Performance Analysis and Comparison of Different Data Rates in Wideband CDMA Using Three Different Transmission Schemes

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Abstract- Wideband CDMA is one of the radio access technologies for the third generation in which voice is the basic service. There has been lot of research work in order to find out the suitable transmission scheme to meet the requirement of accommodating variable type of services in Wideband-CDMA. This paper studies the behavior of different services using different transmission schemes in Wideband CDMA and compares their performance in terms of BER. Different transmission schemes are found to be suitable for different services. Transmission schemes used are- fixed processing gain scheme also called as variable bandwidth scheme, single code transmission and multicode transmission. It is found that fixed processing gain scheme is suitable for high data rates. Single code transmission is suitable for low data rates where as multicode transmission is suitable for low and medium data rates.

1. Introduction

Mobile communications are proliferating through our society at an exponential growth rate. There is rapid growth of cellular subscriber worldwide. The 21st century will become the wireless multimedia society [1]. Provision of a large variety of services is expected in the upcoming third generation wireless systems. Users with very different and time varying rate and quality of service requirements will need to be accommodated. As we approach the millenium, it is clear that the next significant development in wireless communication will be to increase the ability of networks to manage information "traffic" so that they can eventually provide even more advanced services. Current standardization efforts in the mobile communications world are aimed at providing a wide variety of ubiquitous, tether less services anywhere, anytime [2]. The concept of ubiquitous services implies support for any media spanning the spectrum from voice to video and their combinations using devices ranging from an ordinary phone to very limited visual capability to personal computers with large displays. In this context, the ideal 3G mobile system should be able to seamlessly support major applications that run on the Internet today, e-mail to web access to collaborative computing and multicast. In addition, a wireless 3G networks is in a unique position to complement current and upcoming-wired data service with mobility driven applications.

Unfortunately, the existing second-generation wireless networks are not capable of supporting this vision. This is because, second generation systems have been designed for mainly homogenous user population and limit each user to a rate which is a very small fraction of the overall system capacity. This is understandable as the primary goal for second-generation systems has been the provision of predominantly voice and perhaps, very limited low rate data services. 3G standards that are being developed have to provide means for a multitude of services only one of which is voice. These services are expected to require a wide range of data rates and QoS. The DS-CDMA system chosen for personal communication system has 1.25 MHz bandwidth, usually called Narrowband CDMA (N-CDMA). However this N-CDMA system is not able to satisfy the recent revolution of internet services, which can allow users to make video calls to friends and colleagues from a mobile terminal, whilst simultaneously accessing a remote data base from that same terminal, or receiving e-mails and phone calls due to the low data rate.

To provide high capacity, flexible channel assignment and high quality multimedia transmission with various data rates as high as 2 Mbps, high bit rate system is needed to support these advanced multimedia services to expand the information capacity or "bandwidth" of the wireless line. To support all these types of services large spreading bandwidth is required, such as 5, 10, 20 MHz and use of CDMA for this purpose is referred to as WCDMA [3]. The corresponding chip rates for above bandwidths are 4.096 Mchips/s, 8.192 Mchips/s and 16.384 Mchips/s. There are three transmission schemes from which different data rates can be provided. First is fixed processing gain scheme, which is also called as multichip rate scheme. In this scheme the processing gain is kept constant and the different data rates are served using different chip rate. In single code transmission scheme, the processing gain varies according to the data rates. If the data rate is high the processing gain is low. In multicode transmission, higher data rates are splited in to lower basic data rates and different channelization code is used for each stream. In this paper we study these three approaches in terms of their BER performance and compare their performance.

The organization of this paper is as follows. In section 2, we describe all the three transmission schemes in detail. Section 3 presents the system simulation model used for this study. Section 4 describes the performance analysis of those schemes over a Rayleigh fading channel with time delay spread. Finally section 4 is the concluding section.

