Channel Capacity Enhancement using MIMO Systems: A Survey

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***Abstract*- Wireless Communication Systems are facing the challenges regarding increasing number of users, limited bandwidth and a continuous need for high data rates. One of the fundamental mechanisms to enhance channel capacity is the use of Multiple Input-Multiple Output (MIMO) systems for channel capacity enhancement. This paper presents review on the various implementation mechanisms of MIMO-Systems specially focusing on Space Time Block Coding (STBC). A brief introduction pertaining to the basics of MIMO systems have also been put forth for the ease of understanding of MIMO based systems.**

Index Terms- BER, Channel Capacity, OFDM, Wireless communication

I. INTRODUCTION

In wireless communication, the receiver side BER strongly affected by channels noise, interference, distortion, synchronization error and wireless multipath fading channels, Multiple-input and multiple-output(MIMO) systems have resulted in higher spectral efficiency and capacity. In multiple-input multiple-output (MIMO) communications, the system is equipped with multiple antennas at both the transmitter and the receiver technique. The multiple antenna scheme gives a more reliable performance through array gain, diversity and spatial multiplexing. These concepts are briefly discussed below.

The growing demand of multimedia services and the progress of Internet related contents lead to increasing interest to high speed communications network. The requirement for flexibility and wide bandwidth imposes the use of efficient transmission systems that would fit to the characteristics of wideband channels especially in wireless environment where the channel is very challenging process. In wireless environment the signal is propagating since the transmitter to the receiver along number of different paths, collectively referred as multipath communication. While propagating the signal power drops of due to the following effects: a path loss, macroscopic fading and microscopic fading. The fading of the signal can be mitigated by different diversity methods. To obtain diversity, in signal is transmitted through multiple independent fading paths in time, frequency or space and combined constructively at the receiver. The following section illustrates the previous work done in the respective field. The pros and cons of each system have been weighed according to the applications wherein it is used.

II. LITERATURE SURVEY

Orthogonal frequency division multiplexer for multiple input multiple output channels (MIMO-OFDM) is considered by Y. Li et.al for wideband transmission to mitigate inter symbol interference and enhance system capacity. The orthogonal frequency division multiplexer for multiple input multiple output channels (MIMO-OFDM) scheme uses two independent space-time codes for two sets of two transmit antennas. At the receiver, the independent space-time codes are decoded using pre-whitening followed by ML decoding based on successive interference cancellation. Using these techniques in a 4-input 4-output orthogonal frequency division multiplexer scheme, the net data transmission rate can reach 4 Mbits/sec over a 1.25 MHz wireless channel, with a 10-11 dB signal to noise ratio (SNR) required for a 10% SER, depending on the radio environment and signal detection technique for word lengths up to 500 bits [1].

S. Moghe and R. Upadhyay, "Comparison of SISO and MIMO Techniques in 802.11n Wireless Local Area Network", International Conference on Emerging Trends in Electronic and Photonic Devices & Systems, 2009. In this paper introduced a new generation of IEEE 802.11n wireless standard network. The objective is to obtain numerical values for various measures of networking performance of IEEE 802.11n standard network. The initial approach was to investigate the abilities of IEEE 802.11n standard network to model a transmitter and receiver that communicated over a user defined channel. The simulation of single OFDM symbol SISO system followed by MIMO is presented. Also, the performance of the system using Matlab's built in BER tool in both SISO and MIMO Techniques is tested. In the different Variation in BER on varying Parameters like Delay and K factor are carried out in the work. A bit and power allocation strategy for AMC based spatial multiplexing MIMO-OFDM systems is studied by M. S. Al-Janabi et.al. This strategy aims to maximize the average system throughput by allocating the available resources optimally among the utilized bands depending on the corresponding channel conditions and the total transmission power. The average system throughput is represented as a trade-off criterion between the spectral efficiency and BER. The considered AMC technique utilizes distinct modulation and coding scheme (MCS) options rather than adopting fixed or un-coded approaches. The transmitter divides the OFDMA frame at each transmit antenna into bands depending on the number of active users in an assigned base station (BS). The simulation results show superior performance of the MIMO-AMC-OFDMA, which adopts the proposed strategy, over other conventional schemes [2].

