Fbmc System With Low Density Parity Check (Ldpc) Coding For Efficient Communications In 5g

Ravi Sekhar Yarrabothu, Usha Rani Nelakuditi

Abstract: Channel coding is a complicated subject, but vital in cellular communications, which is used for detection and correction of the bit errors caused by various types of noises, interferences. In 3rd generation and 4th Generation (3G and 4G) cellular communications, Turbo codes are predominantly used and currently 3GPP standardization group considering the Low Density Parity Check (LDPC) code in 5G, due to its requirements of 20GB throughput, ultra low latencies and massive Internet of Things. In 5G Communication Filter Bank Multi Carrier (FBMC) wave form is considered for 5G and beyond communication for non-orthogonal communications due to its superior side-lobe suppression characteristics and also no need to use the cyclic prefix, which will save the bandwidth. With FBMC based systems, the Bit Error Rate (BER) performance is still not able to reach the LTE level, which uses Orthogonal Frequency Division Multiplexing (OFDM). In this paper, to achieve a better BER performance, it is proposed to use the LDPC coding with FBMC waveform for 5G communication and was simulated with Keysight SystemVue Software. The BER analysis is performed for both coded and uncoded data transmission for FBMC system with three different modulations: QPSK, 16QAM, 64QAM. The simulated results shows that the LDPC coding with 1/2 code rate is better than other code rates 2/3, 3/4 and 5/6.

Keywords: BER, FBMC, LDPC Codes, Polar codes, OQAM

I. INTRODUCTION

In a typical cellular system, the received data always differ with the transmitted due to the communication errors, which are introduced by the channel conditions like multipath fading, noise and co-channel interference. To correct these errors the channel coding is used in the cellular communication systems. The turbo codes [1] are getting used as the primary channel coding technique for the 3G and 4G cellular standards of Third Generation Partnership Project(3GPP) [2], [3], due to its outstanding error correction ability and flexibility. Although, the Turbo codes are sufficient for the 4G, 3GPP standardization body is presently considering other than the turbo codes for 5G with the Low Density Parity Check (LDPC) code [4],[5], which is a well proven in WiFi, WiMAX, Ethernet and DVB-S2 standards [6]-[9].

The 5G requirements such as peak throughput of 20Gbps, ultra low latency use cases and massive IoT devices connectivity needs an efficient communication coding technique. These requirements of 5G can be accomplished by flexible turbo codes [10], with much better hardware and energy efficiencies rather than by using flexible LDPC codes. However, with the inflexible LDPC coding, it can be achieve the with much superior hardware and energy efficiencies. A hybrid approach of Turbo/LDPC coding [11] for 5G is beneficial, in which flexible turbo codes are used for most of the use-cases and using inflexible LDPC codes for ultra high speed and low latency use cases.

In this paper, for 5G system based on FBMC is used since FBMC provides a better spectral efficiency and suitability for asynchronous communication [12]. This paper is organised in to four sections. II section explains the need for LDPC for 5G requirements and III section discuss the FBMC system design with LDPC code. IV section presents and analyses the results and finally section V conclusions are discussed.

II. LDPC CODES

The 5G New Radio (NR) access technology will make a landmark change in channel coding for 3GPP cellular technologies. Turbo codes, have played a vital role as a key coding scheme in the 3G and 4G cellular communications and is going to be replaced with the LDPC codes. The key driver for this evolution is the high throughput requirement (20 Gb/s) for 5G systems [13]. Both the Turbo and LDPC codes operate in a similar mechanism as the decoders in both are of message passing type where the information is propagated inside a graphical structure, which represents a code. The major distinction of LDPC codes are inherently parallel structured where as turbo codes are inherently serial structured. Hence the computation complexity for LDPC codes can be reduced by implementing greater parallelism in hardware implementations [14].

