FORWARD LINK SIMULATION OF A MULTIUSER CDMA2000 SYSTEM

EE381-K MULTIUSER WIRELESS COMMUNICATIONS

CLASS PROJECT

YUN LIN

INTRODUCTION TO 3G WIRELESS AND CDMA2000

The goal for the next generation of mobile communications system is to seamlessly integrate a wide variety of communication services such as high-speed data, video and multimedia traffic as well as voice signals. The technology needed to tackle the challenges to make these services available is popularly known as the Third Generation (3G) Cellular Systems.

3G systems are required to operate in many different radio environments, such as indoor and outdoor, urban, suburban, or rural. The infrastructure used to deliver 3G services may be either terrestrial or satellite based. The information types may include speech, audio, data, text, image, and video. The data rates are: 144 kb/s or more in vehicular operations; at least 384 kb/s for pedestrians; about 2.048 Mb/s for indoor or low-range outdoor applications.

CDMA2000, also known as IS-2000, is a technology for the evolution of cdmaOne/IS-95 to 3rd generation services. Based upon the direct sequence spread spectrum technology, CDMA2000 works in the FDD mode, operates with one or more carriers, and is backwards compatible with the 2G system CDMAOne.

A CDMA2000 system may operate at different bandwidths with one or more carriers. In a multicarrier system, adjacent carriers should be separated by at least 1.25 MHz. In an actual multicarrier system, each individual carrier usually has bandwidth of 1.25 MHz. to provide high-speed data services, a single channel may be used with a nominal bandwidth of 5 MHz with a chip rate of 3.6864 Mc/s.

Broadly speaking, CDMA2000, like all other 3G technologies, is expected to support the following types of traffic. The data rates may vary from 9.6 kb/s to 2 Mb/s:

- Traditional voice and voice over IP
- Data services which include packet data and circuit-emulated broadband data
- Signaling services

THE PROTOCOL STACK OF CDMA2000

CDMA2000 takes the information – user data and signaling – from the high layers and adds two lower-layer protocols before transferring the data over the air interface. The link layer consists of the link access control (LAC) and media access control (MAC) layers.

Each traffic type coming from the higher layer has a different QoS requirement in terms of delay, delay variations, and error rates. The function of the LAC is to ensure that various types of traffic are transferred over the air interface according to their QoS requirements. The MAC layer also provides a certain degree of transmission reliability.

CDMA2000 physical channels are classified into two groups: Dedicated and Common channels. Dedicated Physical Channels (DPCH) offer a point to point connection while Common Physical Channels (CPCH) offer a point to multi-point access.

Dedicated Physical Channel (DPHCH)

- Fundamental Channel (FCH)

  Designed to transport dedicated data.
- Supplemental Channel Type (SCHT)

  Allocated dynamically to meet a required data rate.
- Dedicated Control Channel (DCCH)

  Transports mobile-specific control information.

- Pilot Channel (R-PICH)

  Provides the capabilities for coherent detection.

- Dedicated Auxiliary Pilot Channel (F-DAPICH) (optional)

  Used with antenna beam-forming and beam-steering techniques to increase the coverage or data rate towards a particular user.

Common Physical Channel (CPHCH)

- Pilot Channel (F-PICH)

  Provide capabilities for soft handoff and coherent detection.

- Common Auxiliary Pilot Channel (F-CAPICH)

  Provides capabilities for soft handoff and coherent detection.

- Common Channel Type (F-CCHT)
  - Paging Channel (F-PCH)
  - Common Control Channel (CCCH)
  - Sync Channel (F-SYNC)
- Access Channel (R-ACH)

  Multiple access channel where mobiles station communicates message with the base station.

THE FORWARD PHYSICAL CHANNEL TRANSMIT FUNCTIONS

The purpose of a forward traffic channel is to send the user data as well as signaling messages to a mobile station during a call. The physical channel is characterized by its associated carrier frequency, scrambling, and channelization codes, the radio frame length and the modulation method used. Fig. 1 shows a simple diagram of the transmit functions of the forward channels of a direct-spread CDMA2000 system.