T.P. Surekha, et.al, IEEE, 2011, modeling and Simulation can play an important role during all phases of the design and engineering of communication systems. An Orthogonal Frequency Division Multiplexing (OFDM) was originally developed from the multi-carrier modulation techniques used in high frequency Military radios. A simulink based simulation system is implemented using Additive White Gaussian Noise channel to study the performance analysis of Bit Error rate (BER) v/s Signal to Noise ratio. The effect of noise over AWGN system is observed by using Constellation diagrams and results are concluded by comparing the simulated data with BER Tool. The BER curve with Model simulation in is compared with BER Tool curve. BER Tool is a Graphical User Interface for analyzing bit error - rate statistics of a communication model. BER Tool helps us to generate and analyze the Bit Error rate (BER) data for a given system with theoretical plot [3].

Sai Krishna Borra; Suman Krishna Chaparala, in this paper is performance evolution of OFDM system with Rayleigh, Rician and AWGN channels, 2013. An Orthogonal Frequency Division Multiplexing (OFDM) scheme offers high spectral efficiency and better resistance to fading environments. In Orthogonal Frequency Division Multiplexing (OFDM) the data is modulated using multiple numbers of sub-carriers that are orthogonal to each other because of which the problems associated with other modulation schemes such as Inter Symbol Interference and Inter Carrier Interference are reduced. This paper deals with the analysis of OFDM System utilizing different modulation techniques over Rayleigh, Rician and Additive White Gaussian Noise (AWGN) fading environments with the use of pilot aided agreement and finally the results are convey. In this paper we compare the performance in terms of Bit Error rate (BER) using different modulation schemes on Rayleigh, Rician and AWGN Channel. This system model that is presented in this paper uses Binary Phase Shift Keying and 16-QAM as sub-carrier modulation technique. We have discussed the advantages of OFDM and the requirement of every block in the system model. Simulation results are provided and from which we can evidently conclude that the QAM gives better performance under Rayleigh channel compared to other modulation scheme's and channels [4].

Ashutosh Kumar Mishra, et.al, 2014.This paper review work based on the Performance analysis of Quadrature amplitude modulation and orthogonal frequency division multiplexer (QAM-OFDM) scheme in AWGN communication. A Digital communication with multi carrier modulation method can play very important role in all phase of designing and engineering. In this paper is work we discuss about the performance analysis of 16 Quadrature amplitude modulation and orthogonal frequency division multiplexer. We compare the performance analysis of different schemes used in the 16 QAM

OFDM and discuss the BER v/s SNR. The previous work the scheme if Noise level will the BER should be decreased so that in higher level Quadrature amplitude modulation(QAM) will be implemented at higher noise level such as 32 Quadrature amplitude modulation(QAM), and 64 QAM as soon as. In the recent advancement have improve the bit error rate some extant but the scheme that analyzed for more no of carriers that decreased the ISI and ISF using deferent method [5].

K. Shamganthet.al, increasing demand for high-performance 4G broadband wireless is enabled by the use of multiple antennas at both transmitter and receiver ends. The multiple antenna technologies enable high capacities suited for Internet and multimedia services, and also dramatically increase range and reliability. In this paper, we focus mainly on Internet users in hotspots like Airport. Requiring high data rate services. In this paper, a high data rate design is proposed using MIMO-OFDM, in which IEEE 802.11a standard design is adopted and the results prove a data rate enhancement from the conventional IEEE802.11a. Shao-Hua Chu, Hsin - Piao Lin and Ding - Bing Linin their paper explorer about excess delay spread and inter-symbol interference problems in indoor radio propagation channel. In their paper they had used Monte Carlo simulation based on the IEEE 802.11a physical layer specification. The paper analyzes the performance of using Ommiad switch-beam antenna in a real office indoor environment. Compared with using Omni antenna, the simulation results show that utilizing switch-beam antenna in AP the BER performance improve about 2dB in light-of-sight (LOS) case, and 6dB in non-light of sight (NLOS) case [6].

