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The Physical Layer of the Communication Standard: The Specifications andChallenges

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Abstract—In the recent years, Vehicular Ad hoc Networks (VANETs) emerged with great interest due to their impact in reducing traffic jams and increasing safety as well as alternative emergency communication system in case ofnatural disasters, when there is lack of ordinary communication systems. IEEE 802.11p standard known as Wireless Access in Vehicular Environments (WAVE) is specially developed to adapt VANETs requirements and support intelligent transport systems (ITS). The performance of WAVE physical layer is one of the important factors that play a great role in the communication process. This paper presented an overview of the physical layer (PHY) of the IEEE 802.11p standard. The specifications, components, performance and challenges of the PHY layer are discussed and analyzed.

Index Terms—VANET, WAVE, IEEE 802.11p, PHY, IEEE 802.11frequency band, OFDM, preamble

INTRODUCTION

IEEE 802.11 is a collection of physical layer (PHY) specifications and media access control (MAC) for implementing WLAN in the 2.4, 3.6, 5 and 60 GHz frequency bands [1]. They are maintained by the IEEE 802 LAN Standards Committee in 1997. The standard and its amendments provide the fundamentals of Wi-Fi technology. While each amendment is officially rescinded when it is incorporated in the latest version of the standard, the corporate world tends to market to the revisions becausethey concisely denote capabilities of their products. Consequently, each revision is preserved as a new standard in the networks community [1-3].

IEEE 802.11p is one of the recent approved amendments to the IEEE 802.11 standard to add wireless access in vehicular environments (WAVE). It appended some enhancements to the latest version of 802.11 that requiredto support applications of Intelligent Transportation Systems (ITS) [4]. This includes data exchange between high-speed vehicles and between the vehicles and the roadside infrastructure in the licensed ITS band. IEEE 802.11pn radio frequency LAN system is initially aimed forthe 5.15-5.25, 5.25-5.35 GHz, & 5.725-5.825 GHz unlicensed national information infrastructure (U-NII) band. The support of sending data at 6, 12, and 24 Mbit/s are mandatory while 9, 18, 36, 48, 54Mbit/s are optional data rates.

The system uses 52 subcarriers which are modulated using binary or quadrature phase shift keying (BPSK/QPSK), 16 quadrature amplitude modulation (16- QAM), or 64-QAM. Forward error correction (FEC) codingis used with a coding rate of 1/2, 2/3, or 3/4. IEEE 1609 is ahigher layer standard based on the IEEE 802.11p to support network security issues in the WAVE standard [1],[2],[5].

Up to now, many research entities presented a numerous researches related to VANET but, majority of researches focused on aspects related to application, security and routing. While several research groups have been examined the results of the 802.11p standard from the MAC layer perspective [4], [6], [7]. Ref. [8] introduced the basic technologies used in WAVE standard, also proposed itslimitations and applications. It studied and evaluated the use of a TDMA MAC layer for solving the real time communication constraints problem while a priority is given for each node in order to consider the unfairness dedication of channel problem. Bilstrup et al. [9] simulated the carrier sense multiple access (CSMA) as a MAC method of the upcoming vehicular communication standard IEEE802.11p in a highway scenario with periodic broadcastof time-critical packets in a vehicle-to-vehicle situation. Their simulation results show that a vehicle is forced todrop over 80% of its messages because no channel access was possible before the next message was generated. A self-organizing time division multiple access (STDMA) for real-time data traffic between vehicles is proposed in [9] to overcome this problem. However,

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the PHY analysis has notbeen thoroughly investigated. A PHY simulator based on NS-3 has been developed by [10]. A bit-error-rate (BER) analysis has been presented in [3], where the authors considered two basic vehicle-to-vehicle communications in highway and urban scenarios. Only one type of channel estimation technique was tested, and that only in non- vehicular stationary models. Ref. [11] implemented a PHY model for IEEE 802.11p that partially describes some

VANET radio channel characteristics, specially the non- stationary property. Also, one of channel estimators is tested based on the pilot structure defined in the standard focusing on low complexity implementations. Also, IEEE802.11 PHY was evaluated by [12] which implemented a practical model using two roadside units (RSUs) along a highway, however the authors concentrated only on the effect of the antenna length on the signal quality.

