Study of MUD on Capacity of WCDMA System with Different Parameters

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ABSTRACT
Third Generation (3G) systems are intended to provide a global mobility with wide range of services including telephony, paging, messaging, internet and broadband with flexible data rate. In CDMA based system, each user transmits a data sequences spread by a code commonly called spreading code. This code is Unique to the mobile station (MS) to base station (BS) connection on both uplink and downlink. The present paper deal with the wireless capacity Model and capacity consumption / utilization models for analysis of the 3G WCDMA system. We formulate the capacity of a 3G WCDMA cell as function of bandwidth and interference. By employing Multiuser Detection technique to suppress the multiple access interference in the presence of loading, sectorization, voice activity, intra & inter interference and constant power at base station in a downlink path at 5 MHz bandwidth.

Keywords: Capacity Model, 3G, CDMA, Multi-User Detection

1. INTRODUCTION

Wireless communications for mobile telephone and data transmission is currently undergoing very rapid Development. Many of the emerging wireless systems will incorporate considerable signal-processing intelligence in order to provide advanced services such as multimedia transmission. In order to make optimal use of available bandwidth and to provide maximal flexibility, many wireless systems operate as multiple-access systems, in which channel bandwidth is shared by many users on a random-access basis. One type of multiple access technique that has become very popular in recent years is direct-sequence code-division multiple-access (DS-CDMA).[1-2] In DS-CDMA communications, the users are multiplexed by distinct code waveforms, rather than by orthogonal frequency bands, as in frequency-division multiple-access (FDMA), or by orthogonal time slots, as in time-division multiple-access (TDMA).

2. WIDEBAND CODE DIVISION MULTIPLE ACCESS (WCDMA)

Third generation (3G) mobile networks such as the universal mobiles telecommunication systems (UMTS) and International mobile telecommunication Union (IMTU), will provide a wide variety of services with high spectrum efficiency to the users. Wideband Code Division Multiple Access (WCDMA) is the leading 3G wireless standard in the world today [3]. Beside voice capability in 2G, new 3G system are required to have additional support on a variety of data rate service using multiple access techniques. Code division Multiple Access (CDMA) is the fastest growing digital wireless technology. CDMA technology can offer about 7 to 10 times the capacity of analog technologies and upto 6 times the capacity of digital technologies such as time division Multiple Access (TDMA) and Frequency Division Multiple Access (FDMA) [4].
The information is spreaded over a band of 5, 10, 20 MHz. The objective of this spreading is to maximize the spectrum utilization .i.e. to provide service to more users with the same amount of spectrum. There are two different modes of operation namely frequency Division Duplex (FDD) & Time Division Duplex (TDD), the transmitter and receiver operates simultaneously on different frequencies. Separation is provided between the downlink and uplink channel to avoid interference between the transmitter and receiver [5]. In TDD mode, bidirectional flow of information is achieved using simplex-type scheme by automatically changing in time in the direction of transmission on a single frequency. The capacity of a system can be defined in several ways. In present study the capacity is treated as the maximum number of simultaneous users, who can access the network with multirate services.
[2] shows comparison of the capacity of CDMA to that of conventional time division multiple access and frequency division multiple access for satellite applications suggested a reasonable edge in capacity for the latter two more conventional techniques. This edge was shown thereafter [6] when it was recognized that since CDMA capacity is only interference limited (unlike FDMA and TDMA capacities which are primarily bandwidth

limited), any reduction in interference converts directly and linearly into an increase in capacity.
Two major factors that limit the performance of DS-CDMA based system are Multiple-Access Interference (MAI) and multipath channel distortion. Many advanced signal processing techniques have been proposed to combat interference and multipath channel distortion, but in present study multiuser detection is used [7] as a capacity enhancing parameter

