Performance Analysis of Multi Carrier CDMA Transceiver System using a Novel Dynamic Decoding and Scheduling Procedure

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Abstract: **Wireless communications is a rapidly growing area of the communication, with high-quality and high data rate information exchange between mobile devices located anywhere in the world. Multi Carrier Code Division Multiple Access (MC CDMA) has emerged recently as a promising possibility for the next generation broadband mobile networks and it can cater to the needs of broadband mobile networks. The Transceiver proposed for a Multicarrier CDMA system is capable of achieving desirable performance with effective interference cancellation. Dynamic decoding algorithm with dynamic threshold determination and scheduling procedure is proposed to increase the system performance**.

***Index Terms*: Bit Error Rate, Signal to Noise Ratio, Multicarrier CDMA**

I. Introduction

The MC CDMA Transceiver provides the best form of communication in a noise and interference free system. Due to fading, the receiver experiences numerous copies of the transmitted signal and each of the signal takes different path.While traversing from transmitter to the receiver each signal suffers a delay and gets attenuated as well.

The interference cancellation procedures available in the literature cannot provide the required Bit Error Rate (BER) for MC CDMA system. To provide minimum BER, we have proposed a dynamic threshold determination and scheduling procedure to combat processing delay of the previous module, which is due to the fact that the system takes more number of iterations to reduce BER and improve signal quality [1],[2]. Another limitation of the previous module is that when the scheme is applied to a multiuser system, Multiple Access Interference (MAI) occurs which may increase the BER of the system [3]. A multiuser parallel scheduling scheme is proposed to combat MAI and increase the spectral efficiency of the system [4], [5], [6]. This system fails to maintain the Bit Error Rate (BER) of the system when number of users are increased. In a frequency selective fading channel, MAI degrades the performance of MC CDMA system. By appropriate usage of codewords , the system reduces BER in a multipath fading environment [7]. A hybrid subcarrier mapping scheme makes use of a superimposing common set of subcarriers [8], [9]. However, most of the work available in literature, fix the threshold value to determine the channel selection [10].

In order to overcome these limitations, the proposed algorithm reduces the number of iterations and at the same time improves BER and the number of scheduled users by varying the threshold in a dynamic manner and adopting an adaptive equalization procedure. The Dynamic Threshold determination for MC CDMA system is proposed to achieve Proper channel selection and estimation, reduce number of iterations to control the processing delay and to minimize BER to increase the performance of MC CDMA Transceiver. The paper comprises of following sections: section II explains the System Description, section III describes the Dynamic Decoding Scheduling Procedure, section IV explains Results and Discussion followed by Conclusion in section V.

II. System Description

The MC CDMA receiver calculates the summation of amplitude of signals that exists from different paths, the phase of the signal being significant. The signal strength of each signal varies depending on the nature of summation of signals. If all signals exists in-phase, they tend to add together. When the signals are out of phase, they tend to subtract from each other. However, this case does not happen, as some signals will be in-phase and others will be out of phase, depending on various path lengths, and therefore some will tend to add to the overall signal, whereas others will subtract. The mathematical model of multipath can be presented using the method of impulse response, from which multipath time can be calculated which defines the time delay between the initial and the last received impulses. After obtaining the channel transfer characteristics, coherence bandwidth decides the nature of the channel, but it is not very significant in deciding the error rate of the receiver over wide range of frequencies.

In the receiver, the signals are de spreaded after the recovery of subcarriers at the output of Fast Fourier Transform (FFT), by applying inverse code matrix. To optimize and mitigate the effects of the channel there arises a need to introduce weighing factor. A linear receiver is used in this case, which arrives at a decision based on linear combination of all subcarrier signals. The receiver should be provided with FFT that can be implemented efficiently using standard butterfly topologies, inverse code matrix c^{-1} and the weighing matrix W. Consider FFT and c^{-1} to b non-adaptive, and an implementation of simple linear receiver can be performed. Inversion is needed to find the Minimum Mean Square Error (MMSE) of the signal in the presence of noise, MAI and Inter Chip Interference (ICI).

