“A Review on Channel Capacity Enhancement in Multiuser OFDM”
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Abstract—Orthogonal Frequency Division Multiplexing (OFDM) has successfully prevented ISI in a frequency selective wireless environment. 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. An interesting application of OFDM is in Multiuser OFDM systems in which multiple users share the same channel and the total transmit power. Due to independent multipath fading characteristic for each user, channel diversity is also created. This survey studies the methods that have been proposed in the literature to allocate the resources and achieve better Performances in data rates and Bit error rates and minimum transmit power levels. And also review on different channel capacity enhancement techniques used in OFDM system is SVD (Singular Value Decomposition), water filling algorithm.

Key words: OFDM (Orthogonal Frequency Division Multiplexing), Channel capacity, Singular value decomposition, Water Filling Algorithm, composite channel

I. INTRODUCTION

Next Generation wireless communication systems will support wireless multimedia and wireless internet access which require high data rate and complex designs. High data rate communication over wideband channels are significantly limited by inter-symbol interference (ISI) due to frequency selective or time dispersive nature of the channels. In a multiuser systems such as cellular systems, users experience ISI as a result of multiple copies (multipath) of the transmitted signal created by the objects (such building, cars, etc.) around them. [1]

To combat ISI, multicarrier modulation techniques, including Orthogonal Frequency Division Multiplexing (OFDM) are among the possible solutions that have been suggested. OFDM [2] divides a broadband channel into narrow subcarrier (of the same width) such that the channel response on a particular subcarrier seems flat. Adding a guard band or cyclic prefix (CP), whose length equals the dispersion time of the channel, to the transmitted symbols, makes each of the subcarriers parallel independent additive white Gaussian noise channels. This setup allows the received signal to be ISI free.

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. [3, 4, 5]

II. RELATED WORKS DIFFERENT PROPOSED PAPER

Zukang Shen[2]: had proposed a proportional rate adaptive optimization in MU-OFDM is analyzed. Subcarrier and power allocation are carried out separately. The optimal power allocation to a determined subcarrier scheme is developed. Arbitrary proportional fairness can be achieved with the proposed algorithm. Simulation results shows that the proposed optimal power allocation improves the capacity significantly over fixed TDMA, and outperforms previously derived suboptimal power distribution schemes.

Farhan Khalid, Joachim Speidelnt. J [15]: Open-loop MIMO techniques provide a low-complexity solution for MIMO diversity and SM. STC or SFC e.g. STBC, orthogonal STBC (OSTBC), STTC, SFBC etc. can be used for diversity maximization. this scheme are also well suited transmission over high speed mobile channels where link reliability is the primary rahterthen throughput maximization. Closed-loop MIMO systems like the SVD-based linear transceivers, are capable of achieving the SU-MIMO capacity by transmitting over the channel eigenmode with optimal water-filling power allocation, provided perfect CSI is available at the transmitter and the receiver. Alternatively, DET can be employed to achieve the maximum diversity and array gain. Closed-loop STC like the closed-loop STBC schemes proposed in which support more than two transmit antennas, also provide diversity maximization. The GMD-MIMO scheme de-composes the MIMO channel into identical sub channels and attempts to combine MIMO diversity and SM in an optimal manner.

L. S et.al [6] 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.

H. Deshmukh et.al [11] 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 filling algorithm had been employed to measure the performance of MIMO OFDM integrated system.

Md.Rahim et.al [10] 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 [7] had proposed optimal cooperative water filling algorithm for power allocation in OFDM system. The transmitter first cooperates by sharing CSI (channel state 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 a cooperative water filling comparative to the common water filling.

III. 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 another. 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.

IV. 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

1) Singular Value Decomposition
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:

\[ H = UΣ \Sigma V^T \]

Where U and V are unitary matrices and \( Vh \) is the hermitian of V. U has proportion of RxR and V has dimension of T x T. 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 T x T pattern and Σ will be formed of square matrix of form R pursued by T – R zero columns [12].

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.

2) 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

![Fig. 1: OFDM System](image-url)
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 $C = B \log (1 + \text{SNR})$. On the other hand, 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

$$\text{CAPACITY} = \sum_{l=1}^{n} \log_2(1 + \text{power allowed} \times H)$$

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 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.[4],[6],[7]

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.[12]

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.[13]

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.[9]

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. [8]

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.[14]

Here, describes the adaptive scheme proposed in which minimizes the total transmitted power with the fixed user data rate and the scheme which maximizes the total capacity under fixed total power mentioned in mentions the Quality of Service (QoS).

