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Performance Analysis of BER in CDMA using Various Coding & Simulation Techniques

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Abstract:-Wireless Communication is the most important part of our life in today's time. CDMA system has made it more secure system to communicate within the system. CDMA system has been developed enough to improve various problems like multipath fading, interference, cross talk etc. This paper inculcated various approaches to improve BER in CDMA system with different Coding & Simulation Techniques. This also represents various advantages and limitations of different evaluation/analysis methodology used to evaluate BER.

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I. Introduction:

Code Division Multiple Access (CDMA) is the more secure communication as compare to GSM. It works on the principle of spread spectrum which improves the system capacity. In areas congested with large physical infrastructure, vehicles, and other obstacles the signal gets faded at some point of time which continuously increases the BER. A lot of research work has been done to evaluate, improve and analyze bit error rate. This paper presents the analysis of certain coding & simulation techniques used to improve the Bit Error Rate of the system.

II. Scope of the Study:

This paper approaches various Coding Techniques (Walsh, Gold, Trellis, and Orthogonal etc.) and Modeling and Simulation Techniques (For Different System Model) to evaluate BER with different parameters which show that which of the techniques works in efficient manner in which environment.

III. Technical Evaluation Methods:

I. Coding Techniques:

There are certain codes used as spreading codes and also there are varieties of coding techniques that are used as an analysis technique for the evaluation process in communication due to their various advantages.

CDMA is based on spread spectrum technique and a particular code assigned to each user for transmitting and receiving data so it uses a spreading code associated with transmitting and receiving information to encode & decode the data correctly with no loss of original information.

Pei Xiao & Erik Strom [11] considered the multistage Parallel Interference Cancellation (PIC) scheme in a DS-CDMA system with Long Scrambling Codes. The authors used an analytical approach to calculate BER of DS-CDMA in a time varying multipath Rayleigh fading environment.

They designed a system model for K-users. The channel used is Rayleigh Fading Channel and the authors have used Parallel Interference Cancellation (PIC) system which is basically multiuser detection technique to increase the system capacity for an interference prone CDMA scenario. PIC works on the principle that transmitted signal are estimated for all the users at the previous iteration by using a decision feedback system.

The overall received signal is the sum of K user's signal along with Additive White Gaussian Noise (AWGN). For the analytical approach the authors concluded that BER has become half as compare to the system when not using PIC scheme. Further the authors compared the analytical results with simulation results. For the simulation process they have considered the fact that the target BER for uncoded system is 10^{-4}. They analyzed the system performance w.r.t BER greater than and less than $10^{-4.}$ They have found that MAI overestimates when small number of users are there (BER>$10^{-4)}$ and MAI underestimates for large number of users (BER<10^{-4}).

It has been seen that PIC is a good approach to reduce interference & noise but for large number of users more number of PIC systems are required which increases the system complexity. Instead of using long scrambling codes with PIC system some of the error correcting codes can also be used so that we can reduce the number of PIC system as error can be removed at the initial level. Then by passing the signal from PIC it could provide a more desirable signal.

Sanjeev Kumar [5] investigated BER of CDMA under AWGN channel. The process at CDMA transmitter part includes convolutional encoding, interleaving, data scrambling and quadrature modulation technique. The processing at the receiver terminal is the reverse process of the transmitter section.

The receiver model uses two types of Viterbi Decoder i.e. Hard Decision and Soft Decision Viterbi decoder. In hard decision Viterbi decoder hamming distance is calculated between received coded signal and transmitted signal. In the soft decision Viterbi decoder Euclidean distance is found between received symbols and transmitted symbols. Finally authors evaluated from the simulation results for the both decoders that BER is less in hard decision as compare to soft decision decoder.

It has also observed that the chip error rate before and after the use of Viterbi decoders are same for both decoders which shows a limitation of the work.

Rosmanyah & Sweeny [12] analyzed a system model in W-CDMA with turbo codes and Space Time Transmit Diversity (STTD). The BER is used as a performance measure. In this paper the authors have designed a system model with three main components transmission, channel & reception. In transmission part random bits are used instead of user data bits along with pulse shaping and matched filter. They have used 16 QAM, 64 QAM & 8 PSK modulation techniques. Analysis is done under different fading channels like AWGN, Rician & Rayleigh.Their simulation results shows that BER reduces in AWGN channel with maximum to least in 64 QAM, 16 QPSK, 8PSK and QPSK respectively with a coding gain differences of about 2db for coding rate 1/2 & 3/4. As compare to AWGN, Rician channel curves has -3db shift for coding rate 1/2 & 3/4 for all the modulation techniques and BER is decreased within a coding gain difference of around -3db. In Rayleigh channel system performance is unfavorably as compare to AWGN & Rician BER reduces very slightly and the coding gain differences ranging from -14 to -18 dB for the same coding rate i.e. 1/2 & 3/4.

