An Efficient Utility & Sum Rate Optimization in MC-CDMA Communication System

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Abstract: ***This paper is mainly concerned with the problem of utility and sum rate optimization in an OFDM network. So first we design the uplink and downlink multicarrier wireless network. The utility is related to the level of satisfaction of the MUs with respect to the communication link, and it could be associated to the efficiency in the data transmission with respect to the required power. Capacity is related to the maximum achievable data rates in the network. The data estimation at the mobile unit (MUs) is carried out by a simple matched filter.***

Keywords: MC-CDMA, utility, capacity, quality of services, sum-rate maximization

1. Introduction

The next generation of broad-band wireless communication requires high data rates and quality of services (QoS), which is achieved by the combination of multicarrier modulation, based on orthogonal frequency division multiplexing (OFDM) and code division multiple access. But the system suffers from multiple access interference and channel distortion.

In order to reduce channel distortion and multiple access interference equalization is used at the receiver side. The equalization used at the transmitter side called pre equalization and at the receiver side called post equalization. Here we are using a zero force equalizer at the receiver side and MMSE estimation is also done.

The MCM modulation protects the signal before transmission using cyclic prefix in time domain and pilot signal in frequency domain. The cyclic prefix avoids the interference of one OFDM from another OFDM i.e., inter symbol interference. The wireless channel is responsible for main interference and noise of telecommunication system. The noise is mitigated increase of signal to noise ratio coding or choosing the robust modulation. However the multipath distortion transforms a channel plane in a frequency selective channel with higher inter symbol interference.

The growth of Internet data and multimedia applications requires high-speed transmission and efficient resource management. To avoid intersymbol interference (ISI), orthogonal frequency division multiplexing (OFDM) is desirable for high-speed wireless communications. OFDM-based systems are traditionally used for equalization and combating frequency-selective fading. From a resource allocation point of view, however, an OFDM system naturally has a potential for more efficient median access control (MAC) since subcarriers can be assigned to different user. Another advantage of OFDM is that adaptive power allocation can be applied for a further performance improvement.

Representing the level of customer satisfaction received for the system, utility functions play a key role in resource management and QoS differentiation. Different applications have different utility function curves or even different parameters. For instance, the utility functions of best-effort applications are with respect to throughput, whereas those of delay-sensitive applications are with respect to delay. There are usually two approaches to obtaining utility functions. For a specific type of application, the utility function may be obtained by sophisticated subjective surveys. Another method is to design utility functions based on the habits of the traffic and appropriate fairness in the network. Therefore, a utility function for an application characterizes its corresponding QoS requirements.

2. Related Woks

Similar to other spread spectrum techniques MC-CDMA also suffers from multiple access interference which degrades the performance [1]. At the transmitter side, efficient interference mitigation techniques can be accomplished in MC-CDMA systems through the use of transmission power adaption or through pre equalization strategies with power constraints. In modern wireless mobile and fixed communication systems such as broadband WLANs, 4G cellular networks. Pre-equalization improves the performance of a wireless link without any complexity increase at the receiver. Most of the previous techniques involve post equalization which increase the complexity.

MC-CDMA is a promising technique for air interface of several emerging wireless communication systems such as cooperative and cognitive radio networks [2]. CSS approaches are investigates under the typical assumption of AWGN channel. A cognitive radio technology has been proposed to improve spectrum efficiency by having the cognitive radios act as secondary users to opportunistically access under-utilized frequency bands. Spectrum sensing, as a key enabling functionality in cognitive radio networks, needs to reliably detect signals from licensed primary radios to avoid harmful interference. However, due to the effects of channel fading/shadowing, individual cognitive radios may not be able to reliably detect the existence of a primary radio. In this paper, we propose an optimal linear cooperation framework for spectrum sensing in order to accurately detect the weak primary signal. Within this framework, spectrum sensing is based on the linear combination of local statistics from individual cognitive radios.

