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Frequency Response Based Resource Allocation in OFDM Systems for Downlink

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ABSTRACT: The efficient use of radio resources is crucial in order for future wireless systems to be able to meet the demand for high speed data communication services. *Orthogonal Frequency Division Multiplexing* (OFDM) is an important technology forfuture wireless systems as it offers numerous advantages over other existing technologies, such as robust performance over multipath fading channels and theability to achieve high spectral efficiency. Resource allocation can fullyexploit the advantages of OFDM, especially in multiple user systems.
In this paper, Static Resource allocation (Subcarrier and Power) is carried out for multiple users in the downlink of a single cell OFDM cellular network. The resource allocation is based on the frequency response of the downlink channels. The focus is on the reduction of BER and the power consumption to ensure that the variations in the outage probabilities experienced by different users are minimal.

KEYWORDS: Resource allocation, Orthogonal Frequency Division Multiplexing (OFDM), Static Resource allocation, Frequency response, BER, Subcarrier and Power.

I. INTRODUCTION

With rapid growth of technology in the field of telecommunications, it is possible to provide high speed, high quality data exchange between portable devices around the world. Various techniques are put forward to share the available channel bandwidth in wireless communication systems. Multiplexing is one form, in which one communication channel carries several transmissions at the same time. The communication channel is shared in such a way, so as to maximize the utilization of the channel capacity. The exact number of simultaneous transmissions depends on the type of communication channel and the data transmission rate.

A.OFDM SYSTEM

Orthogonal Frequency Division Multiplexing (OFDM) can be thought of as a modulation technique as well as a multiple access scheme. As a modulation scheme, it is well suited to handle adverse environmental conditions, while as a multiple access scheme; it offers high spectral efficiency and diversity. The first OFDM was proposed by [2] for the time dispersive channel, which has undergone a dramatic change due the efforts of [3].OFDM is a special form of multi-carrier transmission scheme. It offers better spectral efficiency over the traditional multi-carrier systems. The basic idea of OFDM is to split a high rate data stream into a large number of lower rate data sub-streams and modulate them onto a number of equally spaced carrier frequencies called *subcarriers*. The data is transmitted simultaneously over these parallel subcarriers.

The focus of this paper is on the wireless environment. The wireless channel is much more unpredictable than the wire line channel because of the factors such as shadowing, the multipath effect and the Doppler Effect. These factors impact how the signal level changes as it propagates through wireless medium. OFDM offers greater immunity to the

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impairments and the uncertainties of the wireless channel.The objective of the project is to maintain the given standard probability of error when we change the power of the transmitted signal based on the strength of the frequency response. We will be able to minimize the average power consumption. We give importance to the downlink because we would like to minimize the average power consumption in the base station. This requires continuous monitoring of the frequency response of the channel. We study the allocation of resource with different power factors and compare the results with the simulation results.

II. RELATED WORK

Resource allocation for multiuser OFDM networks has attracted a lot of interest [15], The goal is to jointly allocate subcarriers, rate and power in order to maximize (respectively minimize) the weighted sum of user rates (powers) under a prescribed power (rate) budget. For these problems, a low-complexity yet provably optimal solution is not available. In this context, [15]reported suboptimal algorithms which tradeoff complexity for (sub)optimality. Recently, there has also been interest to expand the scope of resource allocation/scheduling to: i) ensure fairness among users, ii) provide QoS guarantees, and iii) cope with mobility and network dynamics, both of which render the wireless channel uncertain. Fairness and QoS guarantees can be effected by maximizing a suitable utility function of average user rates and introducing minimum rate constraints per user [16]Channel uncertainty on the other hand, can be accommodated through on-line channel-adaptive scheduling schemes that essentially learn the underlying channel distribution on-the-fly [17] The resultant "opportunistic" schedulers, however, are mainly developed for single-carrier, time-division multiplexing systems, and the few extensions to OFDM networks are only limited to best-effort traffic without rate requirements. In addition, existing approaches pertain to either deterministic links or if random fading effects are accounted for, the channel links are confined to obey a fi- nite-state Markov chain model. This is not the case in wireless propagation where fading coefficients take on a continuum of values

