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Energy-Efficient Resource Allocation in OFDMA Systems with Large Numbers of Base Station Antennas

N. Pavan Kumar
Assistant Professor
Department of ECE
Vignan Institute of Technology & Science.

INTRODUCTION

Wireless technologies have evolved remarkably since Guglielmo Marconi first demonstrated radio's ability to provide continuous contact with ships sailing in the English Channel in 1897. New theories and applications of wireless technologies have been developed by hundreds and thousands of scientists and engineers through the world ever since. Wireless communications can be regarded as the most important development that has an extremely wide range of applications from TV remote control and cordless phones to cellular phones and satellite-based TV systems. It changed people's life style in every aspect. Especially during the last decade, the mobile radio communications industry has grown by an exponentially increasing rate, fueled by the digital and RF (radio frequency) circuits design, fabrication and integration techniques and more computing power in chips. This trend will continue with an even greater pace in the near future. The advances and developments in the technique field have partially helped to realize our dreams on fast and reliable communicating “any time anywhere”. But we are expecting to have more experience in this wireless world such as wireless Internet surfing and interactive multimedia messaging so on. One natural question is: how can we put high-rate data streams over radio links to satisfy our needs? New wireless broadband access techniques are anticipated to answer this question.

For example, the coming generation cellular technology can provide us with up to 2Mbps (bits per second) data service. But that still does not meet the data rate required by multimedia media communications like HDTV (high-definition television) and video conference.

Recently MIMO systems have gained considerable attentions from the leading industry companies and the active academic community. A collection of problems including channel measurements and modeling, channel estimation, synchronization, IQ (in phase-quadrature) imbalance and PAPR (peak-to-average power ratio) have been widely studied. High transmission data rate, spectral efficiency, and reliability are necessary for wireless communications systems.

Unlike Gaussian channels, wireless channels suffer from attenuation due to multipath in the channel. Multiple copies of a single transmission arrive at the receiver at slightly different times. Without diversity techniques, severe attenuation makes it difficult for the receiver to determine the transmitted signal. Diversity techniques provide potentially less-attenuated replica(s) of the transmitted signal at the receiver.

Multiple-Input Multiple-Output (MIMO) antenna systems are a form of spatial diversity. In a multipath-rich wireless channel, deploying multiple antennas, at both the transmitter and receiver, achieves high data rate without increasing the total transmission power or bandwidth. Additionally, the use of multiple antennas at both the transmitter and receiver provides significant increase in capacity. When perfect channel knowledge is available at the receiver, the capacity has been shown to grow linearly with the number of antennas. Most MIMO detection schemes are based on

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perfect channel knowledge being available at the receiver.

Nowadays, next generation mobile communication systems have became popular all around the world. However, its services cannot provide a very big dynamic range of data rates, nor can it meet the requirements of a variety of business types. Besides, voice transportation in 4G still relies on circuit switching technology, which is the same method as used in second-generation (2G) communication systems, rather than pure Internet Protocol (IP) approach. Thus, based on consideration listed above, many countries have already carried out research on the next completely evolutionary fourth generation (4G) communication systems which provide a comprehensive and secure IP solution where voice, data, and multimedia can be offered to users at "anytime, anywhere" with higher data rates than previous generations [1]. Multiple input multiple output (MIMO) and orthogonal frequency division multiplexing (OF- DM) have therefore been adopted due to their superior performance. They promise to become key high-speed wireless communication technologies and combining them can provide wireless industry evolution from 4G to 5G system.

Most of the wireless communication systems are designed to support large number subcarriers, offer high data rates and to ensure the fulfillments of quality of service (QoS) requirements, under the constraint frequency spectrum and limited number of channels. Multiple-input multiple-output (MIMO) technology provides extra degrees of freedom which facilitate multiplexing gains and diversity gains. It can be shown that the ergodic capacity of a MIMO fading channel increases practically linearly with the minimum of the number of transmit and receive antennas. Hence, it is not surprising that MIMO has attracted a lot of research interest in the past decade since it enables significant performance enhancement without requiring additional transmit power and bandwidth resources. However, the complexity of MIMO receivers limits the gains that can be achieved in practice, especially for handheld devices. An alternative is multiuser MIMO where a transmitter with a large number of antennas serves multiple single antenna users. In the authors investigated the uplink sum capacity (bit-per-second-per-Hertz) of cellular networks assuming unlimited numbers of antennas at both the base station (BS) and the users. In high throughputs for both the uplink and the downlink were shown for a time-division du- plex multi-cell system which employed multiple BSs equipped with large numbers of antennas. In substantial capacity gains and better interference management capabilities were observed for MIMO, compared to single antenna systems.