2. Different Transmission Schemes in WCDMA

Various studies have been done on obtaining high bit rates at low error rates over wireless channel. The increase of data rate in a WCDMA can be implemented by either of Multichip Rate, Multicode and Orthogonal multi spreading factor (SF) code schemes. In Multichip rate scheme the bandwidth of the system varies as the data rate is varied and the processing gain is kept constant. In Multicode transmission scheme, bit stream to be transmitted is split in to several parallel streams. Each stream is then spreaded by a code out of a set of orthogonal codes and transmitted in parallel [4]. Different data rates can also be supported by changing the size of the sequence-sets used for transmission [5]. The users transmit their messages by choosing one sequence from their sequence-set and transmitting it over the common channel. It has been explained that in single code and multicode, they have same multiuser interference. However the variance of the MUI is much smaller for the sequence sets in multicode than in single code. Due to large Euclidean distance, the multicode code sets result in a better BER for an AWGN channel. Additionally, with every change of data rate for the single code sequence sets almost all users have to change their signal-amplitude to meet the BER criterion.

In Single Code Transmission scheme, the chip rate is constant, and each user transmits on only one CDMA channel with spreading factor that varies inversely with the data rate. For high rates the spreading factor may be very low and for variable rate services, the SF will vary during the call. A drawback of the VSF scheme is that very short code duration leads to Inter Symbol Interference (ISI). A method to obtain variable length orthogonal codes that preserve orthogonality between different rates and SFs based on a modified Hadarmad transformation is presented in [6]. Orthogonality between the different spreading factors can be achieved by tree-structured orthogonal codes [7] as shown in Fig.1. This system using orthogonal multi-spreading factor code is particularly useful in the situations where the data rate varies during communication. We do not need to change the spreading code according to the data rate; instead we can keep on using the same spreading code with SF corresponding to the data rate. A single spreading code can be used for a wide range of data rates and thus the mobile receiver can be significantly simplified.

3. Description of Simulaition Configuration

The performance of different data rates in WCDMA environment is evaluated using single code and multicode transmission schemes. Fig.2 shows the block diagram of low pass representation of the overall system model used for simulation generalized for both the schemes. Different data rates are generated using random data generator. They are convolutional encoded using ½ code rate and constraint length of 7. Encoded data are interleaved using block interleaver. They are then spreaded or splited according to the transmission scheme used. Then they are spreaded, BPSK modulated and passed through channel. In the receiver they are demodulated, despreaded, deinterleaved and decoded and compared with transmitted bits to find out the BER performance. Two types of spreading sequences are used. For multichip rate scheme Gold code of sequence length 31 is used where as for Single code and multicode system, orthogonal variable spreading are used. In multichip rate scheme three data rates 66kbps, 132 kbps and 164 kbps are considered. After decoding and deinterleaving, they are spreaded by using Gold sequence of length 31. As per the data rates three different chip rates of 4.092 Mchips/s, 8.184 Mchips/s and 16.368 Mchips/s are taken in Multichiprate case. In single code scheme, three different data rate of 64 kbps, 128 kbps and 256 kbps are considered. Their spreading factor is varied according to the data rate. After encoding and interleaving, they are spreaded using orthogonal variable spreading factor in order to get fixed chiprate of 4.096 Mchips/s.

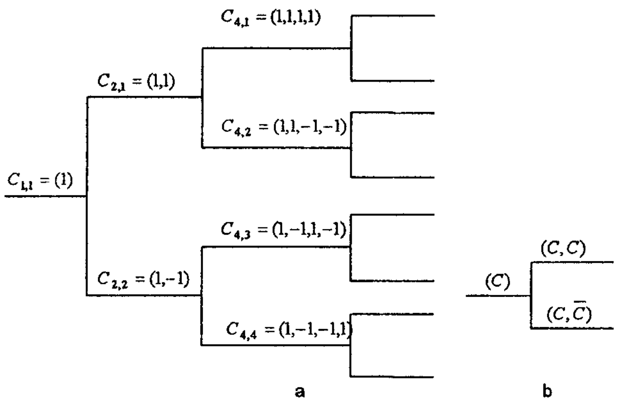

Figure 1: (a) Construction of orthogonal spreading codes for different spreading factors (b) Rule of construction: $\bar{C}$ denotes the complement of C.