3. SYSTEM MODEL OF CAPACITY OF A SINGLE CELL CDMA SYSTEM

Capacity is defined as the total Number of users that can support the system simultaneously with in a cell. The performance of Wideband CDMA system is interference limited. This means that the quality of the system is limited by the amount of the interference power present in the band. Here the quality means as the perceived condition of the radio link assigned to a particular user. In order to derive the expression for the WCDMA system capacity in perfect power control, the energy per chip of all users is the same and equal to E_c. If we ignore the contribution of thermal Noise power spectral density to the effective noise power spectral density, than the effective noise power spectral density (N_o), becomes [8-9]

$$N_o = (k-1)E_c$$

The Bit Energy to effective noise ratio (E_b/N_o) is given by

$$\frac{E_b}{N_o} = \frac{E_b}{(K-1)E_c} \text{-------(1)}$$

As the processing gain G_p is the ratio of bit energy to the chip energy.

$$G_p = \frac{E_b}{E_c}$$

$$\frac{E_b}{N_o} = \frac{GpE_c}{(K-1)E_c} = \frac{Gp}{K-1}$$

The account of background thermal noise (N) with the variance $\sigma^2{}_{n,} E_b / No$, shown in (2,3)

$$\frac{E_b}{N_o} = \frac{Gp}{(K-1)+N/E_c} \text{---(2)}$$

$$\frac{E_b}{N_o} = \frac{Gp}{(k-1)+\sigma^2{}_n/S} \text{----(3)}$$

Rearrange the Eqn (3), for Number of user.

$$K \le 1 + \frac{Gp}{E_b/N_o} - \frac{\sigma^2{}_n}{S} \text{-----(4)}$$

If we ignore the effect of thermal noise, the number of users (K) is given in eqn (5)

$$K \le \left[1 + \frac{Gp}{E_b/N_o}\right] \text{……….(5)}$$

Where (S) is the received signal power and (N) is the one sided noise power spectral density. E_b/N_o is the required value for adequate performance of the receiver within a predefined value of bit error rate (BER), but in term of number of users, the capacity is reduced by the inverse of the signal to noise ratio (SNR) in the total system spread bandwidth W. Reducing Eb/No through improved coding or possibly modulation technique, which rapidly reaches the point of diminishing returns for reaching complexity [9] (and ultimately the surmountable Shannon limit), But Present study E_b/N_o is reduced by multi-user detection technique in presence of different parameters as discussed in 4 subsection.

4. **Study of System Capacity with Different parameters:**

A number of correction factors can be applied to extend its application to a broader range of environments. The paper does not explicitly address modulation techniques and their performance. Rather, assuming an efficient modulation and forward error correcting code for the given channels, established the conditions under which the receiver will achieve an acceptable level of performance, particularly in terms of the maximum number of users supportable per cell.[9] The analysis takes place in the following capacity influencing factor such as loading factor, sectorization, power factor, effect of intra & inter interference and voice activity factor.

4.1 Loading:

The Eqn (1) is effectively describe a model that support the number of users in a single WCDMA cell. This single cell is omni directional and has no neighboring cells, but actually it is not possible. There are many cells in a WCDMA cellular system network. Particular cell A (dominating Cell) is bordered by other cells that supporting the other users. Although these other users from other cells say (Cell-B & Cell-C) are powered controlled by their respective home cells, the signal powers from these other users constitute interference to particular cell A. [10-11] Then the particular cell is said to be loaded by users from other cells. The effect of loading is shown mathematically in (6)

$$K \le \left[1 + \frac{Gp}{E_b / N_o} \cdot \left(\frac{1}{1+\eta}\right)\right] \text{-------(6)}$$

η is the loading factor . Sometime it's inverse of the factor $(1+\eta)$ known as frequency reuse factor F. Its value depends on multicell condition. The effect of loading on the performance of the capacity in a system is shown in fig 1.

