Performance Analysis of Dynamic Sub-Carrier Allocation Technique for Adaptive Modulation based MC-CDMA System

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Summary

Multi carrier CDMA (MC-CDMA) combines the CDMA and OFDM technologies together and potentially offers the advantages of both the technologies. In frequency selective channel, the sub-carrier experiences different amplitude and phase. In frequency domain spreading, the frequency diversity is employed but the best of different sub-carrier conditions are not fully exploited. In MC-CDMA the performance of the system is improved by adaptively loading sub-carriers in accordance with the varying channel conditions. This paper is focused on selecting the best sub-carrier and transmitting the data through that sub carrier by adaptive bit loading algorithm.. Using a fixed modulation technique for the system, the system would have to be built for such a standard which would take care of the worst-case scenario of the channel to offer an acceptable bit error rate (BER). To achieve robust and spectrally efficient communication overmultipath fading channels, adaptive modulation is used which adapts the transmission scheme to the current channel characteristics. Taking advantage of the time-varying nature of wireless channels, the adaptive modulation scheme varies the transmission power, data rate (constellation size), coding and modulation schemes, or any combination of these parameters according to the state of the channel . If the channel can be estimated then the transmitter can adapt to the current conditions by varying the modulation type while maintaining a constant BER. This is typically done by making a channel estimate at the receiver and transmitting this estimate back to the transmitter. Thus, the adaptive technique will have a higher data throughput when the channel conditions are favorable and will reduce the throughput as the channel worsens. In other words, the principle of adaptive modulation consists of allocating many bits to carriers with a high SNR, whereas on carriers with low SNR only a few or no bits at all are transmitted.In this paper water filling algorithm is used to select the best sub-carrier,over the existing subcarriers. The adaptive control technologies, also known as the Intelligent Radio Transmission Technologies, for wireless communication include adaptive equalizer; transmit power control and adaptive modulation.

Key Words:

MC-CDMA ISI, adaptive modulation, ,sub-carrier.

1. Introduction

The most important objective of 4G wireless systems are to take care of the severe inter symbol interference (ISI) resulting from the high data rates, and to utilize the available limited bandwidth in a spectrally efficient manner.Recently, multicarrier code division multiple access systems (MC-CDMA) have been considered as the potential candidate for 4G wireless communications, to handle ISI most effectively. MC-CDMA systems can be of practical interests, the direct sequence (DS) spreading is employed together with multicarrier modulation to derive the benefits of both the techniques.

In a multicarrier transmission system, the available channel bandwidth is divided into multiple subchannels such that data symbols modulated by different subcarriers can be transmitted in parallel. In order to make the most of the available bandwidth, spectra of the adjacent subchannels are allowed to overlap without inter-channel interference (ICI) in such a manner that all information-bearing waveforms of the sub-channels are orthogonal on some time interval. For high bit rate transmission (around 30 Mbit/s) over non-ideal propagation channels, OFDM parallel transmission offers many advantages over conventional single carrier systems, such as robustness against multipath frequency selective fading [1].

Coded OFDM-CDMA with adaptive modulation is under investigation as attractive techniques for 4G mobile systems, in which the received signal is usually corrupted by multipath effects. Steele and Webb proposed burst-by-burst adaptive Quadrature Amplitude Modulation (AQAM) for exploiting the time variant Shannon channel capacity of narrowband fading channels. Fixed rate burst-by-burst adaptive systems, which sacrifice a guaranteed bit error rate (BER) performance for the sake of maintaining a fixed data throughput, are more amenable to employment in the context of low-delay interactive speech and video communications systems. The above burst-by-burst adaptive principles can also be extended to adaptive orthogonal frequency division multiplexing (AOFDM) schemes. Keller and Hanzo] have proposed adaptive modulation techniques with a set of QPSK and QAM modulation schemes for OFDM for duplex transmission while Wasantha investigated an adaptive COFDM-CDMA system with QAM, PSK and MHPM modulation schemes. Furthermore various techniques for signaling, channel estimation, adaptation algorithms and channel coding have been presented. The total number of subcarriers has been divided into sub bands and adaptive modulation is applied to each sub band rather than subcarriers for easy implementation and to facilitate