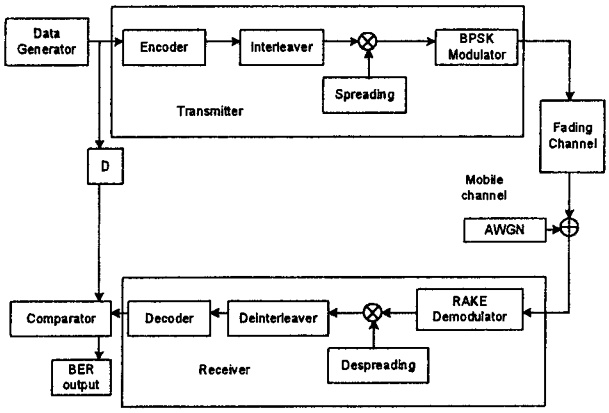

Figure 2: Block diagram of the simulation model

In multicode transmission, after encoding and interleaving, higher data rate like 128 kbit/s and 256 kbit/s are splited in to basic data rate of 64 kbit/s. 128 kbit/s is splited in to 2 streams of 64 kbit/s and 256 kbit/s is splited in to 4 streams of 64 kbit/s. Each stream is spreaded by using orthogonal code of length 32 but different code for each stream. Implementation of system model for all three schemes is shown in Fig. 3. Table 1 summarizes the simulation parameters used in this study. Coherent detection is considered assuming perfect channel estimation. Three paths are selected having the highest magnitudes of their channel tap coefficients. The spreading sequence that is used for spreading in the transmitter de-spreads the combined signal. The implementation of the Rake receiver in the simulation is shown in the Figure 4.

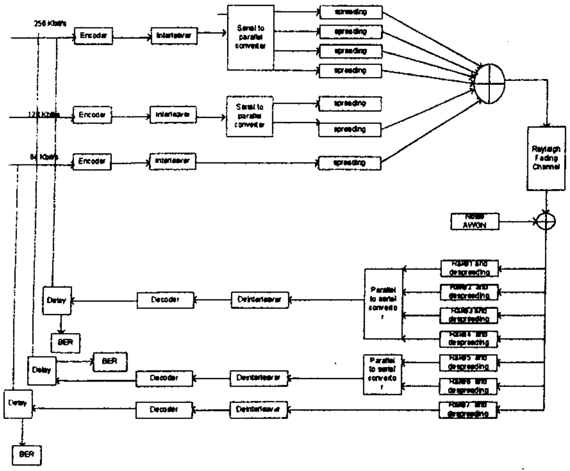

Figure 3: Simulation configuration for multicode

Source data rate	64 kbps, 128 kbps, 256 kbps
Channel coding	Convolutional coding, ½ rate, constraint length=7
Chip rate	4.096 Mchips/s
Frame length	10 ms
Spreading code	Orthogonal variable spreading factor code
Interleaver size	Block interleaver 100 ms and 10 ms size
Link Modulation	Synchronous downlink with BPSK
Channel model	6 taps (FPLMTS ITU-R TG8/1), exponential power delay profile
Carrier Frequency	2 GHz
Mobile speed	100 kmph, 5 kmph
Receiver	3 finger rake receiver, maximal ratio combining
BER simulation method	Monte Carlo method