An ultra low latency of 0.5 ms in end-to-end system has to be achieved for the 5G NR, which is 20 times lower than the 10 ms achieved in 4G. Achieving an end-to-end latency of 0.5 ms implies a physical layer latency of 50 ?s [15], in which channel decoder must contribute a major share of this latency budget as many other physical layer components require higher latencies not possible to reduce.

The crucial factors for the selection of the Forward Error

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Correction (FEC) codes in communication systems are complexity in terms of area and power and its coding gain. In 5G communications, the selection of the channel coding scheme is based on its performance in terms of throughput(should be ultra high), latency (ultra low 0.5 milliseconds), good error correction capability, implementation complexity and the flexibility for various types of use cases. Keeping in view of these requirements, 3GPP standards body have adopted LDPC codes for data channels and polar codes for control channels in the 5G New Radio. In this paper an attempt is made to implement a 5G system with LDPC codes and FBMC as a waveform.

III. FBMC BASED 5G SYSTEM WITH LDPC CODES

FBMC based 5G systems are considered by 3GPP as well as other researchers as one of the potential technique for its superior spectral efficiency and support asynchronous communication [16]-[18]. In FBMC system, at both the transmitter and receiver the poly phase network (PPN) based prototype filters are used, since it provides lesser computational complexity. In this paper, FBMC system also uses offset quadrature amplitude modulation (OQAM) method is used for ICI, ISI elimination [19]. The basic block diagram of PPN FBMC transceiver system is shown in figure.1

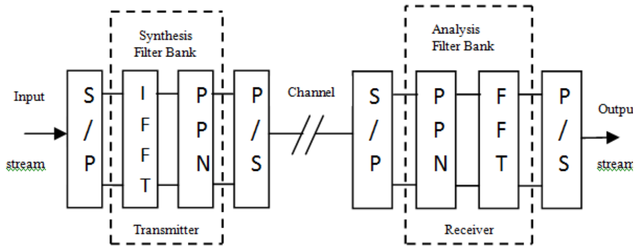

Figure 1. Block diagram of PPN-FBMC

The BER performance of the FBMC is more or less same as the OFDM systems [20] and to improve the BER performance, LDPC are to be used, so that the bandwidth efficiency can be improved. In this paper, LDPC encoding and decoding are chosen to be same as those in WLAN 11ac library. The code rate can only be selected from 4 options: 1/2, 2/3 ,3/4,5/6. The coded length can be selected from 3 options: 1944, 1296, 648. However, in this paper only code length of 1944 is tested as we are interested in higher throughputs.

The simulation of the FBMC system with LDPC code as shown in the figure 2 and is done by using Keysight SystemVue 2018 software.The frame of FBMC is composed of preamble symbols and data symbols. The preamble consists of two superimposed ZC (Zadoff-Chu) sequence. Time & Frequency synchronization, channel estimation and equalization are done at the receiver

IV. SIMULATION RESULTS

The simulated schemas were executed using SystemVue software (2018 version). The parameters that are set for the simulations in this paper are as given in table 2.

