LDPC CODED MULTIUSER MC-CDMA PERFORMANCE OVERMULTIPATH RAYLEIGH FADING CHANNEL

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ABSTRACT

This work presents the simulation of a Low density Parity Check (LDPC) coding scheme with multiuserMulti-Carrier Code Division Multiple Access (MC-CDMA) system over Additive White Gaussian Noise (AWGN) channel and multipath fading channels. The decoding technique used in the simulation was iterative decoding since it gives maximum efficiency with ten iterations. Modulation schemes that used are Phase Shift Keying (BPSK, QPSK and 16 PSK), along with the Orthogonal Frequency Division Multiplexing (OFDM). A 12 pilot carrier were used in the estimator to compensate channel effect. The channel model used is Long Term Evolution (LTE) channel with Technical Specification TS 25.101v2.10 and 5 MHz bandwidth including the channels of indoor to outdoor/ pedestrian channel and Vehicular channel.
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منظومة(LDPC-MCCDMA)متعدد المستخدمين

الخلاصة

يقدم هذا العمل محاكاة (LDPC) مع (MC-CDMA)متعدد المستخدمين خلال قناة (AWGN) وقناة الخفوت متعدد المسارات . تقنية فتح الشفرات المستخدمة في البحث هي فك الشفرات التكراري لأنه يعطي الكفاءة القصوى مع عشرة تكرارات . نوعيات التضمين المتبعة هي (BPSK,QPSK,16PSK) مع (OFDM) . القناة المستخدمة في النموذج هي قناة الجيل الثالث (LTE) ذات المواصفات التقنية TS 25.101v2.10مع عرض قناة مقداره 5MHz وتشمل القنوات داخل وخارج ألابنيه والقنوات المتحركة .

KEY WORDS

MC-CDMA, OFDM, LDPC, SUM-PRODUCDECODING ALGORITHM, CONVOLUTIONAL CODING.

INTRODUCTION

Recent studies by researchers have combined the principles of CDMA with Orthogonal frequency Division Multiplexing (OFDM) which allows one to use the available spectrum in an efficient way to retain the many advantages of CDMA system if the number of spacing between subcarriers is chosen appropriately, it is unlikely that all the subcarriers will be in deep fade and thus provides frequency diversity [Laith 2007]. This combination of OFDM and CDMA is an alternative for 4G systems, which has the property of variable data rates as well as provides reliable communication systems.

Since 1993, MC-CDMA rapidly has becamea topic of research. Wireless mobile communication systems present several design challenges resulting from the mobility of users throughout the system and the time-varying channel (Multi-path fading). There has been an increasing demand for efficient and reliable digital communication systems. To tackle these problems effectively, an efficient design of forward error coding (FEC) scheme is required for providing high coding gain.

Low-Density Parity-Check (LDPC) codes with iterative decoding algorithm were proposed by Gallager in 1962 [Gallager 1962, MacKay 1997]. These codes have been almost forgotten for about thirty years, in spite of their excellent properties. However, LDPC codes are now recognized as good error correcting codes achieving near Shannon limit performance [Gallager 1963].

MC-CDMA SYSTEM DESCRIPTION

A complete block diagram of an LDPC codedmultiuserMC-CDMA systemis shown in Fig. 1. The data coming from each user is first encoded with the LDPC coding technique. A single data symbol is replicated into N parallel copies. Each branch of the parallel stream is multiplied by one chip of a spreading code of length N. The resulting chips are then fed to a bank of orthogonal subcarriers. As is commonly done in MC-CDMA, it is assumed that the spreading sequence length N equals the number of subcarriers. Each user has its own spreading

code C_i.Pilot carriers with double energy are inserted at equal distances within the data.Carrier modulation is efficiently implemented using the inverse fast Fourier transform (IFFT)[Aqiel 2011,Husam 2010,Nathan 1993].

After parallel-to-serial (P/S) conversion, a cyclic prefix (CP) is appended to the resulting signal to minimizethe effects of the channel dispersion. It is assumed that the CP length exceeds the maximum channel delay spreadand therefore, there is no interference among successively transmitted symbols (i.e. there is no interblock interference).

