Performance Evaluation of OFDM-based IEEE 802.11a MAC Protocol Under Indoor Wireless Channel *

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Abstract

In this paper, we evaluate the throughput and delay performance of a wireless Local Area Network(WLAN) employing the OFDM-based IEEE 802.11a Medium Access Control(MAC) protocol by computer simulations under wireless indoor channel. Packet Error Rate(PER) is also investigated for the various Eb/No. It is shown that, with soft-decision Viterbi decoder, throughput and delay performance are close to those of error-free channel at Eb/No above 8dB and PER is about 2×10^{-5} at Eb/No=10dB.

I. INTRODUCTION

Wireless Local Area Networks(WLANs) provide an attractive networking alternative which enables flexible location of terminals and can avoid re-wiring when terminals are relocated [1]-[3]. A WLAN employs wireless communications for interconnecting Wireless Terminals(WTs) among themselves to form an ad-hoc network, or with a backbone Local Area Network(LAN) via access points or Radio Bridges(RBs) to form an infrastructure network [2]-[4].

Performance analysis and evaluation of existing 802.11 WLAN system have been performed by many researchers [5]-[8]. Since WLANs usually operate in the indoor environment where propagation effect such as fading and shadowing degrade system performance, wireless channel characteristics should be applied for performance evaluation of WLAN MAC protocol [9][10]. For this reason, some researchers considered wireless channel characteristics to investigate performance[6]-[8].

At present, IEEE is being proposing the 802.11a standard, whose scope is the definition of the MAC and PHY specifications for wireless LANs [11]. The unique difference between 802.11a and 802.11 is the Physical layer(PHY) as shown in Figure 1 [3][11]. The data rate of existing 802.11 WLAN is 1-2 Mbit/s, which is not proper for high-speed communications. To support high speed WLANs, Orthogonal Frequency Division Multiplexing(OFDM) PHY has been introduced in 802.11a standard. In addtion, OFDM protects against multipath fading in wireless environment and its complexity is less than that of typical single-carrier adaptive equalizers.

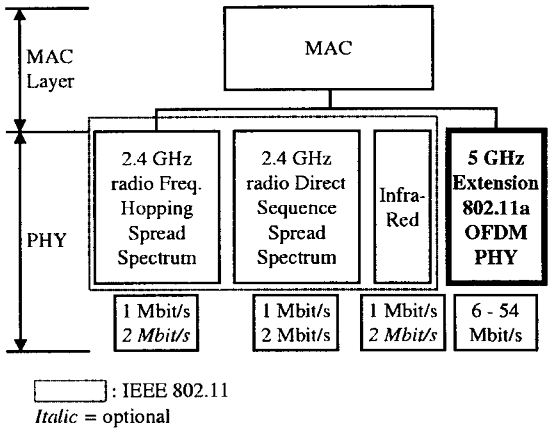

Figure 1: IEEE Std 802.11-1999

A few works applied OFDM PHY into 802.11 to evaluate WLAN MAC protocol in terms of throughput and delay [8]. Even though this work was new joint simulation between Physical and MAC Layer, authors in [8] used not IEEE 802.11 MAC protocol but a similar Markov model as the non-persistent CSMA/CA. Although non-persistent CSMA/CA is close approximation of IEEE 802.11 MAC protocol, throughput performance is getting worse rapidly beyond the offered traffic value, at which provides maximum throughput performance. In addition, the previous works did not consider the channel coding such as convolutional coding included in IEEE 802.11a [11]. Therefore, for accurate performance evaluation of IEEE 802.11a, simulation of WLAN system following MAC and PHY specification of IEEE 802.11a , is needed at this time.

In this paper, the throughput and delay performance of WLAN employing the IEEE 802.11a MAC protocol is evaluated under wireless indoor channel recommended by ITU(Rec.ITU-R M.1225 proposed in [12]) at given Eb/No. All MAC and PHY specifications exactly follow IEEE Std. 802.11a [1].

This work is supported in part by BK-21 Project, MOE, and ERC-UFON, MOST.