4.2. Antenna Sectorization:-

If the cell is in perfectly sectorized form, the interference from other users can be decreased. Instead of having an omni directional antenna, which has an antenna pattern over 360 degrees, Cell A can be sectorized to three sectors so that each sector is only receiving signals over 120 degrees. In effect, a sectorized rejects interference from users that are not within its antenna pattern. This arrangement decreases the effect of loading in a dominating cell.[12] The effect of Sectorization is shown in Eqn (7)

$$K = \left[1 + \frac{Gp}{Eb/No}\left(\frac{1}{1+\eta}\right)\lambda\right] \text{--------(7)}$$

4.3. Voice Activity: - In CDMA systems, reducing multiple access interference from neighboring cells results in a capacity gain. Since CDMA systems use speech coding, reducing the rate of the speech coder with voice activity detection along with variable rate data transmission could decrease the multiple access interference. The Vocoder used in the system with the variable rate, which means that the output rate of the vocoder is adjusted according to a User's actual speech pattern. The effect of this variable rate vocoding is the reduction of overall transmitted power and hence interference [13,14]. By employing a variable rate vocoding, the system reduces the total interference power by this voice activity factor. According to [15], the voice activity factor for human speech averages about 42%. Thus above equation is again modified to account for the effect of voice activity as in eqn (8),

$$K = \left[1 + \frac{Gp}{Eb / No}\left(\frac{1}{1+\eta}\right).\lambda\left(\frac{1}{\nu}\right)\right] \text{----- (8)}$$

4.4 Intra, Inter- Cell Interference

A very important issue in FDD Downlink is the orthogonality of the interference from the own cell. The intra-cell interference caused due to own cell. The inter-cell interference, the interference caused by neighboring cells. The inter-cell interference is non- orthogonal, due to the use of different scrambling and channelisation codes in different Cell. The inter-cell interference can be modeled as AWGN, which means that the power of the inter-cell interference is scaled down by one over spreading factor in the despreading process. But in the same cell all users use the same common scrambling code, and are separated by different channelisation codes which are mutually orthogonal. In a channel with no time dispersion, this means that the intra-cell interference is completely cancelled in the despreading. But in present study we consider the time dispersive, than the intra cell interference will spill over into the desired signal. The attained Signal to interference ratio (E_b/I_o) Value is given where S is the received signal strength, Gp is the processing gain, I_{intra} is the intra-cell interference, I_{inter} is the inter-cell interference form the other cells and N is the thermal noise. [4, 15]

$$\frac{E_b}{N_o} = \frac{S.G_P}{I_{intra} + I_{inter} + N} \text{----------(9)}$$

The fraction of the intra-cell interference caused by the users operating in the same cell to the total interference experienced by the desired user is given in Eqn 6.

$$F = \frac{I_{intra}}{I_{intra} + I_{inter}} \text{-----(10)}$$

In the present paper, assume the thermal noise is zero hence neglected and I_{intra} is (K.S), than the above equation will be

$$\frac{E_b}{No} = \frac{Gp}{(K/F)-1}$$

$$K = F.\left[1 + Gp\left(\frac{E_b}{N_o}\right)^{-1}\right] \text{--------(11)}$$

The value of N is the number of users that are associated with the cell receiving signals from the base station situated at the centre of the cell. N also includes users that are connected to more than one cell while in case of soft handover state. Analytically we are considering only those user which are in single cell but also influenced by the inter cell interference. The combine effect will given in Eqn (12)

$$K = F\left[1 + Gp\left(\frac{Eb}{No}\right)^{-1}.\frac{1}{1+\eta}.\lambda.\frac{1}{\upsilon}\right] \text{------(12)}$$

4.4 Multi-user Detection (MUD)

Multi-user detection deals with the demodulation of digitally modulated signals in the presence of multi- access interference. Multi-user detections find its major application in Code Division Multiple Access (CDMA) receiver design. A major technogical difficulty of CDMA system is near far problem and multiple Access Interference. The optimum multi-user detector for asynchronous multiple access Gaussian channels was obtained in [12,15] where it was shown that the near far problem suffered by the conventional CDMA receiver is overcome by a more sophisticated receiver which accounts for the presence of other interference in the channel.

$$\frac{E_b}{N_o} = \frac{S.G_p}{(1-\beta)I_{intra} + I_{inter} + N_0} \text{--------(13)}$$