At the receiver side, opposite operation to that done at the transmitter is done. These operations are the OFDM demodulation, dispreading, MPSK demodulation, demapping and the LDPC decoding. For more details about the MC-CDMA system refer to references Husam 2009 and Aqiel 2011 published by the author. Finallydecoding the data stream from every user individually using the iterative decoding algorithms for the LDPC coding scheme.

LDPC CODING

LDPC codes are linear block codes specified by a very sparse (containing mostly 0's and only a small number of 1's) random parity-check matrix, but are not systematic. The parity-check matrix of an LDPC is an $M \times N$ matrix **A**, where M is the number of parity bits, and N is the transmitted block length ($N = K + M$, with K as the source block length). The matrix **A** is specified by a fixed column weight j and a fixed row weight $k = j\,N/M$ (in the MacKay's and Neal's codes k is as uniform as possible [MacKay 1999]), and code rate $R = K/N$. it has been reported that when the block length is relatively large, irregular LDPC codes with nonuniform column weight outperform turbo codes with almost the same block length and code rate [Richardson 2000]. LDPC codes can be decoded using probability propagation algorithm known as the sum-product or belief propagation algorithm [Kschischang 2001], which is represented by a factor graph that contains two types of nodes: the "bit nodes" corresponding to a column of the parity-check matrix, which also corresponds to a bit in

codeword and the "check nodes" corresponding to a row of the parity-check matrix, which represents a parity-check equation.

SUM-PRODUCTDECODING ALGORITHM

The decoding problem is to find the most probable vector x such that $\mathbf{A}x \bmod 2 = 0$, with thelikelihood of x given by $x_n \Pi_n f_n$, where $f_n^0 = 1 - f_n^1$ and $f_n^1 = 1/(1 + \exp(-2y_n / \sigma^2))$ for AWGN channel or $f_n^1 = (y_n / \sigma^2) \exp[-y_n^2 / 2\sigma^2]$ for Rayleigh channel, and y_n, σ^2 represent the received bit and noise variance, respectively. We denote the set of bits, n, that participate in check m as $N(m) \equiv \{n : A_{mn} = 1\}$, where A_{mn} represents the element of the mth row and nth column in the parity-check matrix. Similarly, we define the set of checks m in which bit n participates as $M(n) \equiv \{m : A_{mn} = 1\}$. We denote a set $N(m)$ with bit n excluded as $N(m) \setminus n$. The algorithm has two alternating parts, in which quantities q_{mn} and r_{mn} associated with each non-zero element in the matrix A are iteratively update. The quantity x q_{mn} is meant to be the probability that bit n of x is x, given the information obtained via checks other than check m. The quantity r_{mn} is meant to be the probability of check m being satisfied if bit n of is *x* considered fixed at x and the other bits have a separable distribution given by the probabilities $\{q_{mn'} : n' \quad N(m) \setminus n\}$. The aposteriori probabilities for a bit are calculated by gathering all the extrinsic information from the check nodes that connect to it, which can be obtained by the following iterative sum-product procedure [Luis 2006].

Step 1: Initialization The variables q_{mn}^0 and q_{mn}^1, which are the probabilities sent from the nth bit node to the *m*th check node along a connecting edge of a factor graph, are initialized to the values f_n^0 and f_n^1 ,respectively.

Step 2: Horizontal Step (bit node to check node) We define $\Delta q_{mn} \equiv q_{mn}^0 - q_{mn}^1$ and compute eq.(1) and eq. (2) for each m, n and x = 0,1 :

$$q_{mn}^0 = \prod_{n' \in N(m) \setminus n} q_{mn'}^0 \tag{1}$$

$$r_{mn}^0 = \{1 + (-1)^0 \Delta_{mn}\}/2$$

$$r_{mn}^0 = \{1 + \Delta_{mn}\}/2 \tag{2}$$

$$r_{mn}^1 = \{1 - \Delta_{mn}\}/2$$

Where, r_{mn} represents the probability information sent from the m_{th} check node to the nth bit node.