When Space Time Transmit Diversity (STTD) technique is used within the system model it shows best results (minimum BER) with Rician channel as the efficiency of the system improves. STTD techniques is a kind of MIMO antenna technique in which same sub stream of information is transmitted from multiple antenna using different spreading code for every diversity branch.

In this paper the authors evaluated the BER with different techniques for different Channels along with different modulation schemes but the analysis considered only for single user whereas practically we have multiuser environment.

Mohmmad Sadak Ali et al [7] have evaluated BER of the Multicode, Multicarrier CDMA system with AWGN and multipath fading environment. In Multicode-CDMA, the high data rate stream is divided into several low sub streams and then each sub stream is multiplied with an orthogonal code set to separate each sub stream and minimize Inter Sub-Stream Interference (ISSI) before transmitting the data.
In Multicarrier CDMA System, the high data rate stream is divided into several low data rate sub streams, each sub streams modulates a different carrier and spread over the total bandwidth. In transmitter part of a MC-CDMA system for K active users, each chip is copied into P branches and multiplied by corresponding user spreading code. Each of the P branches modulates a particular subcarrier and the different modulated sub carriers are combined together and transmitted.

The Multicode Multicarrier CDMA system uses M-ary symbol selects one of the M code sequences for transmission, and then a similar process is applied like Multicarrier CDMA transmission system. The authors have evaluated BER w.r.t number of users for the entire three system model with both Walsh & Gold codes. By simulation results they have found that in comparison to AWGN channel, the performance of the Multicode system degrades drastically in multipath fading while in Multicode Multicarrier CDMA & Multicarrier CDMA system BER is significant better and is robust to multipath fading.

It is a good approach of analysis by using different combination of system to evaluate BER for CDMA.

The authors Ravindra Babu & Krishna Rao [3] evaluated BER performance of Linear Multiuser Detectors and Conventional Matched Filters. They had used different spreading codes for each of the detectors like Gold, PN, Even Kasami and Odd Kasami sequences. They have analyzed different detectors with BPSK modulation and compared the BER simulation results for each of the spreading sequence w.r.t different detectors.

The major issue in the CDMA system is near-far problem i.e. bit error rate of conventional receiver is so sensitive to the differences between the received signals of the desired user and interfering user that reliable demodulation is impossible unless power control is there. Earlier some schemes has been developed based on the Gaussian noise channels to resolve this issue but these schemes shows system complexity increases as the number of users increases which is not at all suitable for a practical environment. This problem is solved by using multi-user detector algorithms such as de-correlating detector & minimum mean square error (MMSE) detector.

Multiuser detectors assumed that the receiver has the information of codes of all the users. It only works on the uplink transmission. In downlink transmission a detection scheme is required which only needs the code of desired user. Then the authors have discussed about the two types of multi user detectors (i) Decorrelating Detector & (ii) Minimum Mean Square Error (MMSE) Detector.

Decorrelating detector doesn't require the knowledge of user's power; its only requires the knowledge of timing for the code dispreading at the centralized receiver. The received input signal goes to matched filter bank then it is multiplied with the inverse of the cross correlation matrix which has one (1) as its diagonal elements. If the output < 0 then information is -1 otherwise +1. In MMSE the only information required by detector is cross correlation matrix values. Here the input is applied to matched filter bank that is multiplied with inverse of the cross correlation matrix plus the variance of the transmitted signals and decision is taken as output < 0 then info -1 otherwise +1.

The BER performance is measured for Conventional single user Matched Filter, De-correlation & MMSE Detectors using Gold, PN, Even Kasami & Odd Kasmi sequences for 5, 10, 15, 20 & 25 users. The simulation results shows that odd Kasmi sequence provides better results as comparison to Gold, PN, & Even Kasami sequence. In between the detectors MMSE has better performance as comparison to Matched Filter and Decorrelating detector for all the users.

The authors Parvathy & Kumaratharan [4] have investigated BER of MC-CDMA system using Low Density Parity Check (LDPC) code in the presence of Rayleigh Fading.

