Variable Length Error Correcting Code in Long Term Evolution

Prof. Dr. Tarik Zeyad Ismaeel
Department of Electronics and Communication Engineering
Baghdad University, Baghdad, Iraq

Zina Osama Dawood.
Department of Electronics and Communication Engineering
Baghdad University, Baghdad, Iraq

Abstract - This paper presents a MATLAB simulation that has been developed to investigate joint source code with channel code in a single step, with Orthogonal Frequency Division Multiplexing (OFDM) communication system using variable length error correcting Coding process (VLEC). The efficient encoding and decoding algorithm, and the power of error correction capability of (VLEC) make it one of efficient way that used in compression and error correction codes, algorithms, so the code used with OFDM systems to combine the benefits of multicarrier modulation and (VLEC) to get a system that has the excellent performance capability in multipath and fading channels. The bit error rate and the signal to noise ratio are calculated during each test on the system. Simulations show that the realized optimal VLECs in terms of reduce complexity and error rate performance.

Keywords –: Variable-Length Error-Correcting (VLEC) Codes, Joint Source-Channel Coding, Greedy algorithm, Majority voting algorithm, Heuristic algorithm, orthogonal frequency division multiplexing (OFDM) altered Viterbi algorithm.

I. Introduction

With the fast growth of digital communication, the need for high-speed data transmission has increased. Modern multicarrier modulation techniques such as16 -QAM Orthogonal Frequency Division Multiplexing is currently being implemented to maintain with the demand for more communication capacity [1]. So OFDM became practical and economical [2].OFDM is especially suited for high-speed communication because of its resistance to inter-symbol interference (ISI). ISI occurs when a transmission interferes with itself and the receiver cannot decode the transmission correctly. Coding in OFDM systems are able to obtain superior performance on frequency selective channels because of the common benefits of multicarrier modulation and coding [2, 3].Source code used to remove redundancy in source, performs the representation is called a source encoder. This transforms the message into a finite sequence of digits. While channel coding is utilized in communication systems to protect the information from noise and interference. Channel coding introduced additional bits which allow detection and correction bit errors in receiving bits and provided reliable transmission, but protection of information from error was caused reduction in data rate, or expansion in bandwidth [7]. Error correcting code can divide in two classes: block and convolution code. A Block codes process the information on a block –by block basis, dealing with each block of information independently from others, block coding is memory less operation. On the other hand the convolution encoder depend not only the current input information, but also on previous inputs or outputs [8].The primary dispute between these types of codes and variable length error correcting codes is the code words are variable length. But VLECs is similar to block codes in the concept of each information is mapped to code word independently from pervious inputs, also the main characteristics are very similar to those of convolution codes by the fact that the position of any code word within the encoded message depends on the previously occurring code words and "variable length error correcting code shown from of spatial memory". VLECs, which play the dual role of good data compression and error-correcting codes, provides an interesting alternative to the classical separate source channel code scheme, particularly when the system's complexity can be significantly reduced while maintaining a satisfactory performance. [9]

The rest of the paper is organized as follows. Basic concept and parameters of variable length error correcting code proposed in section II. Generation of VLEC, Decoding of VLEC presented in sections III and IV. This is followed by the simulation tests and results in section V. Finally the main concluding remarks are given in section VI

II. BASIC CONCEPTS OF VARIABLE LENGTH ERROR CORRECTING CODE

Let x be a binary code with a finite sequence $x = x_1 x_2 \dots x_l$ of code symbols is called a word over X of length $|x|$=L, where $x_i \in$ X, for all i=1, 2, 3…… l, if x=ps, then p is a proper prefix of x and s is a proper suffix of x, where x,p ∈ X. A set C of words is called a code. Let the code C has s code words $\{c_1, c_2, \dots, c_s\}$ and let $l_i = |c_i|$ and p(c_i) denote the lengths and probability of occurrence of the data source symbol mapped in to word c_i=($c_{i1} c_{i2} c_{i3}$…….c_{il}) where i=1,2,3……s. without loss generality $l_1 \le l_2 \dots \le l_s$.

Let σ denote the number of different code word lengths in code C and let these length be L_1, L_2,…… L_σ, where $L_1 \le L_2 \dots \le L_\sigma$.