Consider a MC CDMA system with k transmitters generating independent data symbols $x_k = \{-1, 1\}$. The coded data $d_k = \{-1, 1\}$ is interleaved and spread by Direct-sequence spreaders

$$S_k = \left\{-1/\sqrt{N}, 1/\sqrt{N}\right\}$$

where N is the Processing Gain.

The received signal is given by

$$y = \sum_{k=1}^{K} S_k d_k + n \quad (1)$$

Where n is AWGN with variance $N_o/2$.

The equation (1) depicts, that the received signal constitutes itself with the message and its unique code along with the noise component.

The amplitude $a_k(t)$ of the received signal at time ‘t’ will be the same for all chip rate 1/Tc . The expectation of the received signal on to the spreading code of signal i after elimination of the signal (i-1) during the m^{th} symbol interval is given by

$$I_{k,m} = \frac{1}{T_k} \int_{(m-1)Tk+tk}^{mTk+tk} r^{(k)}(t) a_k(t - \tau_k) dt \quad (2)$$

Where $r^{(k)}(t)$ is the signal after cancelling users 1 through (k-1) which is used to detect data for user k of $T_k = N_k Tc$ for K^{th} user’s symbol period and N_k is the spreading gain of user k and * represents the complex conjugate operation.

The SNR for signal k is given by

$$\Gamma k = \frac{E^2\{R[I_{k,m}\gamma_k^*]/[I_{k,m}]\}}{Var\{R[I_{k,m}\gamma_k^*]/[I_{k,m}]\}} \quad (3)$$

Where $E^2\{x/y\}$ is the square of expected value of x given y, $\gamma_k = \sqrt{P_k} e^{j\phi k}$ is the complex channel gain and R[x] is the real part of x.

The variance of decision statistics, n_x is

$$n_x = Var\{ R[I_{k,m} \gamma_k^*]/ [b_{k,m}]\} \quad (4)$$

thus

$$n_k = \frac{\sigma^2}{N_k} + \frac{\sigma^2}{N_k} \sum_{i=1}^{k-1} n_i + \frac{\sigma^2}{N_k} + \sum_{i=k+1}^{k} P_i \quad (5)$$

Where σ equals 1 and 0.5.

The above equation depicts the way to determine SNR for a Multicarrier system. By using the unique code word, the desired pulse can be decoded and SNR is calculated. The SNR calculated is kept as threshold so that the Dynamic Decoding algorithm can efficiently recover the transmitted data to its best level.

Now we propose an algorithm that performs efficient decoding of the received estimate.

III. Dynamic Decoding Scheduling Procedure

This system works efficiently by adopting SNR as threshold. In a Multicarrier system, the information is conveyed via multiple carriers which have the same in-phase component but different quadrature phase components. In order to decode the desired information with optimum signal strength, Dynamic decoding schedule algorithm is employed. An optimum detector should have the capability of computing root mean square deviation instead of just reconstructing the received signal. The receiver should make a decision in favor of decoding a signal with least probability of error. In this sense, the receiver can surpass the distorted channel. Now the receiver will estimate the time response of the actual received signal and determine the most likely signal. In cases that are most computationally straightforward, criterion for the lowest error probability is achieved.

The transmitted carriers are to be discretized based on the threshold SNR. If the $(N-1)^{th}$ frequency produces a good SNR compared to $(N)^{th}$ frequency , the threshold will be updated (i.e.) SNR of $(N-1)^{th}$ frequency will be set as threshold, leaving SNR of $(N)^{th}$ frequency signal, so that the process continues for all different combinations of constellation levels of QAM as well as for different throughput levels so that the performance of receiver can be improved in the presence of noise and fading environment. Nu users are multiplexed by allocating M subcarriers in the available spectrum of width W = 1/T.

Each user is assigned a subset of subcarriers according to the prescribed allocation strategy. If the subcarriers Su are uniformly spaced, then

$$S_k = U/T_1 \quad \text{with } T_1=MT, U=0............M-1 \quad (6)$$

Subcarrier allocation methods play an important role for optimization of Spectral Efficiency, the exploitation of Frequency Diversity, and the complexity of the detection algorithm.

Consider a system with K transmitters, each transmitting N subcarriers. Each subcarrier is allocated a different value of chip interval T_C.

(i) Initially 64-QAM modulation scheme is used for all the subcarriers.