III. FREQUENCY RESPONSE BASED RESOURCE ALLOCATION IN OFDM SYSTEMS FOR DOWNLINK

The high rate data stream is spilt into N parallel sub streams of lower rate data which are modulated into N OFDM symbols and transmitted simultaneously on N orthogonal subcarriers. Each of these parallel complex sub channels can be treated as an ISI-free subchannel. Therefore, the performance of the system multicarrier modulation can be analyzed as an aggregate of N ISI-free subchannels. If the number of sub channels is sufficiently large (i.e., the bandwidth of each sub channel is sufficiently small), the frequency response in each sub channel is close to be flat. Further, the frequency spacing between the sub channels ensures the orthogonality of the sub carriers. The complex symbols at the output of the modulators are then transformed into OFDM symbols in time domain by the inverse fast Fourier transform (IFFT) in the transmitter. Before transmission, a cyclic prefix (CP) which is the copy of the last IFFT samples is added to the front of the OFDM symbol. CP is sized appropriately to serve as a guard interval to maintain orthogonality between the subcarriers in the multipath wireless channel. Therefore, the ISI could be eliminated provided that the amount of time dispersion from the channel is smaller than the duration of the guard interval. In the receiver, the guard interval is removed and the time samples are transformed into modulated symbols by means of fast Fourier transform (FFT). The rest of the receiver blocks essentially invert the operations at the transmitter.

A. ***BASIC SYSTEM MODEL FOR OFDM***

Consider the N different complex exponential carriers given by $\exp^{j2\pi kn/N,}$ $0\leq n \leq N-1$. These carriers are orthogonal over N samples. If we modulate the k^{th} carrier by a complex symbol X_k, and collect the first N samples, we get the k^{th} modulated carrier sequence, given by

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$$x_n^k = X_k e^{j2\pi kn/N} \qquad 0 \le n \le N-1 \qquad (2.1)$$

Where, X(k)={X(0),X(1),……………X(N-1)}

The sum of all modulated sub carrier sequence scaled by 1/N is

$$x_n = \frac{1}{N}\sum_{k=0}^{N-1} X(k)\, e^{j2\pi kn/N} \quad 0 \le n \le N-1 \quad (2.2)$$

Here, corresponding to a block of N complex symbols, we get a frame of N samples. To avoid the interference from the symbols of the previous frame the last N_g samples of x_n are placed before the first samples of x_n, where N_g is at least equal to the delay spread of the channel. This is called the cyclic prefix (CP). After adding CP part to the OFDM frame, the sequence transmitted is given by,

$$x_n^c = \frac{1}{N}\sum_{k=0}^{N-1} X(k) e^{j2\pi kn/N} \quad 0 \le n \le N + N_g - 1$$

The processing part of the OFDM contains a serial to parallel converter, IFFT unit, CP insertion unit followed by parallel to serial converter as shown in the figure. The signal is converted into analog using digital to analog converter, translated into RF (radio frequency) spectrum and transmitted.The circular convolution is given by,

$$y_k = \sum_{k=0}^{N-1} h_k\, x_{(n-k)}^c + z_n \quad 0 \le n \le N-1 \qquad (2.4)$$

Where z_n is the additive white Gaussian noise (AWGN) with zero mean. The expression (2.4) has the form of a convolution sum. However, it is not the ordinary linear convolution which relates the output sequence of a linear system to the input sequence and the impulse response. Instead, the convolution sum in expression (2.4) involves the index (n-k) and is circular convolution. Thus we can conclude that multiplication of DFT's of two sequences is equivalent to the circular convolution of two sequences in the time domain.