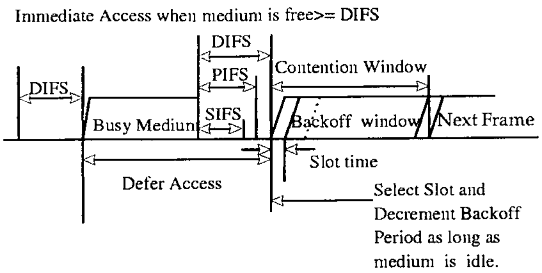

Figure 2: Basic Access Mechanism

II. 802.11a Specification Overview

A. *IEEE 802.11 MAC Protocol*

The 802.11 MAC layer protocol provides asynchronous, time-bounded, and contention free access control on a variety of physical layers. The basic MAC protocol specified in IEEE 802.11 is a Distributed Coordination Function(DCF),which is given in Figure2, that allows for sharing of the wireless channel through Carrier Sense Multiple Access with Collision Avoidance(CSMA/CA) and a random backoff time. The DCF is implemented in all stations and access points. An alternative access is a Point Coordination Function(PCF) which may be implemented on top of the DCF, using a point coordinator to determine which station currently has the right to transmit. In this paper we focus on the DCF for system modeling and performance evaluation. The MAC procedure of DCF is presented in Figure 3.

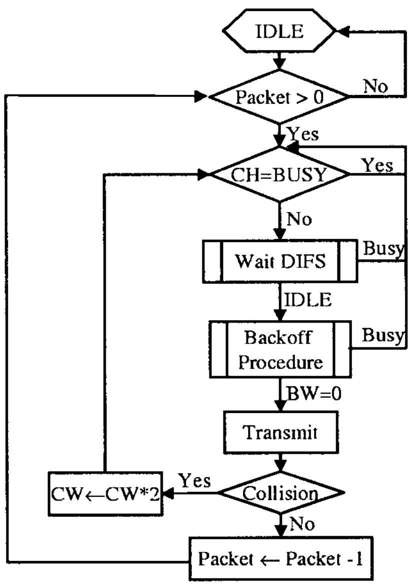

Figure 3: MAC flow diagram

B. *IEEE 802.11a PHY*

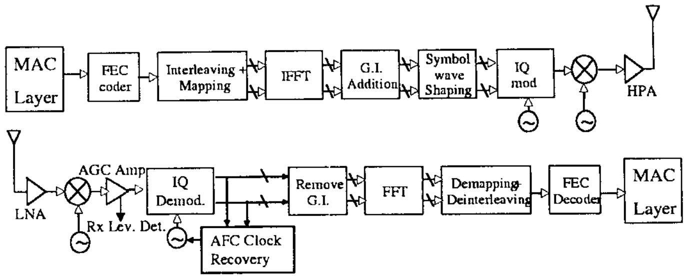

Figure 4: OFDM PHY Block Diagram

The OFDM system provides a wireless LAN with data payload communication capabilities of 6,9,12,18,24,36,48,and 54 Mbit/s. The radio frequency LAN system is initially aimed for the 5.15-5.25,5.25-5.35 and 5.725-5.825 GHz unlicensed national information structure(U-NII) bands and the support of transmitting and receiving at data rates of 6,12 and 24 Mbit/s is mandatory. The system uses 52 subcarriers that are modulated using binary or quadrature phase shift keying(BPSK/QPSK),16-quadrature amplitude modulation (QAM), or 64-QAM. Forward error correction coding(convolutional coding) is used with a coding rate of 1/2,2/3, or 3/4. The transmitter and receiver block diagram and major parameters for the OFDM PHY are described in Figure 4 and Table 1, respectively.

Number of subcarriers	52
OFDM symbol duration	4.0 us
Guard Interval	0.8 us
Occupied bandwidth	16.6 MHz

Table 1: Major parameters of the OFDM PHY

III. SYSTEM CONFIGURATION

A. *Traffic Modeling*

We assume each station generate packet in a slot according to Packet Generation Probability(P_G),which is determined by Normalized Offered Traffic(G), and P_G has geometric distribution. Because only Distributed Coordinate Function(DCF) is implemented, we have assumed all stations generate delay-insensitive asynchrous data traffic(like file transfers and electronic mail).

