Physical Analysis of OFDM Based IEEE 802.11a for Multipath Rayleigh Channel

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***Abstract*—Wireless local area networks(W-LANs) have become increasingly popular due to the recent availability of affordable devices that are capable of communicating at high data rates.The IEEE 802.11a standard is WLAN standard which uses orthogonal frequency division multiplexing technology.The standard provides data rates upto 54 Mbps making it a good candidate for high-speed wireless communication. It utilizes different modulation schemes for different data rates,since the choice of modulation scheme to be used depends upon the current state of the transmission channel,Recent wireless devices often support multiple modulation schemes , and hence multiple data rates are possible.The selection of the best rate is obtained through a rate adaptive MAC protocol called the Receiver-Based Auto Rate (RBAR) protocol[1].The performance of the standard is studied under the indoor wireless environment for Multipath Rayleigh channel.In this paper ,the simulation results for modulation schemes 16-QAM and 64-QAM are estimated.**

***Keywords*—OFDM, WLAN, BER,SNR, RBAR.**

I. Introduction *(Heading 1)*

In 1990,the IEEE 802 committee formed a new working group, IEEE 802.11,specifically devoted to wireless LANs,with a charter to develop a MAC protocol and physical medium specification. The initial interest was in developing a wireless LAN operating in the ISM (industrial,scientific and medical) band.With increase in demand for WLANs the IEEE 802.11 working group developed several new WLANs standard providing different data rates and and operating frequencies[2].The first 802.11 standard to gain broad industry acceptance was 802.11b.This standard is operated in 2.4GHz ISM frequency band and maximum data rate provided by the standard is 11Mbps using Direct Sequence Spread Spectrum(DSSS) modulation. IEEE 802.11a standard operates over 5 GHZ frequency band using OFDM modulation.There are 8 different transmission modes available for this standard with various data rates from 6Mbps to 54Mbps,3 different code rates and 4 types of modulations(BPSK, QPSK, 16-QAM,64-QAM). The mode selection in IEEE 802.11a is done by using Receiver Based Auto Rate (RBAR) mechanism.This selection depends upon sender and receiver current states.

TABLE 1 TRANSMISSION MODES

Mode	Modulation	Code Rate	Data Rate
1	BPSK	1/2	6
2	BPSK	3/4	9
3	QPSK	1/2	12
4	QPSK	3/4	18
5	16-QAM	1/2	24
6	16-QAM	3/4	36
7	64-QAM	2/3	48
8	64-QAM	3/4	54

The above table 1 shows the mode of transmission in IEEE 802.11a standard[3].Basically if the channel condition is suitable, station can increase its sending rate by selecting a new mode. RBAR mechanism try to select the best mode with the help of SNR computed at the receiver side.In section 2 the fundamentals and principles of OFDM are studied in detail.The different modulation schemes are discussed in section 3. The RBAR mechanism is introduced in section 4.In section 5 the results for different fading modes under Multipath Rayleigh Channel are presented.Finally the conclusion and future work are presented in section 6.

II. Multicarrier OFDM Modulation Technique

Single-carrier modulation systems transmit data symbols over a single carrier frequency.Multicarrier modulation systems transmit data symbols over N parallel subcarriers resulting in a longer symbol duration. FDM is a multicarrier multiplexing technique in which number of signals are combined and transmitted on a single communication line or channel.Each signal is assigned different carrier frequency within the main channel. The assigned carrier frequencies are separated by the guard bands, which act as buffer zones to reduce the inter-carrier interference(ICI),or cross-talk ,from adjacent spectral regions. However ,this separation in the spectrum wastes the available bandwidth[4].In FDM, the adjacent bands are non-overlapping but if overlapping is allowed such that transmitting signals are mutually orthogonal to each other,then the resulting transmission technique is known as Orthogonal Frequency Division Multiplexing.(OFDM).

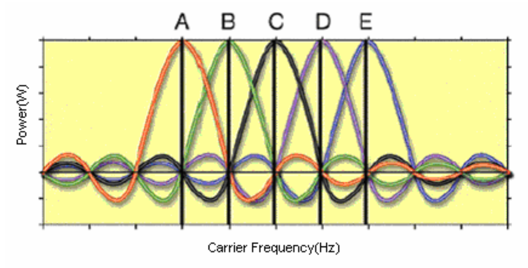

Figure 1.Orthogonally overlapped subcarriers

This property of orthogonality between subcarrier frequencies avoids the cross-talk between subchannels and also eliminates the need of inter-carrier guard bands. Elimination of the inter-carrier guard bands greatly simplifies the design of both transmitter and receiver[5].The orthogonally placed subcarriers are shown in figure 1.