Mehdi Ahmadi, et.al, IEEE 802.22, also called Wireless Regional Area Network, is the newest wireless standard being developed for remote and rural areas. This paper an overview of the standard and more specifically its PHY layer is introduced. In order to evaluate the performance of the scheme, we model the PHY layer in MATLAB/SIMULINK and extract the Bit Error Rate of the technique for different code rates and modulation schemes with noisy channel. In this paper an overview of the standard and more specifically its PHY layer is introduced. In order to evaluate the performance of the scheme, the PHY layer is modeled and the Bit Error Rate of the system for different code rates and modulation schemes with noisy channel is extracted. According to system output curves, in lower modulations such as QPSK and 16- QAM have good performance in channels with SNRs below 7 dB.Though, 64-QAM provides a higher throughput in good channel conditions [7].

T.A.Latef, et.al,in this paper done study on performance of two different FEC code over WLAN and Bluetooth, The results shown in their paper that Turbo coding substantially improves the reliability of the Coded Orthogonal Frequency Division Multiplexing format in Bluetooth interference and can provide reducible PER performance at Signal to Interference Ratio values down to 0 dB [8].

Neeraj Varshney, Aditya Jagannatham, “MIMO-STBC Based Multi Relay Cooperative Communication over Time Selective Rayleigh Fading Links with Imperfect Channel Estimates, IEEE Transactions 2016”, This work analyzes the effect of time-selective fading arising due to node mobility and imperfect channel estimates on the end-to-end performance of multiple-input multiple-output (MIMO) space-time block coded (STBC) multiple relay cooperative communication systems. Both dual-phase and multiphase selective Decode-and-Forward (DF) relaying protocols are considered for end-to-end communication in a multiple relay cooperative system, followed by presentation of complete analyses for the same. For each protocol, closed form expressions are derived for the per-frame average pair-wise error probability (PEP) and asymptotic error floor over independent and non-identical time-selective Rayleigh fading links. A framework is also developed for obtaining the optimal source relay power factors for each of the above protocols, which significantly improve the end-to-end reliability of the system for a given power budget. [9].

III. MIMO SYSTEM MODEL

The basics of the MIMO system model are discussed below.

Array Gain

In MIMO communications, array gain is the average increase in the SNR at the receiver that occurs from the coherent combining effect of the multiple antennas at the transmitter or receiver or both. Usually, multi antenna systems require a perfect knowledge of the channel either at the receiver or the transmitter or both to achieve an array gain.

Transmitter Array Gain: If the channel is known to the transmitter with multiple antennas, the transmitter will weigh the transmission with weights, depending on the channel coefficients, so that there is coherent combining at one antenna receiver. This is the MISO case. This type of array gain is called transmitter array gain.

Receiver Array Gain: If we have a single antenna at the transmitter and no knowledge of the channel and a receiver with multiple antennas, which has perfect knowledge of the channel, then the receiver can suitably weight the incoming signals so that they coherently add up at the output, thereby enhancing the signal. This is the SIMO case. This type of array gain is called receiver array gain.

Diversity Gain

Due to the detrimental effect of multipath fading, the signal transmission over broadband wireless channels always suffers from attenuation, and this can severely degrade the reception performance. In MIMO systems, the same information is transmitted from multiple transmit antennas and simultaneously received at multiple receive antennas. Since the fading for each link between a pair of transmit and receive antennas usually can be considered to be independent, the probability that the information is detected exactly is increased [11]. Apart from the spatial diversity, other forms of diversities exist: temporal diversity and frequency diversity. In temporal and frequency domains, replicas of the faded signals are received in the form of redundancy. The MIMO system achieves diversity through repetition coding that carries the same information symbol at different time slots from different transmit antennas. Space time (ST) coding is a more bandwidth efficient coding scheme [13], which transmits a block of information symbols in different orders from the different antennas.