OVERVIEW OF OFDM

OFDM is becoming a very popular multicarrier modulation technique for transmission of signals over wireless channels. It converts a frequency-selective fading channel into a collection of parallel flat fading subchannels, which greatly simplifies the structure of the receiver.

The time domain waveform of the subcarriers are orthogonal (subchannel and subcarrier will be used interchangeably hereinafter), yet the signal spectral corresponding to different subcarriers overlap in frequency domain.

Hence, the available bandwidth is utilized very efficiently in OFDM systems without causing the ICI (inter-carrier interference). By combining multiple low-data-rate subcarriers, OFDM systems can provide a composite high-data-rate with a long symbol duration. That helps to eliminate the ISI (inter-symbol interference), which often occurs along with signals of a short symbol duration in a multipath channel. Simply speaking, we can list its pros and cons as follows

Advantage of OFDM systems are:

- High spectral efficiency;

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- Simple implementation by FFT (fast Fourier transform);
- Low receiver complexity;
- Robustability for high-data-rate transmission over multipath fading channel
- High flexibility in terms of link adaptation;
- Low complexity multiple access schemes such as orthogonal frequency division multiple access.

Disadvantages of OFDM systems are:

- Sensitive to frequency offsets, timing errors and phase noise;
- Relatively higher peak-to-average power ratio compared to single carrier system, which tends to reduce the power efficiency of the RF amplifier.

OFDM System Model:

The OFDM technology is widely used in two types of working environments, i.e., a wired environment and a wireless environment. When used to transmit signals through wires like twisted wire pairs and coaxial cables, it is usually called as DMT (digital multi-tone). For instance, DMT is the core technology for all the xDSL (digital subscriber lines) systems which provide high-speed data service via existing telephone networks.

However, in a wireless environment such as radio broadcasting system and WLAN (wireless local area network), it is referred to as OFDM. Since we aim at performance enhancement for wireless communication systems, we use the term OFDM throughout this thesis. Furthermore, we only use the term MIMO-OFDM while explicitly addressing the OFDM systems combined with multiple antennas at both ends of a wireless link.

The history of OFDM can all the way date back to the mid 1960s, when Chang published a paper on the synthesis of band limited orthogonal signals for multichannel data transmission. He presented a new principle of transmitting signals simultaneously over a band limited channel without the ICI and the ISI. Right after Chang's publication of his paper, Saltzburg demonstrated the performance of the efficient parallel data transmission systems in 1967, where he concluded that \the strategy of designing an efficient parallel system should concentrate on reducing crosstalk between adjacent channels than on perfecting the individual channels themselves". His conclusion has been proven far-sighted today in the digital baseband signal processing to battle the ICI.

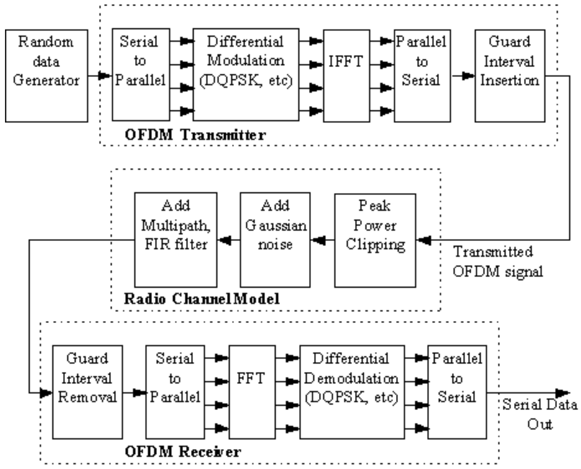

Figure 2.2 : OFDM Model used for simulations

Serial to Parallel Conversion:

The input serial data stream is formatted into the word size required for transmission, e.g. 2 bits/word for QPSK, and shifted into a parallel format. The data is then transmitted in parallel by assigning each data word to one carrier in the transmission.

Modulation of Data:

The data to be transmitted on each carrier is then differential encoded with previous symbols, then mapped into a Phase Shift Keying (PSK) format. Since differential encoding requires an initial phase reference an extra symbol is added at the start for this purpose. The data on each symbol is then mapped to a phase angle based on the modulation method. For example, for QPSK the phase angles used are 0, 90, 180, and 270 degrees. The use of phase shift keying produces a constant amplitude signal and was chosen

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for its simplicity and to reduce problems with amplitude fluctuations due to fading.