(ii) Calculate E_r

$$E_r=E_{(M, i)} / \log 2\,(M_i) \quad (7)$$

Where i=1, 2 ….N, given the subcarrier SNR values using equation (6)

(iii) Set E_{Th} as threshold probability of Error and C_T bein their respective Constellation size.

(iv) Determine $\bar{E}_r$,the mean probability of error ,whose constellation size is $\bar{C}$.

(v) Compare $\bar{E}_r$ with E_{Th}. If $\bar{E}_r$ is less than E_{Th}, then current configuration is kept and algorithm ends.

(vi) Select the subcarrier with worst E_r and reduce the constellation size to 16-QAM and null the subcarrier.

(vii) Repeat the same procedure to compute E_i for all the subcarriers with changed allocation and return to step (v)

(viii) a) Determine the convergence point E_c, the SNR intersection with interference cancellation frequency.

b) Calculate the convergence by evaluating upper and lower boundaries of noise level , BER is calculated as

$$E^* = Q\,(SNR/N_0) \qquad (8)$$

c) Let i=1. Initialize path set to contain only one path $E_m\{(1)\}$ and corresponding metric set $\gamma_m = \{i_{infinite}\}$.

d) i =i+1. For each state 'n' extend E'_m-1 ending in state n' along the defined transition n'→n, producing the new path E_m in $E_{m,n}$ and update the metric in $E_{m,n}$ using $\vartheta_m = i_{inf}(\vartheta')$.

e) Remove all the paths with complexity greater than or equal to that of current optimal path.

f) Define a set of metrics for paths that have reached the target BER, the convergence point for receiver iterations.

g) D $(\bar{S}, S_T)$ denotes the Euclidean distance between the signal constellation $\bar{C}$ and C_T.

Bit Error Rate can be expressed in closed form as

$$P_i . E_{EA} = \lim_{N_{EA}\to\infty} P_b^{QAM} = Q(\sqrt{E}) = Q\left(\sqrt{2\,E_b/N_0}\right) \qquad (9)$$

which is the exact expression for BER in AWGN channel. Evaluation of BER, when coherent detection is applied in fading conditions requires the computation of an average over the fading distribution.

IV. Results And Discussion

In this section, we compare the proposed scheme with conventional Multiuser Scheduling and Parallel Scheduling to evaluate the number of iterations needed to obtain required minimum BER of the system. We exhaustively search all possible sub channel assignments as well as dynamic threshold determination. The simulation results focus on increasing number of scheduled users and minimize BER performance of the system.

Figure 1 and 2 compares the low complexity adaptive equalization and dynamic scheduling with Multiuser scheduling and parallel scheduling approaches. The number of iterations varying from 1 to 6 signifies variation of number of subcarriers from 64 to 2048.Since we need to exhaustively search all possible subchannel assignments as well as the corresponding BER of the system , the complexity grows exponentially. Results for minimum subcarriers 64 and maximum subcarriers 2048 is shown in figure 1 and 2.

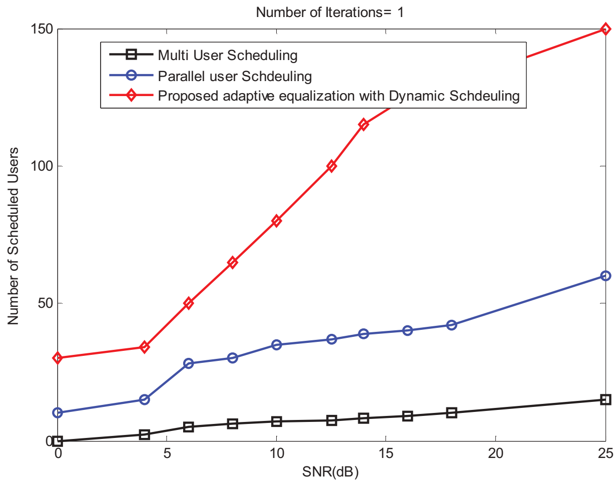

Figure 1. Performance of MC CDMA Transceiver with dynamic threshold determination with 64 Subcarriers