The authors told that MC-CDMA system is a combination of both CDMA and OFDM. They told that the CDMA is used to increase the spectrum utilization and the OFDM to reduce the multipath fading and Inter Symbol Interference (ISI). In MC-CDMA transmission is done over the same set of subcarriers by different users but with a different spreading code which maintains the Orthogonality. In transmission if the Orthogonality of codes has been disturbed then the resultant will be MAI which reduces the system performance. So, to increase the overall performance of the system the data is encoded by using a LDPC encoder at the transmitter and at the receiver it decoded by using a turbo decoder.

The simulation tool used for analyzing the above defined system model is MATLAB (7.12.0). BER per in a MC-CDMA system using LDPC code under Rayleigh fading channel. The evaluation is done for different code rates and code lengths. In first case the dimension of parity check matrix of LDPC codes is changed and code rate is fixed at 1/2 and in second case code length is constant (1536 bits) While code rate is varied.

The code rate is fixed for first case i.e. 1/2 and dimensions of the parity check matrix used is 512x1024, 1024x2048. It is observed that the BER performance also increases as the dimension of parity check matrix increases.

In second case the dimension of parity check matrix are 512x1536, 768x1536 & 1024x1536 for code rates 2/3, 1/2 and 1/3 respectively. It shows that the BER performance increases as the code rate decreases.

So, finally the authors concluded with above simulation results that LDPC code increases the complexity linearly while decoding with respect to block length of the code and enhances the BER performance in a quadratic manner while encoding.

The CDMA & SDMA system using broadside antenna array for a multipath fading channel was presented by the authors Hassan, Fouda, Swelam & Hafez [2]. The performance evaluation was done by calculating BER for DS-CDMA system with the help of Rake Receiver and Convolutional Coding at transmission end. The BER performance of Rake Receiver was examined by varying the interfering cells, number of antennas, Rake fingers, number of users, number of channel multipath and spreading factor.

In order to improve the system performance of CDMA & SDMA system, a broadside antenna array was introduced by the authors. The analysis of BER for Reverse link (Transmitter) system model & multipath channel model with Rake receiver was carried out by them. The fact that, each channel consists of multipath that is resolved in space but not in time, was assumed by them. Spatial Processing (In Space) is a type of spatial separation between users using Space Division Multiple Access (SDMA) technique. The signal in SDMA system is not transmitted from a base station to the cell area, as is done in conventional access techniques. However, it rather focuses power in the direction of the mobile unit to which the signal is aimed to reach.

At transmitter end convolutional coding is used (error control coding). Rayleigh fading channel has been used which is frequency selective in nature.RAKE receiver is used at the receiver end.

The inference from simulation results builds that if there is an increase in spreading factor from 8 to 32, 256 and 512 there is an advantage in BER performance. Advantages of the magnitude of about 4.7 dB, 6 dB, 10 dB, and 12dB is encountered in BER performance of Rake Receiver. Depending on the increase number of antenna, increase number of Rake fingers & increase number of users a tremendous improvement in the BER (decreases) is seen. If there is increase in the number of interfering cells then BER performance will degrade.

IV. Modeling & Simulations Techniques:

There are various simulation tools/techniques used for analysis in the different system model like MATLAB, Xilinx, Antenna Software, FPGA based hardware or software kit etc… The simulation techniques are more easy and feasible way to do the analysis of the particular system as compare to hardware analysis method or numerical methodologies because in programming any of the features can be added or removed easily but in hardware implementation it is not possible once a system is developed and in numerical analysis as well there is a fixed pattern to solve a particular problem which can't be changed or manipulated. There are some reviews are mentioned below in which authors uses different modeling & simulations techniques.

Different M-ary modulation techniques in cellular mobile communication were analysed by Rashmi, Sunil, & Navneet [13]. The performance measure was BER when the system is subjected to AWGN and multipath Rayleigh Fading channel.

The digital communication system has low bit error rate at a relatively low signal to noise ratio and should be bandwidth efficient was told by them in the paper. They chose two types of modulation techniques i.e. M-ary PSK & M-ary QAM for BER vs. E_b/N_o analysis w.r.t AWGN & Rayleigh fading channel.

The authors have also drawn attention and shown the constellation diagram of 16PSK & 16QAM which tells that how different the modulation waveform are, and how well a receiver can distinguish among all possible symbols when random noise is there. The implication that a modulation scheme with a constellation that is densely packed is less energy efficient than a modulation scheme that has sparse

constellation, has been derived from the fact that the probability of bit error is proportional to the distance between the closest points in the constellation.

