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A Review on Channel Capacity Enhancement in OFDM

[1]Pawandeep Kaur, [2]Sonia

[1]Student, [2]Assistant Professor, Dept. of Electronics and Communication, Baba Banda Singh Bahadur Engineering College, Fatehgarh Sahib, India

Abstract: **The growing demand on wireless communication service has created the necessity to support higher data rates for multimedia services. .As next generation wireless communication networks are expected to provide broadband multimedia services such as voice, web browsing, video conferencing etc. For high data rate achievement one must enhance the capacity of the wireless communication system. The capacity of a communication system can be enhanced by using OFDM system. OFDM is commonly used for communication system due to its high transmission rate and robustness against multipath fading So as to enhance the capacity of fading channels the OFDM system are combined to form hybrid system. Capacity is the measure of maximum information that can be transmitted reliably over a channel. This paper review on different channel capacity enhancement techniques used in OFDM system is SVD (Singular Value Decomposition), water Filling algorithm.**

Keywords: **OFDM (Orthogonal Frequency Division Multiplexing), Singular value decomposition, Water Filling Algorithm.**

1. INTRODUCTION

High data-rate wireless access is demanded by many applications. Traditionally, more bandwidth is required for higher data-rate transmission. However, due to spectral limitations, it is often impractical or sometimes very expensive to increase bandwidth. Wireless communication systems disadvantages have esteemed ISI which emerges from multipath propagation and characteristic delay spread. The schemes which are based on multicarrier like Orthogonal Frequency Division Multiplexing (OFDM) can be utilized for varnishing ISI to enhance the capacity and spectral efficiency (bps/Hz) in wireless communication systems. In OFDM, the entire channel is divided into many narrow parallel sub-channels, thereby increasing the symbol duration and reducing or eliminating the ISI caused by the multipath. Therefore, OFDM has been used in digital audio and video broadcasting in Europe, and is a promising choice for future high-data-rate wireless systems. At the transmitter OFDM modulated data is transmitted from multiple antennas in an OFDM system. The signals transmitted with subcarriers from other antennas are mutually orthogonal. The data streams from different subcarriers are concentrate by receiver after OFDM demodulation in consequence with a time varying channel, we ought a easy algorithm which robustly alter transmit specifications for achieving high capacity. System capacity can be further enhanced by using water filling algorithm, singular value decomposition and many other techniques which considerably enhances the capacity of the wireless communication system. The channel matrix is decoupled into spatial domain by SVD (Singular Value Decomposition) scheme. OFDM systems are best choice for increasing the capacity of wireless communication system because of characteristics like reduced ISI, reduced ICI (Inter carrier interference), optimized power consumption and easy transmission of symbol in time, frequency and space Due to the advantages such as inter-symbol interference (ISI) free communication, high spectral effectiveness, and decreased equalization complexity we are focus on high data rate wireless communication. The paper reveals that OFDM system with SVD and water filling algorithm.

2. RELATED WORK

L. S et.al [1] had proposed the iterative water filling algorithm to enhance the channel capacity of MIMO OFDM system. The simulation had been carried out on MATLAB 2010a using different antenna arrangements over Rayleigh, Rician and Nakagami fading channels. Moreover bit error rate (BER) performance of MIMO OFDM system had been compared over different modulation schemes.

R. Hidayat et.al [2] had proposed channel estimation for spatial multiplexing was investigated for MIMO OFDM system. Pilot symbols were used to gather knowledge about the channel and attempt to approximate it. By using the pilot symbol the channel estimation can be done and is called pilot promoting channel estimation. In that analysis, Least Square (LS) mechanism was chosen for beginning channel estimation. Zero Forcing (ZF) algorithms were utilized to recognize and divide the received signal. The result showed that by increasing the SNR channel estimation would be excellent.

H. Deshmukh et.al [5] had implemented water filling algorithm for allocating power to the MIMO channels for enhancing the capacity of the MIMO network. The water filling algorithm had provide solution with the help of channel state information. The singular value decomposition and water filing algorithm had been employed to measure the performance of MIMO OFDM integrated system.

Md.Rahim et.al [8] had presented the singular value decomposition and water filling algorithm had been employed to measure the performance of MIMO OFDM integrated system. Therefore, at the same carrier frequency the capacity was raised by communicating various streams of data over different antennas. Any Inter Symbol Interference (ISI) produced after the transmission was recovered by using spatial sampling integrated with signal processing algorithm.

H.Wang et.al [6] had proposed optimal cooperative water filling algorithm for power allocation in OFDM system. The transmitter first cooperates by sharing CSI (channel sate information) and then jointly optimizes power assigning in the metric of total output, which could be modeled as a convex optimization problem. Based on the resolution, the optimal cooperative power assigning method was constructed, the structure of which could be related to as a cooperative water filling comparative to the common water filling.