Manuscript received February 5, 2007
Manuscript revised February 25, 2007

simple detection methods. A brief description of important system parameters of adaptive system are presented Channel Quality Estimation:In order to appropriately select the transmission parameters to be employed for the next transmission, a reliable prediction of the channel quality during the next active transmit timeslot is necessary.
Choice of the appropriate parameters for the next transmission :Based on the prediction of the expected channel conditions during the next timeslot, the transmitter has to select the appropriate modulation schemes for the subcarriers[2]. Signaling or blind detection of the employed parameters:The receiver has to be informed, as to which set of demodulator parameters to employ for the received packet. This information can either be conveyed within the packet, at the cost of loss of useful data bandwidth, or the receiver can attempt to estimate the parameters employed at the transmitter by means of blind detection mechanisms.

2. System Model

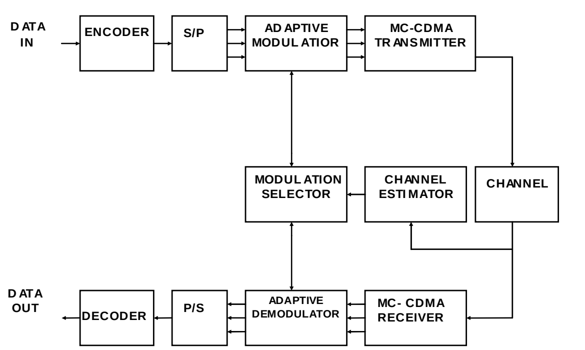

Figure 1:Proposed system model for Adaptive modulation based MC-CDMA system

The block diagram of the adaptive modulation based MC-CDMA system is shown in figure 1. Binary data is first encoded using Turbo coding, followed by serial-to-parallel conversion to produce low bit-rate streams. Each stream is then modulated using a suitable digital modulation method, such as, BPSK, QPSK, 8 PSK, 16 QAM etc, depending on the channel estimate information provided by the receiver. The adaptively modulated streams are then passed through the MCCDMA transmitter block, up-converted by an RF amplifier and transmitted. The receiver performs the reverse operation to demodulate and decode the original information. The channel estimator estimates the quality of the channel (Carrier-to-Noise Ratio, CNR) from the pilot symbols, which are known QPSK symbols and inform the transmitter. Based on this channel quality estimate, the transmitter decides the modulation format to be used for the next transmission. Moreover, it has been assumed that the receiver is aware of the modulation scheme in use.

The insertion of guard time is an effective means of eliminating the Inter Symbol Interference in a dispersive fading channel. However, the time variations of the channel also disrupt the orthogonality between the subcarriers and results in Inter Carrier Interference. The extent to which the channel can vary within an OFDM block period decreases with increasing symbol rate. Hence for some high
data rate applications the literature often assumes that the channel doesn't change significantly within the OFDM block period. The effect of ICI is very prominent for mobile reception in vehicles such as trains or buses. If not compensated, ICI would result in an error floor. If the channel impulse response can be estimated by using some pilot tones it is possible to reduce the ICI through proper equalization. In some pilot tone assisted estimation and equalization is performed to compensate for the ICI[4]. Earlier theoretical expressions are derived for ICI variance by modeling the ICI as additive Gaussian random processes. This approximation is due to the Central limit theorem and is valid when the number of carriers is large. The ICI variance is given as

$$E\left[\left|c_l\right|^2\right]=E_s-\frac{E_s}{N^2}\left\{N+2\sum_{l=1}^{N-1}(N-i)J_0(2\pi f_D T_s i)\right\}$$

where c_l is the ICI, E_s is the Energy per symbol, N is the number of subcarriers, f_D is the Doppler frequency, T_s is the symbol duration and J_0 is the zero-order Bessel function of the first kind. It is interesting to note that the ICI variance is independent of the signal constellation.