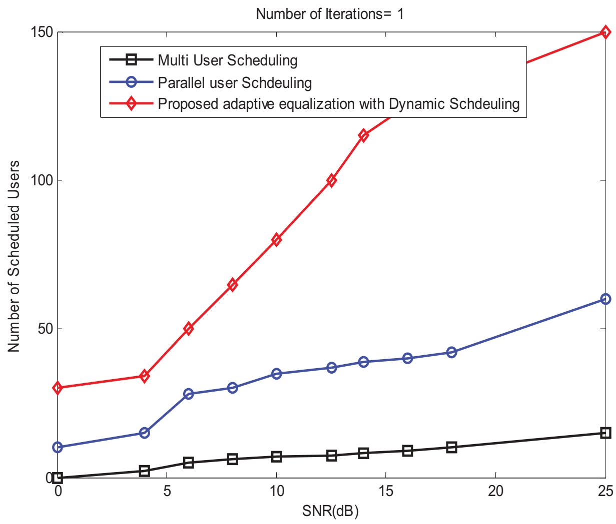

Figure 2. Performance of MC CDMA Transceiver with dynamic threshold determination with 2048 Subcarriers

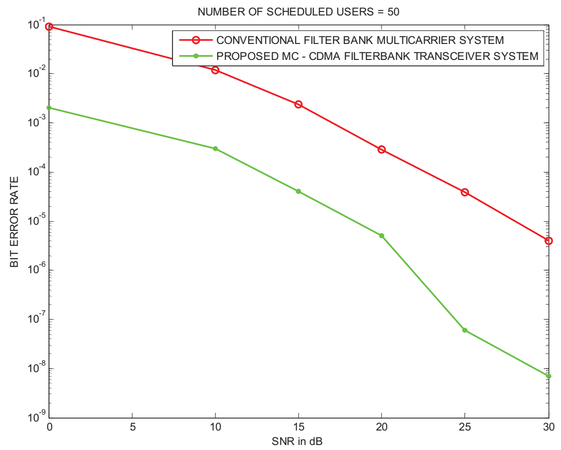

Figure 3. BER Performance of the MC CDMA system with Adaptive Equalization and Dynamic Threshold determination for 50 users

Figure 3 shows the comparison of the BER performance versus SNR of MC CDMA transceiver system employing adaptive equalization with dynamic threshold determination. The conventional system does not guarantee required BER when the number of users is increased.

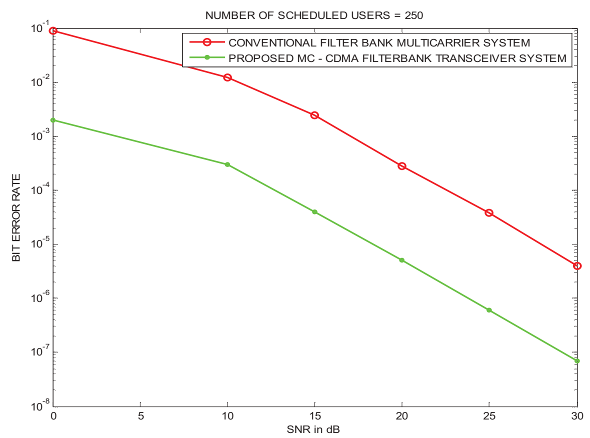

Figure 4. BER Performance of the MC CDMA system with Adaptive Equalization and Dynamic Threshold determination for 50 users

The figure 4 illustrates the operation of algorithm when the users are increased to 250. However, the proposed system requires less number of iterations to converge to minimum BER when compared with conventional techniques. For a low SNR of 10 dB, the proposed system yields a BER of 10^{-4} compared to the conventional techniques which provide a BER of 10^{-2}. When the SNR is increased to 30 dB, the proposed system yields a BER of 10^{-7} compared to the conventional techniques which provide a BER of 10^{-5}.

V. Conclusions

In this method, the dynamic determination of threshold was carried out including the fading scenario. The effective decoding procedure mitigates Inter User Interference (IUI) as well as Multiple Access Interference (MAI). This is evident from the fact that the number of scheduled users increase there by increasing the overall spectral efficiency of the MC CDMA system applying adaptive equalization. The Dynamic Decoding scheduling procedure increases the average throughput and minimizes BER to required level.

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