Improved Genetic Algorithm for The Robust Optimization of WCDMA System

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Abstract

It is proposed to investigate/develop a CDMA signal detection technique for 3G (W-CDMA)/4G Networks when the channel are transmitting multi user data in deep fading environment. This fading environment arises as a result of multipath propagation of a signal existing due to reflection; scattering or services offered by future generation networks like 3G Networks and beyond commonly known as 4G networks. The services include voice, data, video, IP Telephony, ultra broad band internet access, streamed multimedia. The propagation of signal can be Non-Line-of-Sight and Line-of-Sight signal in order to achieve these services. We have proposed a GA based approach that improves the channel capacity and hence improves the overall performance. The work is implemented using MATLAB software.

Keywords

WCDMA Capacity, PN codes, Interference, Voice Activity, Interference Channel capacity

I. Introduction

Wireless communication [1] is one of the most vibrant research areas in the communication field today. While it has been a topic of study since the 60's, the past decade has seen a surge of research activities in the area. This is due to a con sequence of several factors. First is the explosive increase in demand for tether less connectivity, driven so far mainly by cellular telephony but is expected to be soon eclipsed by wireless data applications. Second, the dramatic progress in VLSI technology has enabled small-area and low-power implementation of sophisticated signal processing algorithms and coding techniques. Third, the success of second-generation

(2G)[2] digital wireless standard, in particular the IS-95 Code Division Multiple Access (CDMA) standard, provides a concrete demonstration that good ideas from communication theory can have a significant impact in practice. The research thrust in the past decade has led to a much richer set of perspectives and tools on how to communicate over wireless channels, and the picture is still very much evolving. There are two fundamental aspects of wireless communication that make the problem challenging and interesting. These aspects are by and large not as significant in wire line communication. First is the phenomenon of fading: the time-variation of the channel strengths due to the small-scale effect of multipath fading, as well as larger scale effects such as path loss via distance attenuation and shadowing by obstacles. Second, unlike in the wired world where each transmitter-receiver pair can often be thought of as an isolated point-to-point link, wireless users communicate over the air and there is significant interference between them in wireless communication. The interference can be between transmitters communicating with a common receiver (e.g. uplink of a cellular system), between signals from a single transmitter to multiple receivers (e.g. downlink of a cellular system), or between different transmitter-receiver pairs (e.g. interference between users in different cells).

II. WCDMA Capacity Model

The capacity of WCDMA system is an important parameter in Universal Mobile Telecommunication System Networks. The capacity of WCDMA system is basically determined by signal to noise ratio or mostly said E_b/N_o (Bit energy to effective noise power spectral density) and by the processing gain of the system. The processing gain is defined as the ratio of the spreading bandwidth of the system to the data bit rate for the selected application i.e. voice, data & multimedia etc. The interference is already included in noise power spectral density and can be self interference, co-channel interference and multi-access interference.

Now in order to derive the expression for capacity i.e. the number of user in a cell in WCDMA system, it is assumed that there are K number of users accessing the network at same frequency simultaneously and each user has its own PN code sequence. Now if P_S is the signal power, W is the bandwidth of spreading (PN) code sequence, R_b is the data bit rate; E_b is the energy per bit, N_o is noise power spectral density, then energy per bit can be written as

$$E_b = \frac{P_s}{R_b}$$

and

$$\frac{E_b}{N_o} = \frac{P_s}{R_b \cdot N_o} \quad (1)$$

N_o is noise power spectral density and can be defined as interference power per unit spreading bandwidth. It is given as

$$N_o = \frac{P_I}{W} \quad (2)$$

From (1) and (2), we get

$$\frac{E_b}{N_o} = \frac{P_s}{P_I} \cdot \frac{W}{R_b} = \frac{P_s}{P_I} P_G \quad (3)$$

Where P_G is the processing gain? Now if signal power of all users is same and spreading sequence of all users has same rate then the equation for capacity in terms of number of users is given as below [3]

$$\frac{P_I}{P_s} = (K-1) \quad (4)$$

From (3) and (4), we get

$$(K-1) = \frac{P_G}{E_b/N_o} \text{ and}$$

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$$K = 1 + \frac{P_G}{E_b/N_o} \quad (5)$$

The equation (5) is the basic capacity equation which determines the number of users in a WCDMA cell. This equation completely depends upon the processing gain and E_b/N_o ratio. The capacity of a WCDMA system can be increased or decreased by adjusting the value of processing gain P_G and E_b/N_o. Beside these adjustments, there are some other factors that also affect the capacity of WCDMA network and accordingly the basic capacity equation is modified.

