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K. Shamganth
Engineering Department, Ibra College of Technology, Ibra, Sultanate of Oman, shamkanth@ict.edu.om

M. P.Reena
Electronics & Communication Engineering, Sri Venkateswara College of Engineering, Tamilnadu,India, reena_mp@rediffmail.com

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Capacity Enhancement in WLAN using MIMO

K.Shamganth
Engineering Department
Ibra College of Technology
Ibra, Sultanate of Oman
shamkanth@ict.edu.om

M.P.Reena
Electronics & Communication Engineering
Sri Venkateswara College of Engineering
Tamilnadu,India
reena_mp@rediffmail.com

Abstract- Increasing demand for high-performance 4G broadband wireless is enabled by the use of multiple antennas at both transmitter and receiver ends. Multiple antenna technologies enable high capacities suited for Internet and multimedia services, and also dramatically increase range and reliability. The combination of multiple-input multiple-output (MIMO) signal processing with orthogonal frequency division multiplexing (OFDM) is regarded as a promising solution for enhancing the data rates of next-generation wireless communication systems operating in frequency-selective fading environments. In this paper ,we focus mainly on Internet users in hotspots like Airport etc., requiring high data rate services. A high data rate WLAN system design is proposed using MIMO-OFDM. In the proposed WLAN system, IEEE 802.11a standard design is adopted but the results prove a data rate enhancement from the conventional IEEE 802.11a.

Keywords: WLAN, Next Generation wireless networks, MIMO-OFDM.

I. INTRODUCTION

In recent years, Wireless LANs have gained popularity with the increasing use of laptops in both office environment and in hotspots. The main goals in developing next-generation wireless communication systems are increasing the link throughput (bit rate) and the network capacity. Improvements in throughput can be achieved when multiple antennas are applied at both the transmitter and receiver side, especially in a rich scattering environment.

Multiple Input-Multiple output **(**MIMO**)** system is a promising candidate for future broadband wireless communications capable of data speeds up to 1Gbps. By utilizing multiple antennas (instead of ONE antenna for present systems) at both the transmitter and receiver, together with state-of-the-art signal processing algorithms, MIMO wireless systems are able to achieve data speeds comparable to that of optical fibers. Due to its promising potential, MIMO techniques[1] are almost certain to be included in future wireless systems, such as the 4G cellular network and broadband wireless LAN systems.

OFDM is a modulation scheme that allows digital data to be efficiently and reliably transmitted over a radio channel, even in multipath environments. 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. OFDM is a multi-carrier modulation scheme, which can withstand high levels of multipath delay spread. This property can be exploited to reduce the path loss in WLAN systems the recent advances in Integrated circuit technology have made the implementation of OFDM cost effective.

MIMO technology will predominantly be used in broadband systems that exhibit frequency-selective fading and, therefore, Inter Symbol-Interference (ISI).OFDM modulation turns the frequency selective channel into a set of parallel flat fading channels and is, hence, an attractive way of coping with ISI. These advantages make MIMO and OFDM used together. Hence MIMO-OFDM is a way to meet the next generation wireless challenges.

A potential application of the MIMO principle is the next generation wireless local area network (WLAN). The current WLAN standards IEEE 802.11a [5] and IEEE 802.11g [6] are based on orthogonal frequency division multiplexing (OFDM) [7]. A potential high data rate extension of these standards could be based on MIMO. MIMO framework for Next Generation Internet system for broadband and personal wireless communication is shown in Figure2.

The focus of this paper is on fourth generation (4G) wireless networks. Even though a universal consensus on what is going to be 4G is not yet reached in the industry or the literature, there is a reasonable understanding of some characteristics of 4G mobile networks. Some of the accepted characteristics are:

- All-IP based network architecture

- Higher bandwidth
- Full integration of "hot spot" and "cellular"
- Support for multimedia applications.

A. WLAN STANDARDS

Table1: WLAN Standards

Standard	Description
802.11a	High speed standard operating at 5GHz with data rates up to 54Mbps
802.11b	Operates at 2.4GHz with speeds up to 11Mbps
802.11g	Accommodates for higher speeds up to 54Mbps operating at 2.4GHz following a different modulation technique.