From Eqn 6, Intercell interference can be calculated by

$$I_{inter} = \frac{1-F}{F}.I_{intra} \text{ ------- (14)}$$

Putting the I_{inter} value in Eqn 9,

$$\frac{Eb}{N_o} = \frac{S.G_p}{(1-\beta)I_{intra} + \left(\frac{1-F}{F}\right)I_{intra} + N_0}$$

$$\frac{E_b}{N_0} = \frac{S.Gp}{\left[(1-\beta) + \left(\frac{1-F}{F}\right)\right].I_{intra} + N_0}$$

$$I_{intra} = (K-1)S$$

$$\frac{E_b}{N_0} = \frac{S.Gp}{\left[(1-\beta) + \left(\frac{1-F}{F}\right)\right].(K-1)S + N_0}$$

If we ignore thermal noise

$$\frac{E_b}{N_0} = \frac{Gp}{\left[(1-\beta) + \left(\frac{1-F}{F}\right)\right].(K-1)}$$

For number of user in cell

$$(K-1) = \frac{Gp}{\left[(1-\beta) + \left(\frac{1-F}{F}\right)\right].\left(\frac{E_b}{N_0}\right)}$$

$$K = 1 + \frac{Gp}{\left[(1-\beta) + \left(\frac{1-F}{F}\right)\right].\left(\frac{E_b}{N_0}\right)}$$

Now we take all the different parameter with multi-user detection.

$$K = 1 + \frac{Gp\left(\frac{E_b}{N_o}\right)^{-1}.\left(\frac{1}{1+\eta}\right).\lambda..\alpha.\frac{1}{\upsilon}.}{\left[(1-\beta) + \left(\frac{1-F}{F}\right)\right].} \text{--(14)}$$

5. PERFORMANCE EVALUATION

Processing Gain for FDD downlink mode of WCDMA is given by the ratio of the chip rate to the data rate. Present paper deal with the three different data rates in the various capacity influence parameter and enhancing parameter. The fig 1 shows the variation in number of user as Eb/No is changed from 1 to 10 in the presence of loading factor 30%, Sectorization (1.5), Constant power control 75% to all the user, voice activity (3/8), fraction of Intracell Interference to total interference 73% when the chip rate is 3.84 Mcps & data rate is 12.2 kbps for voice service. [15-18] When the system contain processing gain and signal to noise ratio only than it support only 6 user at Eb/No 5 dB for voice application shown in fig 1 by simple value. Due to the loading factor on desired user by the neighboring cell, it degrade the capacity up to 5 user after that induced capacity enhancement parameter such as sectorization and voice activity. Due to this system support 7 and 15 users with all the parameters. In multicell environment the effect of intra and inter interference directly affect the system capacity and reduces the number of user to 9 at fixed value of signal to noise ratio is 5 dB.

Fig 2 shows the capacity enhancement in term of number of user with multiuser detection comparison between the combined effects of the different parameter with the capacity enhancement multiuser detection technique (β) in multicell environment. It minimizes the multiple access interference and increases the performance upto 16 user per cell at all the same parameter taken in the figure 1.

Figure 3, 4 shows the variation of capacity when bit rate is changed from 12.2 kbps to 64 kbps for data and to 144 kbps for multimedia with the same value of chip rate as used in fig1.

To study the impact of the different operation scenario, different multiuser detection factor will be assumed to represent different multipath propagation condition. The effect is shown in fig 5.

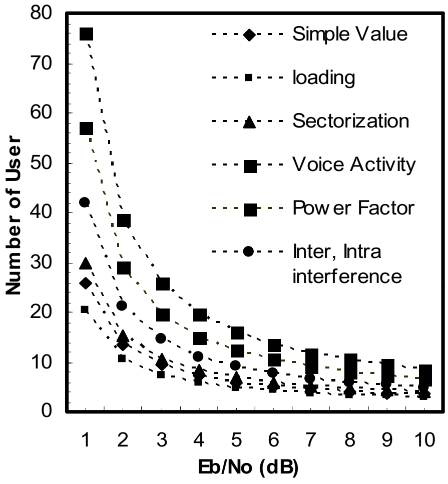

Fig 1 Effect of Variable factor on Capacity in term number of User at varying condition of signal to noise ratio (Eb/No)