We noted that majority of researches have been concentrated in the MAC, routing, security of IEEE802.11p[6, 13]. Beside that IEEE 802.11p is quite new standard andstill under research and its PHY layer has not been thoroughly investigated. The primary objective of this paper

FREQUENCY BAND

The IEEE 802.11p amendment allows the use of the 5.9GHz band (5.850 - 5.925) GHz with channel spacing equal to 20MHz, 10MHz and 5MHz and lays down the requirements for using this band in Europe and US. It utilizes the mechanisms initially provided by IEEE 802.11 to operate in the DSRC, which is a communication technology based on IEEE 802.11a to work in the 5.9 GHz band in United States or 5.8 GHz band in Japan and Europe[3]. It offers data exchange among vehicles (V2V) and between vehicles and roadside infrastructure (V2I) within a range of 1km using a transmission rate of 3Mbps to 27Mbps and a vehicle velocity up to 260 km/h [2].

IEEE 802.11p operates on about 9 channels, each of which has a frequency band as described in Figure 1. CH172-5.860 GHz and CH184-5.920 GHz both are safety dedicated channels. The first one provides a serious security solutions while the second plays a protective role against congestion on other channels. Channel CH178-5.890GHz is a control channel responsible for controlling the transmission broadcast and link establishment. The six other service channels are allocated for bidirectional communication between different types of units. Actually, they are four channels but, the pair of channels 174, 176 and channels 180, 182 can be combined together to form a single 20MHz channel, channel 175 and 181 respectively. There is 5 MHz in the beginning of the band at 5.85used as guard band (GB) [2].

In 802.11p the channel bandwidth is halved in order to keep abreast the requirements of VANETs, resulting in a 10 MHz bandwidth instead of 20MHz in 802.11a. Also, the carrier spacing is reduced by half, typically 0.15625MHz, compared to 802.11a which is 0.3125MHz. While the symbol length for 802.11p is twice (8μs) that of 802.11a (4μs). It mainly involves doubling of all OFDM timing parameters used in the regular 802.11a transmissions as shown in Table 1 and 2. Consequently, the transmission rate is reduced by half. Various modulation schemes are used for efficient packet transmission. The IEEE 802.11 specification, specifies the arrangement of the given 64 subcarriers. 52 subcarriers are useful subcarriers (data + pilot) which are assigned numbers from -26 to 26. The pilot signals are embedded into the subcarriers of -21, -7, 7 and 21 as shown in Figure 2. The rest of subcarriers are null carrier which allocated in the beginning (0) and middle (27 to 37) of the band to eliminate the effect of null carriers in the data subcarriers. Then subcarriers are processed by an Inverse Discrete Fourier Transform (IDFT) modulation in order to be transmitted in time domain after adding a Cyclic Prefix (CP). CP is applied by prefixing of a symbol with a repetition of a part of its end in its inception, so as to serves as a guard interval to eliminate the inter-symbol interference (ISI) caused by the previous symbol. Also, it allows the linear convolution of a frequency-selective multipath channel to be modelled as circular convolution, which in turn transformed to the frequency domain using a DFT. In the receiver unit, after timing synchronization, the CP is detached before the signal demodulated [14-16].

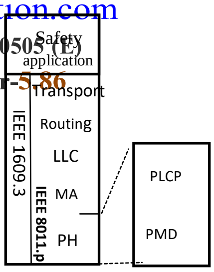

Fig. 3 WAVE Protocol Stack and the sub layers of PHY

I. Physical Layer Structure

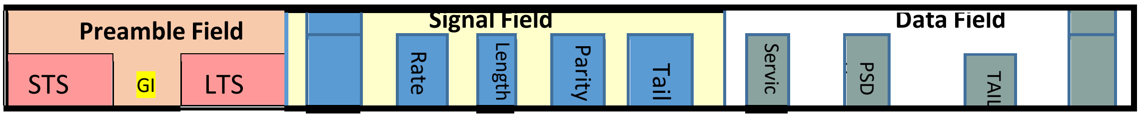

Fig. 4. IEEE 802.11p PHY layer PPDU Frame structure

The physical layer (PHY) represents an interfacebetween the MAC layer and the media that allows sending and receiving frames [17]. PHY is essentially responsible of hardware specification, bits conversion, signal coding and data formatting. The PHY of the IEEE 802.11p is similar to that of IEEE 802.11a. It composed of two sub layers as shown in Figure 3. The first one is the Physical LayerConvergence Protocol (PLCP) which is responsible for communicating with the MAC layer. It is also a convergence process that transforms the Packet Data Unit (PDU) arriving from the MAC layer to compose anOFDM frame. The second sub-layer is the Physical Medium Access (PMD) which is the interface to the physical transmission medium such as radio channels and fiber links. Its task is to manage data encoding and perform the modulation [10, 11, 14, 15].