Step 3: Vertical Step (check node to bit node) For each n, m and x = 0,1 we update eq.(3):

$$q_{mn}^0 = \alpha_{mn} f_n^o \prod_{m' \in M(n) \setminus m} r_{m'n}^0 \tag{3}$$

Where, α_{mn} is a normalization factor chosen such that $q_{mn}^0 + q_{mn}^1 = 1$. We can also update the a posteriori probabilities q_n^0 and q_n^1, given by eq.(4):

$$q_{mn}^0 = \alpha_{mn} f_n^o \prod_{m' \in M(n) \setminus m} r_{mn}^0 \tag{4}$$

Where, α_n is a normalization factor chosen such that $q_n^o + q_n^1 = 1$.

Step 4: Check stop criterion soft decision is made on the q_n^1. The resulting decoded vector x^ is checked against the parity-check matrix A. If $Ax^{\wedge} = 0$,the decoder stops and outputs ^x. Otherwise, it repeats the procedure from the Step 2. The sum-product algorithm sets a maximum number of iterations: if the number of iterations reaches that maximum, the decoder stops and outputs ^x as the results of the decoding.

SIMULATIONRESULTS

The proposed system is illustrated in Fig. 1. A 20 Mbps was transmitted over the system. Since the channel for the 4th generation is not developed yet, therefore, the LTE channel specifications were used in the simulation process. These channels are Additive White Gaussian Noise AWGN, Vehicular channel. The modulation schemes are the MPSK with M=2,4 and 16. The simulation was done using the MATLAB R2010apackage. A flow

chart shown in the Fig.9 show the simulation process.

The system uses LDPC code. The LDPC specifications used are irregular [16384] parity check matrix of rate ½ .The decoding algorithm is Sum-Product Decoding Algorithm,whichis the soft decision type of message passing. This is compared to the convolution code (CC) with the Viterbi decoding algorithm and uncoded system. The performance of the LDPCdecoding depends upon the number of iteration of the decoder. Table 1 summarizes the system specifications for the channel.

Figs.2,3 and 4 shows the variations of BER versus SNR for AWGN channel for uncoded data, convolution coded data and LDPC coded data with MPSK with M= 2,4 and 16 respectively with AWGN channel.

Table 1Simulation parameters for the indoor to outdoor/pedestrian environment

No. of active users	4
Total Number of users	32
Spreading code	Walsh Hadmard
Available bandwidth	5MHz
Sampling Time	170 nS
Spreading factor	64
FFT size	256
Effective symbol Duration	55uS
Guard time duration	¼FFT length
No of paths	8
Doppler velocity	60Km/h
Modulation technique	PSKwith M = 2,4and 16
No. of iterations	10
Convolutional code generator polynomial	[53, 75] octal
CC decoding algorithm	Viterbi

Figs. 5,6 and 7showa comparison for the uncoded data, convolution coded data and LDPC coded data for the Rayleigh fading channel.

The effect of varying the iteration for the decoding algorithm for the LDPC coded data over Rayleigh fading channel is illustrated in Fig. 8 with iterations of 1, 25, 50. 75 and 100.

The increase of the number of iterationimprovesthe performance of the system.

Table 2 summarizes the obtained results as a comparison for AWGN channeland Multipath fading channelfor modulation techniques of bpsk, 4psk and 16psk with uncoded, convolution coded (CE) and LDPC coded data.
It can be noticed that there is an improvement in the results of the use of the LDPCcoding technique over others in many dB's of SNR.

Table 2: A comparison for SNR in dB for Uncoded, CE and LDPC for bpsk, 4psk and 16psk for BER of 10^{-4}.

M-psk	SNR/dB for AWGN channel			SNR/dB for indoor to outdoor// pedestrian channel			
	Uncoded	CE	LDPC	Uncoded	CE	LDPC	
2psk	5	3.8	2.9	18.2	7	5	
4psk	9	4.1	3.2	25	8.7	5.5	
16psk	22	12.4	6	--	19.5	15	

CONCLUSION:

From the results, it can be noticed that the LDPC gives a better BER for both the AWGNchannel and Rayleigh channel for low SNR and increase for higher values of SNR.

