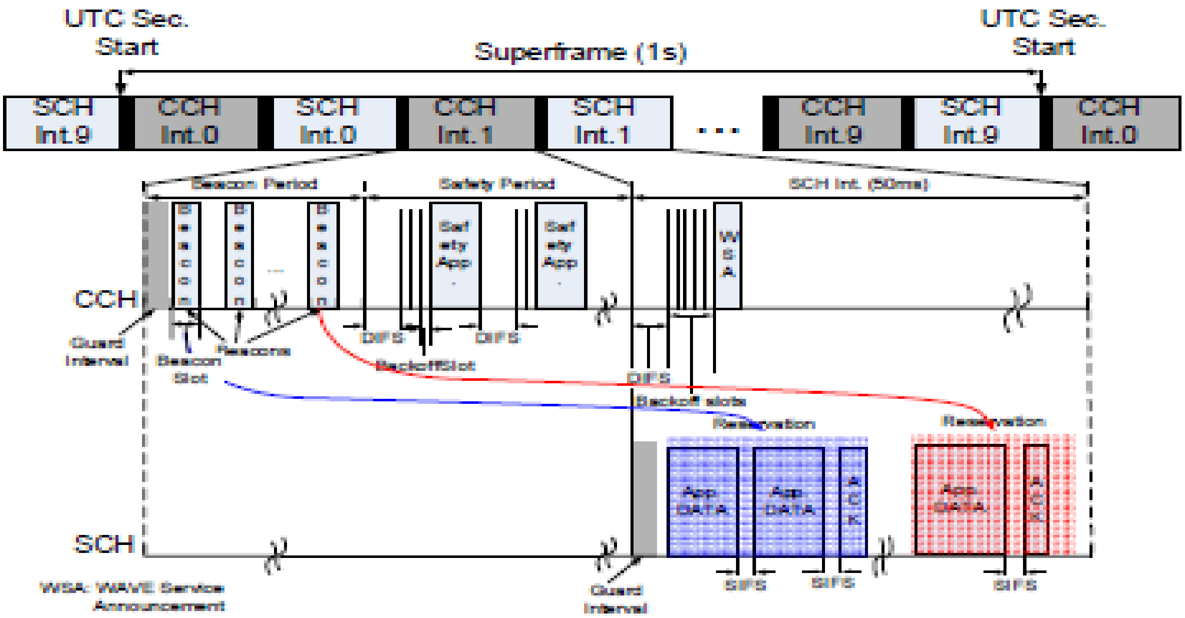

Figure 5. Channel access process of VMESH MAC from [9]

8. Modeling and Simulation of WAVE 1609.4 protocol

Based on these protocols, the service class is implemented at the Physical (PHY) layer through the definition of a dedicated spectrum band for vehicle-to-vehicle and vehicle-to-infrastructure known as Dedicated Short Range Communication (DSRC),[10] and the different applications class is reserved by the realization of seven channels. On each particular channel differentiate among different Access Categories (AC) is achieved at the MAC layer through the EDCA parameters defined in the IEEE 802.11p MAC protocol and multi-channel operations are regulated by the IEEE 1609.4 WAVE protocol. These modeling and simulation have different attributes for multi-channel. First, the implementation of packet delivery delay of safety broadcast messages. Second, the performance of periodic switching between CCH or SCH might be an negative impact on QoS. Third, to minimize the delivery delay of safety messages as well as moderate collision made by synchronous channel. It provides a detailed description of the IEEE 1609.4 model for the Network simulator and validate through comparison with an analytical model. It investigates the performance and QoS parameters of multi-channel VANETs.

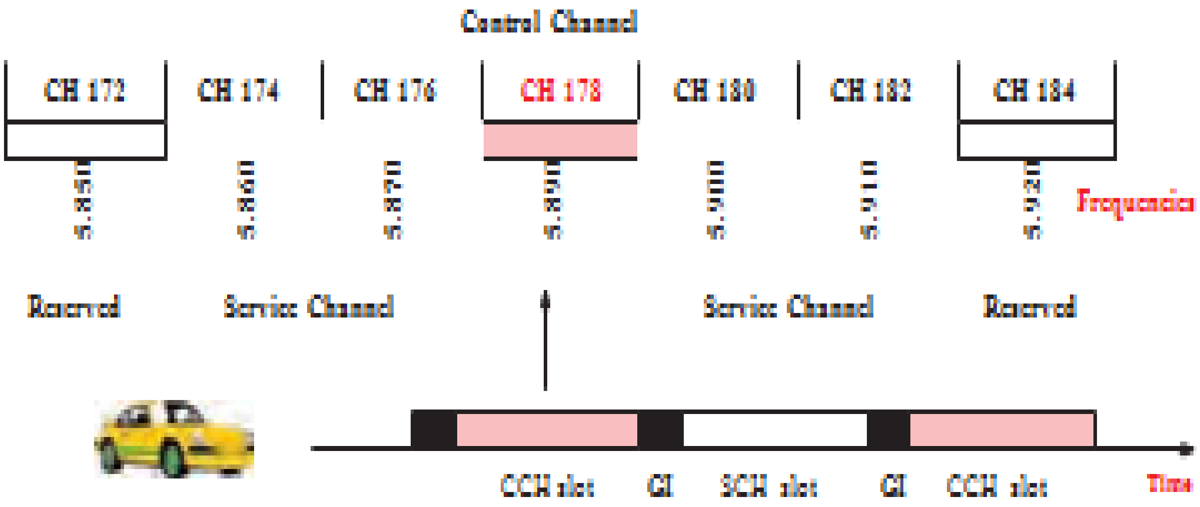

Figure6. The DSRC spectrum frequencies from [8]