The Protocol Packet Data Unit (PPDU) composed of a preamble, signal field and a payload component containing the useful data as shown in Figure 4. The preamble field marks the beginning of the physical frame. It is used to select the appropriate antenna and correct the frequency and timing offset. A preamble is used to train the VCO of the receiver to the incoming signal's clock so as to produce a clocking in the receiver that is synchronized to the received signal, in order to achieve a perfect sampling and demodulation [18]. Also to obtain the channel state information (CSI), training OFDM symbols or pilot symbols embedded in each OFDM symbol are utilized. The pilot symbols are used for the purpose of channel estimation and transmission error correction, because the wireless channel has a great effect on the signal properties. It may alter the phase and frequency of the signal by some values, which may affect the demodulation process. These effects often are phase rotation, Doppler frequency shift, degradation of the amplitude and phase distortion.

All of these effects cause poor SNR. One of the considerable effects is it may alter the place of the frequency of some subcarriers in an OFDM, which may cause the loss of signals orthogonallatiy characteristic. Therefore, at the transmitter a well-known symbol (its frequency, amplitude and phase) is inserted among the subcarriers to carry the effects of the channel, and at the receiver it demodulated and then all the effects are calculated and the received signal is corrected and estimated according to those calculated amounts. The number of pilots used in an OFDM system depends on the characteristics of the channel through which the signal is sent [18].

Training OFDM symbols or equivalently OFDM preambles are transmitted at the beginning of the transmission process, while pilot symbols (complex exponentials in time) are embedded in each OFDM symbol, and they are separated from information symbols in the frequency domain [1-3]. Channel estimation by training OFDM symbols may be sufficient for symbol detection in case of channel remains constant over several OFDM symbols, but in case of channel variation, training OFDM symbols should be retransmitted frequently to obtain reliable channel estimates for detection [16]. On the other hand, to track the fast varying channel, pilot symbols are inserted into every OFDM symbol to facilitate channel estimation. This is known as pilot-assisted (or -aided) channel estimation [2], [4], [18, 19]. The main drawback of the pilot-assisted channel estimation lies in the reduction of the transmission rate, especially when larger number of pilot symbols are inserted in each OFDM symbol. Thus, itis desirable to minimize the number of embedded pilot symbols to avoid excessive transmission rate loss. Generally, to reduce and immune channel effect on signalsa training symbols is time domain mechanism while a pilot is frequency domain mechanism. Training symbols utilizes all subcarriers while pilot is embedded in some subcarriers.

The preamble field of IEEE 802.11p composed of 12 training symbols which are added for providing a description of the frequency channel behavior and temporally synchronization of the reception. It consists of ten Short Training Symbol (STS) and two Long Training Symbol (LTS) [4, 5]. Seven of the 10 STS are short OFDM symbols which responsible of the signal detection, automatic gain control (AGC) and diversity selection. Three of them are responsible for coarse frequency offset and timing synchronization. Also, they allow the estimation of subcarriers frequency and channel estimation. STS is composed of 12 subcarriers ± (4, 8, 12, 16, 20, and 24). Which are generated directly by using the element of the sequence S shown in equation (1) and modulated usingequation (3) to create the corresponding OFDM symbols:

$$S_{\pm 26} = P_w\{0,0,1+j,0,0,0,-1-j,0,0,0,1+j,0,0,0,-1-j,0,0,0,-1+j,0,0,0,1+j,0,0,0,0,0,0,0,-1-j,0,0,0,-1-j,0,0,0,1+j,0,0,0,1+j,0,0,0,1+j,0,0,0,1+j,0,0\} \quad (1)$$

$$P_w = \sqrt{\frac{1}{2}} \times \sqrt{\frac{N_{ST}}{N_{Null}}} \quad (2)$$

$$R_{SHORT}(t) = \sum_{k=-N_{ST}\backslash 2}^{N_{ST}\backslash 2} S_k e^{-i2\pi k \Delta_F t} \quad (3)$$

The multiplication by a factor of is in order to normalize the average power of the resulting OFDM P_w

symbol - typically , which utilizes 12 out of 52 subcarriers. The fact that only spectral lines of S with indices that $\sqrt{13/6}$ are a multiple of 4 have nonzero amplitude results in a periodicity of 1.6μs. The duration of each STSis equal to 1.6μs.