Margin Adaptive: A multiuser subcarrier, bit and power allocation scheme where all users transmit in all the time slots. The authors use the given set of user data rates and attempt to minimize total transmit power, which is also know as Margin Adaptive. Following is the problem formulated in the paper.

$$\text{Pt*} = \sum_{k=1}^{n} \sum_{m=1}^{M} \gamma_k \frac{1}{\alpha^2} k, n f_k(C, k, n)$$

Where $* \text{Pt}$ is the total power, $c \ k \ n$, is the bite rate for kth user on the nth subcarrier, $a2 k, n$ is the channel gain squared for nth subcarrier for the kth user and $f_k$ is the required received power. In the single user case, a subcarrier gets the additional bit if it requires the minimum power to transmit it. [16]

Rate Adaptive: An algorithm that maximizes the total data rate of the multiuser OFDM system by adapting the transmit power for each user and each subcarrier. The total transmit power for the system is fixed and represented by,

$$\sum_{k=1}^{n} \sum_{m=1}^{M} S_k, n = S \rightarrow$$

Where $S$ is the total transmit power and $s \ k \ n$, is the transmit power for $k^{th}$ user and the $n^{th}$ subcarrier.

Hence, the system model takes into account the interference caused by other users on the same subcarrier. To reduce the complexity of maximizing the data rate while keeping the transmit power limited, the authors first find the subcarrier for each user and then apply the power allocation. The maximum number of bits in a symbol to be transmitted for the $k^{th}$ user’s $m^{th}$ subcarrier is expressed as

$$q_k, n = \log_2(1 + y_k, n/T)$$

Where $g \ k \ n$ is the Signal to interference plus noise ratio (SINR) and $G$ is the function of the required Bit Error Rate (BER). The problem is formulated as

$$R = \sum_{k=1}^{K} \sum_{m=1}^{M} q_k, n \ T = \frac{B}{M} \sum_{k=1}^{K} \sum_{m=1}^{M} \log_2(1 + y_k, n/T)$$

Where $T$ is the OFDM symbol duration. In subcarrier allocation the authors determine which user would transmit on a subcarrier, to maximize the data rate on that subcarrier. They present a theorem to maximize the data rate for a subcarrier. It states a subcarrier should be assigned to that user only which has the best channel gain for the subcarrier, Eventually the authors disallow any subcarrier to be shared among other users, similar to the approaches of [16,18]. The authors indicate that data rate may be increased with the increase in the number of users in the system.

Rate Adaptive and Quality of Service: Although the objective of [18] is similar to [17] discussed in section II, the paper addresses the Quality of Service neglected by the former paper. Having constraint on the power with adaptive data rates, does not ensure a good share of the total data rate for each user. This paper adds a set of nonlinear Constraints to enforce the control of capacity ratio among the users. The optimization problem is similar to [17] with the sharing of
subcarriers by multiple users being assumed. The nonlinear constraints or the proportional fairness is given,

\[ R_i : R_2 : \ldots : R_k = \gamma_1 : \gamma_2 : \ldots : \gamma_k \]

Where \( R_i \) are the individual user’s data rates and \( \gamma \) are predetermined values to ensure proportional fairness between users. If all \( \gamma \) terms are equal then it represents a special case which has been presented in maximizes the sum capacity while forcing all the \( R_i \) terms to be equal. To reduce the complexity, the paper derives a suboptimal algorithm by separating the subcarrier and power allocation. The subcarrier allocation is partially similar to the previous paper where a particular subcarrier is assigned to the user which has the best channel gain among the other users. The additional part to the algorithm finds and then allows a user with the lowest proportional capacity to pick the best subcarrier. This process is suboptimal and offers course proportional fairness.

V. CONCLUSION

In this paper, it is concluded that OFDM is a promising technique for achieving high data rate for next generation communication system. OFDM is an effective technique to combat multipath delay spread for wideband wireless transmission. 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.

OFDM represents a successful approach to mitigate ISI from wireless communication. Multiuser systems create channel diversity which increase with the number of users in the system. Exploiting the channel diversity in a multiuser OFDM system increases the performance of the system. Due to the varying conditions of the channel between the transmitter and receiver it is essential to adaptively allocate the subcarrier, bit and power levels based on instantaneous channel knowledge.

REFERENCES

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