IEEE 802.11p WAVE 시스템에서 미드엠블을 이용한 채널추정 기법의 측정

조 웅[*]

A Measurement Study of Midamble based Cannel Estimation in IEEE 802.11p WAVE System

Woong Cho[*]

요 약

무선랜에서 널리 사용되는 OFDM기반의 IEEE 802.11a/g 시스템에서는 채널추정시 프리엠블 (preamble)만을 이용하기 때문에 한 패킷당 한 번의 채널추정을 수행한다. 미드엠블 (Midamble)을 이용한 채널추정은 기존의 프리엠블을 이용하는 방식에 비해 채널의 상태 정보를 주기적으로 추적함으로서 연속적인 채널추정이 가능하도록 한다. 본 논문에서는 IEEE 802.11p기반의 차량통신시스템에서 미드엠블을 이용한 채널추정기법의 성능을 실제 측정된 결과를 바탕으로 분석한다. 측정된 결과를 이용하여 실제 시스템에서 미드엠블을 이용한 채널추정기법의 적용 이슈에 대해 논의 한다.

ABSTRACT

Orthogonal Frequency Division Multiplexing (OFDM) based IEEE 802.11 a/g systems which are widely used in wireless LAN carry out channel estimation in one time per packet since the systems use only preamble. Whereas, midamble based channel estimation supports continuous channel estimation by tracking the channel state information periodically. Using IEEE 802.11p Wireless Access in Vehicular Environments (WAVE) system, we analyze the performance of the proposed system via practical measurements. Based on these results, practical issues on midamble based channel estimation are investigated.

키워드

Midamble, Channel estimation, IEEE 802.11p, WAVE, Vehicular communication

미드엠블, 채널추정, IEEE 802.11p, WAVE, 차량통신

Ⅰ. Introduction

Information and communication technology (ICT) creates a new convergence area by combining other industrial fields. In intelligent transportation systems (ITS), vehicular communication which combines ICT and road/automobile technology provides various services especially focusing on safety related applications. Recently, standards for vehicular communications have been developed by IEEE. The standards are referred as WAVE, and physical layer (PHY)/ medium access layer (MAC) is defined in

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* 중원대학교 컴퓨터시스템공학과(wcho@jwu.ac.kr)

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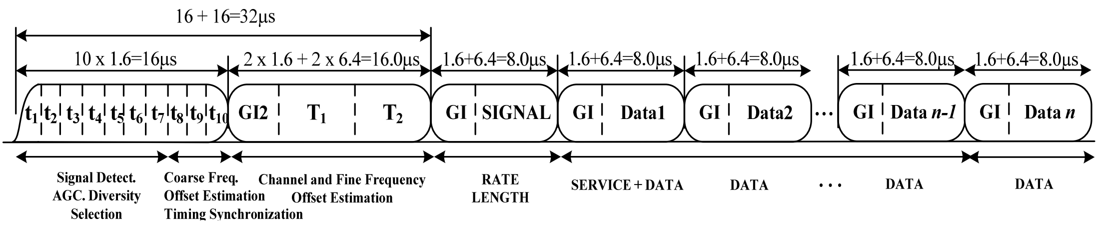

Fig. 1 OFDM packet structure

IEEE 802.11p [1]. PHY related issues and some practical measurement results are introduced in [2] and [3]. In PHY, channel estimation is critical to initiate reliable communication links. The channel estimation scheme in IEEE 802.11p originates from IEEE 802.11a [4], which achieves channel state information in long training symbol period of the preamble and this information is used for the whole packet. Channel estimation scheme for MIMO-OFDM is proposed in [5], which is also using preamble. Preamble based channel estimation is well suitable for time-invariant channels such as low mobility scenarios. However, in vehicular environments, the channel changes rapidly, which distorts and corrupts the travelling signals. These channel variations result in performance degradation of communication systems. To adapt and overcome these problems, the decision directed method and the pilot aided method are considered in OFDM systems [6] [7]. However, the former requires long estimation time and complex operation due to the decoding data process, and the latter is not sufficient to support the high mobility environment. In this paper, we introduce midamble based channel estimation which simply modifies the existing signal structure.