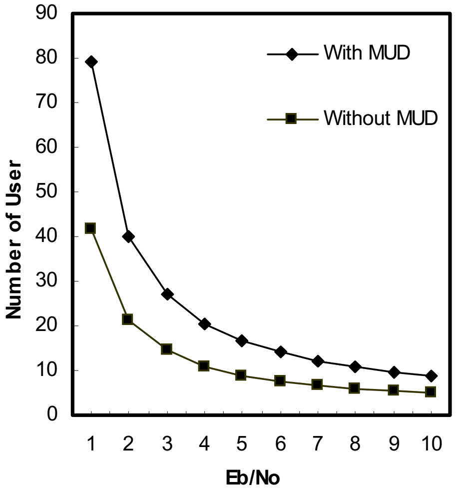

Fig 2 – Effect of MUD on the system capacity at varying condition of Signal to noise ratio for Voice application

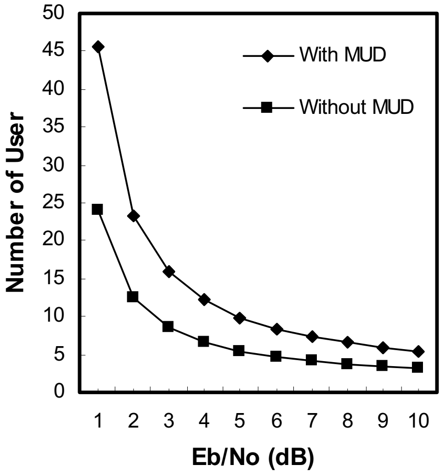

Fig.4 Effect of MUD on the system Capacity at Varying condition of signal to Noise ratio for multimedia Application

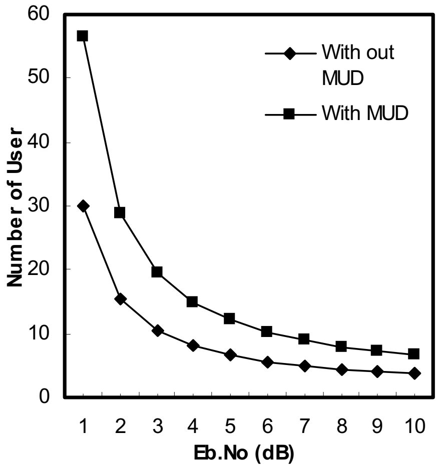

Fig.3 Effect of MUD on the system Capacity at Varying condition of signal to Noise ratio for Data Application

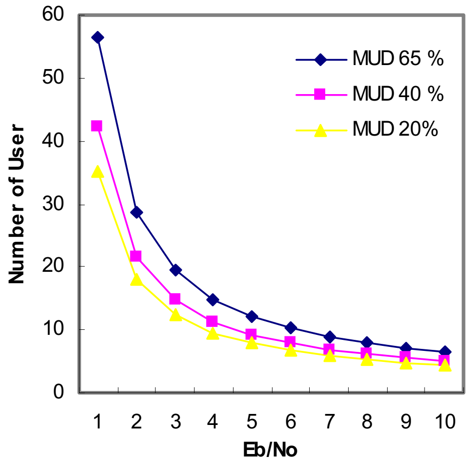

Fig 5 Comparison of different value of MUD factor at fixed data service (64 kbps) on Number of User with varying condition of Eb/No

CONCLUSION:

CDMA based third generation (WCDMA) mobile networks need efficient network planning. The network planning process will allow the maximum number of users with adequate signal strength in a CDMA cell. The simple expression derived in this present work using 12 & 14, describing the relationship between coverage, capacity, data rates, number of users and some capacity degrade and influencing parameters can be used in CDMA cellualar system planning to set limits on the maximum number of users that can be admitted into the cell in order to meet coverage and capacity requirements. An attempt is made in the present study to characterize a WCDMA system in different processing gain conditions using flexible data rate and system parameters for downlink FDD mode configuration. However, there are limitations in our work, as we assumed perfect power control. The work is in progress and it will provide better result with simulation.

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