In the discrete time complex baseband processing part of the receiver of the OFDM system with perfect synchronization, removing the CP part from the received frame and taking the FFT, we get

$$Y(k) = \sum_{n=0}^{N-1} y(k)\, e^{-j2\pi kn/N} \quad 0 \le k \le N-1 \quad (2.5)$$

The k^{th} output of N point DFT unit in the receiver is given by,

$$Y_k = X_k H_k + Z_k (2.6)$$

Where H_k is the frequency response of the channel for the k^{th} subcarrier given by,

$$H_k = \sum_{n=0}^{L-1} h_n e^{-j2\pi kn/N} \qquad 0 \le k \le N-1 \qquad (2.7)$$

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The k^{th} transmitted symbol is detected by multiplying Y_k by $\frac{H_k^*}{|H_k|^2}$ where ()* denotes the complex conjugation operation.Now, consider the OFDM system, initially assuming the data symbols in the frequency domain, the data symbols are inter-leaved and coded using any of modulation technique, parallel to serial conversion and then it is given to the IFFT block. Wherein, L denotes the channel length, j=$\sqrt{-1}$, Ng denotes the length of the CP, N denotes the length of OFDM symbol.

Here the method is, in regular intervals of time the frequency responses of the channels between the users and the base station are computed and the subcarriers in particular channel are allocated to a particular user. In such a case sometimes to a user we may be forced to allocate a subcarrier whose frequency response is not maximum. Hence, the bit error rate for that carrier gets increased. In such a scenario, we would like to develop an allocation scheme in which we assure a particular probability of error and also minimize the power consumption.

B.SUB-OPTIMAL RESOURCE ALLOCATION IN MULTI USER

OFDM: Consider a single-cell K-user OFDM system of N sub-carriers operating on a flat fading channel. Each user is assigned a subset of sub-carriers for use, and each sub carrier is assigned exclusively to one user. The entire bandwidth and power, B and P_{total} respectively are shared among N sub-carriers and this allows all users to transmit simultaneously. K is the total number of users. $P_{kn}$is the power allocated to the k^{th} user in the n^{th} subcarrier; N_k is the number of subcarriers allocated to the k^{th} user.

Assuming that the sub-carrier separation is smaller than the coherent bandwidth, each sub-carrier can be considered as a flat fading sub-channel. Assuming total utilization of transmission power, a general downlink received signal for an arbitrary k^{th}user at its n^{th} subcarrier is modeled as,

$$y_{k,n} = x_{k,n}h_{k,n} + w_{k,n} \quad (2.8)$$

Where $x_{k,n}$ and $y_{k,n}$ are the transmitted and received signal respectively. $w_{k,n}$ is the additive white Gaussian noise(AWGN) and $h_{k,n}$ is the channel coefficient of user k at subcarrier n, which is extracted from the channel vector

$$h_k = [h_{k,1} \dots \dots \dots \dots \dots \dots h_{k,N}]$$

The corresponding SNR for the k^{th} user's nth sub-channel is expressed as $\gamma_{k,n}=|h_{k,n}|^2/\sigma_{k,n}^2$, where $\sigma_{k,n}^2$ is the noise variance of the AWGN. As the overall bandwidth, B, is evenly divided among all sub-channels, the noise variance of any arbitrary user k at all sub-channels are identical i.e., $\sigma_{k,n}^2= \sigma_k^2/N$. The Shannon's capacity for user k is given by,

$$C_k = \sum_{n=1}^{N} \frac{B}{N} log_2(1 + \gamma_{k,n}) \qquad (2.9)$$

Where C_k is the information capacity of the channel. The information capacity is defined as the maximum rate at which information can be transmitted across the channel without error; it is measured in bits per second (b/s). For a prescribed channel bandwidth B and received SNR, the Shannon's capacity theorem tells us that a message signal can be transmitted through the system without error even when the channel is noisy, provided that actual signaling rate in bits per second, at which data are transmitted through the channel, is less than the information capacity C_k.