3. BASIC OFDM SYSTEM

Orthogonal Frequency Division Multiplexing (OFDM) is a famous wireless multicarrier transmission scheme. It is a favorable contender for next-generation wired and wireless systems. The fundamental standard of OFDM is to divide huge data stream into total number of low rate streams so that the lower rate data can be communicated together over a fraction of subcarriers. In OFDM, the quantity of dispersion in time, originated by multipath delay spread, is diminished due to the raised symbol duration for decreased ratio lateral subcarriers. The field of OFDM is also powerful because of the need of nearest channels space. Interferences are interrupted by preparing complete the carriers orthogonal to one other. In this, N subcarriers OFDM scheme, firstly data streams are traveled through an OFDM modulator. After this OFDM symbols are passed at the same time over the transmit antennas. At the receiver side, then OFDM demodulator is used for passing the exclusive received signals. For achieving the desired output, the OFDM demodulators output are decoded and rearranged. Fig.1 depicts the symbolic diagram of a fundamental OFDM system.

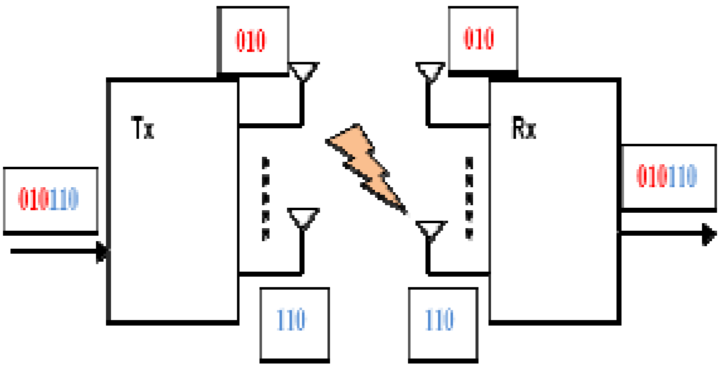

Fig 1: OFDM System

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4. THE PROS AND CONS OF OFDM

***1) Resisting ISI and Compressing ICI*:** When signal passes over a time-dispersive medium, the orthogonality of the data can loss. CP assist to preserve orthogonality among the sub-carriers. Before CP was invented, guard interval was proposed as the solution. Guard interval was defined by an empty space between two OFDM symbols. This empty guard time introduces ICI. Later, a better solution was later found that cyclic extension of OFDM symbol or CP, which is a copy of the last part of OFDM symbol, appended in front of the transmitted OFDM symbol. CP still occupies the same time interval as guard period, but it confirms that the deferred replicas of the OFDM symbols will regularly have a entire symbol inside FFT interval this makes the transmitted signal periodic. This periodicity plays a very significant role as this helps maintaining the orthogonality.

2) ***Spectral Efficiency:*** A prominent spectral ability is attained by preserving orthogonality among the subcarriers. When orthogonally is maintained between different sub-channels during transmission, then it is possible to separate the signals very easily at the receiver side[20] .Orthogonality makes it possible in OFDM to arrange the subcarriers in such a way that the sidebands of the exclusive carriers overlay also still the signals are received at the receiver without being interfered by ICI. The receiver acts as a reserve of demodulators, converting every subcarrier down to DC, with the resulting signal integrated over a symbol period to recover raw data.

3) ***Immunity to selective fading:*** If the channel undergoes frequency selective fading, then complex equalization techniques are required at the receiver for single carrier modulation techniques. But in the case of OFDM the available bandwidth is split among many orthogonal narrowly spaced sub-carriers. [17]Thus the available channel bandwidth is converted into many narrow flat- fading sub-channels. Hence it can be assumed that the subcarriers experience flat fading only, though the channel gain/phase associated with the sub-carriers may vary. In the receiver, each sub-carrier just needs to be weighted according to the channel gain/phase encountered by it. Even if some sub-carriers are completely lost due to fading, proper coding and interleaving at the transmitter can recover the user data.

4) Resilient to narrow-band effects: Using sufficient channel coding and interleaving it is desirable to retrieve symbols disappear.[14] Channel coding refers to the class of signal transformations designed to improve communications performance by enabling the transmitted signals to better withstand the effects of various channel impairments, such as noise, interference, and fading. FEC is adept by calculating redundancy to the transmitted data practicing a predetermined algorithm. Each redundant bit is invariably a complicated function of abundant primary information bits. The primary data may or may not arrive in the encrypted output; codes that combine the direct input in the output are standardized, while those that do not are non standardized. If Channel coding is applied; the performance of OFDM is expected to be significantly improved through time diversity of channel coding as well as through inherent frequency diversity of the OFDM. In a multipath fading channel, if the data loss in a sub carrier channel occurs due to deep fade, it can be recovered from the coded data in alternative sub carrier channels which may not suffer from the same level of fade distortion.