$$T_{short} = 1.6 \times 10 = 16\mu s \quad (4)$$

The two long training symbols are used for channel estimation and fine frequency acquisition in the receiver. LTS consists of 53 subcarriers including a zero value at DC. The receiver uses it for fine-tuning. With this preamble, it takes 32 to train the receiver after first μs

receiving of the frame. Their role is essentially to estimate the transmission channel. They are generated by applying the IFFT as in equation (5) to the training sequence L in (6)

$$r_{long}(t) = \sum_{k=-N_{st}\backslash 2}^{N_{st}\backslash 2} L_k e^{-i2\pi k \Delta_F (t-T_{IG2})} \quad (5)$$

L-26,26 ={-1,1,1,-1,1,-1,1,1,1,1,1,1,-1,-1,1,1,-1,1,-1,1,1,1,1,0,1,-1,-1,1,1,-1,1,-1,1,-1,-1,-1,-1,-1,1,1,1-,1,-1,1,-1,1,-1,1,1,1,1 } (6)

Where TIG2 is 3.2μs guard interval used to avoid interference between STS and LTS. Two period of the long sequence are transmitted in order to improved channel estimation accuracy as in (7):

$$T_{long} = 6.4 \times 2 + 3.2 = 12.8 + 3.2 = 16\mu s \quad (7)$$

The signal field (SIG) is used to specify rate and length information. It consists of one OFDM symbol assigned to all 52 subcarriers. This symbol is BPSK modulated at 6 Mbps and is encoded at a ½ rate. SIG is interleaved and mapped, and has pilots inserted in subcarriers –21, –7, 7 and 21. The SIG is not scrambled. The SIG field composed of 24 bit divided into five sub fields, the RATE, RESERVED, LENGTH, PARAITY and TAIL. The RATE field is the first 4 bit which conveys information about the type of modulation and the coding rate used in the rest of the packet.

TABLE 1. GENERAL SPECIFICATION OF IEEE 802.11A AND 802.11P PPDU

Parameters	Notation	802.11n	802.11p
Total number of subcarriers	N	64	64
Total number of used subcarrier	Nst	52	52
Used subcarrier	Nsd	48	48

Pilot carrier	Nsp	4	4
Short Training carriers	Nsts	10	10
Number of Null subcarriers	Null	12	12
Long training symbols carriers	Nlts	53	53
OFDM available Bandwidth	OfdmBw	20	10
Carrier spacing	Δ_F	0.3125MHz	0.15625MHz

TABLE 2. IEEE 802.1P PPDU TIMING PARAMETERS COMPARE TO IEEE802.11A

Parameters	Notation	802.11n	802.11p
Chip duration	Tc	50ns	100ns
Ifft period or FFT size	Tfft	3.2µs	6.4µs
Guard interval duration (CP) (1/4 × Tfft)	Tgi	0.8µs	1.6µs
OFDM symbol total duration (CP + FFT size)	Tsignal	4µs	8µs
Number of chip per OFDM symbol	Sc	80	80
Number of symbols allocated to CP (N* Tgi/ Tfft)	Ncp	16 chip	16 chip
Short training symbol duration	STS	0.8µs	1.6µs
Short training symbols Total duration	TSTS	8µs	16µs
Long training symbol duration	LTS	3.2µs	6.4µs
Long training symbols total duration	TLTS	6.4µs	12.8µs

II. DESCRIPTION OF THE PHYSICAL LAYER DATA TRANSMISSION PROCESS

The block diagram shown in Figure 5 represents the PHY transmission process, which composed of many complex steps. The following overview describes the details of this procedure. The data will be received from the upper layer which represents the data link layer frames. These data are scrambled to prevent a long bits sequence that can cause errors. A scrambler in this context has no encryption purpose, as the intent is to give the transmitted data some useful engineering properties rather than to render unintelligible message. A scrambler replaces sequences into other without removing undesirable ones. As a result, it changes the probability of occurrence of vexatious sequences to prevent undesirable periodic output sequences.The scrambler used different type of polynomials, to generate a sequence of 127 bits, as an example shown in (8)

$$s(x) = x^7 + x^4 + 1 \qquad (8)$$

In order to reduce bit error cause by ICI, ISI and channel affects, a FEC mechanism should be used. IEEE 802.11p usually uses convolutional encoder, with ½ and ¾ coding rate for error correction. This can assure adding redundancy to the transmitted bit stream. In order to reduce the number of transmitted bits and increase encoder bit rate, a puncturing element is applied to the convolutional encoder output, resulting in coding rates of ¾ and 2/3. The puncturing process is the omitting of selected bits of the coded bits on the transmitter side and in the receiver convolutional decoder side is replaced by zeros [22]. Many methods can be used to perform puncturing operation, however, one of the puncture approach used in IEEE 802.11p is specified by a binary puncturing vector which consistent of two bit sequences 1110,110101 for rate 2/3, ¾ consequently [1].