In single carrier or multicarrier (FDM) transmission systems,for high data rate communication the bandwidth requirement goes on increasing as the data rate increases or the symbol duration decreases.But in OFDM instead of sending S symbols in T seconds serially, they are sent in parallel which increases symbol duration and reduces the bandwidth to a great extent.Thus Using OFDM approximately 50% of the bandwidth is saved[6].OFDM-based IEEE 802.11a uses total 52 subcarriers out of which 48 subcarriers are used as pilot signals.The pilot signals are inserted for the measurement of channel condition.These are also used for synchronization [5].

A. *Cyclic Prefix Addition*

A Guard interval(Tg) or cyclic prefix is inserted between two consecutive OFDM symbols.Cyclic prefix insertion helps to combat against intersymbol interference (ISI).ISI should be minimized as it decreses orthogonality and has an effect that is similar to inter-channel interference.Guard interval should be larger than transmission delay ,otherwise the impact of ISI will be significant .To eliminate the ISI the last 16 subcarriers are copied at the beginning of the OFDM symbol as shown in figure 2.

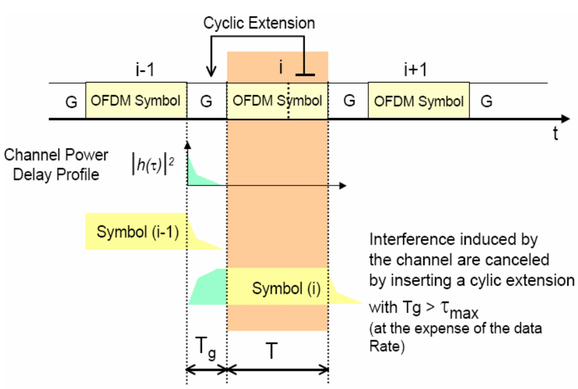

Figure 2. Adding cyclic prefix

Guard interval provides tolerance to multipath delay spread upto several hundreds of nanoseconds depending on the code rate and modulation used in any indoor wireless application.Guard Interval should be larger than the transmission delay otherwise the impact of ISI will be significant .Thus to eliminate the ISI the last 16 subcarriers are copied into the beginning of the OFDM symbol[7].

B. *OFDM Signal Processing*

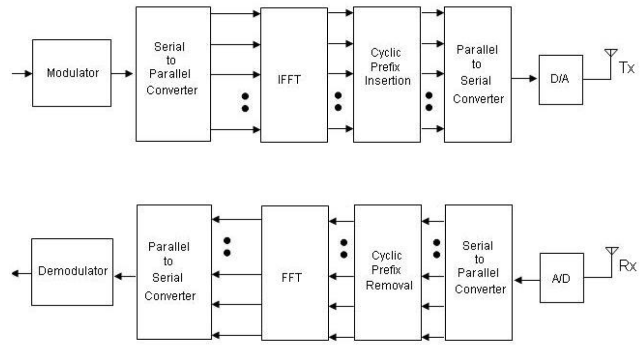

Figure 3.Ofdm transreceiver

In the transmitter ,the input data are encoded using convolutional encoder with the constraint length 7.The mother code of the convolutional encoder is1/2.This mother code rate is changed by using puncturing process corresponding to the desired data rate.Then the coded data is interleaved and mapped. Interleaving avoids the burst errors.Interleaver transforms the burst error of the sequential bits into the form of independent errors.Thus the convolutional decoder can correct these independent errors at the receiver side.After interleaving ,the coded binary bits are mapped into PSK/QAM constellation points.After serial-to-parallel conversion ,each OFDM symbol is modulated over 52 subcarriers by applying an 64-point IFFT.A cyclic extension is added as guard interval to prevent ISI.The OFDM signal processing is shown in figure 3.The parameters coded bits per subcarrier, coded bits per OFDM symbol and data bits per OFDM symbol are rate dependent parameters which are shown in the following table 2.

TABLE 2 RATE DEPENDENT PARAMETERS

Data rate (Mbits/s)	Modulation	Coding rate (R)	Coded bits per subcarrier (N_{BPSC})	Coded bits per OFDM symbol (N_{CBPS})	Data bits per OFDM symbol (N_{DBPS})
6	BPSK	1/2	1	48	24
9	BPSK	3/4	1	48	36
12	QPSK	1/2	2	96	48
18	QPSK	3/4	2	96	72
24	16-QAM	1/2	4	192	96
36	16-QAM	3/4	4	192	144
48	64-QAM	2/3	6	288	192
54	64-QAM	3/4	6	288	216

III. 16-QAM and 64-QAM Modulated OFDM

In order to obtain data rates 24,36,48 and 54,IEEE 802.11a uses the BW efficient M-ary QAM.For square QAM constellation ,the probability of bit error is [7]

$$P_b \approx \frac{4\left(\sqrt{M}-1\right)}{q\sqrt{M}} Q\left(\sqrt{\frac{3q \cdot E_b}{(M-1) \cdot N_0}}\right)$$

Where M is the no. of possible combinations of q bits and q is the no. of bits per symbol.As a result ,q=4 corresponds to 16-QAM and q=6 corresponds to 64-QAM respectively.The constellation diagram for 16-QAM and 64-QAM are given in figure no.4 and 5 as follows.