5) ***Simpler channel equalization:*** By adopting multiple sub-channels it is an advantage of OFDM that the channel equalization becomes much easy.[19]Inserting an equalizer realized as an adaptive system before the FFT processing, the influence of variable delay and multipath could be mitigated in order to remove or reduce considerably the guard interval and to gain some spectral efficiency. In OFDM, the orthogonal subcarriers can be assumed to undergo flat fading in a frequency selective channel permitting operation without an equalizer especially when differential data encoding is used. However, in OFDM, the data symbols are no longer confined to orthogonal subcarriers and, therefore, an equalizer is required for operation in frequency selective channels**.**

6) ***Efficient modulation and demodulation:*** Modulation and Demodulation of the sub-carriers is done using IFFT and FFT methods respectively, which are computationally efficient. By performing the modulation and demodulation in the digital domain, the need for highly frequency stable oscillators is avoided. OFDM makes efficient use of the spectrum by allowing overlap.

7) **It** is less sensitive to sample timing offsets than single carrier systems [20]. To decode the OFDM signal the receiver has to take the FFT of each received symbol, to work out the phase and amplitude of the subcarriers. For an ideal channel with no delay spread the receiver can pick any time offset, up to the length of the guard period, and still get the correct number of samples, without crossing a symbol boundary. Because of the cyclic nature of the guard period changing the time offset simply results in a phase rotation of all the subcarriers in the signal. Provided the time offset is held constant

from symbol to symbol, the phase rotation due to a time offset can be removed out as part of the channel equalization. In multipath environments ISI reduces the effective length of the guard period leading to a corresponding reduction in the allowable time offset error.

8) Intelligent antennas can be combined with OFDM. MIMO structure and space–time coding can be recognized at OFDM.[18].OFDM is a promising digital modulation scheme to simplify the equalization in frequency selective channels and provide simpler implementations. MIMO communications technology, can achieve significant increases in the channel capacity. Therefore, the combination of OFDM with MIMO communications, which is MIMO-OFDM systems, can realize high-performance transmissions .Although, multi-path propagation causes frequency selectivity in broadband wireless channels, most MIMO systems are used for channels with flat fading. Therefore, the MIMO-OFDM technique has initially been proposed to use OFDM to alleviate ISI in MIMO systems and found to be a propitious selection for high data rate wireless broadband communications.

9) Modulation type per subcarrier: Because different modulation schemes will give different performances. Adaptive modulation and bit loading may be needed depending on the achievement required. It is attractive to tone that the performance of OFDM systems with differential intonation correlates with systems utilizing non-differential and coherent detection. Moreover, the computation complication in the detection method is absolutely low in consequence of differential modulations.

Amongst all attractive advantages of OFDM, there are disadvantages of OFDM[21]:

Strict Synchronization Requirement: OFDM signals are subject to synchronization errors due to oscillator impairments and sample clock differences. The demodulation of the received radio signal to baseband, possibly via an intermediate frequency, involves oscillators whose frequencies may not be perfectly aligned with the transmitter frequencies. This results in a carrier frequency offset. Carrier frequency offset degrades the performance of an OFDM system. When the baseband signal is sampled at the A/D, the sample clock frequency at the receiver may not be the same as that at the transmitter. Not only may this sample clock offset cause errors, it may also cause the duration of an OFDM symbol at the receiver to be different from that at the transmitter. Since the receiver needs to determine when the OFDM symbol begins for proper demodulation with the FFT, a symbol synchronization algorithm at the receiver is usually necessary. Symbol synchronization also compensates for delay changes in the channel.

5. CAPACITY ENHANCEMENT TECHNIQUES

Different techniques used for channel capacity enhancement are :

A. Singular Value Decomposition

B. Water Filling Algorithm

Variants of water filling algorithm are

1. Iterative Water Filling Algorithm
2. Improved iterative Water Filling Algorithm
3. Centralized Iterative Water Filling Algorithm
4. Cluster Water Filling Algorithm
5. Cooperative Water Filling Algorithm
6. Genetic Algorithm based Water Filling

A. Singular Value Decomposition (SVD)

SVD decomposes a single user system OFDM channel into multiple parallel sub channels, and then transmitting power can be distributed to these sub channels to obtain channel capacity. This is a valuable method to attain the adequate efficiency of OFDM wireless system. [8] The DFT decouples the channel matrix in a frequency domain similarly SVD techniques decoupling the channel matrix in spatial domain. The TxR channel matrix is denoted by H. Suppose H has separated rows and columns ,SVD yields:

$H = U\Sigma Vh$

Where U and V are unitary matrices and Vh is the hermitian of V. U has proportion of RxR and V has dimension of TxT.If T=R then Σ become a diagonal matrix. If T>R, is made of RxR diagonal matrix followed by T-R zero column. If T<R, it is made of T x T diagonal matrix followed by R – T 0 rows. This operation is called the singular value decomposition of H. In case where T ≠ R the number of spatial channels become restricted to minimum to T and R. if the number of transmit antenna > receive antenna U will be an RxR matrix, V will be a TxT pattern and Σ will be formed of square matrix of form R pursued by T – R zero columns [10].