The simulation results of two modulation schemes were finally compared by the authors.

The increase in E_b/N_o reduce BER monotonically in case of performance of MPSK & MQAM for an AWGN channel for N=1000 samples and M= 4, 8, 16, 32 & 64. The distance between two nearest points in the signal space diagram (constellation diagram) gives BER. The probability of error increases as the distance between two points decreases. Hence it is desired to have distance as large as possible. So, probability of BER increases as M increases.

It is recommended to use modulation with M<16 as the results show that there is no significant change in BER when M>16, so, there is no use of increasing the complexity of system by higher order technique (i.e. 32or 64).

The Performance of MPSK & MQAM for Rayleigh & AWGN channel for N=1000 samples, Doppler Shift = 100 Hz is as follows. The error probability decreases exponentially with respect to E_b/N_o, for larger values of E_b/N_o, in a AWGN channel. Whereas, in a Rayleigh fading channel the probability of error, decreases linearly w.r.t E_b/N_o. Smaller values of BER correspond to the performance degradation. So, for small values, the power required to maintain a particular BER, is much higher in fading channel. Results occurred from simulations show that in AWGN fading, in order to maintain 10^{-1} bit error rate, 8PSK requires 1dB SNR. However, 4dB SNR is required by QAM to maintain the same error in Rayleigh fading.

QAM's and PSK's performance for M=8 is somewhat similar but as the values of M increases to 16 there is a slightly increase in BER (i.e. 10^{-1} to $2*10^{-1}$). If low order modulation technique are used then QPSK is better option than the 4-QAM in case of Rayleigh fading but as the order is increased (M≥8) QAM shows a better performance than PSK.

Arunasi, Jayaraman & Indumati [1] investigated the BER of DS-CDMA system over AWGN, Rayleigh & Rician fading channel based on diversity scheme. They used Space Time Block Code (STBC) antenna diversity scheme. STBC is a transmit diversity technique in which multiple antennas transmit symbols which are orthogonal in nature.

It operates on a block of data stream which is to be transmitted and produces a matrix whose rows and columns represent antenna and time respectively.

They describe the system model as at transmitter part, the data is generated from a random source, consists of series of ones and zeroes. Then the BPSK and QPSK modulation techniques are used to map the bits into symbols. Then the signal is encoded by STBC technique and transmits over different channels like AWGN, Rayleigh & Rician. Finally the signal received by each receiver antenna is a linear superposition of the transmitted signal.

Simulations results show that system performance increases as BER reduces by using STBC scheme. In presence of AWGN & Rayleigh channel, BER is 0.003 for SNR is 5dB using STBC encoding and for the same SNR 5 dB, BER is 0.0642 without using the STBC technique.
In Rician & AWGN channel BER is 0.0001 for SNR is 6 dB when using STBC technique and for same SNR BER is 0.0632 without using STBC technique. In case of Rayleigh channel BER is 0.0004 dB for SNR is 4 dB when using STBC, BER is 0.0771 without using STBC for the same SNR.

Masud & Rahman [9] analyze the BER performance of modulation techniques of wideband CDMA. They considered QPSK & M-ary QAM modulation schemes in W-CMA system when system is subjected to AWGN & Rayleigh channel. The authors give a brief introduction about QPSK & QAM modulation techniques. An example of M-ary PSK modulation technique (M=4) where it transmits 2bits/symbol is QPSK. One of four equally spaced values, such as 0, Л/2, Л and 3Л/2 is taken by the phase carrier, where a unique pair of message bits is represented by each value of phase. QAM is a modulation technique where its amplitude varies with phase. The combination of Amplitude Shift Keying (ASK) as well as Phase Shift Keying (PSK) gives QAM modulation.

The discussion about the Auto Correlation Function (ACF) & Cross Correlation Function (CCF) is done by the authors. The result of chip-wise convolution, correlation or matched filtering operation between two times shifted versions of the same code is defined as the Auto Correlation Function. The result of a chip wise convolution operation between two different spreading codes in a family of codes is defined as The Cross Correlation Function.