9. A Multi channel VANET providing concurrent safety and commercial services

Authors assume the spectrum used by the safety and non-safety applications has split up into multiple channels. This makes us to agree with the FCC mandated band plan for DSRC [11]. The DSRC spectrum is divided into seven channels, each channel of 10 MHz. One of these seven channels is identified as a control channel. It can be used to send safety messages. The remaining six channels are called service channels. Providers of non-safety services are expected to obtain licenses to use these channels to conduct their transactions. They may use the control channel to publish services and form the service channel communication link between responding vehicles and the service provider. Accordingly, Authors assume all the safety messages are sent on a single channel while all non-safety communications are to be conducted mainly on several, separate, service channels. Authors design for concurrent safety and non-safety communications relies on roadside access points. Authors distinguish between two kinds of access points as follows:

i. Service access point: A roadside unit (RSU) that gives non-safety services, called a service access point, may conduct these services within an access point service region (APSR).These services will be given to those which are only within the APSR. It services in the control channel but conducts the transactions in a service channel

ii. Coordinating access point: An RSU that coordinates the passing in its proximity is called a coordinating access point. A single access point may be configured to function as both the service AP and the coordinating AP.

The coordinating AP divides the control channel resource in both space and time. . Time is partitioned into periodic, regulated intervals, called the repetition period. The period should be of length T, where T is the lower bound on the latency of safety messages.

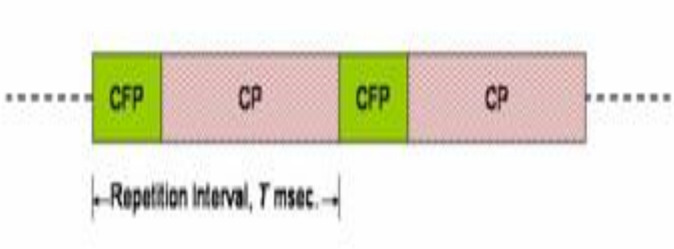

Figure 7. Basic time division in the control channel from [10]

10. Conclusion

The wireless medium for vehicular communication is prone to the problem of broadcast storm. This produces collisions (due to contention) and redundancy (due to rebroadcast) as manifests. A better insight into the working mechanism of the multi-channel operation is always of prior importance when devising routing algorithms for Vehicular Networks. This paper presented the relevant literature to discuss the multi-channel operation of 802.11p MAC.

References and notes

1. Jiang, Daniel, and Luca Delgrossi. "IEEE 802.11 p: Towards an international standard for wireless access in vehicular environments." *Vehicular Technology Conference, 2008. VTC Spring 2008. IEEE*. IEEE, 2008.

2. Park, Cheol Wook, and Bong Dae Choi. "Performance Analysis of MAC with DCF on CCH and Reservation for Multi-Channel for IEEE 802.11 p/1609.4 WAVE Networks." *Quality Technology and Quantitative Management* 12.3 (2015): 409-422.

3. Chen, Qi, Daniel Jiang, and Luca Delgrossi. "IEEE 1609.4 DSRC multi-channel operations and its implications on vehicle safety communications." *Vehicular Networking Conference (VNC), 2009 IEEE*. IEEE, 2009.

4. Morgan, Yasser L. "Notes on DSRC & WAVE standards suite: Its architecture, design, and characteristics." *Communications Surveys & Tutorials, IEEE* 12.4 (2010): 504-518.

5. Eichler, Stephan U. "Performance evaluation of the IEEE 802.11 p WAVE communication standard." *Vehicular Technology Conference, 2007. VTC-2007 Fall. 2007 IEEE 66th*. IEEE, 2007.

6. Cordeiro, Carlos, and Kiran Challapali. "C-MAC: A cognitive MAC protocol for multi-channel wireless networks." *New Frontiers in Dynamic Spectrum Access Networks, 2007. DySPAN 2007. 2nd IEEE International Symposium on*. Ieee, 2007.

7. Campolo, Claudia, Alessandro Cortese, and Antonella Molinaro. "CRaSCH: a cooperative scheme for service channel reservation in 802.11 p/WAVE vehicular ad hoc networks." *Ultra Modern Telecommunications & Workshops, 2009. ICUMT'09. International Conference on*. IEEE, 2009.

8. Lu, Ning, et al. "A dedicated multi-channel MAC protocol design for VANET with adaptive broadcasting." *Wireless Communications and Networking Conference (WCNC), 2010 IEEE*. IEEE, 2010.

9. Zang, Yunpeng, et al. "A novel MAC protocol for throughput sensitive applications in vehicular environments." *Vehicular Technology Conference, 2007. VTC2007-Spring. IEEE 65th*. IEEE, 2007.

10. Ghandour, Ali J., et al. "Modeling and simulation of WAVE 1609.4-based multi-channel vehicular ad hoc networks." *Proceedings of the 5th International ICST Conference on Simulation Tools and Techniques*. ICST (Institute for Computer Sciences, Social-Informatics and Telecommunications Engineering), 2012.

11. Mak, Tony K., Kenneth P. Laberteaux, and Raja Sengupta. "A multi-channel VANET providing concurrent safety and commercial services." *Proceedings of the 2nd ACM international workshop on Vehicular ad hoc networks*. ACM, 2005.