Channel matrix singular value decomposition (SVD) method is employed in OFDM systems in order to overcome sub-channel interference, to allocate transmitted power through sub-channels in an optimum manner and also to design the space-time coding algorithm efficiently. Thus the SVD estimation is primary method to achieve the adequate capacity of OFDM systems. The SVD is a nonlinear function and its estimation may become a more complicated problem because it involves nonlinear optimization methods. The estimation algorithm is developed based on the linear constrained LMS technique and achieves good performance.

B. Water filling algorithm: Water filling algorithm is a common name disposed to the concept in communication system design and practice for equalization. As name suggests, just as water find its level uniformly though filled in single section of a vessel with many opening as a consequence of Pascal's law. Water filling is used to determine the power transmitted in each channel to achieve greatest possible capacity. Water filling is the solution of various optimization problem related to channel capacity. Water filling algorithm solves the problem of maximum mutual information between input and output of a channel. Water filling indicates to a scheme by which the power for the spatial channels are accommodated depended on the gain of channels. The channel along huge gain and Signal-to-Noise Ratio is lying down higher power. Enhanced power stretches the amount of data rates in entire sub channels. The data rate in each sub channel is related to the power allocation by Shannon's capacity theorem C = B log (1 + SNR). On the other hand, bec due to the capacity is a logarithmic part of power, the data rate is commonly indifferent to the precise power distribution. The Capacity of a MIMO system is algebraic sum of the capacities of all channels and is given by the formula below

$$Capacity = \sum_{i=1}^{n} \log_2 (1 + PowerAllocated * H)$$

We have to maximize the total number of bits to be transported.

1. Iterative Water Filling Algorithm: In consideration of find the accurate value of water level iterative water filling was proposed. As without water filling the total power is allocated equally between all sub carriers. Water filling algorithm allocates power among all the sub carriers according to channel gain that greater portion of power goes to sub channel with higher gain and less or even none to the channel with small gain. Iterative water filling algorithm converges to get the optimal solution. When there is negative value of power allocation stop iterations.[1],[3],[5]

2. Improved Iterative Water Filling Algorithm: As iterative water filling power allocation among all the users could result in large computational complexity. To get the quick and accurate calculation of channel capacity and diversity. Its basic idea is to select a small number of active users, and then to allocate the total power among the effective users using water filling algorithm, thus to compute the channel capacity.[10]

3. Centralized Iterative Water Filling Algorithm**:** This algorithm maximizes the system capacity throughput subject to per Base Station power constraints in downlink OFDM network. It is assumed that central unit could get access to perfect channel state information and data of all users.[2]

4. Cluster Water Filling Algorithm**:** Water Filling gives solution to only subcarrier while for the whole sub carrier it is not water filling, as value of power may vary from one sub carrier to other named as Cluster Water Filling because in each cluster value of power does not vary. Cluster water filling was proposed to solve the problem of robust transceiver design as robust design is better than non-robust design.[7]

5. Cooperative Water Filling Algorithm**:** In cooperative water filling two transmitter and multiple receiver were employed to maximize the capacity of the system as one receiver should jointly transmitted by two transmitters, and all other receivers are transmitted only by one of two transmitters. Transmitters have their own perfect CSI (Channel State Information), first cooperate by exchanging CSI and then accordingly enhancing the power assigning in the metric of total capacity.[6]

6. Genetic Algorithm based Water Filling: Water Filling algorithm maximize the bit rate for entire MIMO-OFDM transmission system and genetic algorithm is a biologically inspired technique inspired by natural evolution such as inheritance, selection and crossover. Water Filling is combined with genetic algorithm to find the optimum power vector that maximize the overall throughput of OFDM system while satisfying the total power constraints, bit allocation and in addition to quality of service.[13]

6. CONCLUSION

OFDM is an effective technique to combat multipath delay spread for wideband wireless transmission. In this paper, it is concluded that OFDM is a promising technique for achieving high data rate for next generation communication system. So we discuss the different technique which significantly enhances the capacity of the OFDM wireless communication system. The various techniques which we discussed have their own advantages and disadvantages.

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