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Performance Evaluation of Channel Capacity of Mimo-Ofdm in Wireless Communication

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Abstract: *Multiple-input multiple-output (MIMO) wireless technology in combination with orthogonal frequency division multiplexing (MIMO-OFDM) is an attractive air-interface solution for next generation wireless local area networks (WLANs), wireless metropolitan area networks (WMANs), and fourth-generation mobile cellular wireless systems. MIMO system increases the diversity gain or to enhance the system capacity on time-variant and frequency-selective channels, OFDM may be combining with multiple transmitter antenna and receiver antenna, thus resulting to MIMO- OFDM system. MIMO-OFDM, a new wireless 4G technologies, has capability of enhance data rate transmission and robustness against multi-path fading. This paper, provides an overview of the basics of MIMO-OFDM technology*

Keywords - *MIMO-OFDM system, Energy and Bit Allocation, BER Performance*

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I. Introduction

The demand of wireless communications is constantly growing, Future wireless system will require a much more efficient use of the available frequency resources. MIMO is known to boost channel capacity. For high data rate transmission, the MIMO channel is frequency selective (multipath). OFDM can transform such channel into a set of parallel frequency-flat channel attractive combination of these two powerful techniques, the key challenge faced by future wireless communication systems is to provide high-data-rate wireless access at high Quality of Service (QoS). Combined with the facts that spectrum is a scarce resource and propagation conditions are hostile due to fading (caused by destructive addition of multipath components) and interference from other users, this requirement calls for means to radically increase spectral efficiency and to improve link reliability. Multiple-input multiple-output (MIMO) wireless technology seems to meet these demands by offering increased spectral efficiency through spatial multiplexing gain, and improved link reliability due to antenna diversity gain. Even though there are still a large number of open research problems in the area of MIMO wireless, both from a theoretical perspective and a hardware implementation perspective, the technology have reached a stage where it can be considered ready for use in practical systems

1.1 What is MIMO?

As we know MIMO is multiple antenna technology in which more than one antenna are used at transmitter and receiver stations. In this smart antenna technology type, different set of data symbols are transmitted in order to achieve high data rate compare to SISO (i.e. single antenna based system). The data at receive end from these antennas are passed through mathematical algorithms in order to recover the original transmitted information without any errors. This helps in achieving higher data rate or throughput while maintaining good BER (Bit Error Rate) of the system.

There are other variants in multiple antenna technology viz. MISO (Multiple Input Single Output) and SIMO (Single Input Multiple Output). In MIMO, multiple antennas are used at both transmit and receive ends. The 2x2 MIMO modes are depicted in the figure-1. In MISO, multiple antennas are used at transmit end and single antenna is used at receive end. In SIMO, single antenna is used at transmit end and multiple antennas are used at receive end. There are many variants of MIMO based on antenna configurations at the transmit and receive ends viz. 4x4, 8x8 etc.

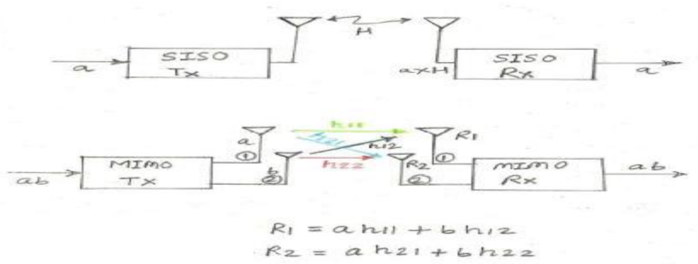

Fig 1. Diagram for MIMO vs. SISO

II. Mimo Systems And Ofdm Modulation Performance Gains In Mimo Systems

Traditionally, multiple antennas (at one side of the wireless link) have been used to perform interference, cancellation and to realize diversity and array gain through coherent combining.

The use of multiple antennas at both sides of the link (MIMO, Fig. 1) offers an additional fundamental gain, spatial multiplexing gain, which results in increased spectral efficiency.

A brief review of the gains available in a MIMO system is given in the following. Spatial multiplexing yields a linear (in the minimum of the number of transmit and receive antennas) capacity increase, compared to systems with a single antenna at one or both sides. The corresponding gain is available if the propagation channel exhibits rich scattering and can be realized by the simultaneous transmission of independent data streams in the same frequency band. The receiver exploits differences in the spatial signatures induced by the MIMO channel onto the multiplexed data streams to separate the different signals, thereby realizing a capacity