The initial scope for the development of WLAN standards [3], that are to replace coaxial cables and remove the need to drill holes and string wires to connect devices in home and corporate environments, has been enlarged to cover for outdoor connectivity needs as well. The following schema depicts the three application scenarios as shown in Figure 1, where publicly available WLAN refer to information-rich or densely populated in hotspots such as airports, hotels, and parks. Table 1 describes the different WLAN standards with increase in data rate.

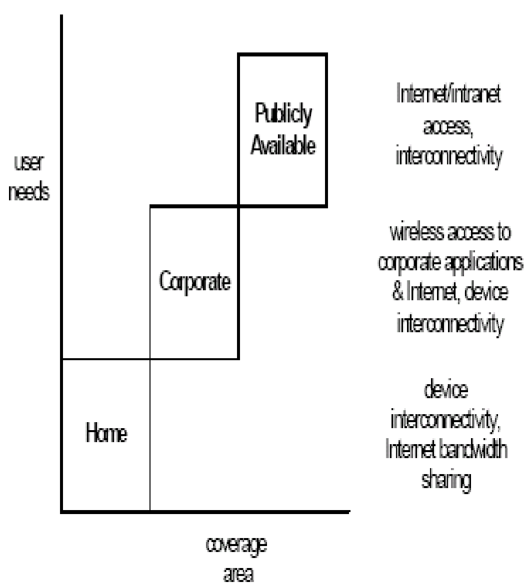

Figure 1: WLAN application scenarios

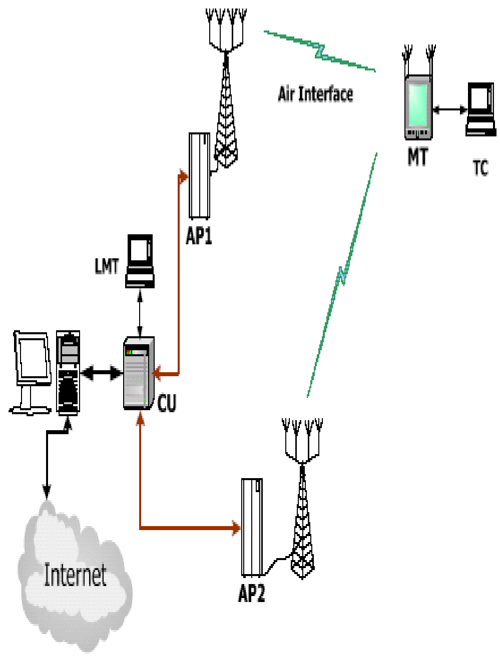

Fig.2 MIMO frame work for Next Generation Internet system for Mobile and Laptops.

Theoretical capacity of MIMO channels:

Traditionally, enhancements to the capacity of single-user communication channels have been achieved by either increasing the baud rate (which leads to larger bandwidths) or by increasing the signal constellation size (which requires higher signal-to-noise ratios). Since bandwidth is a limited resource in both wireless and copper wired communication systems, new signal processing techniques based on the MIMO (multiple-input multiple-output) principle are emerging that exploit the spatial dimension for increasing the channel capacity.

A Single Input-Single Output (SISO) channel is characterized by single transmitter injecting electromagnetic energy into the channel and a single receiver extracting electromagnetic energy from the channel.

Capacity of a SISO [4] channel disturbed by Additive White Gaussian Noise (AWGN) is

$$C = B \log_2(1+SNR) \quad (1)$$

C is the upper bound on the channel capacity in bits/sec. B is the bandwidth of the information bearing signal. SNR is the signal to noise ratio at the input of the data detector in the receiver.