B. *MAC Layer Modeling*

Packet transmission mechanism follows IEEE 802.11a MAC protocol exactly. The procedure is described in Figure 3. Following CSMA/CA, when a station has packet to transmit, it has to wait until channel idle for a period of time called Inter Frame Space(IFS). After channel idle for

IFS, it uses a random number generator to set a random backoff time. In the coming slot, the user decreases its backoff time by one if it finds channel idle. In case channel is found busy, the backoff time counting should be frozen till channel being idle for IFS again.

C. Simulation parameters

Major simulation parameters is presented in Table 2 . Rec.ITU-R.M.1225 indoor channel B is in Table 3

Simulation time	3×10^6
Packet Length	100 slots
aSlotTime	9 us
aSIFSTime	16us
aDIFSTime	34us
Channel Frequency	5.15GHz
Data Rate	6 Mbps
Modulation	BPSK
Interleaver1	16 × 3
Interleaver2	3 × 16
Channel Coding	K=7, rate=1/2 g1=133, g2=171
Convolutional Decoder	Soft-Decision Viterbi dec.
Channel	Indoor Fading Channel Rec.ITU-R.M.1225

Table 2: Major parameters of the simulation

Tab	Channel B		Doppler Spectrum
	Relative delay(us)	Average Power(dB)	
1	0	0	Flat
2	100	-3.6	Flat
3	200	-7.2	Flat
4	300	-10.8	Flat
5	500	-18.0	Flat
6	700	-25.2	Flat

Table 3: Rec. ITU-R M.1225 Indoor Channel Model B

IV. SIMULATION RESULTS

The simulation was performed under multipath fading channel according to Rec.ITU-R.M.1225(proposed in [12]). We assume that channel characteristic does not change in one OFDM block and frequency offset and timing offset can be negligible due to Guard Interval(GI) .

Figure 5 shows Packet Error Probability(PER) versus Eb/No. At Eb/No=10dB, PER is about 2×10^{-5}. In the case of BPSK without channel coding(K=7 convolutional coding), required Eb/No must be about 16.7dB to achieve

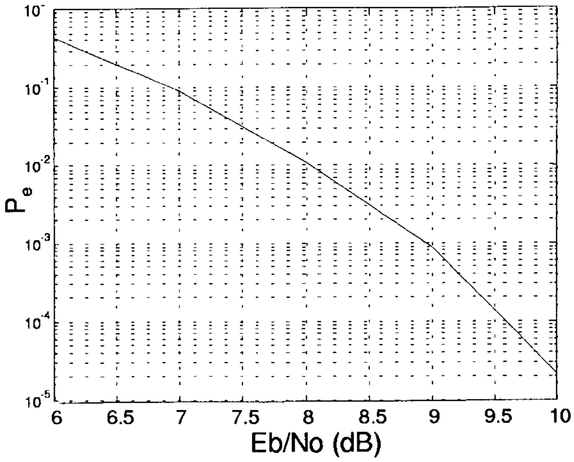

Figure 5: Packet Error Probability

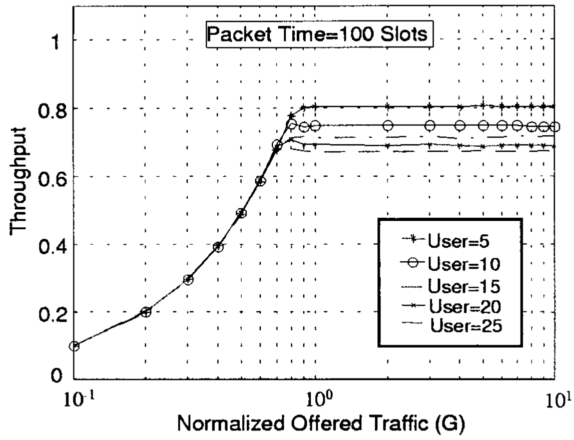

Figure 6: Throughput vs. Normalized Offered Traffic under Ideal Channel

PER=2×10^{-5}. About 6.7dB gain is from both convolution coding and soft-decision Viterbi decoder. However, this gain is less than theoretical performance improvements due to both convolutional coding and soft-decision Viterbi decoder, because soft-decision Viterbi decoder is optimized for Additive White Gaussian Noise(AWGN) not fading channel.