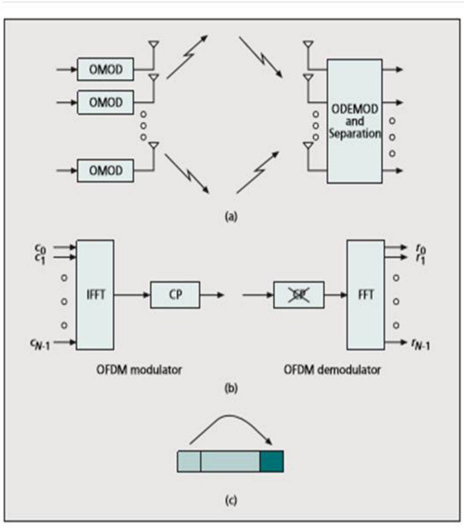

Fig 2. (a) Schematic of a MIMO-OFDM system. OMOD and ODEMOD denote an OFDM-modulator and demodulator, respectively; (b) single-antenna OFDM modulator and demodulator.

2.1 Diversity

Diversity leads to improved link reliability by rendering the channel "less fading" and by increasing the robustness to co-channel interference. Diversity gain is obtained by transmitting the data signal over multiple (ideally) independently fading dimensions in time, frequency, and space and by performing proper combining in the receiver. Spatial (i.e., antenna) diversity is particularly attractive when compared to time or frequency diversity, as it does not incur expenditure in transmission time or bandwidth, respectively. Space-time coding realizes spatial diversity gain in systems with multiple transmit antennas without requiring channel knowledge at the transmitter.

2.2 Array gain

Array gain can be realized both at the transmitter and the receiver. It requires channel knowledge for coherent combining and results in an increase in average receive Signal-to-Noise Ratio (SNR) and hence improved coverage. Multiple antennas at one or both sides of the wireless link can be used to cancel or reduce co channel interference, and hence improve cellular system capacity.

2.3 OFDM Concept

The receiver can be use fast signalling processing transforms such as FFT (Fast Fourier Transform) for OFDM implementations. OFDM has been adopted in several wireless standards, such as IEEE802.11a (LAN) and IEEE 802.16(LAN/MAN). Popular technique for transmission of signals over wireless channels; the TX can adapt its signalling to match the channel if knowledge of channel condition is available at TX OFDM modular can be implemented as an Inverse Fast Fourier Transform(IFFT) followed by an DAC(Direct Access Carrier).

Time duration of an OFDM symbol is N times larger than that would correspond to a single carrier system. A block of N information symbols is transmitted in parallel on N subcarriers, Each block of N IFFT coefficient is preceded by a Cyclic Prefix(CP) to mitigate ISI caused by channel time spread convert a frequency-selective channel into a parallel collection of frequency –flat sub channels. Sub-carrier has minimum frequency separation required to maintain orthogonally of their time domain waveforms. Adaptive strategies in OFDM can approach water pouring capacity of frequency-selective channels (large collection of narrowly spaced sub channels). Signal spectra of the different subcarriers overlap in frequency (efficient use of available bandwidth).

2.4 OFDM Modulation

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. Figure 1 depicts the schematic of a MIMO-OFDM system. The basic principle that underlies OFDM is the insertion of a guard interval, called cyclic prefix (CP), which is a copy of the last part of the OFDM symbol, and has to be long enough to accommodate the delay spread of the channel. The use of the CP turns the action of the channel on the transmitted signal from a linear convolution into a cyclic convolution, so that the resulting overall transfer function can be diagonali zed through the use of an IFFT at the transmitter and an FFT at the receiver. Consequently, the overall frequency-selective channel is converted into a set of parallel flat fading channels, which drastically simplifies the equalization task. However, as the CP carries redundant information, it incurs a loss in spectral efficiency, which is usually kept at a maximum of 25 percent.

III. MIMO-OFDM Principles

3.1 MIMO-OFDM TX

Source bit stream encoded by FEC encoder coded bit stream mapped to a constellation by digital modular and encoded by MIMO encoder.

Each of parallel outputs symbol stream corresponding to a certain TX antennas follows the same Tx (transmitter) process:

- Insertion of pilot symbols (synchronization)
- Modulation by inverse FFT
- Attachment of CP and preamble
- Finally ,data frame is transferred to IF/RF stage for Tx

3.2 MIMO-OFDM RX

- Remaining OFDM symbols demodulated by FFT
- The receiver system stream from different RX antennas are first synchronized
- Preambles and CPS are extracted from RX symbol stream, Frequency pilots are extracted from demodulated OFDM symbol, and are used for channel estimation, estimated channel matrix aids the MIMO decoder, Estimated TX symbols are demodulated and decoded.