The rest of the paper is organized as follows. In section II, we review IEEE 802.11p PHY and channel characteristics. Midamble based channel estimation is introduced in III. In Section IV, we demonstrate experimental measurement results including some discussions, and conclusion remarks are given in section V.

Ⅱ. IEEE 802.11p PHY and channel characteristics

PHY of IEEE 802.11p standard adopts OFDM with 10MHz channel bandwidth to support high mobility at 5.850-5.925GHz frequency band, where the subcarrier spacing is 156.25KHz, and IFFT/FFT period and Guard Interval (GI) are 6.4μs and 1.6μs, respectively. Therefore, the symbol interval is 8.0(6.4+1.6)μs. Depending on modulation schemes, WAVE supports from 3 to 27Mbps. OFDM packet structure is depicted in Fig. 1, where the first part of packet is preamble which consists of ten short training symbols and two long training symbols. The short training symbols are used for signal detection, automatic gain control (AGC), coarse frequency offset estimation, and synchronization. The long training symbols are used for fine frequency offset estimation and channel estimation. In conventional wireless LAN systems, i.e., IEEE 802.11 a/g, only preamble is used for channel estimation. Therefore, channel estimation occurs one time per one packet transmission. This scheme may be suitable for low mobility environments. However, we may require additional channel information in high mobility to support reliable communication links.

In [8], four criterions for channel characteristics are measured with vehicle-to-vehicle (V2V) environments at 5.9GHz, and Table 1 represents the worst value of four criterions. To provide reliable communication links, four criterions have to satisfy the following conditions:

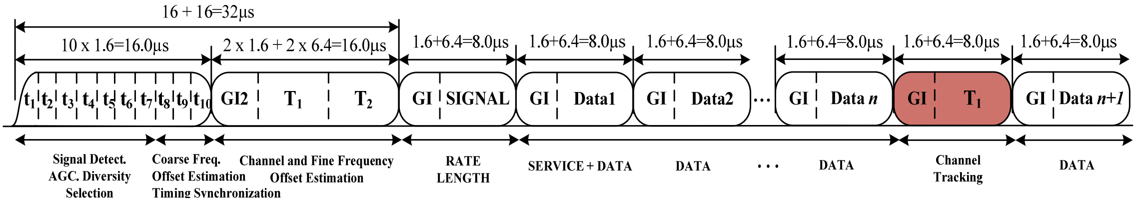

Fig. 2 OFDM Packet structure with midamble

1. Guard interval > Maximum excess delay
2. Coherence bandwidth > Carrier spacing >> Doppler spread
3. Interval between channel estimates < Coherence time

Table 1 represents the measured data of vehicular communication channel, and the data indicates that the signal satisfies first two conditions. However, the coherence time has to be carefully considered since it is directly related to the packet length. To guarantee stable communication quality, the packet duration (the interval between channel estimation) must be smaller than the coherence time of the channel. Table 2 shows the total packet length which includes preamble, signal field and data field depending on various data lengths. The table reveals that IEEE 802.11p standard satisfies the coherence time condition only for short packet transmission, while long packet transmission, i.e. greater than or equal 1000bytes packet length, may induce performance degradation due to long packet duration. Motivated by this point, we propose the midamble based channel estimation.

Table 1. Measured channel properties.

Criterion	Worst value
Max. excess delay	1.5μs
Min. 90% coherent bandwidth	410KHz
Max. Doppler spread	1.11KHz
Min. 90% coherence time	0.3ms

Table 2. Total packet length depending on data length.

Data rate (Mbps)	Modulation	Total packet length (ms)		
		Data length (bytes)		
		100	1000	2000
3	BPSK	0.32	2.7	5.384
6	QPSK	0.184	1.384	2.712
9	16QAM64	0.112	0.712	1.376
12	QAM	0.072	0.344	0.64

III. Midamble based channel estimation

The basic idea of proposed scheme is to insert midamble periodically into the data symbols. The packet structure with midamble is represented in Fig. 2. For channel tracking, midamble is inserted in the middle of data symbol, which is the only difference compared with the original packet structure. The initial channel estimation is carried out using preamble, and updating/tracking of the rest channels are processed by midambles. The proposed scheme enables continuous channel estimation, which compensates the drawback of coherence time condition in vehicular environments. Therefore, the overall performance of communication systems will be enhanced, and it is verified that the proposed system provides better performance. For detailed scheme and simulation results, we refer the reader to [9].