To reduce burst errors caused by channel fading, the output data of the encoder are interleaved. Interleaving is often used to scramble the data bits so that standard error correcting codes can be applied, because errors usually are random. The interleaving process composes of a permutation in time and frequency domain. Applying permutation in time is to ensure that two successive bits are never coded in two adjacent subcarriers while permutation in frequency to ensure that the successive bits are represented alternately in the most and least significant bits of the used constellation.

According to modulation type the interleaved data is grouped using a signal mapper. Digital modulation types used by

Modulation Type	BPSK		QPSK		16-QAM		64-QAM	
Coding Rate	1/2	3/4	1/2	3/4	1/2	3/4	2/3	3/4
Coded bit rate in Mbps	6		12		24		36	
Data Rate in Mbps)	3	4.5	6	9	12	18	24	27
Data bits per OFDM symbol	24	36	48	72	96	144	192	216

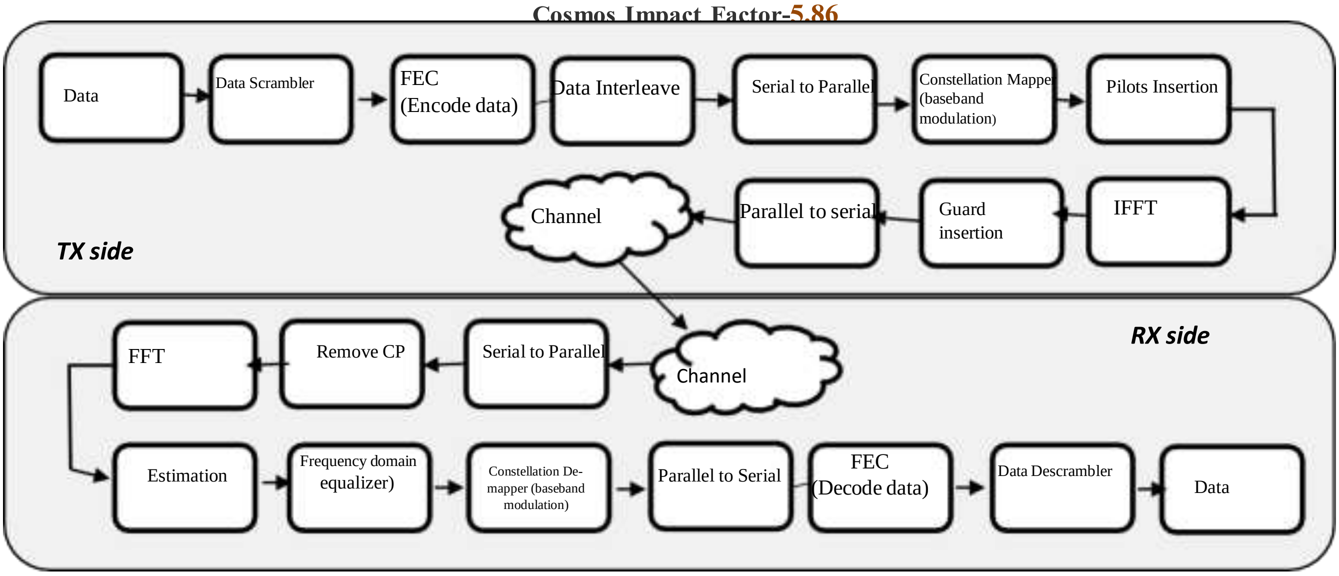

Fig. 5. Simple PHY Data Transmission Process Block Diagram

and 64-QAM. The selection of code rate and modulation type has a direct effect in the data rate of the system, which ranging from 3 Mb/s using BPSK and 1/2 coding rate up to 27 Mb/s using 64-QAM and 3/4 coding rate. The combination of data rate and modulation scheme is according to Table 3 [23].