To realize the potential of utilizing sub-carrier and power allocation to improve spectral efficiency the feedback of accurate CSI is necessary. As we are addressing power allocation problem, we are only interested in channel amplitude, not its phase. We define the instantaneous transmission power and sub-carrier assignment vector of user k

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as, $P_k=[P_{k,1},\ldots\ldots, P_{k,N}]$ and $\beta_k=[\beta_{k,1},\ldots\ldots, \beta_{k,N}]$ where $P_{k,n}\geq 0$ and $\beta_{k,n}$ indicates the assignment of subcarrier n to user k, such that

$$\beta_{k,n} = \begin{cases} 1, if\ subcarrier\ n\ is\ assigned\ to\ user\ k, \\ 0, otherwise. \end{cases} \quad (2.10)$$

There are two criteria that must always be met. Firstly sum of all transmission power is bounded by a total power budget, i.e.

$$\sum_{k=1}^{K}\sum_{n=1}^{N}\beta_{k,n} P_{k,n} \leq P_{max} \quad (2.11)$$

Where, P_{max} is the total available power. Secondly, not more than one user is permissible for transmission in any nth subcarrier, i.e.

$$\sum_{k=1}^{K}\beta_{k,n} \leq 1 \quad (2.12)$$

Assuming that the feedback channel condition is given as $\gamma_{k,n}$ for all k and n, the achievable transmission rate for user k is denoted as

$$R_k = \sum_{n=1}^{N}\frac{B}{N} log_2\left(1+\beta_{k,n}P_{k,n}\gamma_{k,n}\right) \quad (2.13)$$

On receiving the data, cyclic prefix is removed and the received data is de-convolved. The BER is calculated by comparing the output received to the input data using soft decision method.

Sub carrier allocation is done utilizing the total power at the transmitter initially. The main focus is to allocate power in such a way that the utilization of power is minimized. In this project, power allocation is dealt with after the sub carrier allocation. At the transmitter, power is varied by multiplying the data with a constant value varying from 1 to 0.1, i.e., the amount of power supply at the transmitter is reduced by certain percentage to check if less power is sufficient for the transmission of same data resulting in less BER and also avoiding the wastage of extra power utilization at the transmitter. Maximum BER that can be allowed in a transmission is baseline and importantly the following condition is to be met,

$$BER_n \leq Pe_n \forall\, n \quad (2.14)$$

BER_n is the bit error rate for user n and $Pe_n$is the bit error rateconstraint for user n.

Reduction in the power utilization results in increase in BER. Power utilized at the transmitter can be varied (reduced) until BER does not exceed the maximum BER which is taken as baseline. Finally, the least amount of power required for the data transmission resulting in lesser BER than that of baseline BER is found out, hence resulting in saving power. Baseline BER is the resulting BER when all subcarriers in a OFDM symbol is used.

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In [5] and [6], first, a set of nonlinear equations has to be solved in order to get the power distribution among users. Then to a particular user, the greedy water-filling algorithm is used for power allocation. Since the power is allocated to every user separately the time consumed by this system will be more compared to our system where, the power is allocated uniformly to all the users. We mainly concentrate on reducing the power consumption and the bit error rate, whereas the efficiency will be reduced because the frequency responses below threshold are left unused.

IV. SIMULATIONRESULTSANDDISCUSSIONS

For all simulations, we assume that

- Cyclic Extension of OFDM symbols are used as guard interval.
- The channel impulse response is shorter than the cyclic prefix to avoid ISI.
- Channel is assumed to remain unchanged during one OFDM symbol, to avoid ICI.

An OFDM system is modeled using Matlab to allow various parameters of the system to be varied and tested. The aim of doing the simulations is to measure the performance of OFDM system under different channel conditions, and to allow for different OFDM configurations to be tested. Two main criteria are used to assess the performance of the OFDM system are its tolerance to multipath delay spread and channel noise. The input signal which we used is the random data generated by randn() function of the Matlab, and limit the data to its maximum value. The notations used in simulations are as given below. N is number of symbols in OFDM frame and CP is the length of cyclic prefix. *max*is the maximum magnitude of the frequency response.