The actual channel estimation is carried out the following methods:

1. Initial channel estimation: uses the long training symbol by applying least square (LS) algorithm. The estimated channel value $H = Y/X$, where Y is received signal and X is long training

symbol. For detailed channel estimation, the average value of long training symbol T1 and T2 are used. This channel information is used for channel equalization before midamble appearing.

2. Additional channel estimation: uses midamble, where midamble is the copy of one long training symbol. As we depicts in Fig. 2, the long training symbol T1 is the same as midamble. This channel information is used for compensating and tracking channel variation. The length of midamble is the same as one data symbol, i.e., 8μs.

Fig. 3 describes the block diagram of channel estimation and equalizer. As depicted in Fig. 3, the estimated channel value (initial channel estimation) is stored in RAM using two long training symbols, and the additional channel value is also stored in RAM when midamble is inserted. The existence of midamble is detected by looking SIGNAL field and DATA field of OFDM packet as shown in Figs. 1 and 2.

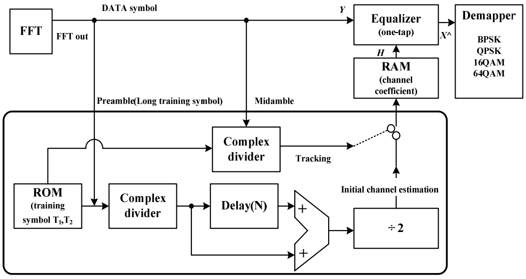

Fig. 3. Block diagram of channel estimation and equalizer

It is worth mentioning that midamble insertion ratio is adjustable. For example, the midamble insertion ratio in Fig. 2 is n. The large value and small value of n correspond to the low rate (occasional insertion) and high rate (frequent insertion) of midamble insertion, respectively. Therefore, we may achieve accurate channel state information by inserting midamble frequently. However, the actual data transmission rate decreases due to communication overhead. More detailed discussion about this aspect will be made in the following section. In the next section, we also provide experimental measurement results of midamble based channel estimation.

IV. Experimental measurement

4.1. Measurement results

To measure the effects of proposed system in practical system, we build an 802.11p based communication system using FPGA. We measure the packet error rate (PER) using 16QAM with and without midamble. The midamble is inserted every 4 data symbols (n=4 in Fig. 2). With 100km/h speed and 5.86GHz center frequency, two channel scenarios are considered in freeway environments. In scenario 1, line-of-sight (LOS) environment is considered, and some obstacles is placed in scenario 2, i.e., partially non-LOS environment. To measure the PER, both short packet and long packet are transmitted. We use 100 bytes packet length for the short packet and 1000 bytes packet length for long packet. We measure the error rate with vehicle-to-infrastructure (V2I) communication. 100km/h of vehicle speed is used and distance between the infrastructure and vehicle is approximately 400m to 600m. The 1000 packets are transmitted from the infrastructure and the number of correctly received packets and error packets are recorded.

Table 3 shows the measurement results of average PER. In general, short packet transmission has better performance than long packet transmission, which agrees with the simulation results in [9]. It is worth recalling that the corresponding packet durations including preamble and signal field are 0.112ms for the short packet and 1.384ms for the long packet. In long packet transmission, the performance degradation is expected since the total packet duration is longer than the coherence time.

For short packet transmission, there is no big difference in PER for the systems with and without midamble. For long packet transmission, the performance is different depending on the environments. If the midamble is inserted, the average PER is improved by 1.6% and 8.4% for scenario 1 and scenario 2, respectively. This result indicates that the effect of midamble is more critical in bad channel, and the proposed scheme can support long packet transmission with high-order modulation such as 16QAM and 64QAM.