Let the number of code words with lengths L_i be s_i,and number of code words with length less than L_i be $\hat{s}_i$, i.e. $\hat{s}_i = \sum_{j=0}^{i-1} s_j$. Note that $\hat{s}_1$=0 and that $L_1 = L_{\hat{s}_{1+1}} = l_1$, $L_2 = L_{\hat{s}_{2+1}}$,……., $L_\sigma = L_{\hat{s}_{\sigma+1}} = l_s$ and s=$\sum_{i=1}^{\sigma} s_i$ (s_1@L_1; s_2@L_2…….s_σ@L_σ).[10]

Let $f_i = c_{i1}, c_{i2}$,……. c_{in}, $c_{ij} \in$ C ∀j=1,2,3……n ,be the concatenation of n words of VLEC code C. The set $F_N = \{f_n : |f_n| = N\}$ is called the extended code of the variable length error correcting code of order N[13].

A. VARIABLE LENGTH ERROR CORRECTING CODE PARAMETERS

The variable length error correcting code will be considered to be trills codes, their "memory "not from storage element, but from the locative information. Then, the properties of VLEC should be similar to those of trills codes or convolution codes.

Definitions1*:* The hamming weight W(C) is defined as the number of non-zero symbols in the code word.

Definitions2: The minimum block distance b_m associated to codeword l_m of code C defined as the minimum hamming distance between all codeword in the same length (with length l_m). [10]

$$b_m = \min \{h(c_i, c_j)\} \qquad (1)$$

Where (c_i, c_j) ∊ C , $i \neq j$ and $|c_i| = |c_j| = l_m$

Definitions3*:* The diverge distance defined as the Hamming distance between two code word of unequal length d(ci , cj) ,| ci | and | cj |.

$$d_{min}\{d(ci , cj)\} \qquad (2)$$

Where c_i and $c_j \in C$, $|c_i| \neq |c_j|$.

Definitions4*:* The converge distance defined as the Hamming distance between two code word of unequal length d(ci , cj) ,| ci | and | cj |.this is mean length suffixes of code word c_i and c_j.

III.GENERATION OF VARABLE LENGTH ERROR CORRECTING CODE

1. The Greedy Algorithm (GA) or the Majority Voting Algorithm (MVA) is the first step in the flow chart," fixed-length code of length L1 and minimum distance b_{min}. This step, as all the following determination of sets of same length words at a given distance, is done either by (GA) or (MVA). [4]
2. Specify a set of W that contains all L_1-Tuples having at least a distance d_{min} from each codeword in C. If the set W is not empty, an extra bit is affixed at the end of all its words. This new set having twice the number of words replaces the previous set W.
3. Delete all words in the set W that do not have at least a distance c_{min} from all code words of C. At this point, the set W satisfies both the d_{min} and c_{min} minimum distance requirements with respect to the set C.

4. Select the specific code words from the set W that are at a distance of b_{min} using the GA or the MVA. The selected code words are then added to set C.

This procedure is repeated, until it gets the required number of code words or has no more options to explore. If no more code words of the required properties can be found, or if the maximal code word length is reached, shorter code words are deleted until one finds the required VLEC code structure.

5. This procedure stops when there are no further passable words to be found or else when the required number of code words reached [11, 12].