Figure 3.1 is the graph for scheduling 4 users. CP length of 5 is considered. Power factor is equal to 1 i.e., all the power available is utilized and the total number of subcarriers is equal to 64. Therefore, the number of subcarriers allocated will be *M*=16 to a user.

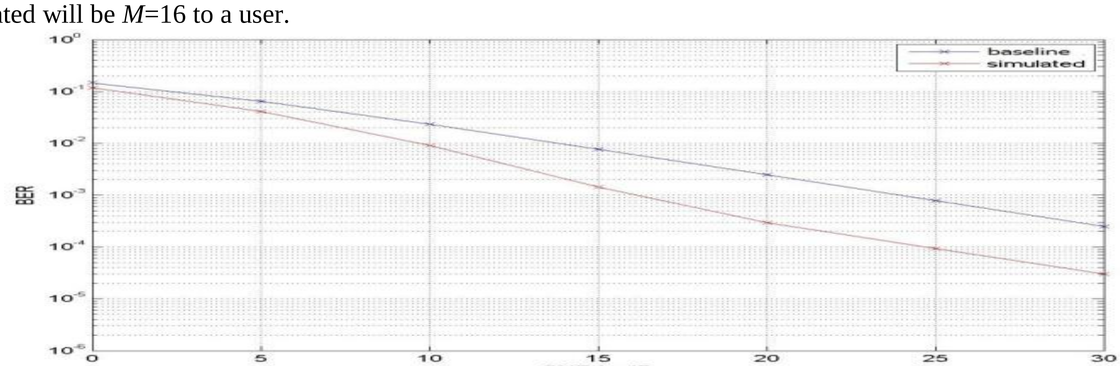

Figure 3.1: BER vs. SNR, Scheduling for four users, CP=5 and BER plot with 1.0pf

Respectively, graphs 3.2, and 3.3 depict the BER plot for different number of subcarriers and also power factors. Whereas, graph 3.4 depict the BER plot for various number of subcarriers and graph 3.5 depict the BER plot for different threshold values.

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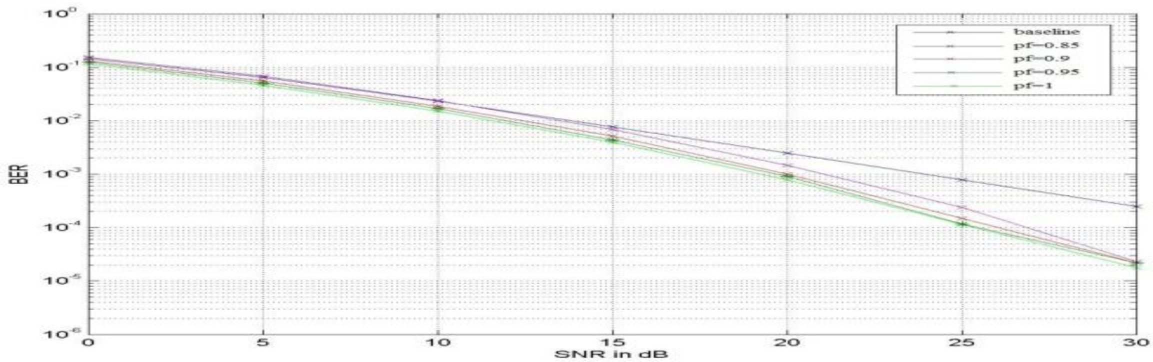

Figure 3.2: BER vs SNR plot for users=4, M=8, th=max/16

Figure 3.2 represents the graph for BER to SNR curves for baseline and simulation results. The cyclic prefix CP equal to 5. The total number of subcarriers is 32. Therefore, the number of subcarriers allocated will be M=8 to a user. The maximum of magnitude of frequency response is divided by 16 and threshold is set accordingly. The power factor is varied from 1 to 0.85, i.e., the amount of power utilization is varied (decreased) to find out the minimum power requirement and every time the power utilization is varied a curve is drawn and it is compared with the baseline curve. When the power factor is 1, total available power is utilized whereas when power factor is 0.95 only 95 percent of the available power is used and so on.