Spatial Multiplexing

The capacity of a MIMO system is much higher than that of a single-antenna system. The channel capacity can be linearly increased in proportion to the number of antennas. MIMO systems provide more spatial freedom or spatial multiplexing, so that different information can be transmitted over multiple antennas simultaneously, thereby enhancing the system throughput. At the receiver, spatial multiplexing needs a dedicated detection algorithm to sort out the different transmitted signals from the mixed one.

Multi Antenna Systems

Multi antenna systems can be classified as single-input multiple-output (SIMO), multiple-input single-output (MISO), and multiple-input multiple-output (MIMO) systems. In order to develop the input-output relations of SIMO, MISO, MIMO systems, we first describe the single-input single-output (SISO) system [14].

Single-Input Single-Output System

The schematic block diagram of a SISO system is depicted in Figure 1.

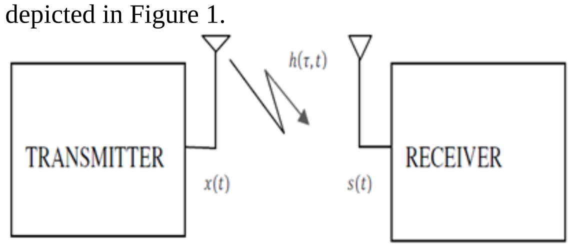

Fig.1: Block diagram of SISO systemThe input-output relationship of the SISO system is given by

$$s(t) = \int_0^{\tau total} h(\tau, t)x(t-\tau)d\tau = h(\tau, t) * x(t)$$

Where, x(t) is the transmitted signal, s(t) is the received signal at time$t, \tau total$ is the duration of the impulse response, and denotes the convolution operation

Single-Input Multiple-Output System

The schematic block diagram of a SIMO system with single transmit antenna and receive antennas is depicted in Figure 2.

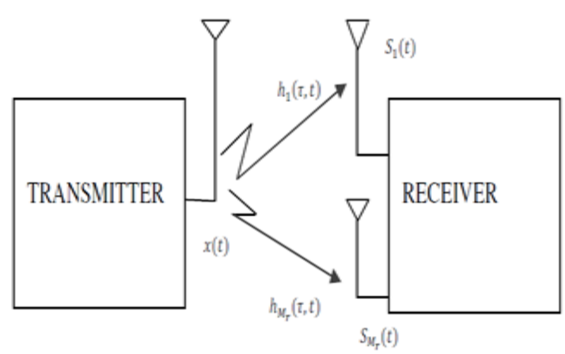

Fig.2: Block diagram of a SIMO system

The received signals at the respective receive antennas are given by

$$S_1(t) = h_1(\tau, t) * x(t)$$
$$S_2(t) = h_2(\tau, t) * x(t)$$
$$S_{Mr}(t) = h_{Mr}(\tau, t) * x(t)$$

Therefore, the input-output relationship of a SIMO system can be expressed as

$$S(t) = H(\tau, t) * x(t)$$

Where

$S(t) = [S_1(t)S_2(t) \dots \dots \dots . S_{Mr}(t)]^T$ in the received signal vector

$h(t) = [h_1(t)h_2(t) \dots \dots \dots . h_{Mr}(t)]^T$ in the channel vector

Multipath Environment

In wireless environment, transmitted signal follow several propagation paths. Many of these paths, having reflected from surrounding objects, reach the receiver with different propagation delays. This multipath leads to delay spread, inter symbol interference (ISI), fading and random phase distortion. Figure 4.4 describes this phenomenon. The corresponding channel impulse response is shown in Figure 3.