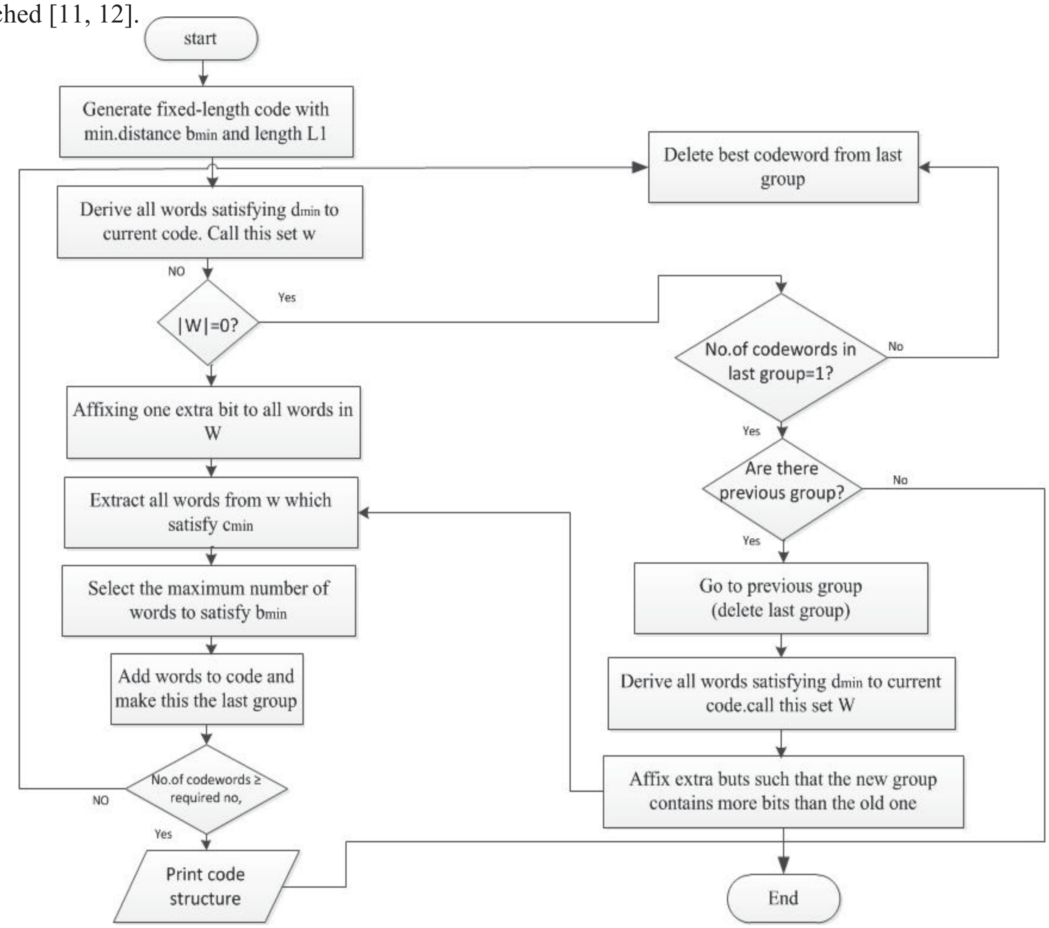

Figure 1. Flow chart of the heuristic algorithm

IV. DECODING OF (VLEC)

The trellis of convolution codes has a regular structure, by taking advantage of the repetitive design of trellis in decoding. The Maximum likelihood is simply too complex and inefficient to implement an effective solution for decoding problem is a dynamic program algorithm known as the viterbi decoder (VD). [12]

The VLEC codes very much like convolution codes therefore this algorithm is modified to altered version of viterbi decoding algorithm [9].A maximum likelihood decoder dealing with received code bit –by –bit and when assuming all paths are equally probable). The altered version of the viterbi decoding algorithm will be, as follows:

Let the received sequence of N bits y=y_1 y_2 ....y_n and M_1 denote the metric of the surviving path at state s_1. A basic decoding steps Initialization: assign M_0=0, and $M_1 = \infty, \forall$ i > 0. Assume the current state and take initial value i=0.

1. Branch metric computation $c_j \in C$ for all code words, evaluate the branch metric m_j=h(c_j, y_{i+1}, y_{i+lj}).

2. Flag, compare and store

Flag Si+lj as a visited state. If mj + Mi < Mi+lj, then store this code word for the transition

Si → Si+lj (overwriting any other previously stored transitions to state Si+lj), and make Mi+lj = mj + Mi.

3. Increment counter (i): Increment i to the next visited state and until i > N–l_1.

4. The surviving path to state $S_N$represented the decoding sequence of receiving message, and the number of bits in the decoded codeword sequence is equal to N, the decoded sequence is a codeword ofF_N.