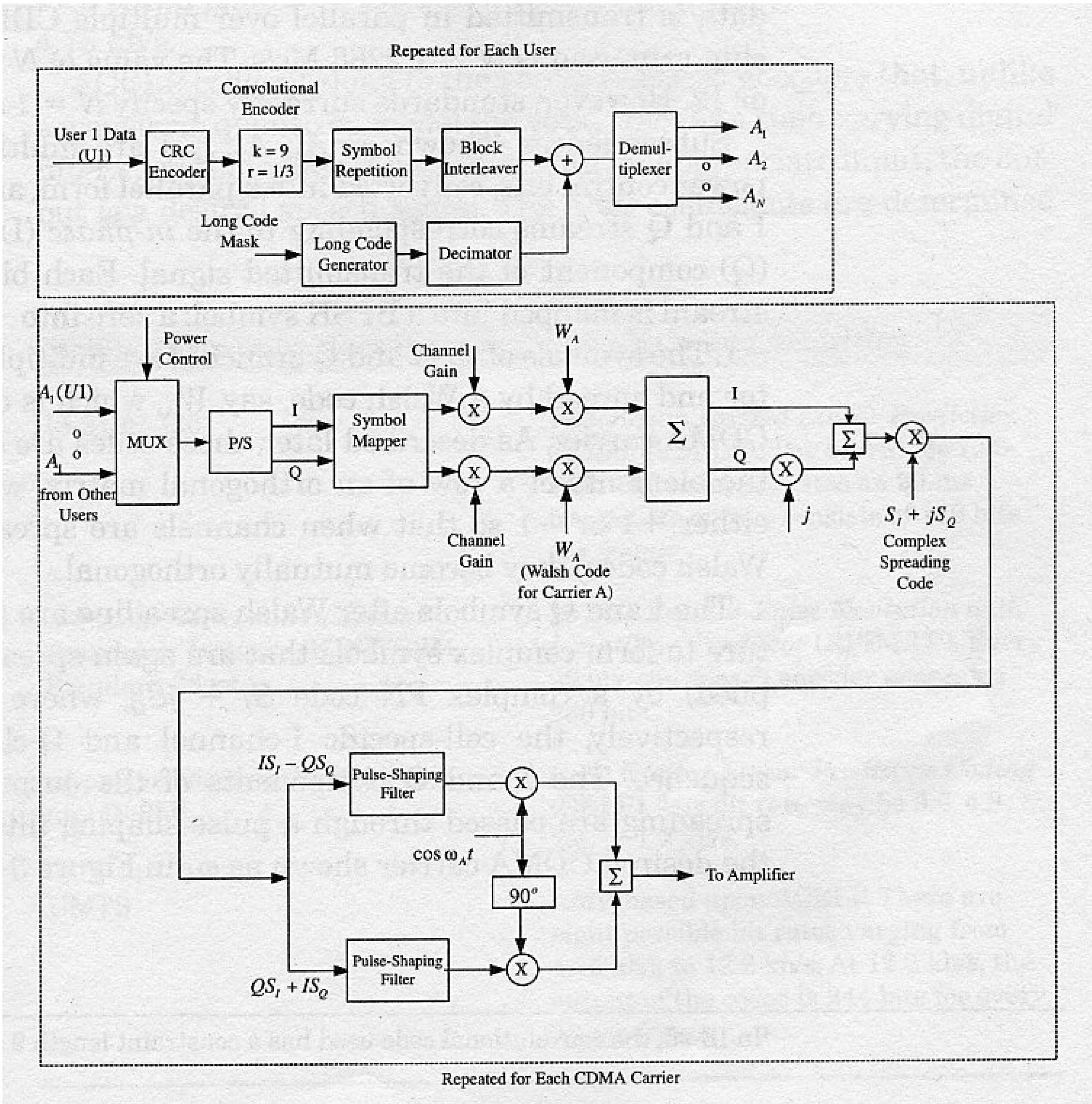


Fig. 1: Simplified block diagram of the transmitter of a multicarrier cdma2000 system

Single user data from the upper link layer arrives at the input of the transmitter in blocks. Each of these blocks is encoded into a cyclic redundancy check code and then serially concatenated. The generator polynomial of the CRC code is usually one of the following:

g1(x) = x^24 + x^23 + x^6 + x^5 + x + 1

g2(x) = x^16 + x^12 + x^5 + 1

$g3(x) = x^{12} + x^{11} + x^3 + x^2 + x + 1$

$g4(x) = x^8 + x^7 + x^4 + x^3 + x + 1$

Next depend on the output length from the CRC encoder, it may be necessary to segment the output data into a number of smaller code blocks before passing them through a channel encoder, where the input stream is encoded into either a convolutional code of rate 1/3 or 1/2 or turbo code of rate 1/3. The constraint length of the convolutional encoder is normally 9. The generator polynomials of the encoder are usually represented by octal numbers; for example, 561(that is, 101 110 001 binary) or 753 in rate 1/2 encoder and 557, 663, or 711 in rate 1/3 encoder.