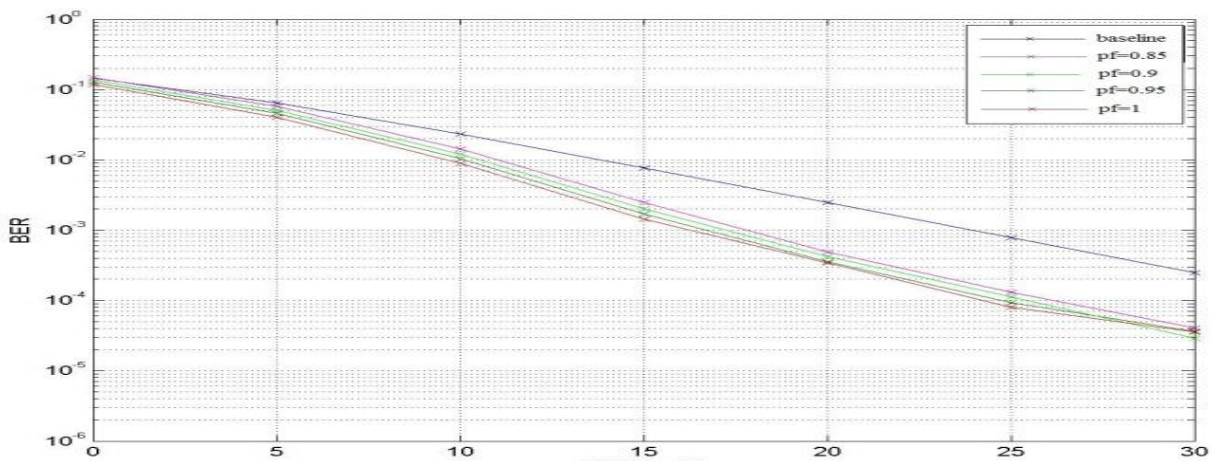

Figure 3.3: BER vs SNR plot for users=4, M=16, th=max/4

It is evident in the above graph that the simulated curve crosses over the baseline curve i.e., BER exceeds the maximum acceptable BER according to baseline when only 85 percent of the available power is utilized. Hence considering all the curves, the minimum power required for the transmission of the given data at certain conditions is 90 percent of the available power.

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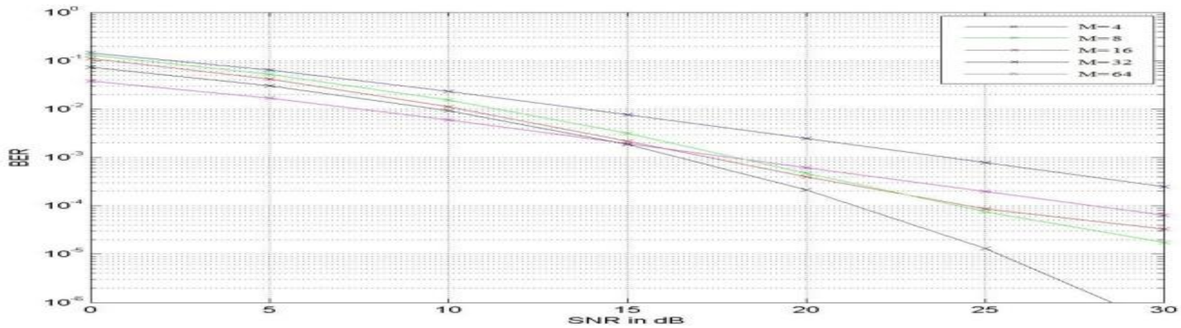

Figure 3.4: BER vs SNR plot for users=4, th=max/8, pf=1

Figure 3.4 depict the BER plot for various number of subcarriers.Figure 3.5 depict the BER plot for different threshold values.