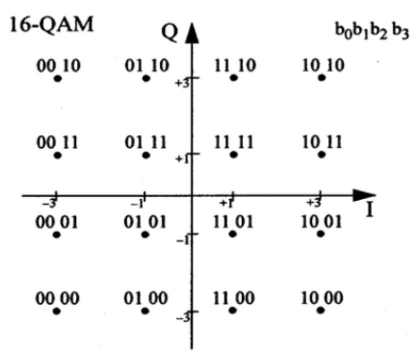

Figure 4. 16-QAM constellation points

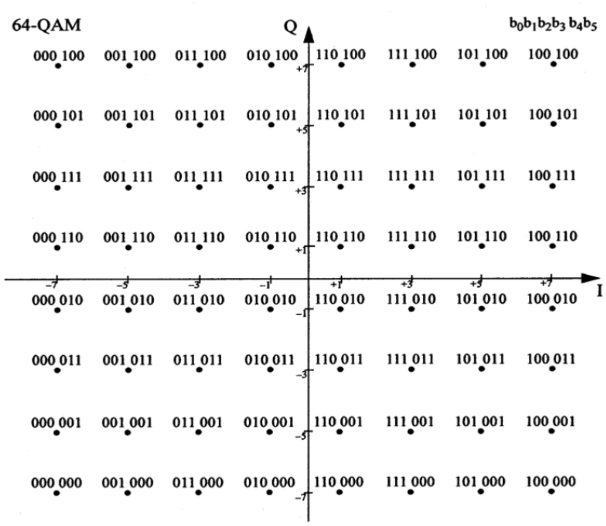

Figure 5. 64-QAM constellation points

IV. RBAR Mechanism

Receiver-Based Auto Rate is rate adaptive protocol. RBAR mechanism employs RTS/CTS reservation scheme. Rate adaption is the process of dynamically switching data rates to match the channel conditions. The Switching mechanism has the goal of selecting the rate that will give the optimum throughput for the given channel condition. The novelty of RBAR is that its rate adaptive mechanism is in the receiver side instead of sender. This protocol is based on the request-to-send (RTS) and clear-to-send (CTS) signals which avoids the frames collision specially for high dated like 54 Mbps[8]. The automatic data rate selection in IEEE 802.11a with RBAR technique is described in detail.

The sender chooses a data rate in some heuristic way (such as the most recent rate that was successful for transmission to the the receiver) and then stores the rate and the size of the data packet into RTS.Other stations overhearing the RTS, calculate the duration of the requested reservation using the rate and packet size carried in the RTS .They update their NAV (Network Allocation Vector) to reflect the reservation . While receiving the RTS , the receiver uses the information concerning the channel conditions to compute an estimation of the conditions for pending data packet transmission. Receiver then selects the appropriate rate with a simple threshold mechanism and transmits it along with the packet size in the CTS bank to the sender. Other stations at this side overhearing the CTS calculate the duration of the reservation similar to the procedure used by stations when they receive RTS and then update their NAV to reflect the reservation . Finally, the sender responds to the receipt of the CTS by transmitting the data packet at the rate selected by the receiver [1].

V. Performance Evaluation

To study the physical layer performance of IEEE 802.11a WLAN standard ,the channel consist of Multipath Rayleigh Fading channel followed by AWGN channel.Because in wireless communication the channel is often modeled by random attenuation (known as fading) of the transmitted signals followed by additive noise[9].In wireless system,fading is caused due to multipath propagation .Fading results in a loss of signal power without reducing the power of the noise.If the fading is more then there is severe drop in the channel SNR ratio and this may cause the temporary failure of the communication .The three different fading modes are considered for performance evaluation. In dispersive fading mode the channel has a dispersed gain(scattered).Since the gain is scattered the strength of the transmitted is weakened heavily over the distance .In this mode the spectral characteristics of the transmitted signal are dispersed (scattered) and cannot be Preserved.There is severe drop in the SNR of the multipath channel.In flat fading mode, as the channel has constant gain the strength of the transmitted signal is weakened slowly over the distance.Spectral characteristics of the transmitted signal are preserved properly at the receiver side as compared to the dispersive fading mode.There is no sever drop in the SNR of the multipath channel.

In no fading mode, there is no fluctuations in the gain of the channel hence the strength and spectral characteristics of signal are well preserved in this mode as compared to above modes [10].

The required PHY mode specified with modulation scheme, code rate and data rate is achieved by the particular SNR and Low SNR Threshold Setting. Figure 6,7,8,9 shows the SNR verses BER plot for different PHY modes under particular simulation setting mode.

