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Research paper

Arithmetic and Huffman Coding using Quasi-Cyclic Low Density Parity Check Techniques with F-OFDMA for 5G System

Azlina Idris[1]*, Nurul Aini Amran[2], Mohd Syarhan Idris[3], Idris Taib[4], Murizah Kassim[5], Suzi Seroja Sarnin[6], Wan Norsyafizan W Muhammad[7], Norsuzila Ya'acob[8]

[1235678]Faculty of Electrical Engineering, Universiti Teknologi MARA (UiTM)
Wireless Communication Technology (WiCOT)
40450 Shah Alam, Selangor, Malaysia.
[4]Infrastructure University Kuala Lumpur, 43000 Kajang, Selangor, Malaysia.
**Corresponding author E-mail: azlina831@salam.uitm.edu.my*

Abstract

The rising demand of the future 5th generation (5G) wireless systems has led to the development of wireless communication technologies that can provide higher user capacity. Therefore, filtered orthogonal frequency division multiple access (F-OFDMA) was introduced to accommodate large number of users. F-OFDMA has the advantage over OFDM since it is capable of overcoming the high side lobes and increasing the spectrum utilization by eliminating the out-of-band emission which can degrade the system's performance. In this paper, a joint method between two block coding techniques (Arithmetic coding (AC) and Huffman Coding (HC)) with an error correcting code (Quasi-Cyclic Low Density Parity Check (QC-LDPC))was proposed. AC-QC-LDPC and HC-QC-LDPC schemes were compared in terms of BER performance. Based on the simulation results, AC-QC-LDPC technique has been proven to give the 44.75% BER improvement to the F-OFDMA system which outperforms the HC-QC-LDPC technique. It is clear from the results that Arithmetic coding always give better BER improvements compared to Huffman coding with QC-LDPC.

Keywords: *Filtered-Orthogonal Frequency Division Multiple Access (F-OFDMA), Arithmetic Coding (AC), Huffman Coding (HC), Quasi-Cyclic Low Density Parity Check (QC-LDPC)*

1. Introduction

In the recent exponential growth of modern wireless communication, the development of wireless technologies is expected to accommodate the increasing number of consumers that demands for high data rate wireless communication access. Due to this, efficient and easily accessible services of wireless applications are highly demanded by many telecommunication companies all over the world in order to satisfy their customers' needs [1]. This generation of wireless technologies is now becoming an essential platform that can provide short and long range communications which can connect worldwide users. Many current wireless applications such as internet access, mobile computing, and multimedia stream require high data rate wireless communication access in order to suit the recent lifestyle of users. Therefore, the 5th generation wireless system (5G) is the next generation wireless networks standard that can fulfill these criteria as it aims for achieving higher user capacity, more reliability and higher data rate than the 4th generation wireless system (4G) [2].

However, one of the most challenging issues that occur in F-OFDMA system includes the high peak to average power ratio (PAPR) in the transmitting signal which causes the system to become very sensitive to the non-linear high power amplifier (HPA) at the transmitter [3], [4]. As a result, the degradation of receiver's detection efficiency increases and the system's performance is severely reduced [5]. The high PAPR causes the non-linear HPA to produce additional interference into the system which degrades the bit error rate (BER). Since the inter-symbol interference (ISI) is associated with BER, therefore it also increases and becomes a factor for the impairment of the overall system's performance [6].

Over the years, various techniques have been proposed to address these impairments but they still encounter with some drawbacks in terms of BER degradation and computational complexity [5], [7],[8]. Moreover, research made on BER reduction for F-OFDMA systems are very limited. Block coding techniques such as Arithmetic Coding (AC) and Huffman Coding (HC) are classified as lossless data compression algorithms which can be used to overcome the PAPR problem in OFDM system [9],[10]. However, the BER degradation and computational complexity still need further improving. This paper proposes a joint technique between AC and HC with an error correcting code, QC-LDPC with the aim to further reduce the high BER and give better improvement in 5G system.