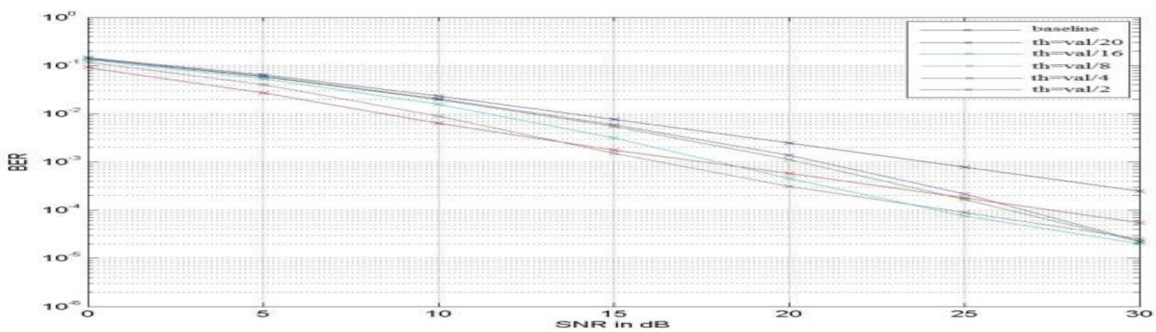

Figure 3.5: BER vs SNR plot for users=4, M=16, pf=1

Above Figure 3.5 represents the graph for BER to SNR curves for baseline and simulation results for different threshold values. The cyclic prefix CP equal to 5. Total number of subcarriers is 64. The subcarriers are allocated to 4 users. Therefore, the number of subcarriers allocated will be M=16 to a user. The power factor is 1. The maximum of magnitude of frequency response is divided by different values and threshold is set accordingly, then the curve is plotted for every simulation. Every time the threshold is set differently the BER curve is drawn and it is compared with the baseline curve. Values 2, 4, 8, 16 and 20 are used to divide magnitude of maximum frequency response to set threshold. Smaller the number used to divide, higher will be the threshold, resulting in lesser BER, because of the data transmission taken place only on the subcarriers in good condition. Similarly, as we increase the magnitude of the value to divide, threshold will be set at lower level hence, resulting in higher BER. Lower the threshold is set, the BER increases because of the transmission of data over subcarriers in bad condition as well. Above graph shows the effect of threshold in the data transmission.

V. CONCLUSION

In this project, the Resource allocation (Subcarrier and Power) is carried out for multiple users, single cell OFDM cellular network focusing on downlink communications, on the reduction of BER and the power consumption to ensure that the variations in the outage probabilities experienced by different users are minimal.

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We focus on resource allocation. In resource allocation, subcarrier and power allocation are performed to maximize the overall rate while achieving proportional fairness amongst users under a total power constraint. The proposed algorithm adopts a two step approach. In the first step, the algorithm outlined is employed for subcarrier allocation. In the second step, power allocation is done in such a way that the minimum power is consumed of the total available power. Allocation of minimum power also takes the BER into consideration. Minimum power required is the one using which the BER does not cross over the baseline BER. Further reduction in power might lead to increase in BER that crosses over the baseline BER which is not desirable. The proposed algorithm takes into account the frequency selective nature of users' channels and performs subcarrier and power allocation.

VI. SCOPE FOR FUTURE WORK

As we have seen in the above proposed method, there is a lot of scope for future work which gives the platform for further development of the system.This project was basically concentrated on OFDM and the study of its performance in the mobile radio channel. However, much work needs to be done to study the forward error correctionschemes for OFDM. Also in our project we used a particular modulation technique irrespective of the type of data that is to be transmitted like BPSK. However suitable techniques can be studied whereby different modulation schemes could be used for different types of data. Many works has been done on SC-FDMA, our work can be extended to SC-FDMA. In our model we used a fixed data rate. However a study of adaptive modulation and coding overa dispersive multipath fading channel can be carried out wherein the data rate is varied dynamically.

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