First, the transmitter uses each user's orthogonal spreading sequence to spread the modulated data symbol into chips where different users are assigned to one or more different spreading codes. Then, the chips from different users are summed together before interleaved and mapped into the sub-carriers. Spreading is only performed in the frequency-domain, and the user symbols are sent over all sub-carriers. At the output of each channel between the transmitter and each mobile terminal, the MC-CDMA receiver observes the noise corrupted OFDM symbol affected by the frequency-selective characteristics of the multi-path channel. Each receiver then equalizes its sub-carriers and using its assigned spreading code de-spreads the noise-corrupted chips into an estimate of the modulated data symbol.
Now, consider a single user case and let the user's modulated data symbol be X_1. After spreading with a Walsh code W_{1i} of length L where $W_{1i} \in \{\pm 1\}$ for i =1,..., L, it becomes a sequence $X_1 W_{1i}$ for i =1,..., L, where the ith element (i.e., chips) of the spread data symbol is transmitted by the ith

sub-carrier. After the front-end OFDM demodulation, the *i*th received frequency-domain data symbol is,

$$Y_i = X_i W_{1i} H_i + \eta_i \quad (1)$$

where H_i is the sub-carrier's sampled frequency response and η_i is the AWGN component for the *i*th sub-carrier.

After a zero-forcing equalizer the received sub-carrier symbol becomes,

$$\frac{Y_i}{H_i} = X_1 + \frac{\eta_i}{H_i} \quad (2)$$

Then, through de-spreading with the user's spreading sequence, we may obtain an estimate $\hat{X}_1$ of the original data symbol X_1,

$$\hat{X}_1 = \frac{1}{L}\sum_{i=1}^{L} X_1 W_{1i} W_{1i} + \frac{1}{L}\sum_{i=1}^{L}\frac{\eta_i}{H_i}W_{1i}$$

$$= X_1 + \frac{1}{L}\sum_{i=1}^{L}\frac{\eta_i}{H_i}W_{1i} \quad (3)$$

since $W_{1i}W_{1i} = 1,\ i = 1,.....,L.$

Due to multi-path, the frequency function H_i is non uniform across the *L* sub carriers, and the de-spreading operation is seen to average the noise across the sub-carriers. Similar analysis may be extended to the general *m* user's case. Each of the *m* user's data symbols may be recovered by despreading with their spreading sequence that is pair wise orthogonal with all other spreading sequences used in the system[6].

We consider a proposed MC-CDMA system with K users. Differently from conventional MC-CDMA system, in the proposed scheme, a best conditioned sub-carrier is first chosen for each user, and a narrowband direct sequence waveform is transmitted through the chosen sub-carrier instead of all the sub carriers. Then the transmitted signal is given by [7]

$$s(t) = \sqrt{2ME_c}\sum_{k=1}^{K}\sum_{l=-\infty}^{\infty} d_l^{(k)} c^{(k)}(t - lT) \cdot \cos\omega_{j_k} t \quad (4)$$

where

$$c^{(k)}(t) = \sum_{n=0}^{N-!} c_n^k\, p(t - nT_c) \quad (5)$$

In (4), $d_h^{(k)}$ is the binary symbol bit of the k th user, c_n^k is the signature sequence of the k th user, $T = NMT_c$ is the symbol duration with MT_c the chip duration for MC system,

and E_c is the energy per chip. M is the number of sub- carriers, j_k indicates the best transmission sub-carrier, and $p(t - nT_c)$ is a rectangular pulse with duration MT_c.

We assume the channel is frequency selective Rayleigh fading, but the sub-carriers are frequency nonselective and independent of each other: this can be achieved by selecting M properly. Then the complex low pass impulse response of the sub-carriers can be modeled as,

$$h_{k,m}(t) = \alpha_{k,m} e^{j\phi_{k,m}} \delta(t) \quad (6)$$

where $\alpha_{k,m}$ is the fading amplitude, $\phi_{k,m}$ is the random phase of the sub-carrier. The amplitude $\{\alpha_{k,m}, m = 1,2,....M\}$ are independent and identically distributed (i.i.d.) Rayleigh fading random variables and $\{\phi_{k,m}, m = 1,2,....M\}$ are uniform i.i.d. random variables over [0,2π).