III. Factor Affecting WCDMA System Capacity

There are many factors that increase or decrease the capacity of WCDMA systems. Some of them are loading of cell, interference factor, voice activity factor, configuration of antenna, type of coding scheme used, Interference cancellation techniques etc. Some of above mention factors that affect the capacity of WCDMA system is discussed as below.

A. Loading of cell

In cellular system, a single cell is surrounded by many cells and due to handoff's strategies, a particular cell is said to be loaded by users from other cell using the particular cell and producing loading effect. This loading effect decreases the performance of a particular cell or we can say that capacity of cell decreases and this effect is measured by loading factor. The loading factor is given as [4]

$$L.F. = \frac{K'}{1+\frac{P_G}{E_b/N_o}} \quad (6)$$

Where K' is the number of users in a particular cell after loading from other cell? Generally, the loading factor is the percentage of capacity K as referred in eqn. (5) and from this capacity K, a practical cell capacity K' after loading in a WCDMA cell can be calculated as

$$K' = K \times L.F.(\%) \quad (7)$$

From eqn. (7), it is clear that as the loading factor increases in percentage, the number of active users in a particular cell decrease. Mathematically, the effect of loading on the capacity of WCDMA system is also given as [5]

$$K = 1 + \frac{P_G}{E_b/N_o}\left(\frac{1}{1+L.F.}\right) \quad (8)$$

B. Interference

Interference is an important factor that limits the capacity of WCDMA systems. The interference in a WCDMA cell can be from the same cell, from the neighboring cell i.e. during handoffs and can be due to thermal noise of the cell. In order to calculate the capacity of WCDMA systems in the presence of these interferences i.e. own cell interference I_{own}, other cell interference I_{other} and thermal noise or background noise of the cell I_o, it is necessary to first calculate the noise rise. The noise rise (NR) is defined as the ratio of total wideband power to the thermal noise power (P_o) received at base station during uplink [4] [6]. The noise rise (NR) is given as

$$NR = \frac{P_{total}}{P_o} = \frac{P_o + P_{other} + P_{own}}{P_o} \quad (9)$$

On introducing the other-to-own cell interference ratio/factor ***i*** in eqn. (9), the NR can be written as

$$NR = \frac{P_{total}}{P_o} = \frac{P_o + P_{own}.(1+i)}{P_o} \quad (10)$$

The relation between noise rise (NR) and uplink loading μ_{UL} is given as [4]:

$$\mu_{UL} = \frac{1}{1-NR} \quad (11)$$

The uplink loading means number of users accessing the WCDMA cell base station and the users may be from the same cell or from the surrounding cells. In eqn. (6), cell loading is given in terms loading factor and as uplink loading is related to noise rise which in turn is related to total interference as given in eqn. (10) and (11); the capacity in terms of number of users with uplink loading is given as [4].

$$K = \mu_{UL}\left(1 + \frac{P_G}{E_b/N_o}\right) \quad (12)$$

C. Voice Activity Factor

It is also called service activity factor. Service activity means continuous use of some service in a cell. Monitoring of voice/data activity in a cell is an important technique to reduce interference or to increase the capacity as each transmitter is switched-off during the period of no activity and these periods can be used for other data flow without losing the Quality of Service (QoS).

In CDMA systems, reducing multiple accesses interference from neighboring cells results in a capacity gain. In order to remove multi-access-interference, CDMA system uses speech coding technique in which rate of speech coder is reduced by voice activity detection along with variable data rate transmission. Voice activity factor depends upon the type of vocoder used, channel coding and the actual application. By the use of convolution codes for different type of services like voice/ video, system capacity can be increased by 1.5 times to that of without coding and about 1.2 times to that of block code without disturbing the QoS [7]. The value of Voice activity factor varies according to type of service involved i.e. voice, video or multimedia. The activity factor is set to 0.6 for voice application and 1.0 for video or data application [8]. The relation between activity factor v and cell capacity K is given as [5]

$$K = \left(1 + \frac{P_G}{E_b/N_o}\right) \cdot \frac{1}{v} \quad (13)$$

IV. Interference Cancellation

In a conventional matched filter receiver, the Signal to Noise ratio of m^{th} user at the i^{th} antenna can be written as

$$SNR(\gamma)_{m,i} = \frac{P_{m,i}}{P_{total,i} - P_{m,i}} \quad (14)$$

Where $P_{m,i}$ is the received power from user m at i^{th} antenna and $P_{total,i}$ is the total received power at i^{th} antenna which includes thermal noise power(P_o), other-cell interference power ($P_{other,i}$) and the own-cell interference power ($P_{own,i}$) at the i^{th} antenna.