The total number of available subcarriers is 64 but only 52 information carriers are used for mapping. Before applying IFFT, 4 carriers out of 52 is selected to carry the pilot signal. The pilot symbols are used to estimate the channel and examine the changes made to the transmitted signal. Pilot subcarriers are used to make a robust detection in receiver against frequency offsets and phase noise. They are inserted in the subcarriers -21, -7, 21, and 7 as shown in Figure 2. The modulated serial bit streams are converted into symbols to be transmitted in parallel. So, the OFDM technique converts the serial data stream into several parallel ones. It modulates those data onto orthogonal subcarriers using IFFT. This step places the complex symbols associated with different constellation points on subcarriers. To carry data and pilot symbols on subcarriers, the OFDM symbols are converted from frequency domain to time domain by applying IFFT. The guard interval (GI2) is inserted before each OFDM symbol in order to avoid the ISI and ICI problems caused by multipath propagation [24]. It is composed by copying the end of OFDM symbol in the beginning of symbol. The output of guard insertion operation is converted to serial stream of bits that composed the OFDM symbol frames applied to the channel. The GI1 guard subcarriers are used on the OFDM spectrum sides to provide separation from adjacent sub-bands. In simulation environment the transmitted signal will pass through the frequency selective time varying fading channel with additive noise. The channel in this case is composed of a simple AWGN channel plus Rayleigh fading and Rican radio channel because it represents both line of sight and reflected links between sender and receiver. A reverse operation is performed in the receiver side in order to recover the transmitted data back. Thereafter, send the data to the receiver data link layer. The frequency domain equalizer block in the receiver is added, because the channel includes Rayleigh fading.

CHALLENGES OF THE PHYSICAL LAYER

WAVE networks have a group of technical challenges not encountered in other wireless networks. One challenge is the use of WAVE technology in collision avoidance between fast moving vehicles which raise the mobility challenge of a high impact in communication quality and several technical problems. Fundamentally, WAVE networks have to be extremely robust and high speed response, because their failure may cause the loss of life and property. Furthermore, some messages transmitted on a WAVE network have a tight latency requirement, and a decision based on delayed information could be quite harmful. The WAVE networks may operate in a wide range of hash environments. Vehicles quantity, quality and density can vary in the radio coverage area. IEEE defined that the latency for safety applications in VANET should be 50ms and not exceeds 100ms, however, for other applications more than 100 milliseconds is allowed [2, 8].

To overcome these challenges, the PHY must be robust, scalable, reliable, low latency and minimum BER. Due to nodes mobility and variation in transmission environment, such as urban, deserts, forest and highways, PHY may perform transmission within variable channels, because sand, dust, rain and other environmental factors directly affect the transmission process. Also, multiple technical factors that include encoding, modulation, frame size, data rate CP and unused subcarriers, have numerous effects in the performance of PHY. All these factors have diverse effects on transmission quality.

A. Effect of Noise in Bit and Symbol Energy

To simulate an OFDM system, required amount of channel noise has to be generated that is representative of required Eb/N0. In case of Es/N0, the required noise can be generated from zero-mean-unit-variance-noise using severalmethods [25, 26]. The generated zero-mean-unit-variance noise has to be scaled accordingly to represent the required Eb/N0 or Es/N0. Normally for a simple BPSK system, bit energy and symbol energy are same. This mean Eb/N0 and Es/N0 are same for a BPSK system, but for an OFDM BPSK system, they are not the same. This is because, each

OFDM symbol contains additional overhead in both time domain and frequency domain. In the time domain, the CP is an additional overhead added to each OFDM symbol that is being transmitted. In the frequency domain, not all the subcarriers are utilized for transmitted the actual data bits, rather a few subcarriers are null and are reserved as guard bands.

1. Effect of unused subcarriers on symbol energy

Out of N subcarriers, only Nst carriers are used which includes data and pilot subcarriers. In frequency domain, the useful bit energy is spread across Nst subcarriers, whereas the symbol energy is spread across N subcarriers. The relationship between Es and Eb is as below:

$$E_s \times N = E_b \times N_{st} \tag{9}$$

$$Es = \frac{N}{(N_{st})} E_b \tag{10}$$

$$\frac{Es}{N_o} = \frac{N}{N_{st}} \frac{E_b}{N_o} \tag{11}$$

$$(\frac{E_s}{N_o})_{dB} = (\frac{N}{N_{st}})_{dB} + (\frac{E_b}{N_o})_{dB} \tag{12}$$

This mean $10 \log(\frac{N}{N_{st}})\ dB$ is a wastage power which allocated for null subcarriers.