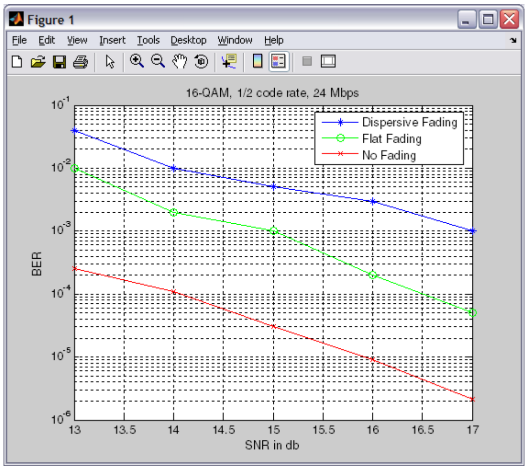

Figure 6: 16-QAM ,1/2 code rate, 24 Mbps

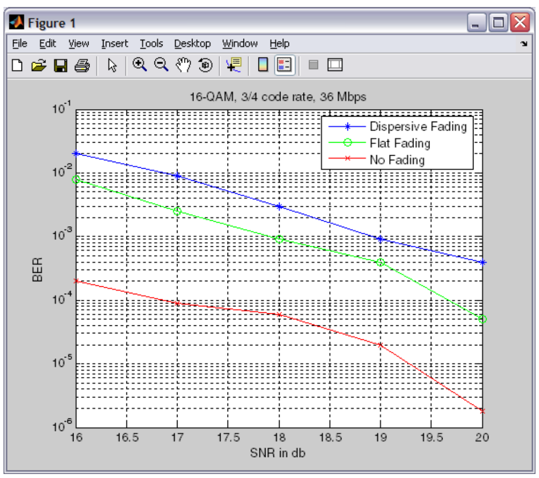

Figure 7: 16-QAM ,3/4 code rate, 36 Mbps

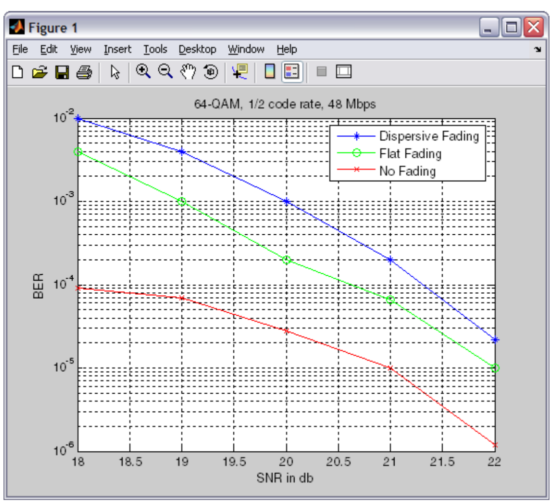

Figure 8: 64-QAM ,2/3 code rate, 48 Mbps

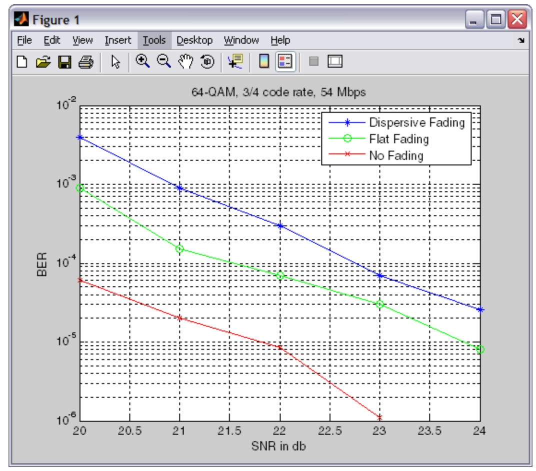

Figure 9: 64-QAM ,3/4 code rate, 54 Mbps

VI. Conclusion

We can see in figure 6,7,8 and 9 that for every data rate under different fading modes, the bit error rate (BER) reduces as the Signal-to-Noise Ratio increases.

From figure 6 and 7 it is clear that for the SNR of 16 dB under dispersive fading mode the BER is 0.003 at 24 Mbps and 0.02 at 36 Mbps which is increased. Thus The performance study of this model shows that less BER is obtained in PHY mode 5 than in PHY mode 6 for the same SNR under dispersive fading mode.

The Multipath channel in dispersive fading mode causes the deep fades and thus required more Signal-to-Noise Ratio to achieve low bit error rate (BER) during the times of deep fades as compared to the channel in Flat fading mode and No fading mode. The quality of services of this standard can be improved by setting high Signal-to-Noise Ratio and appropriate low Signal-to-Noise Ratio thresholds for achieving particular data rate.

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