The received signal at the k th mobile is given by

$$r(t) = \sqrt{2ME_c}\sum_{k=1}^{K}\sum_{l=-\infty}^{\infty} d_l^{(k)} c^{(k)}(t - lT) \cdot \alpha_{k,j_k}\cos(\omega_{j_k} t + \phi_{k,j_k}) + n_W(t) + n_J(t) \quad (7)$$

where $n_W(t)$ is the additive white Gaussian noise with a double side spectral density of $N_0/2$, and $n_J(t)$ is partial band interference with spectral density of $S_{n_J}(f)$ [5].The pdf of the partial band interference, $S_{n_J}(f)$ is defined as

$$S_{n_J}(f) = \begin{cases} \frac{N_J}{2}, & f_J - \frac{W_J}{2} \le |f| \le f_J + \frac{W_J}{2} \\ 0, & elsewhere \end{cases} \quad (8)$$

3.Simulation Result and discussion

In this section, the figure 2 shows the performance of a BPSK modulated MC-CDMA system for different number of users (K=2,4,8 and 16). It is found that, as the number users increases the BER performance degrades. When the number of users, K=2,4,8 and 16, for fixed SNR of 12 dB, the BER is 10^{-5}, 10^{-4}, and 10^{-3} respectively.

Also in this section, the performance of the proposed scheme is investigated along with that of conventional MRC MC-CDMA system. In this following simulation, the total available bandwidth is the same for both the systems and set NM=512. Then the processing gain for each sub carrier signal is N=256 and 128 when the number of sub carriers is M=2 and 4, respectively. The number of users is, K=50.The BER performance for different number of sub carriers and different narrowband interference power to signal power ratio (JSR) is considered.
From the figure 3, we can visualize that the proposed system outperforms the conventional MRC MC-CDMA and direct sequence systems. This is achieved by eliminating the bad-conditioned sub carrier and allocating the signal energy to good-conditioned sub carrier. It is also observed that, with the number of the best conditioned sub carriers increasing, the SNR gain of the proposed system over the conventional MC CDMA system increases.

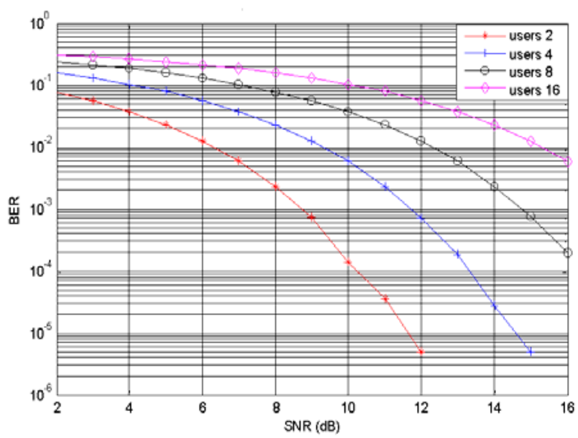

Figure 2: BER of BPSK based MC-CDMA system.

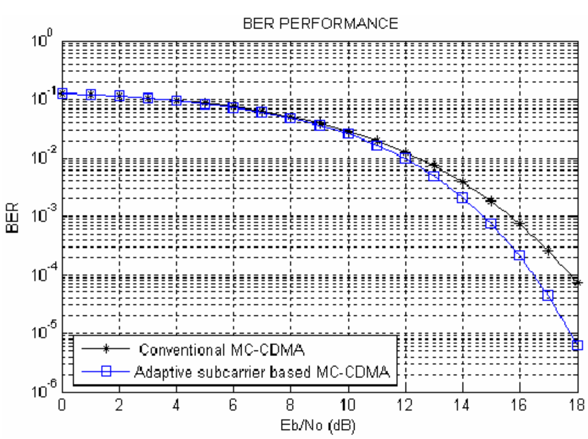

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Figure 3. BER performance of proposed MC-CDMA scheme.

5. Conclusion

In this paper, we presented an improved MC-CDMA system with dynamic sub carrier allocation in which each user's waveform is transmitted over all the sub carriers. Adaptive subcarrier system improves the BER and throughput performances of the traditional MC-CDMA systems. It has been found that the majority of bit errors occur on severely degraded subcarriers, and this tends to dictate the overall BER performance. As a result, eliminating transmission on poor subcarrier or using robust modulation, can considerably improve the BER performance of the system. At the same time, higher order modulation can be utilized on favourable subcarriers to maximize the throughput

We analyzed the performance characteristics of the proposed system in frequency selective fading environment with narrowband interference existing. The result shows that the proposed adaptive MC-CDMA system outperforms the conventional MRC MC-CDMA system. The work can be extended for performance improvement in Ultra wide band MC-CDMA ,to improve the overall system performance.

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