2. Effect of Cyclic Prefix on symbol energy:

In time domain each OFDM symbol contains both useful data and a CP. The bit energy represents the energy contained in the useful bits. In this case, the bit energy is spread over N bits (where N is the FFT size). On top of the useful data, additional Ncp bits are added as CP, which forms the overhead. So considering the entire OFDM symbol the symbol energy is spread across N + Ncp bits instead of N.

$$Es\left(N_{cp} + N\right) = E_b N \tag{13}$$

$$\frac{E_s}{N_o} = \frac{N}{(N+N_{cp})} \frac{E_b}{N_o} \tag{14}$$

$$\frac{E_s}{N_o} = \frac{1}{1+cp_r} (\frac{E_b}{N_o}) \tag{15}$$

$$(\frac{E_s}{N_o})_{dB} = \left(\frac{1}{1+cp_r}\right)_{dB} + (\frac{E_b}{N_o})_{dB} \tag{16}$$

This mean $10 \log\left(\frac{1}{1+cp_r}\right)$ dB is a wastage power due to CP. Where cp_r is the CP ratio which in IEEE 802.11p equals $\frac{1}{2}, \frac{1}{4}$. The overall effect of CP and unused subcarriers on E_s/N_0 is given by:

$$(\frac{E_s}{N_o})_{dB} = \left(\frac{1}{1+cp_r}\right)_{dB} + (\frac{N}{N_{st}})_{dB} + (\frac{E_b}{N_o})_{dB} \tag{17}$$

Around 0.07 dB in each OFDM Symbol is a wastage power due to both CP plus unused carriers, however, this amount of power in some special cases with a high gain antenna is almost quite enough to cover small room with Wi-Fi coverage.

B. Multipath Effects

1. Rayleigh fading

In vehicular networks, due to mobility, some objects such as building, trees, mountains and other vehicles and according to road environment a reflection of the transmitted signal may occurs. This directly leads to multiple transmission paths at the receiver. The relative phase of multiple reflected signals can cause constructive or destructive interference at the receiver. This is experienced over very short distances typically at half wavelength distances, which is known as fast fading. These variations can vary from 10-30dB over a short distance [27].

2. Frequency Selective Fading

Reflections off near-by objects can lead to multipath signals of similar signal power as the direct signal. This canresult in deep nulls in the received signal power due to destructive interference. Also in any radio transmission, dueto reflections and mobility the channel spectral response has fades in the response causing cancellation of certain frequencies at the receiver. For narrow bandwidth transmissions if the null in the frequency response occurs at the transmission frequency then the entire signal can be lost. This can be partly overcome by transmitting a wide bandwidth signal or spread spectrum as CDMA, any dips inthe spectrum only result in a small loss of signal power, rather than a complete loss. Another method which used by IEEE 802.11 is to split the transmission spectrum into many small bandwidth carriers, as in OFDM transmission. The original signal is spread over a wide bandwidth and so nullsin the spectrum are likely to only affect a small number of carriers rather than the entire signal. IEEE 802.11 used 12 subcarriers as null subcarriers and assigned them in middle of the OFDM spectrum to reduce the effect of null in the main frequencies. The information in the lost carriers can be recovered by using FEC techniques [19]. However this method has some drawback and it has several negative impact especially in term of receiver and transmitter design.

3. Delay Spread

The received radio signal from a vehicle transmitter consists of typically a direct signal, plus reflection signals. The arrival time of these signals is vary according to the path length of each one, multiple paths leads to a slightly different arrival times, which spreading the received energy in time. The delay spread is the time spread between the arrival of the first and last significant multipath signal seen by the receiver. The delayed multipath signal overlapping with the following symbols leads to ISI. This can cause significant errors in high bit rate systems, as the transmitted bit rate is increased the amount of ISI also increases. The effect starts to become very significant when the delay spread is greater than ~50% of the bit time. Inter-symbol interference can be minimized in several ways. One methodis to use a coding scheme that is tolerant to inter-symbol interference such as CDMA. Another method which used by IEEE 802.11p is to reduce the symbol rate by reducing the data rate for each channel using OFDM and applying a guard interval as described above [28]. This technique has a disadvantages, because it reduces the bit rate and as we mentioned above the vehicular network application needs to be treated as fast as possible.

How can we enhance and improve IEEE802.11p PHY built-in OFDM techniques or find more alternative in order to reduce the effect of fading solve frequency selective and delay challenges? May be to get benefits of the multipath property in vehicular networks – i.e. being as a Solution more than a problem?