2. Research Method

2.1. Filtered Orthogonal Frequency Division Multiple Access (F-OFDMA)

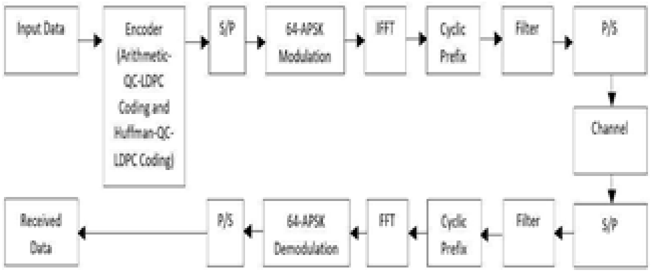


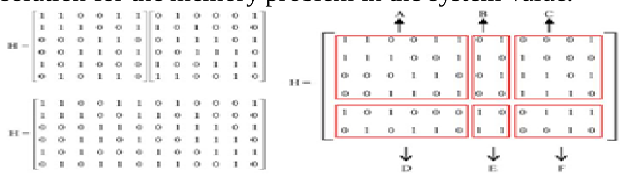
Figure 1: Block Diagram of F-OFDMA Transceiver System [11]

The F-OFDM system was previously proposed in order to overcome the drawbacks of OFDM since OFDM have a high sensitivity to the carrier frequency offset (CFO) mismatch which occurred between the user equipment. Figure 1 illustrates the block diagram of the F-OFDMA transceiver system. The proposed system is able to provide better BER over OFDM and F-OFDM. In this paper, F-OFDMA has been proposed to fulfil the 5G requirements by providing massive connectivity for the wireless access with the implementation of FDMA. The F-OFDMA algorithm is as follows: Firstly, the F-OFDMA split up the assigned bandwidth into a number of subbands after the process of encoding using QC-LDPC technique [12].

Next, the signal waveform of conventional OFDM in each subband is arranged in order to suit the requirements of the types of services and channel characteristics. Then, filtering is applied for suppressing the inter-subband interference. In each subband, the time-domain orthogonality between the consecutive OFDM symbols is intentionally broken to provide lower out-of-band emission (OOBE) that has negligible performance loss. Therefore, the asynchronous transmission across subbands can now be supported where the global synchronization is no longer required [13].

2.2. Quasi-Cyclic Low Density Parity Check (QC-LDPC).

A joint technique between AC and HC with an error correcting code known as Quasi-Cyclic Low Density Parity Check (QC-LDPC) was proposed in this paper in order to obtain a further reduction in the BER values. QC-LDPC has the ability to reduce BER in F-OFDMA system and can be used for error correcting performances in the system. This is due to the structure of the QC-LDPC code which allows for parallel encoding and decoding processes and hence, can be considered as a trade off between the encoding complexity and encoding speed [14]. Moreover, the QC-LDPC code has a linear time encoding ability which makes the memory requirement of the code really small thus giving a solution for the memory problem in the system value.



2(a) 2(b)

Figure 2: (a) Parity Check Matrix after Circulant Shift (b) Obtained QC-LDPC Block Structure

Figure 2(a) represents the obtained weight of the matrix after the shifting operation is done. The weight of the column and row remains uniform throughout the shifting process and the codeword that has been encoded through the generator matrix must follow the property of CHT = 0, where C is a codeword [14]. Finally, the block structure of QC-LDPC based on the parity check matrix was obtained as in Figure 2(b).

3. Results and Analysis

3.1. BER Performance

i. F-OFDMA System

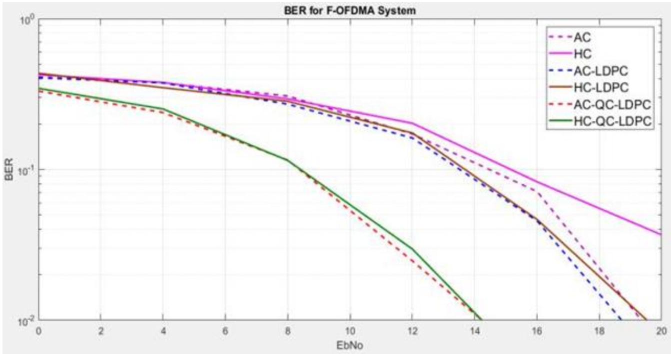


Figure 3: BER vs SNR (Eb/No) for F-OFDMA System

Table 1: BER Values for F-OFDMA Systems

F-OFDMA						
SNR (dB)						
BER	HC	AC	HC-LDPC	AC-LDPC	HC-QCLDPC	AC-QCLDPC
10^{-1}	15.15	14.46	13.68	13.52	8.40	8.37

Figure 3 shows the bit error probability curve for F-OFDMA system where the BER values are read at 10-1 and are listed in Table 1. For comparison purpose, the bench mark is set to the BER value of F-OFDMA using HC technique. From analysing the BER values listed above, it can be seen that the BER performance for F-OFDMA with AC-QC-LDPC gives the highest improvement of 44.75% whereas HC-QC-LDPC improves the BER value by 44.55%. Moreover, the BER for F-OFDMA system with AC-LDPC and HC-LDPC is better by 10.76% and 9.7% respectively, while AC only gives an improvement of 4.55% to the BER value compared to HC.