Figure 6 shows throughput performance under error-free channel. As number of users increased, maximum throughput is decreased. This is from increment of probability of collision among users. According to analysis results of conventional CSMA/CA, the throughput performance of infinite number of users will be fallen rapidly to 0 at high offered traffic.

Figure 7 shows throughput performance versus normalized offered traffic under indoor wireless channel at different Eb/No. The throughput performance saturates as Eb/No is above 8dB. At Eb/No=10dB, the throughput is almost same as that of error-free channel. In wireless indoor environments, the IEEE 802.11a WLAN system has terrific performance with endurance for wireless channel

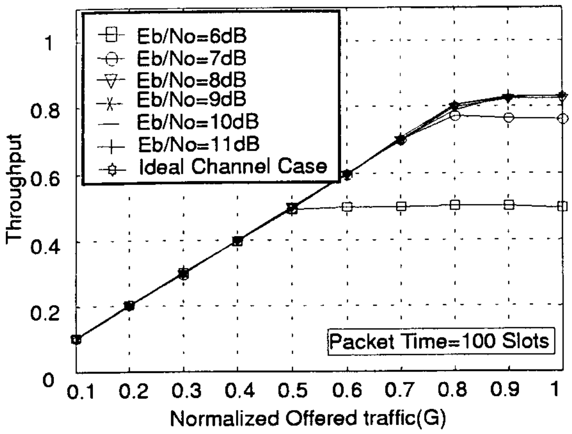

Figure 7: Throughput vs. Normalized Offered Traffic under given Eb/No

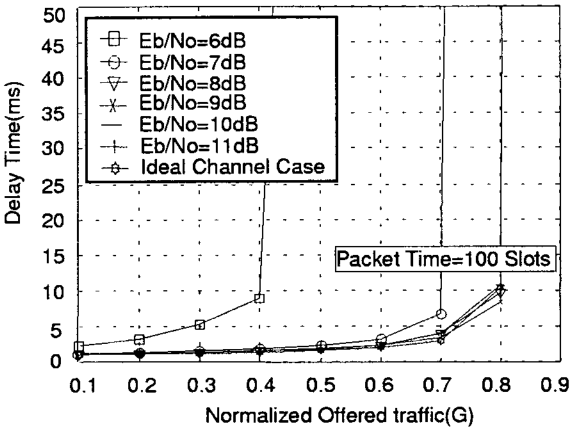

Figure 8: Delay vs. Normalized Offered Traffic under given Eb/No

impairment.

Figure 8 shows delay performance versus normalized offered traffic under indoor wireless channel. Delay time increases rapidly from the value of the normalized offered traffic which provides maximum throughput performance. Delay performance also shows similar trend like that of throughput performance.

V. Conclusions

In this paper, we evaluated throughput and delay performance of IEEE 802.11a WLAN standard under indoor channel recommended by ITU. Also, we investigated Packet Error Rate at various Eb/No values.

According to the simulation results, In spite of multipath fading channel, the IEEE 802.11a WLAN system has almost the same performance as that under error-free channel at Eb/No above 8dB. when normalized offered traffic is 0.9 at 8dB, throughput is about 0.8. When it comes to delay time, each station has delay time less than 10 ms at normalized offered traffic below 0.8. The trend, performance measures saturate to ideal channel case, is obtained, when both convolutional coding with interleavings and soft-decision Viterbi decoder were applied. In coded case, about 6.7dB gain is obtained compared to uncoded case at PER=2×10^{-5}.

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