Inverse Fourier Transform:

After the required spectrum is worked out, an inverse fourier transform is used to find the corresponding time waveform. The guard period is then added to the start of each symbol.

Guard Period:

The guard period used was made up of two sections. Half of the guard period time is a zero amplitude transmission. The other half of the guard period is a cyclic extension of the symbol to be transmitted. This was to allow for symbol timing to be easily recovered by envelope detection. However it was found that it was not required in any of the simulations as the timing could be accurately determined position of the samples.

After the guard has been added, the symbols are then converted back to a serial time waveform. This is then the base band signal for the OFDM transmission.

Channel:

A channel model is then applied to the transmitted signal. The model allows for the signal to noise ratio, multipath, and peak power clipping to be controlled. The signal to noise ratio is set by adding a known amount of white noise to the transmitted signal. Multipath delay spread then added by simulating the delay spread using an FIR filter. The length of the FIR filter represents the maximum delay spread, while the coefficient amplitude represents the reflected signal magnitude.

Receiver:

The receiver basically does the reverse operation to the transmitter. The guard period is removed. The FFT of each symbol is then taken to find the original transmitted spectrum. The phase angle of each transmission carrier is then evaluated and converted back to the data word by demodulating the received phase. The data words are then combined back to the same word size as the original data.

MIMO-OFDM:

Orthogonal frequency division multiplexing (OFDM) is a popular method for high data rate wireless transmission. OFDM may be combined with antenna arrays at the transmitter and receiver to increase the diversity gain and/or to enhance the system capacity on time-varying and frequency-selective channels, resulting in a multiple-input multiple-output (MIMO) configuration.

MIMO-OFDM combines OFDM and MIMO techniques thereby achieving spectral efficiency and increased throughput. A MIMO-OFDM system transmits independent OFDM modulated data from multiple antennas simultaneously. At the receiver, after OFDM demodulation, MIMO decoding on each of the sub channels extracts the data from all the transmit antennas on all the sub channels.

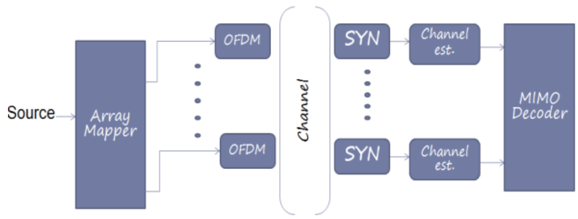

Fig 6.7: Basic MIMO-OFDM Block Diagram

However, the combination of MIMO and OFDM (Orthogonal Frequency Division Multiplex) has the following advantages.

- OFDM is adapted for multi-path propagation in wireless systems. The length of the OFDM-frames is determined by the Guard Interval (GI). This guard Interval restricts the maximum path delay and therefore the expansion of the network area.
- OFDM provides a robust multi-path system suitable for MIMO. At the same time OFDM provides high spectral efficiency and a degree of freedom in spreading the time dimension of Space-Time Block Codes over several sub-

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carriers. This results in a stronger system based on the principle described previously.

ANTENNA BASICS

An antenna is a metallic object which acts as a medium for receiving and transmitting electromagnetic energy. It acts as a transitional structure between the transceivers and the free space. Officially the Institute of Electrical and Electronics Engineers (IEEE) defines an antenna as **"The part of a transmitting or receiving system that is designed to radiate or receives electromagnetic waves"**. By moving electrons in the antenna, electromagnetic waves are formed. The antenna is connected to a transmitter which is designed to output current as a function of time. This current is an electromotive force (EMF) which forces free charge in the conductive element of the antenna to travel back and forth along the transmitting antenna. In the receiving antenna, there is free charge in the conductive element. They are affected by the movement of charge in the transmitting antenna. As there is usually a long distance between the transmitting antenna and the receiving antenna, that movement of charge in the receiving antenna is much smaller than the quantity of charge and movement in the transmitting antenna. This small and somewhat distorted signal is then amplified by the receivers. In order to understand the basic antenna principle, there are some parameters which have been taken into account. The basic antenna parameters include radiation pattern, antenna efficiency, bandwidth, directivity and antenna gain.

Radiation Pattern

An antenna radiation pattern is the angular distribution of the power dissipated by the antenna. It is a graphical explanation of the relative field strength transmitted and received by an antenna. As an antenna radiates through open space, several graphs are sometimes needed to describe the characteristics of an antenna. The graphs can be drawn using Cartesian (rectangular) coordinates or a polar plot. The radiation pattern of a half-wave dipole antenna is shown in figure 1.