In the case of MC-CDMA system, utility and sum rate criterion are the two important factors related to the network performance. In the utility maximization was also addressed but for MC-DS-CDMA networks, which impose a completely different transmission setup, as compared with MC-CDMA. The utility is related to the level of satisfaction of the MUs with respect to the communication link, and it could be associated to the efficiency in the data transmission with respect to the required power. Meanwhile capacity is related to the maximum achievable data rates in the network. On other hand, the problem of capacity maximization in MC-CDMA system was also addressed in, by a joint design of transmitting waveforms and power allocation for a MISO configuration. The capacity was considered for a MIMO communication system under a pre coding structure with linear zero forcing property along with an heuristic search method. The proposed solution derived for the sum rate maximization shares the same structure of utility maximization, but the optimal SINR is different for each MU and depends on a transmission power bound. Consequently, this solution employs its maximum allowable transmission power to maximize its SINR and it improves its transmission capacity.

Applications of the proposed schemes could be associated among others to cellular networks, wireless metropolitan and local area networks, and wireless networks of actuators. Advantages of the system is high data rate, quality of services, low multiple access interference.

3. System Model

In this work, the uplink and downlink transmission of a quasi-synchronous MC-CDMA wireless network is studied. Figure 1 illustrates the uplink for a MC-CDMA system. In satellite communication, an uplink is the portion of a communications link used for the transmission of signals from an Earth terminal to a satellite or to an airborne platform. An uplink is the inverse of a downlink. An uplink or forward link is distinguished from reverse link or forward link. Pertaining to GSM or cellular networks, the radio uplink is the transmission path from the mobile station to base station. Traffic and signalling flows within the BSS and NSS may also be identified as uplink and downlink. Pertaining to computer networks, an uplink is a connection from data communications equipment toward the network core. This is also known as an upstream connection.

The system consists of modulator, IFFT, FFT, demodulator. Here we are using BPSK modulation. BPSK is the simplest form of phase shift keying (PSK). It uses two phases which are separated by 180° and so can also be termed 2-PSK.. This modulation is the most robust of all the PSKs since it takes the highest level of noise or distortion to make the demodulator reach an incorrect decision. FFT and IFFT are both two linear transformations on signals and are the reverse of each other. An inverse FFT is computed on each set of symbols, giving a set of complex time-domain samples. Figure 2 shows the downlink for a MC-CDMA system. The system consists of a base station and a mobile station.

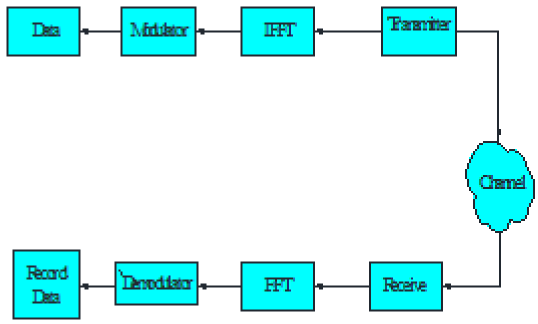

Figure 1: Diagram of the uplink for a MC-CDMA wireless network

The cyclic prefix is used to eliminate the inter symbol interference. Also it is referred as prefixing the symbols with a repetition of the end. At the receiver side, the cyclic prefix is discarded. It is used in OFDM in order to combat multipath by making channel estimation easy. The matched filter is used at the receiver for data estimation at the mobile units. Zero force equalizer is used at the receiver side in order to eliminate the multiple access interference, channel distortion and inter symbol interference. Zero force equalizer is a linear equalizer used in communication system which applies the inverse of the frequency response of the channel. MMSE estimation is also done here. A minimum mean square error (MMSE) estimator is an estimation method which minimizes the mean square error (MSE) of the fitted values of a dependent variable, which is a common measure of estimator quality.