For AWGNchannel with LDPC coded data, the BER is around 10^{-4} for about 1 dB better than convolution coding and 2 dB better than uncoded system for BPSk and 6 dB gain over uncoded for QPSK . The gain increases as the order of modulation increases showing superiority for higher data rates. For low SNR the results contain a little difference from both uncoded data and convolution coded data.
For Rayleigh channel, at a BER of 10^{-4}, the performance of the LDPC coded MC-CDMA system is better than that with convolutional coding one by about 2 and 3 dB for BPSK and 4PSK modulation schemes respectively. It's better by 4.5dB than convolutional coding for 16PSK. The number of iterations was set to 10 which represents a low computational

complexity comparableto covolutional decoder. For better performance and higher computational complexity, the number of iterations can be increased to 100 as shown inFig. 8.

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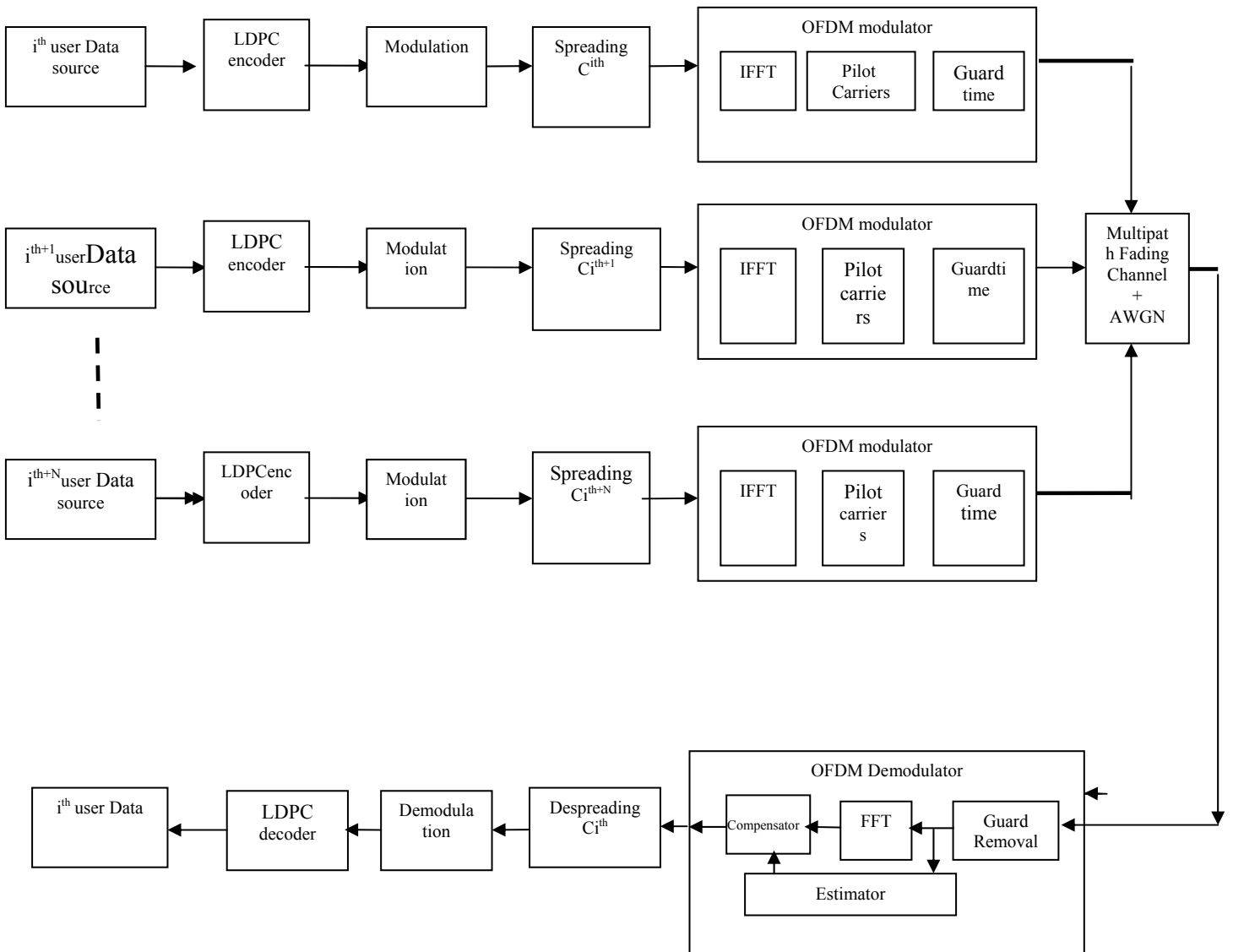
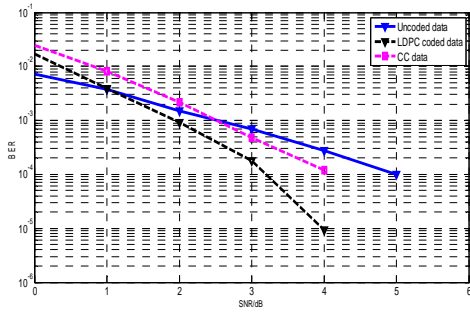**Figure 1 Block Diagram of the LDPC Coded MC-CDMA System.**