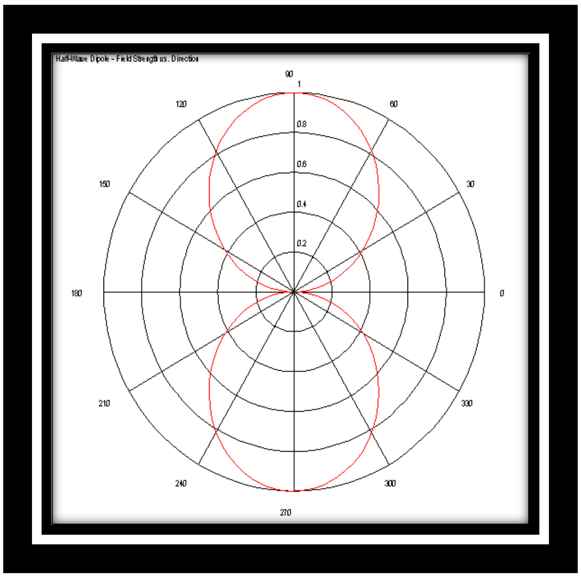

Figure 1: Radiation pattern of half-wave dipole antenna

Antenna Efficiency

The ratio of the total radiated power to the total input power is the antenna efficiency. The total radiated power is the measure of how much power is radiated by an antenna while it is connected to a transmitter. Most of the power from a high efficiency antenna is radiated away while a low efficiency antenna has most of the power absorbed as losses within the antenna or reflected away due to impedance mismatch. The antenna efficiency can be described by the following equation:

$$\epsilon_R = \frac{P_{radiated}}{P_{input}}$$

Where, ϵ_R is the antennas radiation efficiency, $P_{radiated}$ is the radiated power and, P_{input} is the input power. Efficiency is a ratio which is often described as a percentage. It is quoted in decibels (dB).

Bandwidth

Bandwidth is the range of frequencies in which the antenna remains effective. According to IEEE, bandwidth is "the range of frequencies within which the performance of the antenna, with respect to some characteristic, conforms to a specified standard". Bandwidth is a key factor upon choosing the right

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antenna. For instance, antennas with narrow bandwidths cannot be used for wide band operations. Bandwidth is typically quoted in VSWR (Voltage Standing Wave Ratio).

For example, an antenna may be described as operating at 100-400 MHz with a VSWR<1.5. This statement implies that the reflection coefficient is less than 0.2 across the quoted frequency range. Hence, of the power delivered to the antenna, only 4% of the power is reflected back to the transmitter.

Directivity

A commonly used parameter to measure the overall ability of an antenna to direct radiated power in a given direction is directive gain. The maximum directive gain of an antenna is called the directivity of the antenna. It is the ratio of the maximum radiation intensity to the average radiation intensity. Then the formula for directivity (D) can be written as

$$\mathbf{D} = \frac{4\pi|E_{max}|^2}{\int_0^{2\pi}\int_0^{\pi}|E(\theta,\emptyset)|^2 \sin\theta \, d\theta \, d\emptyset}$$

Where, "E" is the electric field intensity.

MULTIPLE ANTENNA TECHNIQUES

Traditionally, wireless communications mainly focused on voice and smaller data transfers, whereas most high-rate data transfer products were using wired communications. In recent years, however, there has been a dramatic boost in wireless multimedia applications, such as cell phones having an integrated camera, emailing capability and GPS. As a result, the focus has now shifted towards wireless high speed data transfers which traditional antennas are not capable of delivering because of multipath and co-channel interference. Apart from the needs of high speed data transfers, there is also an issue of quality control, which includes low error rate and high capacity.

In order to maintain certain Quality of Service (QoS), multipath fading effect has to be dealt with. As the transmitted signal is reflected onto various objects on its way to the receiver, the signal is faded and distorted. This phenomenon is called multipath fading. Co-channel interference refers to the interference caused by different signals using the same frequency. Hence as an alternative, multiple antennas can be used to reduce the error rate as well as, improve the quality and capacity of a wireless transmission by directing the radiation only to the intended direction and adjusting the radiation according to the traffic condition and signal environment. All multiple antennas are equipped with several antennas either in the transmitter or the receiver or both of them. A sophisticated signal processor and coding technology is the key factor in multiple antennas. Multiple antenna technique can be broken down into three categories, Spatial Diversity (SD), Spatial Multiplexing (SM) and Adaptive Antenna System (AAS).