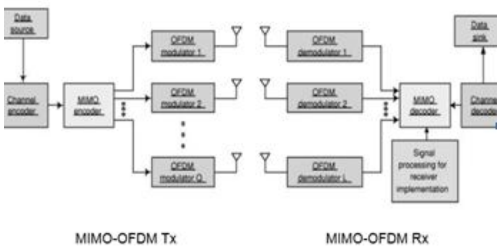

Fig 3. MIMO-OFDM Principles

IV. MIMO-OFDM Frame Structure

In the time domain, a frame is a minimum transmission unit that includes 10slots

- Each slot consist of 1 slot preamble and 8 OFDM symbols
- The preamble is used for time synchronization
- Each OFDM symbol in a slot is attached to a CP that is used to reduce ISI and simplify channel equalizer .The frame is structured such that data and pilot symbols are transmitted over subcarriers (timing phase, timing frequency, and frequency offset estimation)

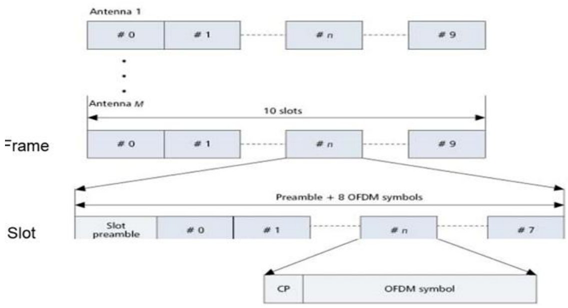

Fig 4.MIMO-OFDM Frame Structure

V. Types Of MIMO-OFDM

5.1 SPACE-FREQUENCY SIGNALING IN MIMO-OFDM SYSTEMS

The signalling schemes used in MIMO systems can be roughly grouped into spatial multiplexing , which realizes capacity gain, and space-time coding , which improves link reliability through diversity gain. Most multi-antenna signalling schemes, in fact, realize both spatial-multiplexing and diversity gain. A framework for characterizing the trade-off between spatial-multiplexing and diversity gains in flat-fading MIMO channels was proposed in. In the following, we describe the basics of spatial multiplexing and space-time coding with particular emphasis on the aspects arising from frequency-selective fading through multipath propagation.

5.2 SPATIAL MULTIPLEXING IN MIMO-OFDM SYSTEMS

Multiplexes multiple spatial channels to send as many independent data as possible over different antennas **.**There are four spatial multiplexing schemes: diagonal BLAST, horizontal BLAST,V-BLAST and turbo BLAST .The method to estimate Tx signals has three steps:

- Estimate the channel matrix (training sequence)
- Determine optimal detecting order and nulling vectors
- Detect the received signals based on optimal detecting order and successive interference cancellation.

The basic idea of spatial multiplexing is described above, that the spatial-multiplexing gain or, equivalently, the number of spatial data pipes that can be opened up within a given frequency band, is given by the minimum of the number of transmit and receive antennas, provided the receiver knows the channel perfectly. The transmitter does not need to have channel state information (CSI).In an OFDM-based MIMO system, spatial multiplexing is performed by transmitting independent data streams on a tone-by-tone basis with the total transmit power split uniformly across antennas and tones. Although the use of OFDM eliminates ISI, the computational complexity of MIMO-OFDM spatial-multiplexing receivers can still be high. This is because the number of data-carrying tones typically ranges between 48 (as in the IEEE 802.11a/g standard) and 1728 (as in the IEEE 802.16e standard) and spatial separation has to be performed for each tone.

5.3 SPACE-TIME CODING FOR THE MULTIUSER CASE

The main difference between space-frequency coding in point-to-point channels and in multiple access channels (representative of the uplink in a multiuser system) is that in the point-to-point case joint encoding across all transmit antennas is possible, while in the multiple-access case individual users cannot coordinate their transmission. This observation suggests that the space-frequency code-design problem in the multiple-access case is fundamentally different from the point-to-point case, and joint (across users) code designs that take the multiuser aspect explicitly into account will be required in general. The number of receive (base station) antennas plays an important role in delineating the regions where joint code designs are necessary from those regions where independent single-user codes are optimal. Generally, increasing the number of receive antennas for fixed SNR results in an increase of the relative (compared to the capacity region) size of the latter region. This is due to the fact that for a large number of receive antennas there are more spatial degrees of freedom available to separate the individual users' signals so that imposing "separation" through appropriate joint code design is required for a smaller set of (high) rates.

VI. Adaptive Modulation and Coding (AMC)

Time-varying wireless channel conditions implies a time varying system capacity ,The principle of AMC is to change the modulation and coding format in accordance with instantaneous fluctuations of channel conditions, Channel conditions should be estimated based on feedback from the receiver. The implementation of AMC offers several challenges: Errors in channel measurements, Delay in reporting the channel measurements.