Figure 2 LDPC coded MC-CDMA performance for AWGN channel with BPSK modulation.
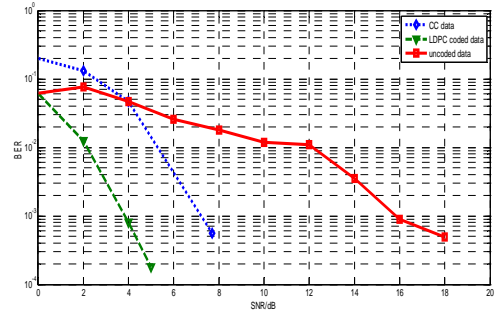

Figure 5 LDPC coded MC-CDMA performance for Rayleigh Fading channel with BPSK modulation.
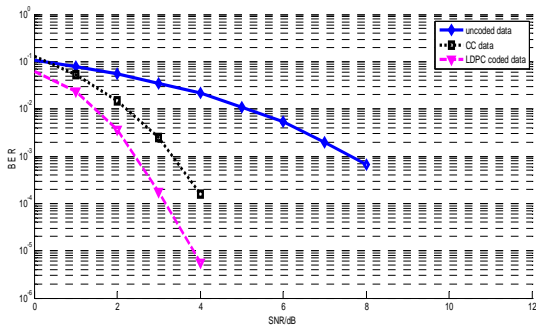

Figure 3 LDPC coded MC-CDMA performance for AWGN channel with QPSK modulation.
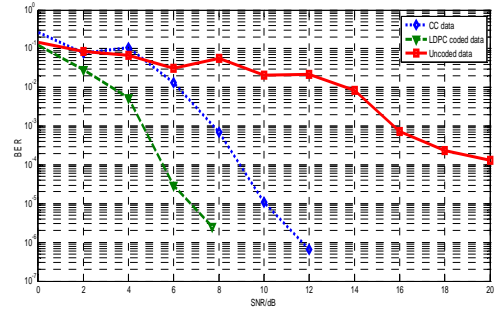

Figure 6 LDPC coded MC-CDMA performance for Rayleigh Fading channel with 4PSK modulation.
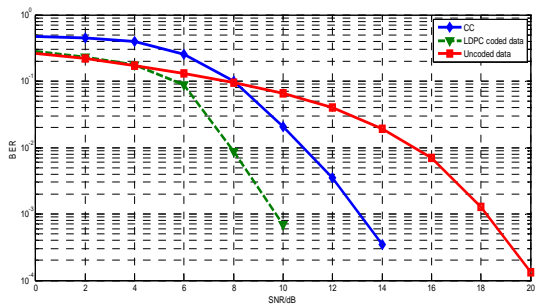

Figure 4 LDPC coded MC-CDMA performance for AWGN channel with 16PSK modulation.

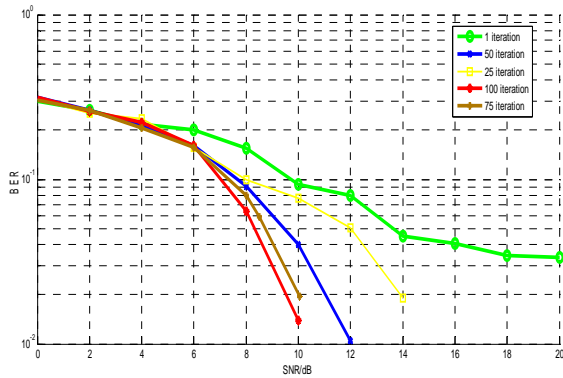**Figure 7 LDPC coded MC-CDMA performance for Rayleigh Fading channel with 16PSK modulation.**

Figure 8 LDPC coded MC-CDMA performance for Rayleigh Fading channel with 16PSK modulation with different number of iterations for decoding process.