Spatial Diversity (SD)

Spatial diversity is a part of antenna diversity techniques in which multiple antennas are used to improve the quality and reliability of a wireless link. Usually in densely populated areas, there is no clear Line of Sight (LoS) between the transmitter and receiver. As a result, multipath fading effect occurs on the transmission path. In spatial diversity several receive and transmit Antennas are placed at a distance from each other. Thus if one antenna experiences a fade, another one will have a LoS or a clear signal. Figure 6 shows the basic principle of Spatial Diversity.

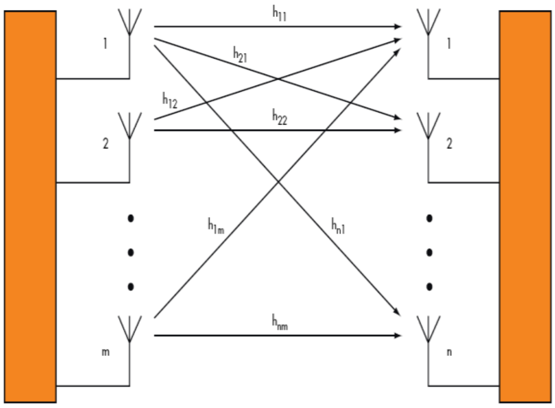

Figure 6: Spatial diversity

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The same signal is fed through a single antenna or multiple antennas, and the same signal is captured by a single antenna or multiple antennas. In figure 6 several antennas are placed in a distance from each other. There are various obstacles on the signal's path. In the case of base stations in a macro cellular environment, with large cells with high antennas, a distance up to 10 wavelengths is needed to ensure a low mutual fading correlation. However, in case of handheld devices, because of lack of space, half a wavelength is enough for the expected result. The reason behind this space is usually in the macro/cell scenario, the fading of which is caused by multipath correlations that have occurred in the near zone of the terminal. Therefore, from the terminal side, different paths arrive in a much wider angle, thus requiring smaller distances, whereas from the transmitter side, the path angle is relatively slow. That is why a larger distance is required. Recognized spatial diversity techniques involving multiple transmit antennas are, for example, Alamouti's transmit diversity scheme as well as space-time trellis codes invented by Tarokh, Seshadri, and Calderbank. For systems in which multiple antennas are available only at the receiver, there is well-established linear diversity combining techniques dating back to the 1950's.

Spatial Multiplexing

Multiple antenna systems are capable of establishing parallel data streams through different antennas. This is done in order to increase the data transfer rate. This process is called spatial multiplexing. The bit stream to be transmitted is divided or de-multiplexed into several data segments. These segments are then transmitted through different antennas simultaneously. As several antennas are in use, bit rate increases dramatically without the requirement of extra bandwidth or extra transmission power. The signal captured by the receiving antenna is a mixture of all individual segments. They are separated at the receiver using an interference cancellation algorithm. A well-known multiplexing scheme was developed by Bell Labs, known as BLAST.

Antenna Array

Single element antennas are not always sufficient for required antenna gain and radiation pattern. Combining several single element antennas into an array provides a much better solution. When multiple active antennas are joined together to a common source in order to achieve a directive radiation pattern, this is called an antenna array. Each individual antenna is known as the element of an array antenna. The radiation pattern from the array in a linear medium is determined by vector addition of the components of the electromagnetic fields radiated from the individual antennas or elements. This process is also known as the principle of superposition. Antenna arrays can be one, two or three dimensional. A typical array antenna is shown is figure 7.

Figure 7: A typical array antenna

There are several different configurations available for array antennas. If the elements are arranged in a straight line, then it is called linear array. If they are arranged parallel to each other, then a plane array in two dimensions is made. An array is linear when all the elements are placed at a constant distance. The array is called uniform when current of the same magnitude is fed into the array. A broadside array is formed when all the current fed into the arrays are of the same time-phase. There are some key elements otherwise known as array factors that are responsible for the shaping of the radiation pattern of an antenna array.

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MULTIPLE-INPUT MULTIPLE-OUTPUT

Multiple-Input Multiple-Output (MIMO) uses multiple antennas on both the transmitter and receiver. They have dual capability of combining the SIMO and MISO technologies. They can also increase capacity by using Spatial Multiplexing (SM). The MIMO method has some clear advantages over Single-input Single-output (SISO) methods. The fading is greatly eliminated by spatial diversity; low power is required compared to other techniques in MIMO.

Basic Building Block

A basic building block of the MIMO system is presented in figure.