The output from the channel encoder may have to be repeated a few times in the symbol repetition block, depending on the data rate, so that the resulting output matches the physical channel rate. The output of the symbol repetition block is then applied to an interleaver that spread out in time adjacent bits of the input stream to provide protection against burst errors in the channel.

A long PN code that is *unique to each user* scrambles the output of the interleaver and applies the scrambled sequence to a demultiplexer where it is grouped into N subsequences, N being the number of CDMA carriers (current standard specify 1 and 3 only for cdma2000 systems). Each of these subsequences is transmitted over a separate CDMA carrier.

Subsequences are multiplexed with the power control bits at 800 Hz, converted into a parallel form, and then split into I (odd) and Q (even) streams corresponding to the in-phase (I) and quadrature (Q) component of the transmitted signal. Each bit of the I and Q stream are mapped into a BPSK symbol: a zero into +1 and one into -1, thus the overall modulation scheme becomes QPSK.

The symbols of the I and Q branches are then multiplied by a gain factor and spread by a Walsh code, also known as orthogonal variable spreading factor (OVSF) code. Forward physical channels are spreaded with different Walsh codes so that they can be separated at the receiver. For example, Walsh code 0 is assigned to the pilot channel, code 32 to the synch channel, and code 1-7 to paging channels etc. In cdma2000, Walsh code used on different channels may vary from 4 to 128 chips.

The I and Q symbols after Walsh spreading are added in quadrature to form complex symbols that are again spread by a complex PN code Si + jSq, where Si and Sq are respectively, the *cell-specific* I-channel and Q-channel pilot PN sequence. With complex spreading, the output of the wave-shaping filter goes through zero only with low probability, thus leading to improved power efficiency.

SIMULATION SETUP

Simulink is a suitable tool for this project due to its easy-to-use user interface to build system block diagrams, performing simulations, as well as analyzing results. The CDMA radio transmitter and receiver functions that have been implemented in the project are similar to those described in Fig. 1, with some simplifications (shown in Fig. 2 and Fig. 3). For example, since we are only simulating a single cell/single carrier system, the cell-specific complex spreading and despreading function in the transmitter and receiver are omitted. Also omitted are the pulse shaping and analog modulation and demodulation functions blocks.