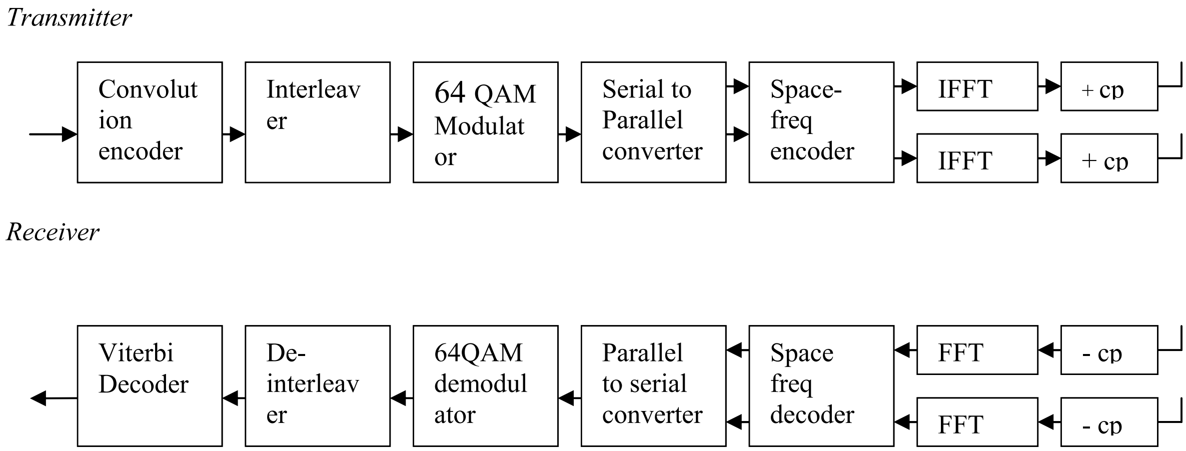

Fig. 3 MIMO-OFDM System

Practically realized capacity R is smaller than C due to implementation losses and due to finite dimensionality of constellations.

If a SISO communication channel is considered as a spatial pipe, then an intuitive technique for increasing capacity would be to transmit information simultaneously on parallel pipes. A communication channel that supports Multiple Inputs and Multiple Outputs is called a MIMO [8] system.

The received vector Y can be written as

$$Y = H \otimes X + n \quad (2)$$

Where H is the channel matrix of the order NxM with M being the number of transmitter antennas and N being the number of receiver antennas. $\otimes$ denotes element wise convolution and n is the noise vector at the receiver. If there is no temporal dispersion (frequency selectivity) in the channel, then convolution reduces to multiplicative operation.

$$Y = HX + n \quad (3)$$

Capacity of a MIMO [10] channel assuming the noise n to be Additive White Gaussian is

$$C = B \log_2 \det\left[\frac{E\{YY^{*T}\}}{E\{nn^{*T}\}}\right] \quad (4)$$

$$C = B \log_2 \det\left[I_N + \frac{HE\{XX^{*T}\}H^{*T}}{E\{nn^{*T}\}}\right] \quad (5)$$

Where $E\{.\}$ is the expectation operator. It is assumed that noise is uncorrelated among the receiver branches

$$E\{nn^{*T}\} = \sigma^2 I_N \quad (6)$$

Where σ^2 is the noise power in each receiver antenna.

II WLAN SYSTEM MODEL

Wireless networking is an emerging technology allowing users the freedom of movement. The huge uptake rate of mobile phone technology, LAN and the exponential growth of the Internet have resulted in an increased demand for new methods of obtaining high capacity wireless networks. The aim of WLAN systems is to provide users with a data rate comparable with wired networks within a limited geographic area.

MIMO-OFDM [9] system block diagram shown in Figure 3.Error control coding can possibly detect and correct the errors that occur during transmission of data. So input data is encoded using a rate ¾ convolution encoder. Interleaver avoids burst errors in a communication system by randomizing the bits. The modulator maps the input symbols to points in the constellation. In a space frequency encoder [2], coding is performed across space and OFDM tones i.e., when two input symbols are given to the space frequency encoder, it produces a matrix

$$C = \begin{pmatrix} s_1 & s_2 \\ -s_2^* & s_1^* \end{pmatrix} \quad (7)$$

The symbol s_1 goes to the first subcarrier on antenna 1 and $-s_2^*$ on the adjacent subcarrier on antenna 1.Similarly s_2 and s_1^* on adjacent subcarriers on antenna 2.IFFT transforms the subcarriers from frequency domain to time domain .Cyclic prefix is a copy of the last portion of the data symbol appended to the front of the symbol. Then the parallel data is converted to serial for transmission in the multipath Rayleigh fading channel. The received signal after affected by Additive White Gaussian Noise is

$$Y = HX + n \quad (8)$$

Y is the received vector, H is matrix consisting of channel gains, X is the transmitted vector, n is a vector of Additive White Gaussian Noise.

$$\begin{pmatrix} Y_1 \\ Y_2 \end{pmatrix} = \begin{pmatrix} H_{11} & H_{12} \\ H_{21} & H_{22} \end{pmatrix} \begin{pmatrix} X_1 \\ X_2 \end{pmatrix} + \begin{pmatrix} n_1 \\ n_2 \end{pmatrix} \quad (9)$$

$$Y_1 = H_{11}X_1 + H_{12}X_2 + n_1 \quad (10)$$

$$Y_2 = H_{21}X_1 + H_{22}X_2 + n_2 \quad (11)$$

A. DATA RATE

Data Rate(Mbps)=(0.0675 * channel bandwidth * number of spatial streams * number of coded bits per subcarrier * code rate).