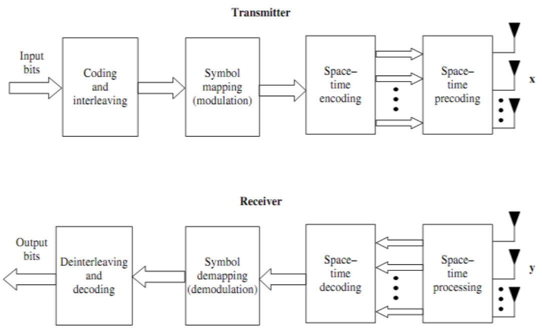

Figure :Buildingblocks of MIMO

In the figure, x and y represents transmit and received signal vectors respectively. At first, the information to be transmitted Is encoded and interleaved. The symbol mapper maps the encoded information to data symbols. These data symbols are then fed into a space-time encoder which creates some spatial data streams. The data streams are then transmitted by different antennas. The transmitted signals propagate through channels and are received by receiving arrays. The receiver then collects all the data from the antennas and reverses the operation to decode the data using a space-time processor, space time decoder, symbol de-mapper and at last the decoder.

Forms of MIMO

The Multiple Input multiple Output (MIMO) method can be divided into various forms depending on uses. MIMO is basically the combination of all the multiple antenna techniques such has SISO, SIMO and MISO. It can use the beam forming or the spatial Multiplexing methods. MIMO can be categorized into two types, multi-antenna types and multi-user types.

Multi-antenna types are listed below:

- SISO (Single-input Single-output)
- SIMO (Single-input Multiple-output)
- MISO (Multiple-input Single-output)
- MIMO (Multiple-input Multiple-output)

MIMO Transmitter and Receiver Structure

A basic two chain MIMO transmitter is shownin figure.

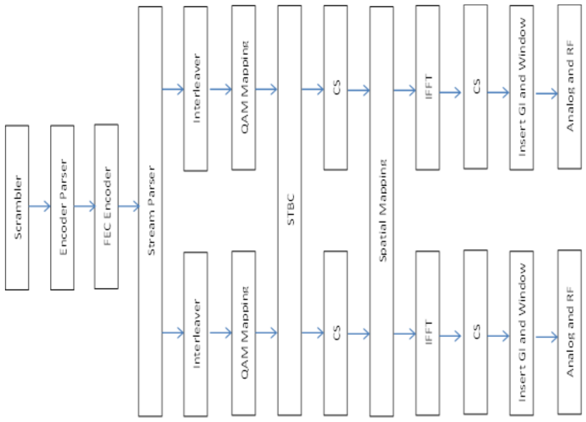

Figure : MIMO transmitter diagram

A few explanations of the transmitter diagram are given below:

Scrambler: The scrambler replaces the zeros and ones in the data.

Encoder Parser: De-multiplexes the scrambled bits and encodes them, among the number of FEC (Forward Error Correction) encoders.

FEC Encoder: Encrypts the data to allow error adjustment.

Stream Parser: Splits the output of the encoders into blocks for sending to different interleaverandmappingdevices.Theblocksofthebitssentt otheinterleaverare known as spatial streams.

Inter leaver: Encloses the bits of each spatial stream to avoid long sequences of noisy bits from entering into the FEC decoder.

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QAM (Quadrature Amplitude Modulation) Mapping: Charts the sequence of bits in each spatial stream to different patterns.

Uses of Multiple Antenna Techniques

Smart antenna technology can be added to any existing antenna technology in order to improve its performance. As an ever growing technology, multiple antenna techniques are proved to be useful in the following areas:

Wi-Fi (Wireless Fidelity): Small devices with in an indoor environment generally support adaptive array systems. The main benefits that multiple antennas have to offer incase of Wi-Fi include range increase, modifying interference and uniform coverage. Various VoIP (Voice over Internet Protocol) applications can be benefited from uniform coverage where static Quality of service(QoS) is needed. Multiple antennas can be implemented either in access points or in mobile clients, as the same frequencies are always in use. Higher data rates are a perfect solution given by smart antennas.

MIMO CHANNEL

Multiple-Input Multiple-Output (MIMO) systems yield vast capacity increases when the rich scattering environment is properly exploited. When examining the performance of MIMO systems, the MIMO channel must be modeled properly. The MIMO channel models used throughout this thesis are described in this section. The primary MIMO channel model under consideration is the quasi-static, frequency non-selective, Rayleigh fading channel model. Figure 25 shows a block diagram of a MIMO system with N_t transmit antennas and N_r receive antennas.

