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The effects of OFDM design parameters on the V2X communication performance: A survey

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ABSTRACT

DSRC (Dedicated Short Range Communications) technology is particularly important for V2V (Vehicle-to-Vehicle), V2I (Vehicle-to-Infrastructure) and V2R (Vehicle-to-Roadside) communication in ITS (Intelligent Transportation System). The IEEE (The Institute of Electrical and Electronics Engineers) 802.11p standard known as WAVE (Wireless Access in Vehicular Environments) is entirely thought for DSRC, a technology used by VANETs (Vehicular Ad hoc NET-works) to achieve vehicular communications. Its modulation format is established upon OFDM (Orthogonal Frequency Division Multiplexing). The objective of this paper is to review the performance parameters and the effects of OFDM design parameters on the V2X (Vehicle-to-everything) communication performance. Our performance analysis and results for developing the V2V and V2I communication performance will be presented and compared with this survey in the next work.

1. Introduction

The V2X communication system is an important fundamental part of the ITS future architecture. V2X is a wireless technology aimed at increasing road safety and improve traffic management, introducing a new concept of ITS, capable of reducing environmental impact. The V2X abbreviation is used for encompassing V2V, V2I (which can be e.g., cellular), V2R (where "R" denotes new dedicated vehicular access sites), and most generally, vehicle-to-universe (including satellite, GPS, public safety, pedestrian, etc.) modes in Intelligent Transportation Systems area. DSRC is a key enabling wireless technology for V2V, V2I and V2R communications [1,2]. The examination of the application of DSRC technology in ITS is an ideal starting point for the improvement of other vehicle-to-vehicle and vehicle-to-infrastructure communication [3].

ITS applications have generally been classified into three main categories with respect to their functionalities: safety, efficiency, and comfort applications [4–7]. Table 1 shows each category of ITS applications with potential carriers. As seen in Table 1. Potential wireless communication technologies for ITS applications, DSRC/WAVE is a common technology that can be used by all safety and efficiency applications, particularly when an application requires solely V2V and V2I direct communication within a limited range not greater than 1 km [2]. WAVE networks have to be robust and have fast response, because if there is a delay there may be loss of life or property.

Big consortium projects such as CVIS (Connected Vehicles, Co-operative Vehicle-Infrastructure Systems), SAFESPOT (Cooperative Systems for Road Safety), SPITS (Strategic Platform for Intelligent Traffic Systems) and Car-2-Car have showed the feasibility of DSRC systems for vehicle safety applications [8,9].

The measurements in [10] proved that the IEEE 802.11p has obviously better general performance and behavior in the vehicular networking environment, in comparison to the traditional Wi-Fi (Wireless Fidelity) solutions used for V2V communications [10–13].

Fig. 1 illustrates the protocol stack for DSRC communication, including shorthand names of protocols and standards planned for use at the various layers. At the PHY (Physical) and MAC (Medium Access Control) layers DSRC utilizes IEEE 802.11p WAVE, a modified version of the familiar IEEE 802.11 (Wi-Fi) standard. As shown in Fig. 1, IEEE 802.11p WAVE is only a part of a group of standards related to all layers of protocols for DSRC based operations [14].

In the middle of the stack, DSRC employs a suite of standards: The IEEE 1609.4 standard (for channel switching) sits right on top of the IEEE 802.11p and enables operation of upper layers across multiple channels, without requiring knowledge of PHY parameters [15]. The IEEE 1609.3 standard (for Network Services, including the WAVE Short Message Protocol-WSMP) covers the WAVE connection setup and management [16]. IEEE 1609.2 standard defines secure message formats and processing for use by WAVE devices, including methods to secure WAVE management messages and methods

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Table 1
Potential wireless communication technologies for ITS applications [2].

Functionalities	ITS application categories	Recommended carrier(s)
Safety	Collision avoidance (safe distance, intersection collision avoidance)	DSRC, WAVE
	Road sign notifications (in-vehicle signage, curve speed warning)	DSRC, WAVE, CALM (M5)
	Incident management (emergency vehicle warning, post-crash warning)	Wi-Fi, DSRC, WAVE, cellular network
Efficiency	Traffic management (intelligent traffic flow control, Free-flow tolling)	DSRC, WAVE, cellular network, DAB
	Road monitoring (vehicle tracking and tracing, road condition monitoring)	IR, ZigBee, DSRC, WAVE
Comfort	Entertainment (distributed games, download music)	MMWAVE, WLAN, WiMAX, DVB, DVB-H
	Contextual information (restaurant information, parking booking)	DSRC, WAVE, cellular network, DAB