Doppler Shift

When a source vehicle and a receiver vehicle are moving relative to each other the frequency of the received signal will not be the same as the source. When they are moving toward each other, the frequency of the received signal is higher than the source, and it decreases when they are approaching each other [29]. This is one kind of Doppler Effect which has a great effect in vehicular networks due to VANET mobility characteristic. The amount the frequency changes due to the Doppler depends on the relative motion between vehicles and the propagation velocity of the signal. Fundamentally, the Doppler shift in frequency can be calculated according to (18):

$$\nabla f_c \approx \pm f_0 \frac{\nabla v}{c} \qquad (18)$$

, where ∇f_c is the deviation of the source vehicle frequency at the receiver. The frequency of the source is f_0, ∇v is the speed difference between the source and transmitter vehicles, and c is the light velocity. In the ideal situation the amount of c is equal to light speed however with variation of environment in

VANET the amount of c can vary accordingly. The relative velocity between two vehicles moving toward each other is the sum of their individual speeds. Also in case of a vehicle moving with a high speed trying to communicate with RSU or a stop vehicle the value of ∇v is extremely high. In vehicular networks the range of ∇v is between 0 and 250 Km/h, accordingly the amount of frequency deviation is vary between about ±7.708kHz. The amount of shift may be very small, however, this shift has significant problems in PHY transmission because the transmission technique (OFDM) is very sensitive to carrier frequency offset [30, 31]ز In IEEE 802.11p subcarrier spacing has been halved since the WAVE OFDM receiveris more sensitive to carrier frequency offset and Doppler shift.

V2V and V2I communication is susceptible to much faster fading and more Doppler frequency spread and higher multi-path delay spread than any other wireless systems. In addition, it has to be extremely robust in abnormal situations because, collisions and accidents seldom occur in normal conditions.

So, *how can we overcome the existent Doppler and multipath solutions to grantee at the same time a high bit rate, low BER and reliability? Depending on the limitation of the existent solutions how can we find alternative solutions? Is it possible to find a mechanism that able to train transmitter or receivers to adjust their frequency according to given Doppler equations parameters? Considering the variation on the channel response due to the movement of the vehicles in different environments?How can we implement a complete model to represent vehicular network transmission channel?*

C. Channel variation and channel estimation

VANET usually work in different environments and various types of channel, i.e. channel response (y=Hx + n) always is variable. This raise up the problem of channel estimation. In these situations the used of statistical CSI is sensible, because of the fast fading and mobility properties of the channels where channel conditions vary rapidly under the transmission of a single information symbol. On the other hand, according to environments and vehicles status instantaneous CSI can be utilized with acceptable accuracy for transmission estimation [32]. The challenge here is how to find an appropriate estimation system that adapt vehicular network and achieve low BER, high reliability and simple receiver design.

D. Network Coverage Range

Considering the use of VAENT in different environmentswhere the quantity and density of vehicle may be verysmall. In these situations the use of multi-hop may not be applicable, consequently, a more communication distance between vehicles is needed. The maximum coverage area ofvehicular network according to WAVE standards is about 1Km, however 7db is needed for 150m using IEEE802.11p technology [12]. This means, to increase the coverage, more power is needed. How to increase the coverage area within the maximum allowable power?

E. Bit rate enhancement techniques

VANET can be used for carrying video, audio, internet data, images (maps) and many application that require high data rate, specially with advert of internet of vehicle (IoV) [33]. The previous IEEE 802.11 version bit rate was up to 54Mb/s while that of IEEE 802.11p has been reduced to half, because of the limitations of PHY layer regard some of vehicular network characteristic exactly mobility. The challenge here is how can we improve communication techniques such as modulation, FEC and frame size, in order to increase the bit rate and reduce BER, with maximum utilization of the bandwidth?

Finally, however, some of those issues are not unique to VANETs such as multipath propagation effects, Doppler shift and so forth. These challenges have been partiallyaddressed in legacy cellular communications systems. The important question is whether solutions proposed for cellular communications systems are applicable for VANETS. And what are the new challenges introduced by VANETs?

CONCLUSION

VANETs have emerged as a new technology that helpsin providing vehicles safety and driving comfort. In addition to their impacts in the new emerging concept known as internet of vehicle (IoV) and many applications related to human safety and cosiness. The PHY is key factor in achievement of the objectives of these networks. This paper presented general overview of PHY of IEEE 802.11p standard. The frequency band, specifications and block diagram of the WAVE PHY have been presented and discussed. Moreover, some of the effective PHY challenges are listed out and analysed. Our future researches will concentrate on those challenges however, interested researchers can referred to this work so as to review PHY fundamentals and find solutions to those challenges. Also it can be developed in order to design a general evaluation platform for VANET PHY, and carry out an extensive simulation model for the PHY of IEEE802.11.

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