Table 1: Simulation parameters for single code and multicode transmission

4. Simulation Results

The performance variation of different data rates in different transmission schemes is compared through the simulation configuration discussed in the previous section. Fig. 5 shows the performance comparison of single code to multicode transmission scheme. In this case different data rates are simulated together. This shows that, in a single code scheme, varying the spreading factor as the data rate varies to get a fixed chip rate, lower data rate performs better because of the higher spreading factor. However, the performance also depends on the interleaving size and according to the mobile velocity. The medium data rate, which has more code than lower data rate and less code than higher data rate, performs better. In this case, the code selection seems to be of great importance. For higher data rate, the number of codes used is higher which in turn may create self-interference compared to medium and low data rate. In addition, the performance of the OVSF code in multipath is different for different code sequences. However, multicode case outperforms single code for medium data rates. Similarly, Fig. 6 shows the comparison between single code and Multichiprate schemes [8]. For Multichiprate scheme, three data rates of 66 knit/s, 132 kbit/s and 264 kbit/s are considered. Processing gain is fixed and chip rate is varied, which creates the situation of variable bandwidth. It is seen from Fig.6 that Multichiprate is better for higher data rates and single code is better for lower data rate. It is to be noted that the requirement of bandwidths in Multichiprate is 4 times higher than that in the case of single code transmission for the same date rate of 256 kbps.

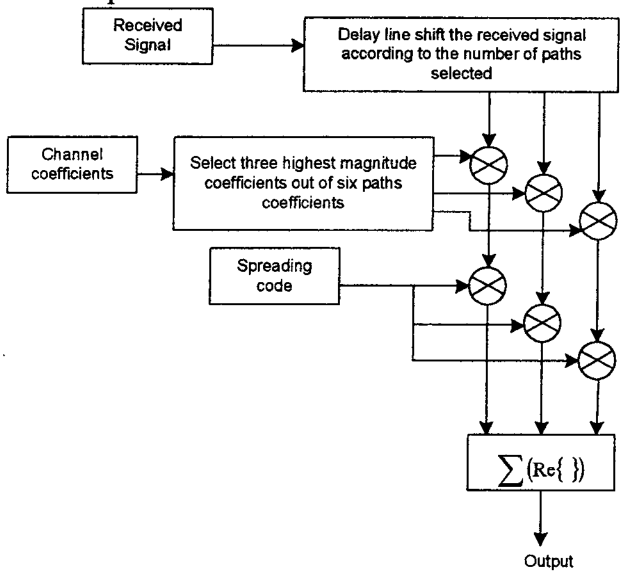

Figure 4: Rake receiver

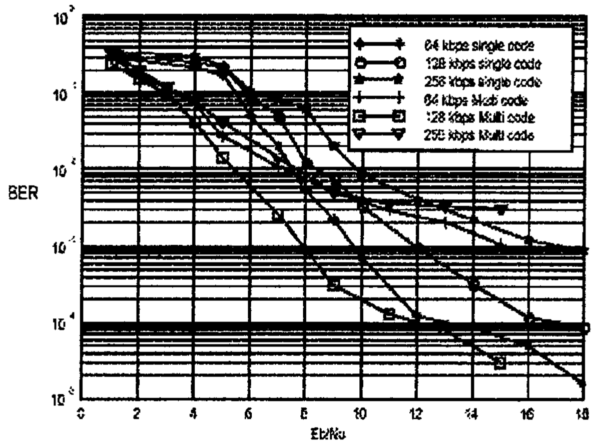

Figure 5: Comparison of single code and multicode transmission (64 kbit/s basic rate), 4.096 Mchips/s, 10 ms interleaving, 100 km/h mobile speed.

When performance comparison is made between different spreading factors, the medium data rate 128 kbps performs better for lower spreading factor i.e. 32 but lower data rate performs better at higher spreading factor 128, as shown in Fig.7. The performance of higher data rate is also better at lower spreading than that at higher spreading (more code).

When multicode is compared with multichip rate scheme, as shown in Fig.8, performance of highest data rate is better in multichip rate but performance of medium data rate is better in multicode. Performance of lowest data rate is better in multicode to the region of SNR 12 dB and after that is performance in better in multichiprate scheme.