In a WCDMA system, IC receiver performs well only to reduce own-cell interference [6]. The interference cancellation efficiency β of a receiver is defined as the ratio of own-cell interference removed after the use of IC receiver to the own-cell interference present before the use of IC receiver. It means that with the help of IC receiver, we can remove a fraction β of total interference. Generally, β indicates the quality of signal reconstruction and has value $0<\beta<1$. $\beta=1$ represents perfect cancellation and a small positive β represent a signal that is not fully reconstructed and there is residual interference after cancellation. $\beta=0$ represents no interference cancellation and a negative value of β represents that we have falsely reconstructed signal, and instead of removing interference, we have added more interference to the waveform. The signal to noise ratio of user m at the i[th] antenna with IC receiver is given as [9]

$$\gamma_{m,i} = \frac{P_{m,i}}{(P_{own,i}-P_{m,i})\cdot(1-\beta)+P_{other,i}+P_o} \quad (15)$$

Also,

$$P_{total,i} = P_{own,i} + P_{other,i} + P_o$$

If, we put $\beta=0$ in eqn. (15), then this reduces to eqn. (14). It means that if there is no interference canceller at the receiver then the interference/noise level will increase which result into decrease in target signal to noise ratio at the output. In order to maintain the target signal to noise ratio it is necessary to have an IC receiver with sufficient value of β. IC receiver with $\beta=40\%$ can be implemented at the base station with acceptable level of complexity [10], but $\beta=70\%$ is hardly feasible for practical implementation.

V. Simulation And Results

The main objective of this simulation is to analyze the effect of different parameters on the capacity of WCDMA system when the user is accessing different data rate services. Matlab simulation is used to present the effect of different data rate services, effect of loading, interference and the effect of antenna diversity with IC receiver on the capacity of 3G based WCDMA system. For this, chip rate is taken 3.84 Mcps and data rate 12.2 kbps for voice, 64 kbps for video telephony or video streaming, 144 kbps, 384kbps and 768kbps for multimedia services that includes File Transfer Protocol (FTP), World Wide Web (WWW) etc.

In simulation, each user will use the same data rate application at a time and spreading sequence of all users will have same rate i.e. same chip rate. Capacity performance analysis is mentioned at target bit energy to noise power spectral density (E_b/N_o) of 5db and it is found that the capacity performance decreases with increase in E_b/N_o beyond 5db.

The processing gain will be different for different data rate services and varies inversely with increase in data rate for a constant chip rate condition. The value of processing gain for voice service i.e. at 12.2 kbps is taken as 314, for video service at 64kbps it is 60, for 144kbps service it is 26 and for 768kbps data rate service the value of processing gain is 5. For selected application, given processing gain, varying bit energy to noise ratio and varying affecting factor values like loading factor, interference factor and efficiency of IC receiver is used to analyze the capacity performance of WCDMA system.

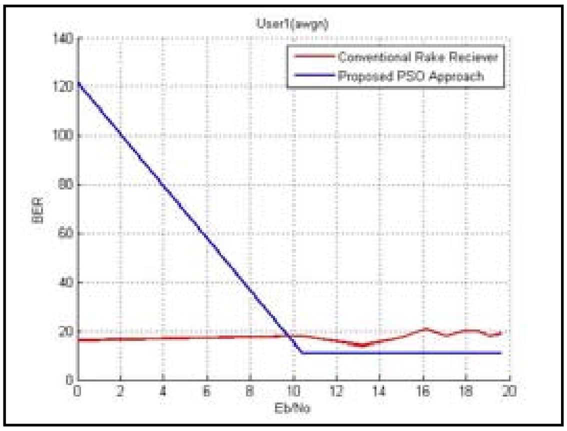

Fig.1.

In the figure 1, it is shown that for a given spreading bandwidth of 5 MHz i.e. 3.84 Mcps chip rate, as the data rate increases, the number of users in a cell decreases for a given bit energy to noise ratio. For a target E_b/N_o of 5db, there are 100 users of 12.2kbps data rate, 20 users of 64kbps data rate, 9 users using the cell having 144kbps data rate and only approximately 3 users accessing the WCDMA networks with data rate of 768kbps. So as the bit energy of a particular service increases, the number of user decreases.