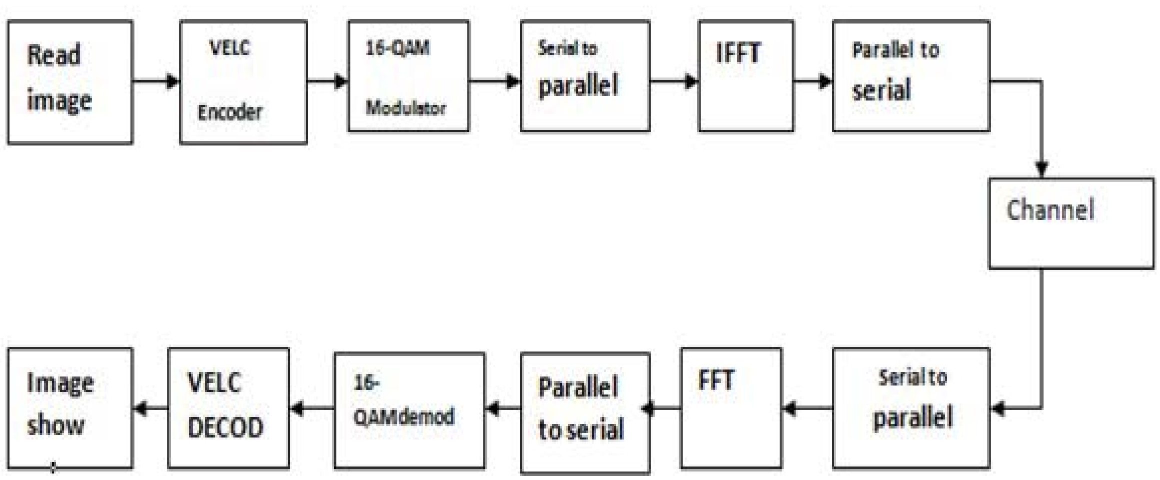

Figure 2. The block diagram of VLEC with OFDM modulation technique

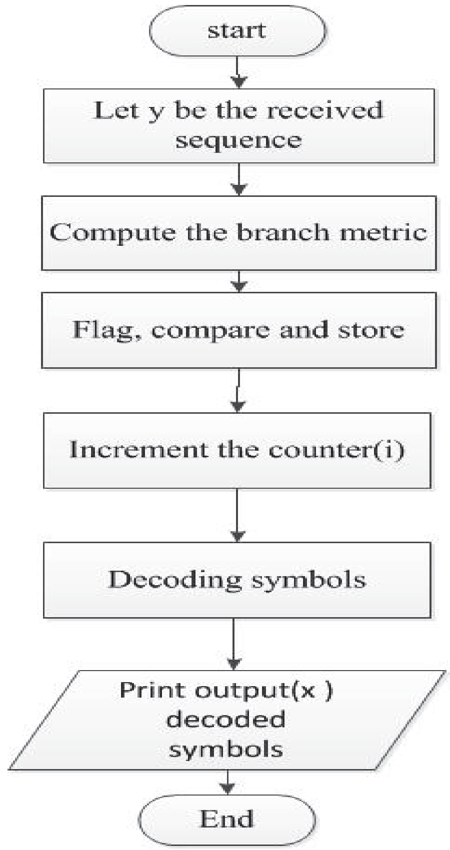

Figure 3. Flow chart of altered viterbi decoding algorithm

V. SIMULATION TESTS AND RESULTS

This section introduced the results, which are implemented by Mat lab (2015a) .The OFDM with 16-QAM inter modulation system with different input data types likes (text, image), and different channel types such as (WGN, relight fading channel). The bit error rate during each test is calculated. VLEC Coding is used with the systems to correct errors and reduce the bit error rate .Figure (4) shows the simulated performance curves of 'Lena image' picture and VLEC codes of d_{free}=2, , rate of coding =0.8 ,and average length=10. The performance of VLEC code as it varies with different error SNR shows generally a great improvement in the SNR values on white Gaussian noise channel.

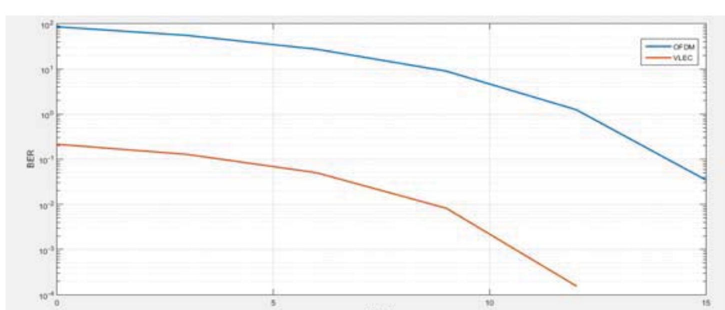

Figure 4. Performance comparison using VLEC codes with 16-QAM OFDM in image processing, blue curve represent 16-QAM OFDM, red curve represent VLEC-with 16-QAM OFDM.