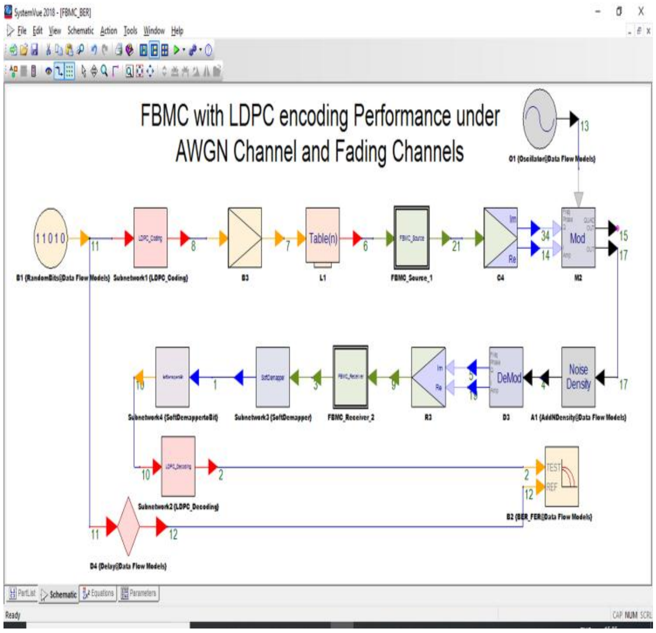

Figure 2.FBMC with LDPC Coding Schema

The BER analysis of FBMC system with various LDPC coding rates of 1/2, 2/3 ,3/4,5/6 and a coding length of 1944 bits under AWGN channel conditions. And also a comparison is performed with and without LDPC coding along various modulation techniques QPSK, 16QAM and 64QAM and are shown in the figures 3, 4 and 5.

Table 1. Simulation Parameters

Parameter	Value
Number of sub-carriers per symbol	128
Number of data symbols per frame	20
Type of modulation	OQAM
Channel Type	AWGN
Spreading factore	4
Filter bank structure	PPN-IFFT
Number of preamble symbols in a frame	6
LDPC Coding Rates	1/2, 2/3 ,3/4,5/6
LDPC Code Length	1944 bits

From figure 3, it can be observed that to achieve a BER of 10-4 for an uncoded data with QPSK modulation, it has to maintain an Eb/No value of 8.5 dB, where as for LDPC coded data with a rate of 1/2 can maintain an Eb/No value of 2.2 dB. This shows a gain of 6.2 dB due to LDPC coding rate of 1/2. One interesting aspect is for achieving the BER rates of 10-5 and 10-6, the coding gains are 7.2 dB and 8.0 dB as shown in the figure 3, which is better than compared to the higher BER values.