The user data rate was assumed to be as Bernoulli distributed, in the transmitter model, by the authors. A different PN code produced by PN generator is then multiplied with each user data with the help of XOR operator. Then with the help of QPSK and 16 QAM signal modulation is carried out. At the receiver, before the signal gets demodulated, the user data is separated from PN code by XOR logical operator. The bit rate of 384Kbps for the signal generator was assumed by them throughout the work. In AWGN & Rayleigh channel QPSK modulation technique has a better performance compared to that of 16-QAM, this is consistent with the simulations results obtained. As the mobility is increased from 60kmph to 120 km/ph for both QPSK and 16-QAM, the performance of QPSK and 16-QAM modulation technique in W-CDMA system degrades.
Vikas Gupta & Ruby Tiwari [6] analyzed the BER performance of MC-CDMA system for Rayleigh fading channel in presence of Additive White Gaussian Noise. BER is evaluated for, different different path gains, number of users and different number of subcarriers.

They introduce MC-CDMA as DS-CDMA system modulated by an OFDM carrier, the number of sub carriers depends upon the length of spreading code used with DS-CDMA. They also told that the major difference between MC-CDMA and OFDM is the subcarriers in MC-CDMA at any instant transmit the one symbol but in OFDM each subcarrier transmit separate symbol. They also compare MC-CDMA system with DS-CDMA system. DS-CDMA is a method to share spectrum among multiple users simultaneously. DS-CDMA with a spread factor N can accommodate N simultaneous users only if highly complex interference cancellation techniques are used which is practically difficult to implement. MC-CDMA can handle N simultaneous users with good BER, using standard receiver techniques.

At the transmitter, each user's modulated signal is spread by a pre-assigned spreading code. The frequency domain spread signal is interleaved and then converted into time domain by IFFT. Here the interleaving operation is used to map the chips of each symbol into equally-spaced subcarriers. At the receiver, after removing the cyclic prefix, the time domain signal is converted into frequency domain by FFT and a frequency domain MMSE (Minimum Mean Square Error) equalizer is implemented to recover the orthogonality of the spreading codes. Then the equalized signal is despread directly to obtain the desired user's signal. They used BPSK modulation at the transmitter and detected by using the maximum likelihood method in the demodulation at the receiver. Cyclic Prefix is added to protect the symbol and Walsh codes are used as spreading codes.

All results are evaluated for 10^3 bits of transmission, the length of spreading code is same as number of sub-carriers and the SNR varies from 0 to 20 db. For the Rayleigh channel, four paths has been considered and the delay for each path is taken as multiple of $\lambda/2$.

Simulation results show that BER reduces for increase in sub-carriers as it decreases the effects of multipath fading (For single user, 4, 16 & 64 subcarriers are there and path gains are P_1=0.7, P_2=0.3, P_3=0.0 & P_4= 0.0). In case of single user and multiple users (2, 8 & 32 users) for 4, 16 & 64 sub carriers and path gains P_1=0.7, P_2=0.1, P_3=0.1 & P_4= 0.1 BER response is almost same.

Aun & Zhao [10] analyze modulation techniques of W-CDMA in Multiple Rayleigh Fading Channels. They estimate the BER for analytical designed QAM and QPSK system model. For AWGN channel QPSK is better technique than QAM, BER degrades when number of users are there and it also reduces in both AWGN & Rayleigh channel for Doppler shift from 60 Km to 120 Km.

Rim Haddad & Ridha Bouallegue [8] estimates the BER evaluation of two types of Antenna Array based receivers in a multipath channel. The authors use an analytical model for evaluating the mean BER of two smart antenna receivers i.e. BPSK smart antenna receiver and OQPSK smart antenna receiver. The analysis is performed assuming Rayleigh and Rician fading multipath environment.

They assume that all signals are uncorrelated and each user transmits Binary Phase Shift Keying (BPSK) symbols. BPSK receiver model also consist of adaptive antennas and multiuser detection receivers.

OQPSK signal model is defined for K users and two independent BPSK signals are combined. OQPSK receiver model consists of the antenna array block, PN despreading, Beamforming, Walsh correlation and demodulation.
For BPSK receiver model simulation results shows that for average BER vs. number of users K for no fading and Rayleigh fading channels (L=1 path), for M= 8, 16 antennas BER is almost same even for number of paths L=1,2, 4.

For OQPSK receiver model BER vs. E_b/N_o for M=8, K=1 for single path and Rice Factor K_r= 1,5, 7, 10 dB in Rician fading. For low values of Rice factors, performance closes to Rayleigh fading. For larger Rice factors, there is tremendous improvement in average BER and also as the number of user increases performance of the system decreases gradually.

V. Conclusion:

It has been seen that various coding techniques can be efficiently used to improve BER with different parameters and these can also simulate within different system model. Some of the limitations & advantages are also summarized for some particular methods to improve these kinds of issuses.

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