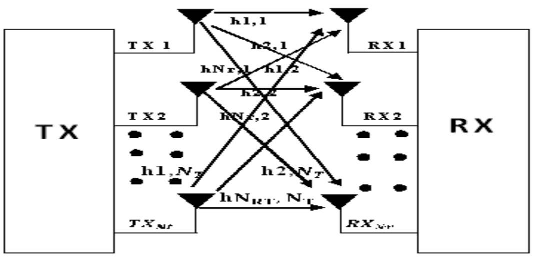

Figure: MIMO system block diagram

OFDM DOWNLINK NETWORK

Notation:

A complex Gaussian random variable with mean μ and variance σ^2 is denoted by CN (μ,σ^2), and means "distributed as". In this paper the following conventions are adopted. $0(g(x))$. if $\lim_{x\to\infty} \frac{f(x)}{g(x)} \leq N$ for o<N<∞ $[x]+=\max\{o,x\}$, $[x]_b^a = x$,if b≤x≤a; $[x]_b^a$ = b, if b>x. .0(g(x)) denotes the asymptotic upper bound $C^{N\times M}$ is the space of all N×M matrices with complex entries. _·_ and |·| denote the Euclidean norm of a matrix/vector and the absolute value of a complex-valued scalar, respectively. [·]† , [·]T, and [·] represent the conjugate transpose, transpose, and conjugate operations, respectively. tr(**S**) denotes the trace of matrix **S**. _R(·) denotes the real part of a complex number. 1(·) denotes an indicator function which is 1 when the event is true and 0 otherwise.

Channel Model:

We consider an OFDMA network which consists of a BS with multiple antennas and K mobile users equipped with a single antenna. The impulse responses of all channels are assumed to be time-invariant (slow fading). There are n_F subcarriers in each orthogonal frequency division multiplexing (OFDM) symbol. The downlink received symbol at user $K \in \{1, \ldots, k\}$ on subcarrier $i \in \{1, \ldots, n_F\}$ is given by

$$y_{i,k} = \sqrt{P_{i,k} l_k g_k h_{i,k}^T \hat{f}_{i,k} x_{i,k}} + \sum_{j\neq k} h_{i,k}^T \hat{f}_{i,j} x_{i,j} \sqrt{P_{i,j} l_k g_k s_{i,j}} + z_{i,k}$$

where $x_{i,k}$ and $f_{i,k} \in C^{N_{T_{i,k}}} \times 1$ are the transmitted data symbol and the precoding vector used by the BS to transmit to user k on subcarrier i, respectively. $N_{T_{i,k}}$ is the number of active antennas allocated to user k on subcarrier i for transmission. $P_{i,k}$ is the transmit power for the link from the BS to user k in subcarrier i. $s_{i,j} \in \{0,1\}$ is the subcarrier allocation indicator in subcarrier i for user j. $h_{i,k} \in C^{N_{T_{i,k}}} \times 1$ contains the small scale fading coefficients between the BS and user k on subcarrier i. l_k and g_k represent the path loss

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and the shadowing between the BS and user k, respectively. $z_{i,k}$ is the additive white Gaussian noise (AWGN) in subcarrier i at user k with distribution CN(0,N0), where N0 is the noise power spectral density

Channel State Information:

In the following, since path loss and shadowing are slowly varying random processes which both change on the order of seconds for low mobility users, we assume that the path loss and shadowing coefficients can be estimated perfectly. For the multipath fading, we assume that the users can obtain perfect estimates of the BS-to-user fading gains $h_{i,k}^{T}\hat{f}_{i,k} \in \mathbb{C}^{1\times 1}$, i∈{1, . . . , n_F }, k∈{1, . . .,K} for signal detection purpose. However, the corresponding CSIT, i.e., $h_{i,k} \in \mathbb{C}^{N_{T_{i,k}}} \times 1$ may be outdated/inaccurate at the BS because of the mobility ofthe users or errors in uplink channel estimation. To capture this effect, we model the multipath fading CSIT of the link between the BS and user k on subcarrier i as