The original image is transmitted, the noise will cause the amount of distortion between the original image and the same received image, The *PSNR* is used here to show the performance of VLEC codes in image process.

PSNR is usually measured in dB, *PSNR* is given by

$$\text{PSNR}=10\log_{10}\frac{M*N*(L-1)^2}{\sum_{r=1}^{M}\sum_{c=1}^{N}[T(r,c)-R(r,c)]} \quad (3)$$

Where:-

M: height of transmitting image (no. of pixels).

N: width of transmitting image (no. of pixels).

L: in gray scale extends from 0 to 255.in this case use L=256...

r: row number in image matrix.

c: column number in image matrix.

T(r,c): transmitted image.

R(r,c): received image.

Table -1 The PSNR values in (dB), using VLEC.

SNR(dB) step3 ***Range [0 30]***	***PSNR at VLEC code with*** $d_{free}=2$
0	***35.009***
3	***35.874***
6	***41.737***
9	***37.821***
12	***49.489***
15	***62.703***
18	***Infinity***
21	***Infinity***
24	***Infinity***
27	***Infinity***
30	***Infinity***

Figure 5. Lena image

Lena image is transmitted and received through AWGN channel by simulation with different values of SNR using 16-QAM (OFDM) modulation; the obtained simulations curve from this test are shown in Fig.6. At the SNR =15 dB the difference between the transmitted and the received image is null. The PSNR was calculated for each image, as shown in Table 1. Another evaluation includes the performance code of VLEC in (relight fading channel) with maximum Doppler shift =100 Hz. and tow path delays= [0 8/bitrates] with average path gain for two bath is equal = [-8-8] dB, rate code =0.8 and d_{free}=2, also, Lena image is used and .simulation result are listed in Table (2) which shows the values of PSNR for this case.

Table -2 The PSNR values in (dB), using VLEC (Lena image).

SNR(dB) step3 Range [0 30]	***PSNR at VLEC code with $d_{free}=2$***
0	**35.315**
3	**35.866**
6	**36.609**
9	**37.787**
12	**42.552**
15	**38.957**
18	**64.953**
21	**44.323**
24	**59.31**
27	**50.797**
30	**Infinity**

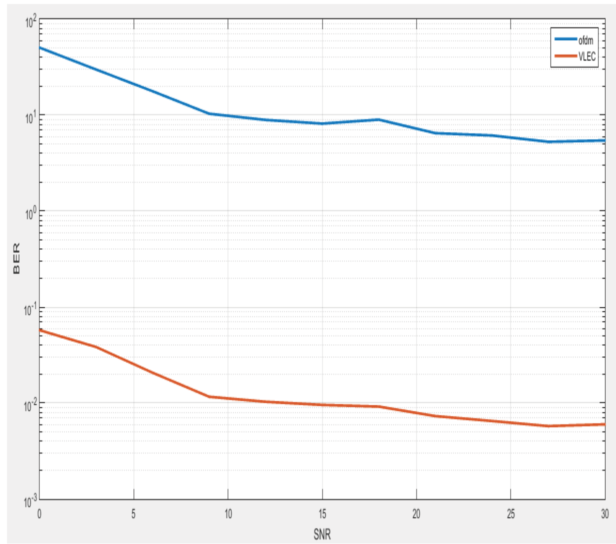

Figure 6. Performance comparison using VLEC codes and 16-QAM OFDM in image transition on fading channel, blue curve represent 16-QAM OFDM, red curve represent VLEC-with 16-QAM OFDM.

VI. CONCLUSION

Error detection and correction techniques are fundamental for reliable communication over a noisy channel. In this paper, Simulations show that the developmental performance of OFDM modulation techniques when using VLEC codes in terms error rate performance and decoding complexity. Also shown in this paper is that our VLEC system exceeds separate source/channel coding systems of similar overall rate at low to medium SNRs with the advantage of smaller decoding complexity. By using VLEC code in image processes gives butter improvement in terms of Peak Signal to Noise Ratio (*PSNR*) of about 18dB if compared with variable-length source code on binary symmetric channel(BSC) with (binary phase shift keying) BPSK modulation technique .

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