Start

Initialize system parameters
From table (1),
Encoder, decoder modulator OFDM, Channel

Start SNR counter

Start Active users counter M

Generate binary data for each user

LDPC framing

LDPC Coding

QAMModulation

CDMASpreading and framing of ith user

Pilot carrier insertion

FFTand guard insertion

Multipath fading channel

Add the signal from active users' channel

Active users=M

No

Yes

Guardremoval IFFT

Pilot carriers extraction/ Channel estimation / equalization

CDMADespreading and Deframing of ith user

OAM Demodulation

LDPC decoding

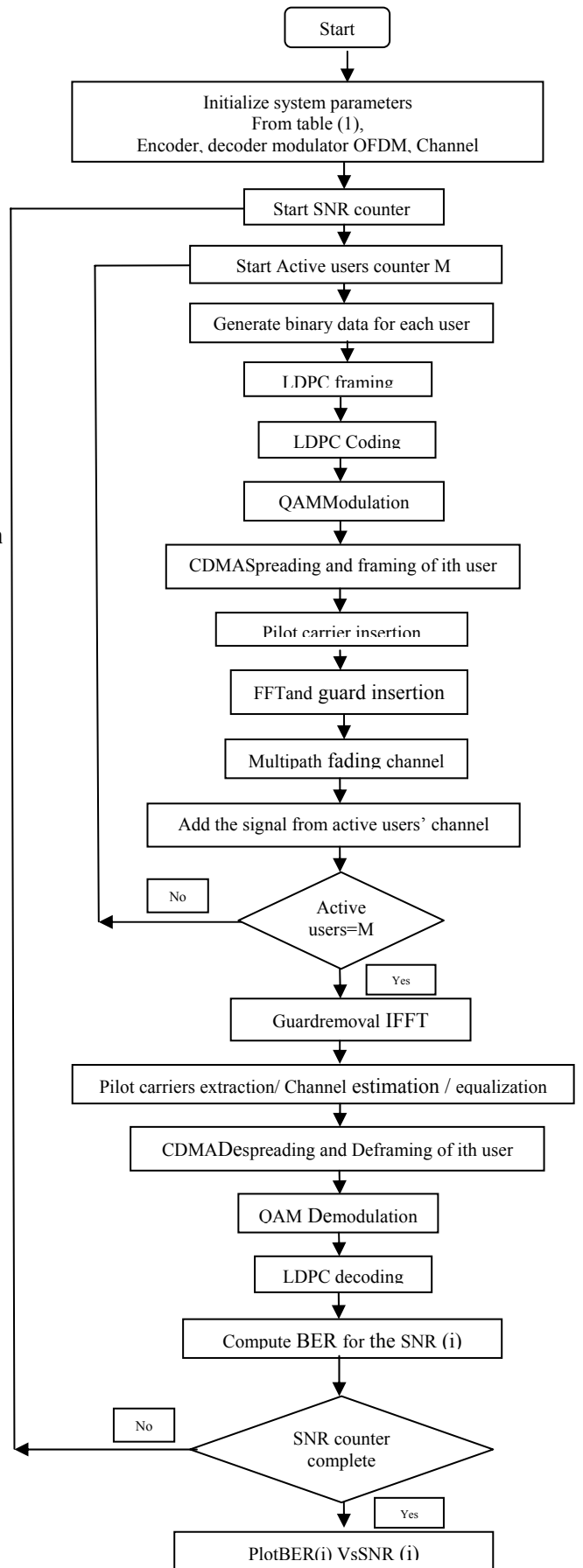Compute BER for the SNR (i)

SNR counter complete

No

Yes

PlotBER(i) VsSNR (i)

Figure 9Flow chart describe the simulation of the proposed system