Figure 2 shows the effect of loading on the WCDMA capacity for 64kbps data rate i.e. used for video services. Result is shown for 75% loading factor and 45% loading factor. From the result, it is observed that as the loading factor i.e. loading on the desire user by the neighboring cell increases, the number of active users in the cell decreases.

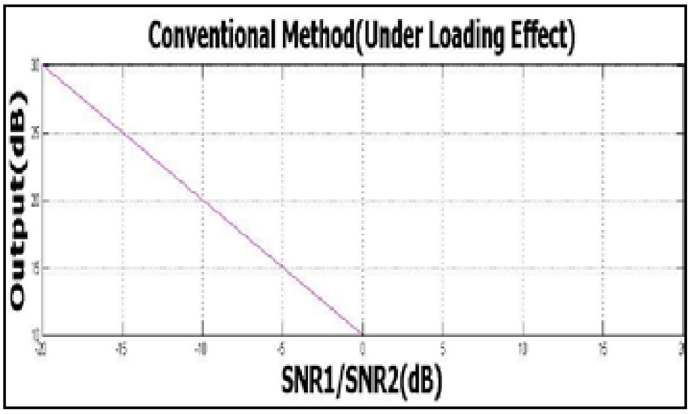

Fig. 2.

In the figure 3, the effect of interference on the WCDMA capacity for the video services is presented. Result is shown for 60% & 30% interference factor and as the interference from the inter-intra cell increases, the number of active users in a cell decreases. This decrease in number of users in a cell is in order to maintain the quality of service.

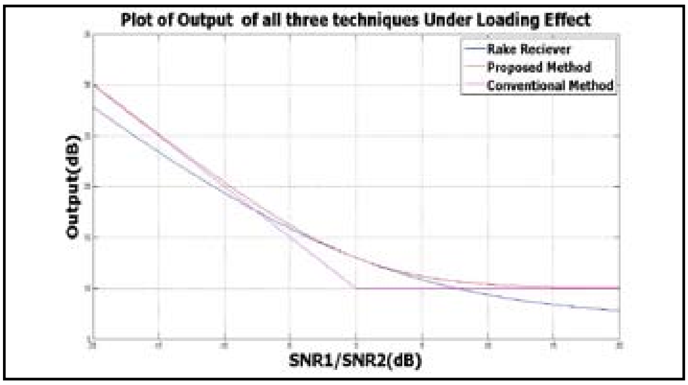

Fig. 3:

Figure 4 shows the effect of voice activity factor as discussed in section (III) on the WCDMA capacity. Result is shown for voice activity factor of 0.6 used for voice services i.e. at 12.2 kbps data rate and the effect of this factor increases the number of users about 1.5 times. For the target E_b/N_o of 5db, the number of user is about 100 without using the effect of voice activity factor and it is about 168 with voice activity factor effect.

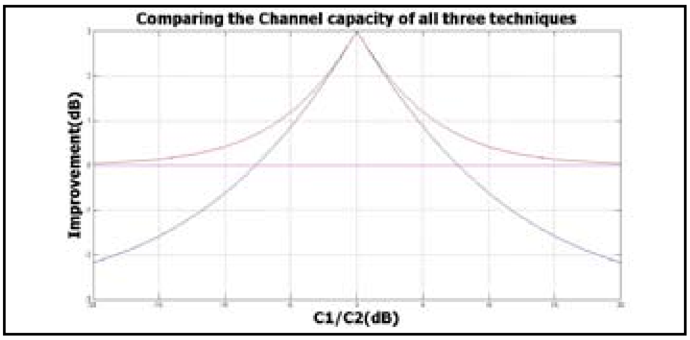

Fig. 4 :

VI. Conclusion and Future Work

This paper presents the parameters like loading, interference, voice activity that affects the WCDMA capacity and capacity enhancement method using interference cancellation receiver. The analysis of capacity in terms of number of users is done for high data rate services utilizing the same channel bandwidth. From the analysis, it is concluded that loading and interference decreases the capacity of WCDMA system and voice activity factor, interference cancellation receivers increases the WCDMA capacity. This work can be extended by the use of antenna array structure with the given IC receiver that will not only increase the capacity of WCDMA system at high data rates with better quality of service but will also reduce the cost and maintenance approach used in implementing IC receiver of such high efficiency.

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