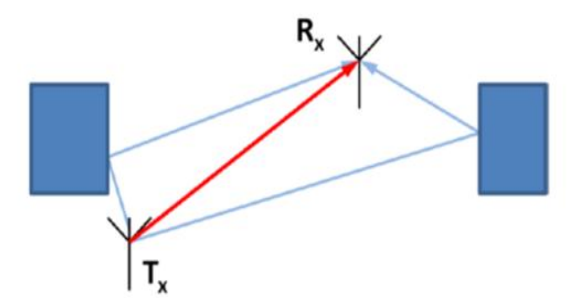

Fig.3:Multipath Environment in Wireless Communications

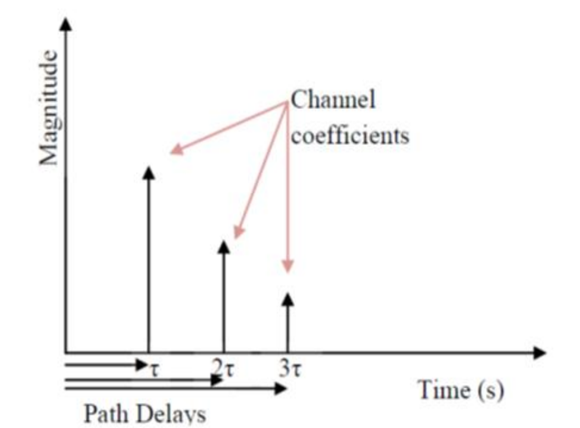

Fig.4: Channel Impulse response in Multipath Environment

Delayed copies of the transmitted signal interfere with subsequent signals, causing Inter Symbol Interference (ISI). Therefore transmitted symbol rate is limited by the delay spread of the channel. Multipath Propagation causes MIMO channels to be frequency selective which cannot have flat frequency response. To combat this effect MIMO is combined with OFDM. OFDM transforms the frequency selective fading channel into parallel flat fading sub channels, but the length of CP inserted should be greater than the channel length.

For a 2 x 2 MIMO-OFDM configuration the received OFDM symbols are given the equations 2. The same thing is represented in matrix form in equation 3. Here the term Xi represents the transmitted symbol from the ith transmitting antenna, the term Yj represents the received symbol from the jth receiving antenna, the term Ni represents the noise component present in the ith symbol and the term Hij represents the channel coefficient corresponding to the ith transmitting antenna and jth receiving antenna.

$$R_x.Ant\ 1: Y_1(K) = H_{11}(K)X_1(K) + H_{12}(K)X_2(K) + N_1(K)$$

$$R_x.Ant\ 2: Y_2(K) = H_{21}(K)X_1(K) + H_{22}(K)X_2(K) + N_2(K)$$

$$\begin{bmatrix} Y_1(K) \\ Y_2(K) \end{bmatrix} = \begin{bmatrix} H_{11}(K) & H_{12}(K) \\ H_{21}(K) & H_{22}(K) \end{bmatrix} \begin{bmatrix} X_1(K) \\ X_2(K) \end{bmatrix} + \begin{bmatrix} N_1(K) \\ N_2(K) \end{bmatrix}$$

In a Direct path environment, where the reflected waves from multiple objects are absent, in channel looks to be flat and contains a single co-efficient in its impulse response. This type of channel is can be modeled using Additive White Gaussian Noise (AWGN) channel. The model does not account for the phenomena of fading, interference, frequency selectivity, and nonlinearity or dispersion. In a multipath environment, the channel is always frequency selective type. This type of channel can be modeled using Rayleigh random distribution.

IV. CONCLUSION

It can be concluded that MIMO systems and moreover massive MIMO systems are the only way out to provide limited bandwidth yet bandwidth hungry applications. Massive MIMO may serve as a technique to increase the system capacity and date rate. This paper proposes the basics of MIMO systems and their advantages and applications.

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