6.1 Intercarrier Interference Cancellation

The frequency offset caused by oscillator inaccuracies or Doppler shift results in ICI that degrade BER performance. Although frequency synchronization is used, the residential frequency offset causes a number of impairments: Attenuation and rotation of each of the subcarriers, ICI between subcarriers, ICI mitigation is needed to increase the achievable data rates over the wireless medium.

6.2 Peak-to-average Power Ratio (PAPR)

The main limitation of OFDM-based transmission systems is the high PAPR of the transmitted signal Large peaks will occasionally reach the amplifier saturation region and result in signal distortion Several PAPR reduction schemes have been proposed and investigated: Partial transmit sequence (PTS) scheme: efficient and distortion less scheme by optimally combining signal sub blocks Selective mapping (SLM): some statistically independent sequences are generated from the same information, and the sequence with the lowest PAPR is transmitted.

6.2.1 Energy and Bit Allocation

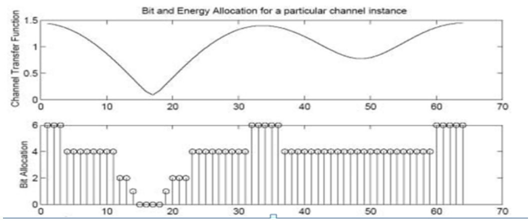

Fig 6. Energy and Bit Allocation

6.2.2BER Performance

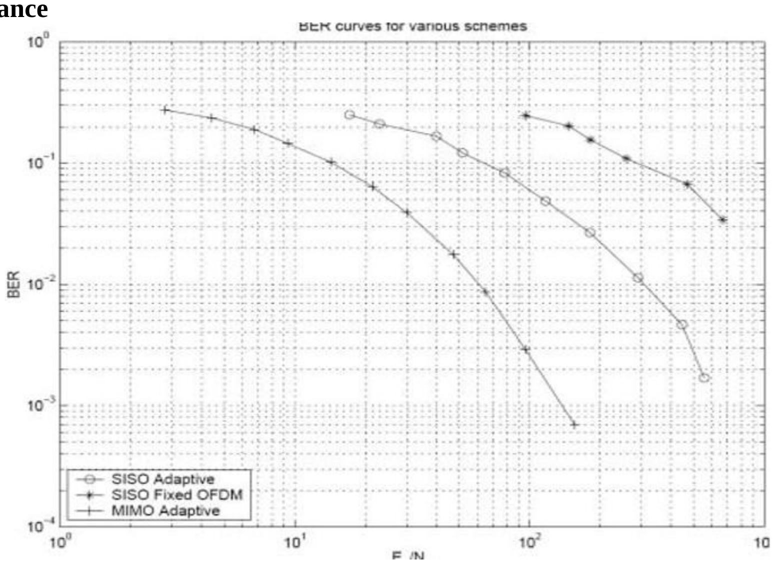

Fig 7. BER (Bit Error Rate) Performance

VII. Advantages Of MIMO

It helps in achieving reduction in BER (Bit Error Rate) due to application of advanced signal processing algorithms on the received data symbols by multiple antennas.

The techniques such as STBC (Space Time Block Coding) and BF (Beam forming) when employed in MIMO system helps in achieving extension of cell coverage.

MIMO based System Minimize fading effects seen by the information traveling from transmit to receive end. This is due to various diversity techniques such as time, frequency and space..The wide coverage supported by MIMO system helps in supporting large number of subscribers per cell.

Equipped with multiple antennas at TX(transmit) and RX(receiver)

Allows to Apply signal processing techniques in transmission and reception to:

- .Enhance the quality of the communication
- .Increase the throughput of the system

VIII. Disadvantages Of MIMO

The resource requirements and hardware complexity is higher compare to single antenna based system. Each antenna requires individual RF units for radio signal processing. Moreover advanced DSP chip is needed to run advanced mathematical signal processing algorithms. . The hardware resources increase power requirements. Battery gets drain faster due to processing of complex and computationally intensive signal processing algorithms. This reduces battery lifetime of MIMO based devices.

MIMO based systems cost higher compare to single antenna based system due to increased hardware and advanced software requirements.

IX. Conclusion

MIMO Technology in wireless communication systems highlights the space dimension to improve range, system capacity and reliability. It offers significant changes in data throughput and link range without additional bandwidth or increased transmit power. More antennas contribute to more data transmission is the basic idea behind MIMO technology.

In order to meet higher demands in our wireless networks, it has been seen that MIMO is a very promising transmission technique but it should be noted that not all features of this technology can be exploited simultaneously due to different demands on the spatial degrees of freedom (or number of antennas).

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