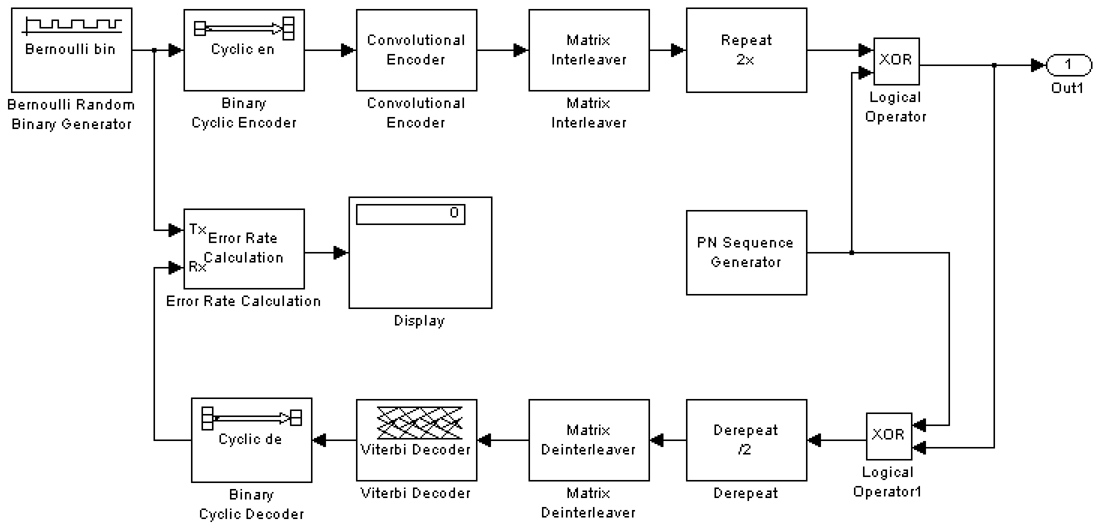


Fig. 2: Single user transmitter/receiver block diagram in Simulink

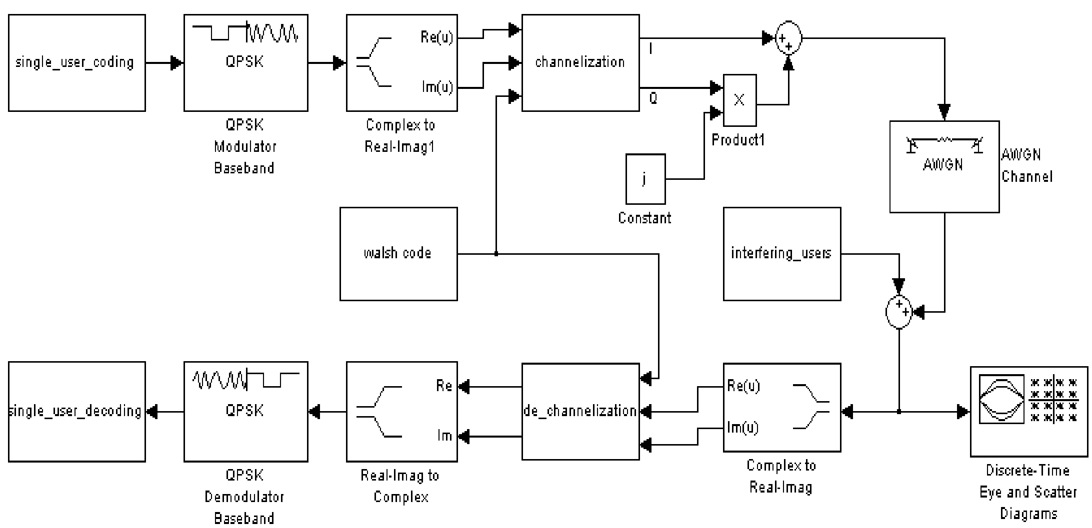


Fig. 3: Multi-user CDMA system block diagram in Simulink

To illustrate the effect of user interference on system performance, the number of users in the system N increases from 1 to 2, 4, 8 and 16. Suppose all users transmit at the same power P, it is obvious that the interference seen by each user will increase proportional to N, and system BER will increase correspondingly.

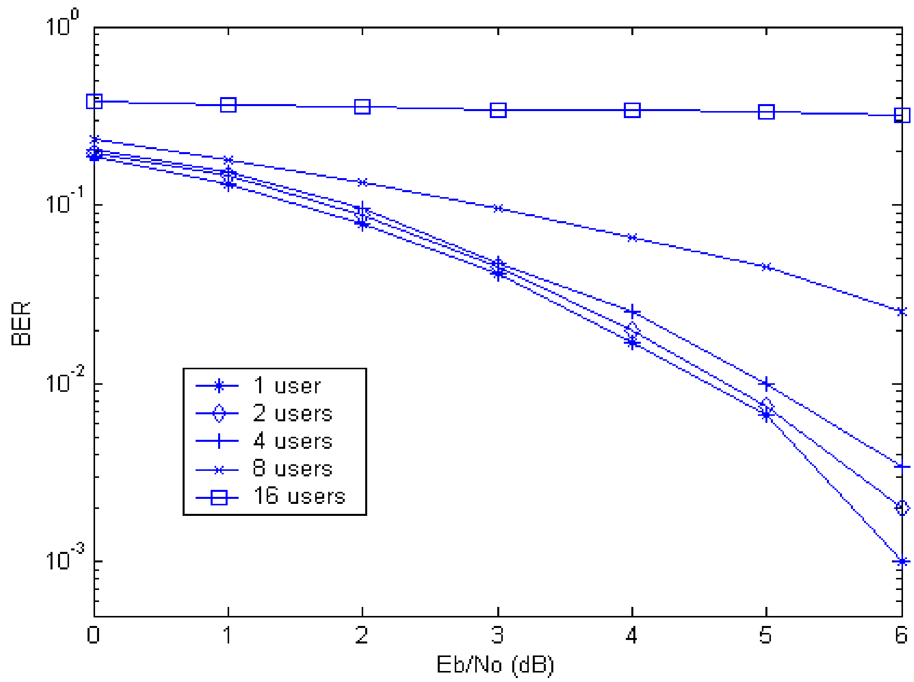
Detailed simulation parameters are listed in the table below:

Number of Cells	1
Number of CDMA Carriers	1
Number of Users	1 ~ 16
CRC Encoder Polynomial	x^8 + x^7 + x^4 + x^3 + x + 1
Convolution Encoder Polynomial	[557 663 711]
Block Interleaver (row * column)	7, 3
PN Code Generator	[1 1 0 1 1]
Modulation	QPSK
Walsh Code Generator order	5
AWGN Channel SNR (dB)	0 ~ 6
Channel Models	AWGN