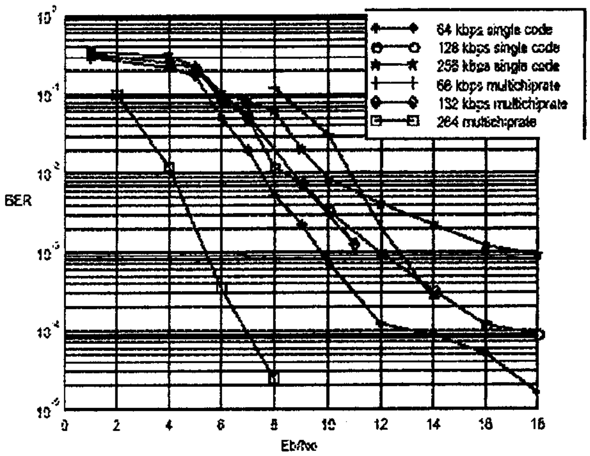

Figure 6: Comparison between single code and Multichiprate schemes, 10 ms interleaving, 100 km/h mobile speed.

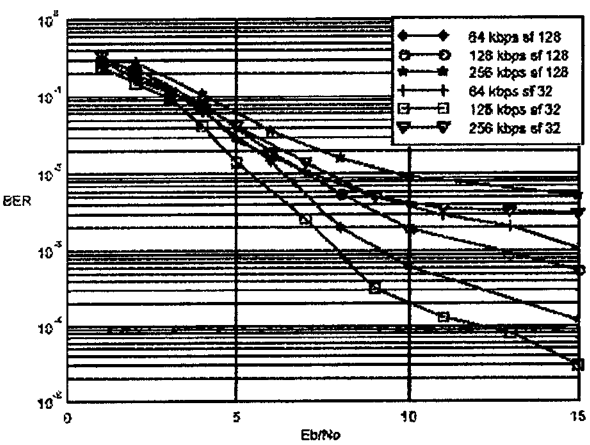

Figure 7: Comparison between different spreading factors in multicode, 4.096 Mchips/s, 10 ms interleaving delay, mobile speed of 100 km/h.

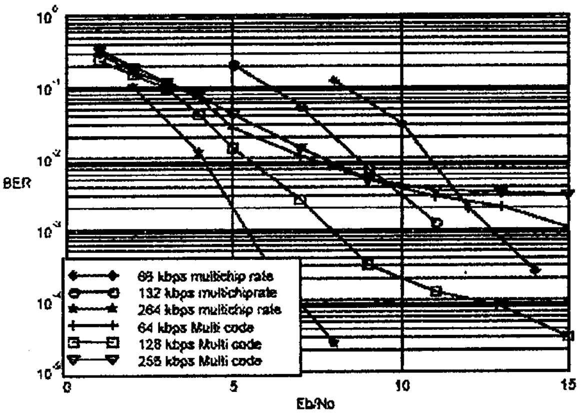

Figure 8: Comparison of multicode and Multichiprate schemes, 10 ms interleaving delay, 100 km/h mobile speed.

5. Conclusions

From above discussion it can be seen that variable chip rate scheme is suitable for providing higher bandwidth services. Multicode and single code can also be used to provide high data rate services when the bandwidth and chip rate are fixed. In such case the performance of high data rate is very poor in comparison to other data rates when the lowest chip rate of WCDMA is used.

Multicode transmission is suitable for medium data rate services. This scheme could also be suitable for lower data rates services if the more codes are used. This scheme is not suitable for higher data rate services since it requires more codes and there can be more intercode interference.The performance of higher data rate in this scheme depends also on mobile speed and interleaving size used. Simulation results also show that performance also varies with the allocation of different codes in Rayleigh fading channel. Single code transmission is suitable for providing services requiring lower data rate. Its performance is better in higher mobile speed and higher interleaving delay.

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