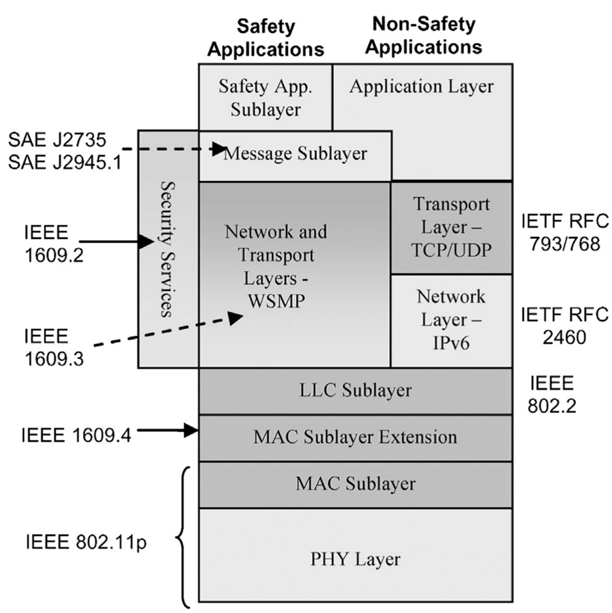

Fig. 1. Layered architecture for DSRC communication in the US [14].

to secure application messages. It also describes administrative functions necessary to support the core security functions [14,17].

DSRC also supports use of well-known Internet protocols for the Network and Transport layers, i.e., IPv6 (Internet Protocol version 6), UDP (User Datagram Protocol) and TCP (Transmission Control Protocol) [14].

The performance of WAVE physical layer is one of the important factors that make an immense effect in the communication process [18].

The DSRC PHY protocol is described in IEEE 802.11 [19] (specifically clause 17), as amended by IEEE 802.11p [20]. In 2004 the IEEE began to work on the standardization of the WAVE architecture. The MAC and PHY layers are stated explicitly in the IEEE 1609.4 [21] and IEEE 802.11p [20] standards.

The overall capacity of vehicular networks making use of WAVE and 802.11p, the anticipated communication ranges and the delay performance are examined. The simulation results demonstrated that the traffic prioritization schemes chose for the standards work well [22].

The access technology ITS-G5 is a European profile of IEEE 802.11 and has features of IEEE 802.11p as well. Therefore, the ETSI (European Telecommunications Standard Institute) standard document ES 202 663 [23] describes the MAC and PHY layers of an ITS-G5 station and relies greatly on 802.11 and the 802.11p revision [24]. The conceived European system ETSI ITS G5 is similar: it also utilizes an IEEE 802.11p PHY Layer, but, it particularizes own algorithms for medium access [25].

IEEE 802.11™-2012 revision is issued in 2012 supersedes all earlier amendments and revisions [26].

The leftover of the paper is organized as follows. Section 2 examines DSRC Physical Layer specifications in IEEE 802.11-2012 and ITS-G5 standards. Section 3 focuses on Physical Layer (OFDM) Parameters. Section 4 examines the effects of OFDM parameters and further challenges on communication performance. Section 5 supplies finishing remarks.

2. DSRC physical layer – OFDM

The IEEE 802.11 standard utilizes OFDM which is a modulation scheme that allows digital data to be efficiently and reliably transmitted over a radio channel, even in multipath environments as the modulation scheme. IEEE 802.11p adopts OFDM to compensate for both time and frequency fading [19] due to the movement of both communicating terminals and objects in the environment [27].

OFDM transmits data by using a large number of narrow bandwidth carriers. These carriers are regularly spaced in frequency, forming a block of spectrum. The frequency spacing and time synchronization of the carriers is chosen in such a way that the carriers are orthogonal, meaning that they do not cause interference to each other. This is despite the carriers overlapping each other in the frequency domain [28].

The elementary idea in OFDM is that a large number of closely-spaced orthogonal sub-carriers are used to carry data. The data is divided into several parallel data streams or channels, one for each sub-carrier. Each sub-carrier is modulated with a conventional modulation scheme, such as QAM (Quadrature Amplitude Modulation), BPSK (Binary Phase-Shift Keying) and QPSK (Quadrature Phase-Shift Keying), at a low symbol rate, preserving total data rates similar to conventional single-carrier modulation schemes in the same bandwidth. OFDM provides effective bandwidth utilization and sturdiness against time dispersive channels [29].

The features and system parameters of The Physical Layer (OFDM) has been issued in chapter 18 of IEEE-802.11™-2012 standard.

The IEEE 802.11 specification particularizes the arrangement of the given 64 subcarriers. 52 subcarriers are convenient subcarriers (data + pilot) which are appointed numbers from −26 to 26. The pilot signals are inserted into the subcarriers of −21, −7, 7 and 21 [18].

The OFDM system provides a WLAN (Wireless Local Area Network) with data payload communication capabilities of 6, 9, 12, 18, 24, 36, 48, and 54 Mb/s. The support of transmitting and receiving at data rates of 6, 12, and 24 Mb/s is obligatory. The system uses 52 subcarriers that are modulated using binary or quadrature phase shift keying (BPSK or QPSK) or using 16- or 64-quadrature amplitude modulation (16-QAM or 64-QAM). Forward error correction coding (convolutional coding) is used with a coding rate of 1/2, 2/3, or 3/4 [26].

The OFDM system also provides a “half-clocked” operation using 10 MHz channel spacing with data communications capabilities of 3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s. The help of transmitting