Table 3. Average packet error rate depending on the packet length and channel environment.

packet length	100bytes		1000bytes	
Midamble	off	on	off	on
LOS	0.4%	0.4%	5%	3.7%
NLOS	2%	1.9%	21.7%	13.3%

4.2. Discussions

The benefit of the proposed scheme is verified by practical measurements. Let us consider some practical issues on the midamble based channel estimation. One is communication overhead and the other is backward compatibility. Midamble insertion induces communication overhead compared with the conventional preamble based system. In our measurements, without using midamble, the short packet and the long packet consist of 9 data symbols and 168 data symbols, respectively. By inserting the midamble every four symbols, each packet has 2 and 42 midambles, which correspond to approximately 18% and 25% communication overhead, respectively. By sacrificing the performance, the communication overhead can be reduced by adjusting the midamble inserting rate. Therefore, there is a trade-off between the midamble and the performance requirement. The optimal midamble insertion rate can be chosen by the system design level. The other issue is that the proposed scheme cannot support the backward compatibility with the current OFDM based systems. To fully adopt the proposed scheme in practical system, it may be required to obtain the international agreement.

V. Conclusions

We proposed the midamble based channel estimation which is suitable for vehicular environments. Practical measurements using IEEE 802.11p WAVE system reveal that the proposed scheme can improve the performance of communication systems especially for the long packet transmission and in bad channel. We also address some practical issues on the implementation of midamble based channel estimation.

References

[1] IEEE Std 802.11p, IEEE standard for information technology-telecommunications and information exchange between systems-local and metropolitan area network-specific requirement, Part 11 Amendment 6: Wireless Access in Vehicular Environments, July 2010

[2] W. Cho, "Physical layer issues in vehicular communications", The Journal of the Korea Institute of Electronic Communication Sciences, Vol. 7, No. 5, pp. 1229 - 1234, Oct. 2012.

[3] W. Cho, "Usage of RSSI in WAVE handover", The Journal of the Korea Institute of Electronic Communication Sciences, Vol. 7, No. 6, pp. 1449 - 1454, Dec. 2012.

[4] IEEE Std 802.11, IEEE standard for information technology-telecommunications and information exchange between systems-local and metropolitan area network-specific requirement, Part 11: Wireless LAN medium access control (MAC) and physical layer (PHY) specifications, 2007

[5] S. S. Hwang, "Channel estimation based on LMS algorithm for MIMO-OFDM system",

The Journal of the Korea Institute of Electronic Communication Sciences, Vol. 7, No. 6, pp. 1455–1461, Dec. 2012.

[6] H. Chen and X. Chen, "Decision directed techniques for channel estimation in OFDM mobile systems", Proc. of Wireless Communication, Networking and Mobile Computing, September 2006, pp. 1–4.

[7] M. Dong, L. Tong, and B. M. Sadler, "Optimal pilot placement for channel tracking in OFDM", Proc. of Milcom, October 2002, Vol. 1, pp. 602–606.

[8] L. Cheng, B. E. Henty, D. D. Stancil, and F. Bau, "A measurement study of time-scaled 802.11a waveforms over the mobile-to-mobile vehicular channel at 5.9 GHz", IEEE Communication Magazine, Vol. 2, No. 4, pp. 84-91, May 2008.

[9] W. Cho, S. I. Kim, H. K. Choi, H. S. Oh, and D. Y. Kwak, "Performance evaluation of V2V/V2I communications: the effect of midamble insertion", Proc. of Int. Conf. on Wireless Communications, Vehicular Technology, Information Theory and Aerospace & Electronic systems Technology, May 2009, pp. 793-797, 2007.

저자 소개

조 웅(Woong Cho)

1997년 울산대학교 전자공학과 졸업(공학사)

1999년 한양대학교 대학원 전자통신공학과학과 졸업(공학석사)

2003년 Univ. of Southern California 대학원 전기전자공학과 졸업(공학석사)

2007년 Univ. of Florida 대학원 전기컴퓨터공학과 졸업(공학박사)

2008년 2월～2011년 2월 한국전자통신연구원

2012년 3월～현재 중원대학교 컴퓨터시스템공학과 교수

※ 관심분야 : 무선통신, 협력통신, ITS