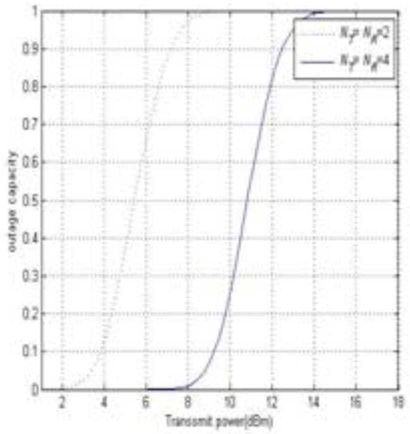
$$h_{i,k} = \hat{h}_{i,k} + \Delta h_{i,k}$$

where $\hat{h}_{i,k}$ and $\Delta h_{i,k}$ denote the estimated CSIT vector and the CSIT error vector, respectively. $\hat{h}_{i,k}$ and $\Delta h_{i,k}$ are Gaussian random vectors and each vector has independent elements with respect to user index k. Besides, the elements of vectors $h_{i,k}$, $\hat{h}_{i,k}$ and $\Delta h_{i,k}$ have zero means and normalized variances of 1, $1-\sigma_e^2$ and σ_e^2, respectively. Assuming a minimum mean square error (MMSE) estimator, the CSIT error vector and the actual CSIT vector are mutually uncorrelated. However, the fading gains of a given user may be correlated across different subcarriers.

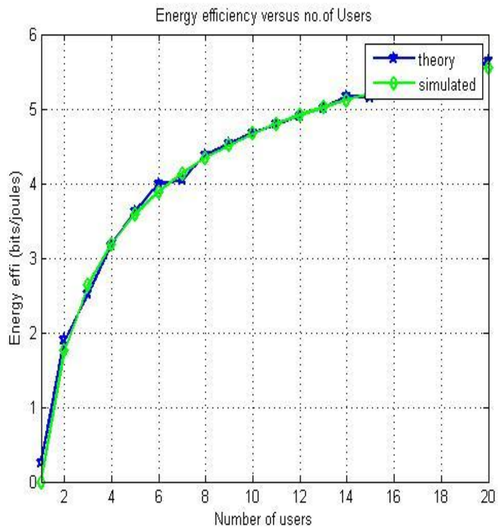
SIMULATION RESULTS

Outage capacity Vs Transmit Power:

Below figure shows the simulation results for the outage capacity of the MIMO system with respective to the transmit power. As discussed in above sections the outage capacity or carrying capacity of the MIMO system increases only when the number of active antennas increases and which is indirectly need to higher power requirements. Whenever the transmit power increases then correspondingly the outage capacity of the system increases. Here we have to remember that, the meaning of increasing the transmit power is indirectly increasing the active antennas.



In figure, whenever the transmitting and receiving antennas both are 2 then their required transmitting power is small and therefore their corresponding outage capacity is also less. And in other hand whenever the transmitting and receiving antennas both are increased to 4 then automatically the transmitting power also increased and the total outage capacity of the system increases gradually as shown in figure 3. Thus the simulation results for Outage capacity Vs Transmit Power shows a clear description among the capacity of the MIMO system, Transmit power requirement and number of active antennas.



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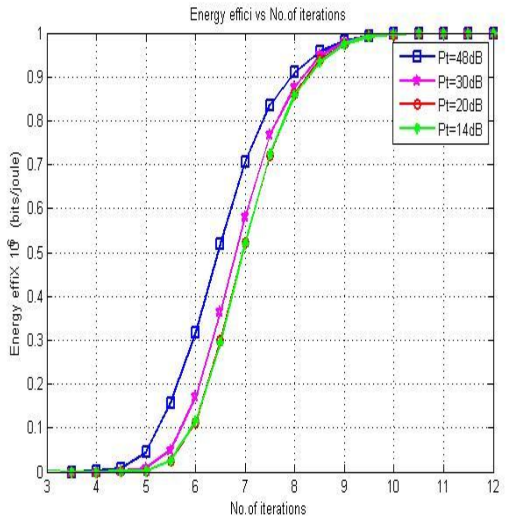

From the simulation results of our proposed method it is clear that the objectives our project achieves successfully. From the above simulation results, the energy efficiency of the MIMO system good for high amount of power transmission, compared to less power transmission system under equal iterations i.e. from our discussions at equal number of iteration the MIMO system which has more number of active achieves high energy efficiency than with less antenna MIMO system ender available unique power resource only

CONCLUSION

From the above simulation results, the energy efficiency of the MIMO system good for high amount of power transmission, compared to less power transmission system under equal iterations i.e. from our discussions at equal number of iteration the MIMO system which has more number of active achieves high energy efficiency than with less antenna MIMO system ender available unique power resource only. The use of a large number of antennas is always beneficial for the system outage capacity, even if the CSIT is imperfect. However, an exceedingly large number of antennas may not be a cost effective solution for improving the system performance, at least not from an energy efficiency point of view.

In simple words, by efficiently allocating the power among all the active antennas and by gradually increasing the outage capacity using proposed iterative scheme the energy efficiency of the OFDMA system increased which is our "An Efficient Resource Allocation in MIMO-OFDMA Networks".

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