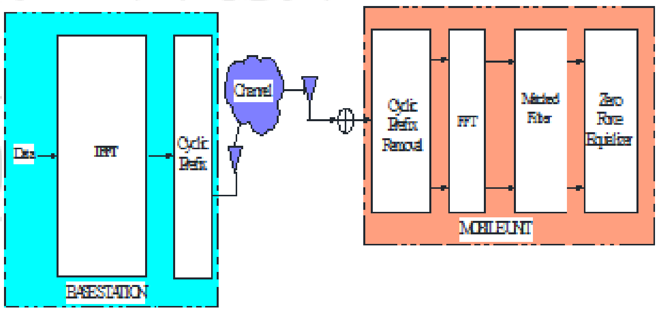

Figure 2: Downlink MC-CDMA wireless network

4. Implementation

A. Utility Maximization:

The utility is related to the level of satisfaction of the MUs with respect to the communication link, and it could be associated to the efficiency in the data transmission with respect to the required power.

$$\mu[k] = \frac{Lrf(\gamma[k])}{M} \frac{1}{\frac{1}{N} \| p[k] \|} \quad (1)$$

Where L is the number of information bits per frame, and M the total number of bits in each frame (M>L); f (Ɣ[k]) is an efficiency function related to the FSR and consequently to the modulation technique. Then we consider the network oriented philosophy, the network utility is given

$$Uj(pi[k],......pu[k]) = \sum_{j=1}^{U} u j[k] = \sum_{j=1}^{U} \omega j \frac{f(\gamma j[k])}{\| pj[k] \|} \quad (2)$$

Motivated by these works, we follow the utility definition for *j*-th user at *k*- instant as the ratio of its throughput Tj[k] to the transmission energy.

B. Sum- Rate Maximization

Here we are discussing a different scheme called capacity. Hence the performance objective is different from the utility maximization problem, the network capacity is improved as much as possible, under power constraint at the transmission.

$$C(pi[k].....pu[k]) = \sum_{j=1}^{U} \log(1+\gamma[k]) \quad (3)$$

In the MC-CDMA system, the maximum value for the network capacity can be directly increased by raising the bound on the transmission power of each MU. Contrary to the utility function, the capacity in (3) is an increasing function of the transmission power for a fixed interference.

5. Simulation Results

First, in fig. 3, the plots for the Bit Error Rate. BER is inversely proportional to the signal to noise ratio. From the fig we can see that when BER increases signal to noise ration decreases.

Figure. 4 shows the network capacity C increases monotonically with the upper bound on the transmission power P*max*. It requires less computational complexity for their implementation in the network.

Figure 5 represents the network utility *U* as a function of number of active users. The utility is directly proportional to the number of active users. As expected, MUS achieves always the largest utility.

Figure 6 represents the capacity C as a function of number of active users. As expected the MCS achieves the largest capacity independently of the number of active users. From the results in fig 3 & 4, for any given number of active users in the network, MUS and MCS strategies guarantee the optimal performance, network utility or capacity.

Figure 7 represents the network utility as a function of the SNR. As a results the plot is accomplished at the predicted SINR value of 10Hz (bits/s).