For a 2 x 2 Antenna configuration with rate ¾ convolution encoder and 64 QAM modulator using 40MHz bandwidth, we have

Data Rate (Mbps) =0.0675 x 40 x 2 x 6 x ¾ =243

B. CHANNEL BANDWIDTH

20MHz or 40MHz channels can be used.20MHz channels have 54 subcarriers and 40MHz channels have exactly twice as many as 108.

C. NUMBER OF SPATIAL STREAMS

It must be 1, 2, 3 or 4 less than or equal to the number of transmission antennas. Support for at least two spatial streams is mandatory.

D. CODED BITS PER SUBCARRIER

This will be either 6 for 64QAM or 4 for 16 QAM or 1 for BPSK or 4 for QPSK.

E. CODE RATE

Code rate may be ½, ¾ or 5/6 when used with 64 QAM.

III SIMULATION MODEL

Using the MIMO-OFDM system block diagram the simulation is carried in MATLAB environment. The simulation parameters shown in Table 2 are used for the simulation. In Figure 4 we obtain the OFDM signal from antenna 1 of the transmitter. Rate ½ convolution coder is used in this analysis it is a type of error control coding to detect and correct the errors occur during transmission. Rayleigh fading channel is considered in the simulation. Effect of channel on the transmitted signal from antenna 1 is shown in Figure 6. The received signal is affected by Additive White Gaussian Noise (AWGN). The received signal on antenna 1 & 2 is shown in Figure 7. Bit error rate comparison of transmitted and received bits is shown in Figure 8.

Table 2: Simulation Parameters

Parameters	Specification
FFT size	128
Pilots	6
Zeroes	14
Cyclic Prefix	32
OFDM Symbol duration	3.2us
OFDM Symbol duration + cyclic prefix	4us
Modulation	64 QAM