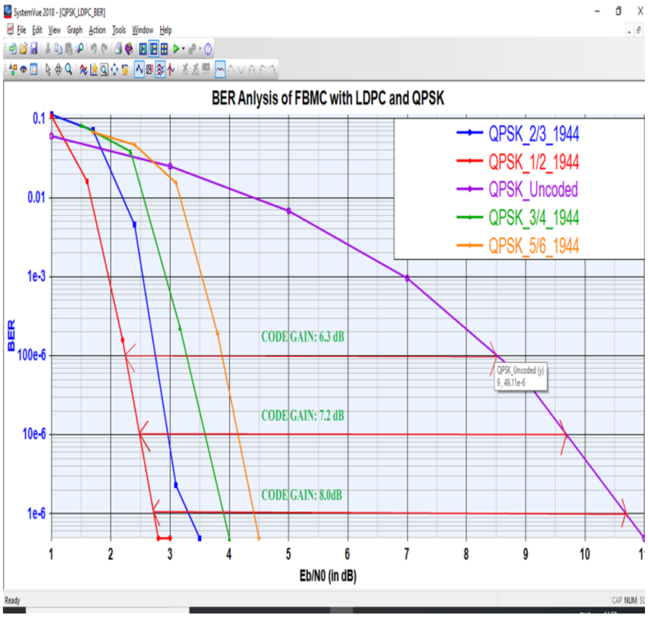

Figure 3. BER Analysis of FBMC with LDPC Coding and QPSK modulation

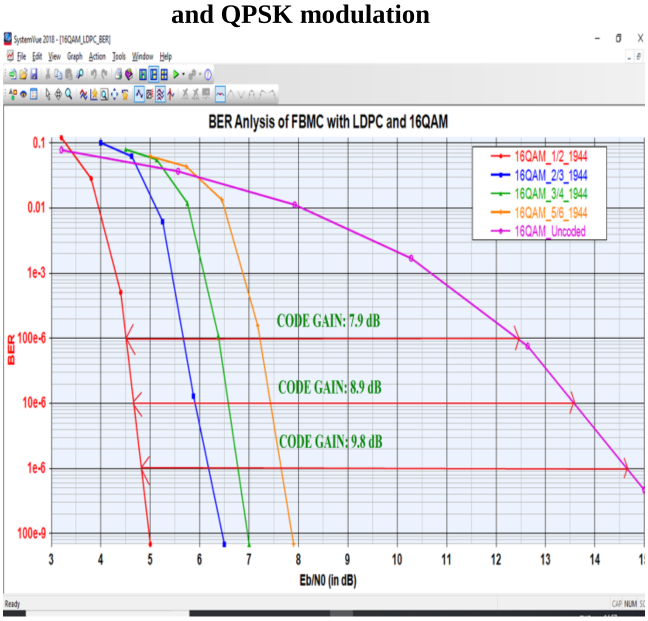

Figure 4. BER Analysis of FBMC with LDPC Coding and 16QAM modulation

From figure 4, it can be observed that to achieve a BER of 10-4 for an uncoded data with 16QAM modulation, it has to maintain an Eb/No value of 12.4 dB, where as for LDPC coded data with a rate of 1/2 can maintain an Eb/No value of 4.5 dB. This shows a gain of 7.9 dB due to LDPC coding rate of 1/2. One interesting aspect is for achieving the BER rates of 10-5 and 10-6, the coding gains are 8.9 dB and 9.8 dB as shown in the figure 4, which is better than compared to the higher BER values.

From figure 5, it can be observed that to achieve a BER of 10-4 for an uncoded data with QPSK modulation, it has to maintain an Eb/No value of 16.7dB, where as for LDPC coded data with a rate of 1/2 can maintain an Eb/No value of 7.3 dB. This shows a gain of 9.4 dB due to LDPC coding rate of 1/2. One interesting aspect is for achieving the BER rates of 10-5 and 10-6, the coding gains are 10.4 dB and 11.4 dB as shown in the figure 5, which is better than compared to the higher BER values.

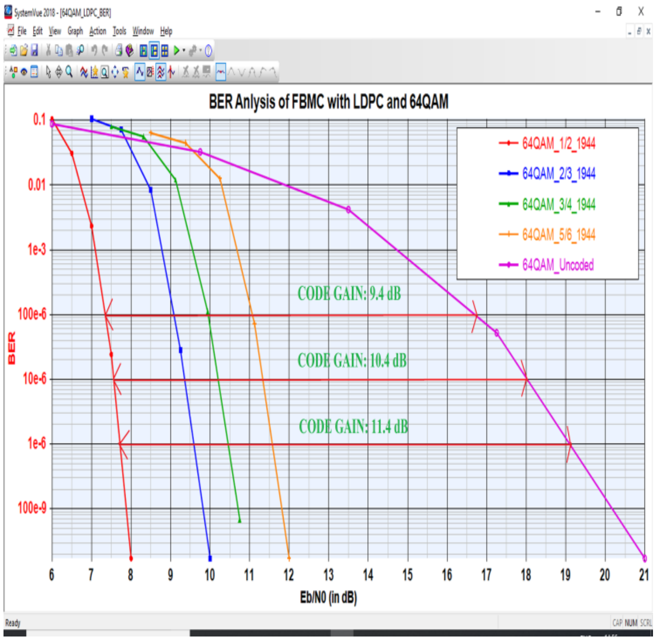

Figure 5. BER Analysis of FBMC with LDPC Coding and 64QAM modulation

One more observation from figures 3,4 and 5 is the coding gain increases as the order of QAM modulation increases and also coding rate of 1/2 gives a better performance when compared to the other coding rates.

V. CONCLUSION

In this paper The FBMC system with LDPC coding is simulated and performance is evaluated for various modulation techniques and also with various coding rates 1/2, 2/3 ,3/4,5/6 and a fixed coding length of 1944 bits under AWGN channel conditions. It has been concluded that the LDPC codes provide a very good coding gain when compared with un-coded data and also the coding gain increases gradually as order of QAM modulation increases. And also as we achieve better BER performance the coding gain also higher. This work can be extended to perform the BER analysis for multipath fading conditions, so that the real time cellular conditions can be tested.

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