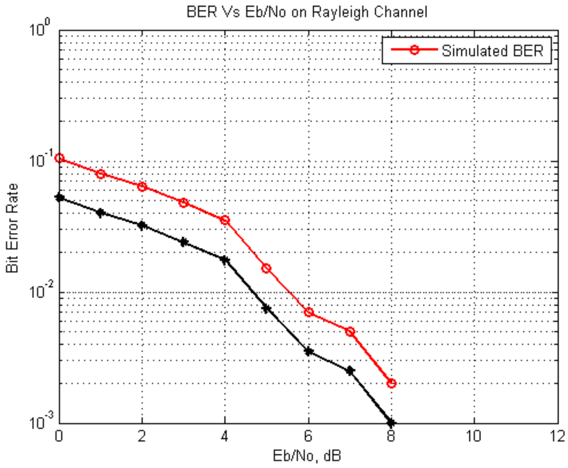

Figure 3: BER Vs SNR in a Rayleigh fading channel

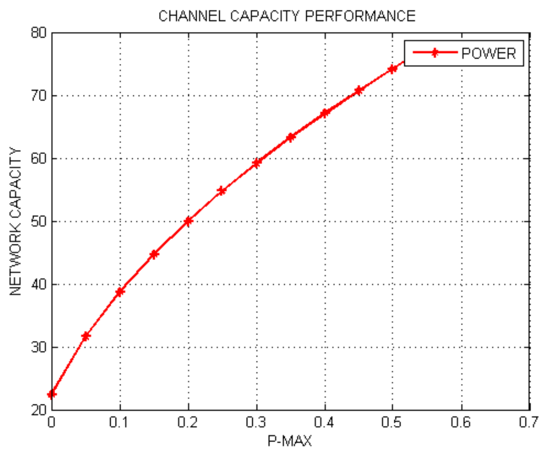

Figure 4: Network capacity Vs Pmax

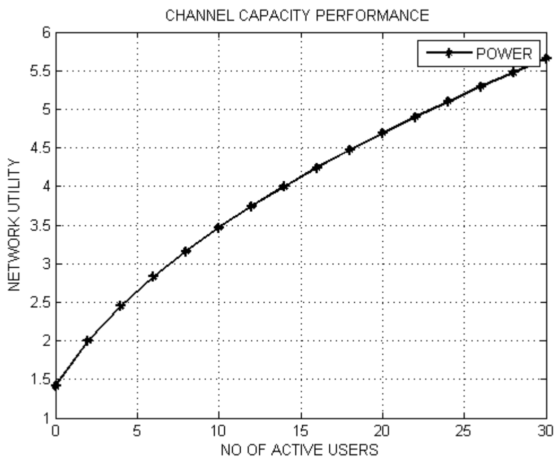

Figure 5: Network Utility Vs Number of active users

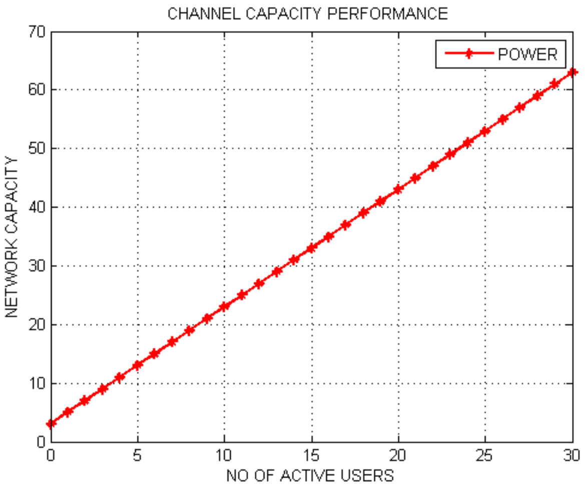

Fig 6. Channel capacity performance

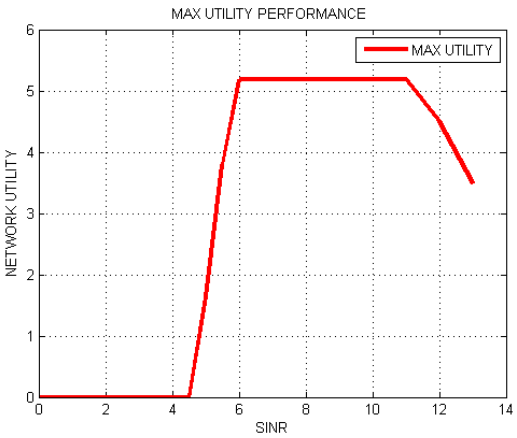

Figure 7: Maximum utility performance.

6. Conclusion

This paper addressed with the problem of utility and sum rate optimization in an OFDM network. The uplink and downlink of a MC-CDMA system is studied. A zero force equalizer is used in order to reduce the multiple access interference. The matched filter is used for the data estimation. The construction of the optimal solution requires in each case a two step procedure. First, the optimal SNR is computed for the maximum utility and sum- rate solutions based on the efficiency mapping and on the bound of transmission power. In addition this solution employs its maximum allowable transmission power to maximize its SINR and as a consequence to improve the capacity.

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