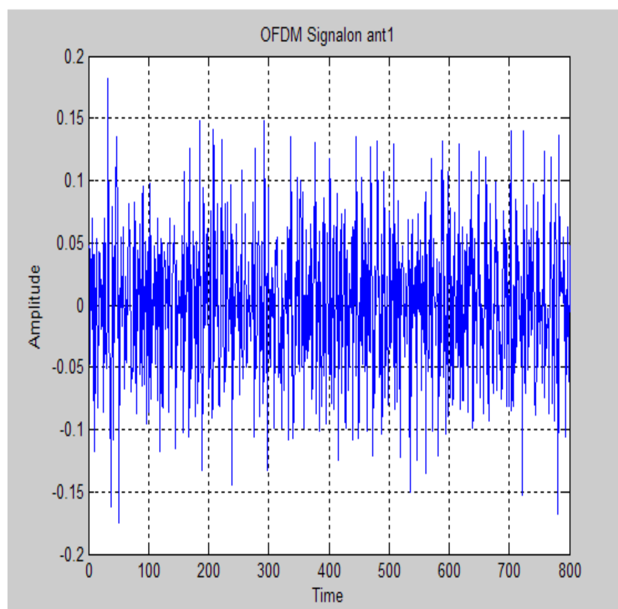

Fig .4: Transmitted OFDM signal from Antenna 1

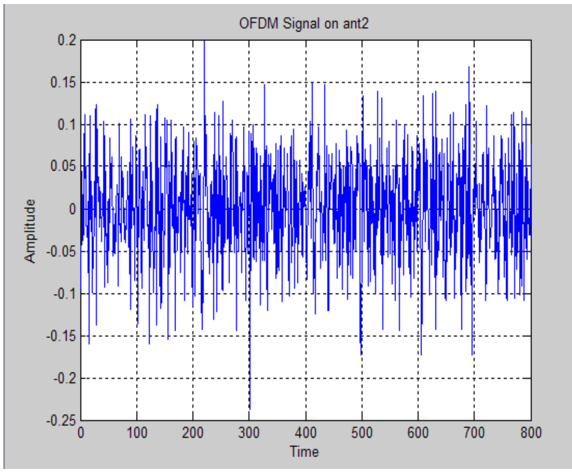

Fig. 5 Transmitted OFDM signal from Antenna 2

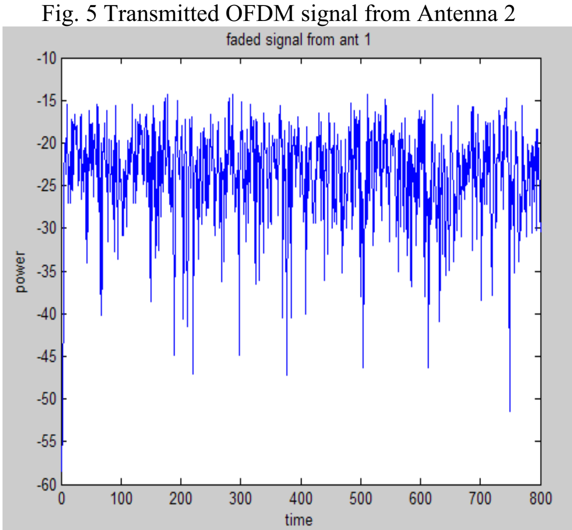

Fig. 6 Faded signal from Antenna 1

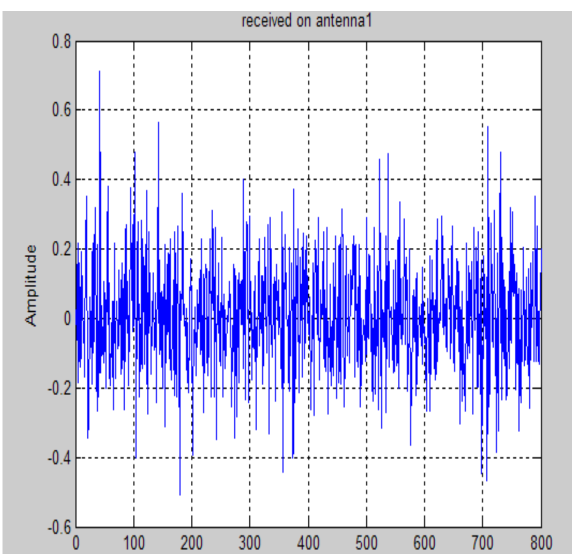

Fig.7 Received signal on Antenna 1

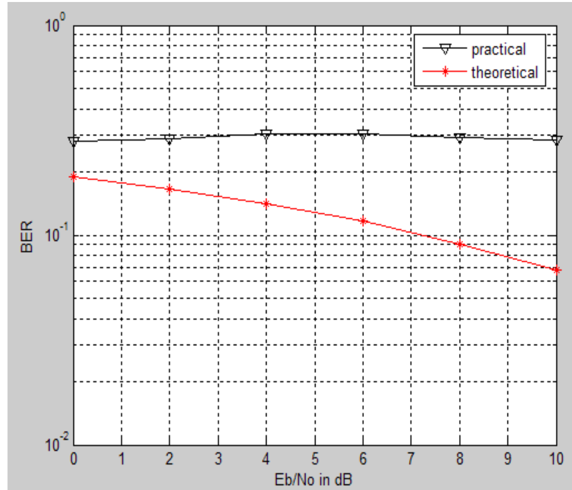

Fig.8 Bit Error Rate analysis

IV CONCLUSION & FUTURE SCOPE

In this paper a high data rate WLAN system design is proposed using MIMO-OFDM. In the proposed WLAN system, IEEE 802.11a standard design is adopted but the results prove a data rate enhancement from the conventional IEEE 802.11a. MIMO-OFDM system is simulated using MATLAB. The signal to noise ratio and channel capacity analysis were carried out using analytical approach. Currently the number of WLAN systems is relatively low and thus interference between most systems is low. In addition to this, most operate within buildings, which provide significant interference shielding by the outer walls. This results in the SNR being primarily limited by transmission power not intercellular interference. If we can therefore minimize the path loss over the coverage area of the WLAN, we can therefore maximize the SNR and the corresponding data rate.

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