SIMULATION RESULTS

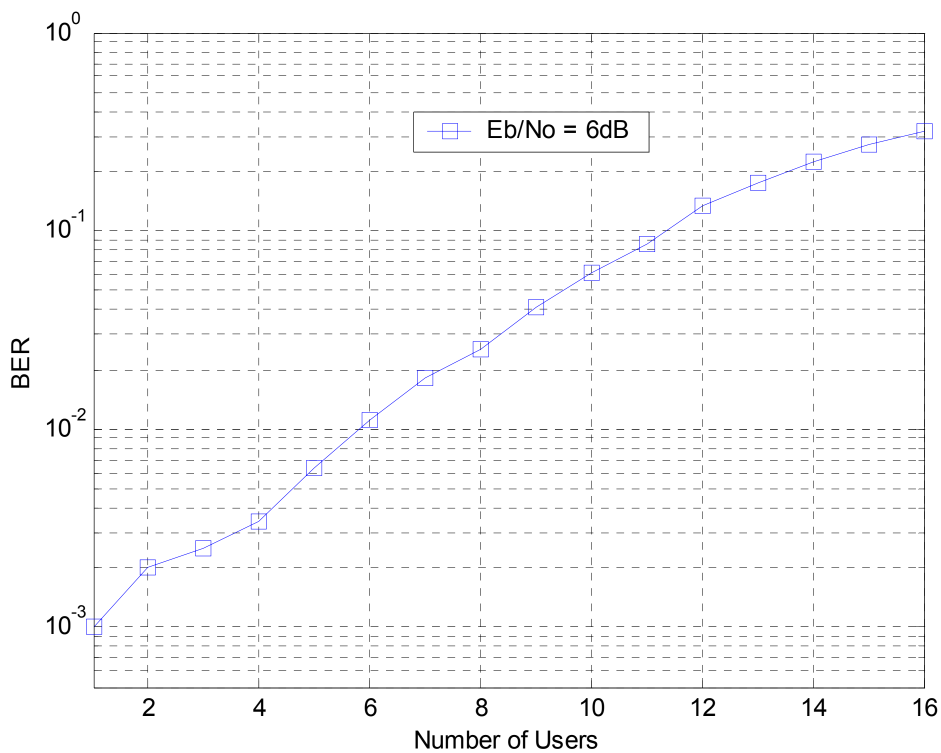
The BER performances of the system under the above parameters are plotted in Fig. 2. The results are straightforward. At the same channel Eb/No level, BER value increases as the number of users in the system increases. This effect becomes very obvious when the channel noise level is low (Eb/No = 6dB) and user number is high (8 or 16). The system capacity changes from noise limited to interference limited.

The effect of multiuser interference is better demonstrated in Fig. 3. At the same channel noise level, increase the number of users in the system increase BER value steadily. A 15 users system at channel Eb/No = 6B has the same BER performance of single user system at channel Eb/No = 0dB, a 6dB degradation due to the multiuser interference.



10^0
10^{-1}
10^{-2}
10^{-3}
BER
1 user
2 users
4 users
8 users
16 users
0
1
2
3
4
5
6
Eb/No (dB)

Fig. 4



10^0
10^{-1}
10^{-2}
10^{-3}
BER
Eb/No = 6dB
2
4
6
8
10
12
14
16
Number of Users

Fig. 5

FUTURE WORK

A Rayleigh fading multipath channel is available to replace the current AWGN channel model to simulate the system under more adverse environment. The simulator is also flexible to allow one to incorporate complex statistical channel model based on measurement of practical mobile channel condition. The improvement in system performance by using multiuser detection and interference cancellation can also be investigated.

CONCLUSIONS

This purpose of the project is to study the forward link of a 3G CDMA2000 system; understand the basic building blocks of the transmitter and receiver; and simulate the BER performance of the system under a multi-user environment. it is shown from the simulation result than the system BER/capacity in limited by both the channel condition and the amount of interference from other users in the system.

REFERENCE

[1] M. R. Karim. *W-CDMA and cdma2000 for 3G MOBILE NETWORKS*. 2002 McGraw-Hill.

[2] Keiji Tachikawa. *W-CDMA Mobile Communication Systems*. 2002 Halsted Pr.

[3] Tero Ojanpera and Ramjee Prasad, "An Overview of Air Interface Multiple Access for IMT-2000/UMTS," *IEEE Communications Magazin*e, vol. 36, pp. 88-95, September 1998.