ii. OFDMA System

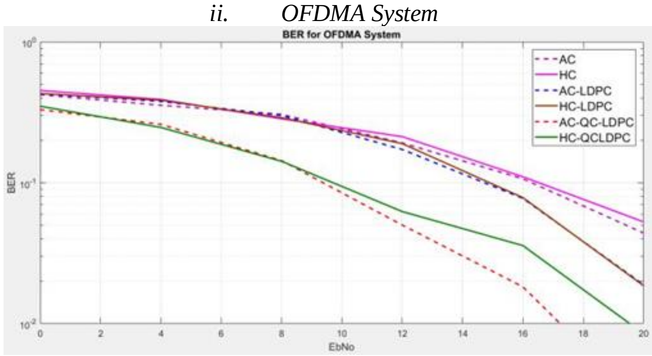


Figure 4: BER vs SNR (Eb/No) for OFDMA System

Table 2: BER Values for OFDMA Systems

OFDMA						
SNR (dB)						
BER	HC	AC	HC-LDPC	AC-LDPC	HC-QCLDPC	AC-QCLDPC
10^{-1}	16.54	16.30	14.90	14.72	9.72	9.38

Figure 4 represents the BER performance for OFDMA system while Table 2 shows the BER values obtained at 10-1. As previously mentioned, the threshold value is set to the BER for OFDMA system when using HC method. Based on the results, the BER performance for OFDMA using AC-QC-LDPC is increased by 43.29% whereas HC-QC-LDPC improved the BER value by 41.23%. Furthermore, BER improvement of 11% and 9.92% is obtained for OFDMA using AC-LDPC and HC-LDPC respectively, while AC reduces the BER degradation by only 1.45%.

As QC-LDPC error correcting codes achieved good BER reduction for both F-OFDMA and OFDMA systems, it also helps the system to achieve high BER performances. This can be proven by analysing the results obtained from Figure 3 and Figure 4. It can be clearly seen that there is a significant improvement in the BER performances after implementing the QC-LDPC codes to the block coding techniques. LDPC codes also reduce the BER value by giving a considerable BER improvement to the system. Thus, QC-LDPC is still better than LDPC in terms of achieving high BER as well as high PAPR performances to the system. Similar to the PAPR results, AC always provide better BER improvements compared to HC. Hence, the joint technique of AC with QC-LDPC gives the best BER and PAPR improvements to the OFDMA system.

It can be concluded that the BER performance of the F-OFDMA and OFDMA systems can be further improved by implementing the joint technique between QC-LDPC error correcting codes with block coding techniques which is AC and HC.

Table 3: Summary of BER Values for F-OFDMA and OFDMA

BER Values		
	F-OFDMA	OFDMA
Arithmetic	14.46	16.30
Arithmetic + LDPC	13.52	14.72
Arithmetic + QC-LDPC	8.37	9.38
Huffman	15.15	16.54
Huffman + LDPC	13.68	14.90
Huffman + QC-LDPC	8.40	9.72

Table 3 shows the summary of all BER values for F-OFDMA and OFDMA systems. Referring to the Tables 3, it is clearly seen that QC-LDPC coding gives the BER improvement to both systems and much better than LDPC coding. Other than that, AC always outperforms HC in achieving better BER improvements. Moreover, F-OFDMA system provides significant BER reduction as compared to OFDMA.

4. Conclusion

In this paper, the two block coding techniques Arithmetic and Huffman coding were combined with an error correcting code which is QC-LDPC and was proposed as a method to improve the BER performance in F-OFDMA system. The simulation results show that AC-QC-LDPC for F-OFDMA system provides the improvement of BER performance by 44.75% and hence the AC-QC-LDPC technique for F-OFDMA gives better BER performance compared to the OFDMA. Furthermore, QC-LDPC was chosen as the best error correcting technique over LDPC due to its circulant shift structure that provides significant improvements of BER performances to the system.

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