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Comparative Study between Variable Length Error Correcting Code and Turbo Code with Orthogonal Frequency Division Multiplexing

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Abstract : Variable length error correcting (VLEC) has gained very high importance in recent years. In this paper, focusing on inducing the best execution of variable length error correcting (VLEC) as a Source coding and error correcting in single step with16-QAM orthogonal frequency division multiplexing (OFDM) for Long Term Evolution (LTE). The execution of these codes with maximum likelihood decoding algorithm built on a modified edition of the viterbi decoding algorithm is examined and a comparison between cascade source-channel coding with same parameters is created. Also VLEC was compared with turbo code as channel coding. The scheme is implemented by (MATLAB R2015a) technical programming language.

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

I. Introduction

The digital information is represented as a sequence of binary digits, which are mapped to carrier signal waveforms and transmitted over communication channel [1]. The modulated signal suffers from noise during travel along the channel, at the receiver demodulated received signal and mapped back to binary information. Bit error caused by noise and interference in the communication channel. Source code used to remove redundancy in source, performs the representation is called a source encoder. This transforms the message in to a finite sequence of digits. While Channel coding is used in communication systems to protect the information from noise and interference, channel coding introduced additional bits will 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 [2]. The main difference between these types of codes and variable length error correcting codes is that the block codes deals with information independently from pervious inputs. But the main characteristics of VLEC are very similar to those of convolution codes. This is due to the fact that the position of any codeword within the encoded message depends on the previously occurring codewords and variable length error correcting code exhibits from of spatial memory.

II. Methodology

The joint point of the two main issues of the Shannon theory is the Separation source-channel coding theorem. This theorem states that the source and channel coding functions achieved without any loss of performance of the overall system [3].

Basic Concepts of Variable Length Error Correcting Codes

Let x be a binary code with a finite sequence $X=x_1x_2\ldots\ldots x_l$ of code symbols.It is called a word over x of length $|x|$=L, where $x_i \in X$, for all $i=1,2,3\ldots\ldots l$. If x=ps, the p *is* a proper prefix *of x and* s *is a* proper suffix *of x,* where x,p$\in X$.A set C of words is called a code.

Let the code C has s codewords $\{c_1, c_2, \ldots\ldots, c_s\}$ andlet $l_i = |c_i|$ indicates the length of data source, while $p(c_i)$ indicates probability of occurrence of data source symbol which is mapped into word $c_i=(c_{i1}c_{i2}c_{i3,}\ldots\ldots c_{il})$ where i=1,2,3……s. without loss of generality $l_1 \leq l_2 \ldots\ldots \leq l_s$.

Let σdenote the number of different codewords lengths in code C and let these lengths be $L_1, L_2, \ldots\ldots L_\sigma$, where $L_1 \leq L_2 \ldots\ldots \leq L_\sigma$.

Let the number of codewords with lengths equals L_i be s_i and number of codewords with length less than L_i be $\hat{s}_i$, i.e. $\hat{s}_i = \sum_{j=1}^{i-1} s_j$,where j=1,2,….,σ Note that $\hat{s}_1$=1 and that $L_1=L_{\hat{s}_{1+1}} = l_1$, $L_2 = L_{\hat{s}_{2+1}}$,……., $L_\sigma = L_{\hat{s}_{\sigma+1}}$ and $s=\sum_{i-1}^{\sigma} s_{i.}(s_1@L_1;s_2@L_2\ldots\ldots s_\sigma@L_\sigma)$[4].

The minimum block distance

Minimum block distance b_m associated to codeword of length l_m in code C is defined as: Minimum hamming distance between all codewords of the same length (with length l_m)[10]. b_m=min $\{h(c_i,c_j)\}$, Where $(c_i,c_j) \epsilon C, i \neq j$ and $|c_i|=|c_j|=l_m$.

Diverge distance

The diverge distance is defined as the Hamming distance between two codewords of unequal lengths

d (c_i,c_j),| c_i | ≠ |c_j|.

Generation of variable length of error correcting code

Step1: The first step of VLEC codeword sets C is a fixed-length code of length L_1 owning a minimum distance b_{min}. The first step produces a set of identically-length codewords having a given distance which is done by either the Greedy Algorithm (GA) or the Majority Voting Algorithm (MVA).

Step 1 The Greedy Algorithm (GA) or the Majority Voting Algorithm (MVA) is the first step in a VLEC generation. These algorithms generate a fixed-length code of length L_1 and minimum distance b_{min}. Therefore, first stages in flow charts of these two algorithms are used and then, the heuristic algorithm is explained.

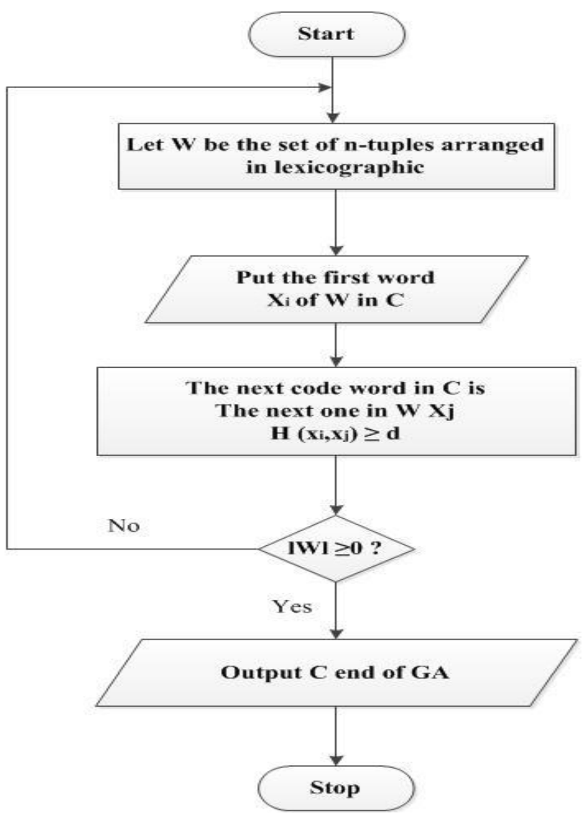

Fig. 1 Flow chart of the GA.

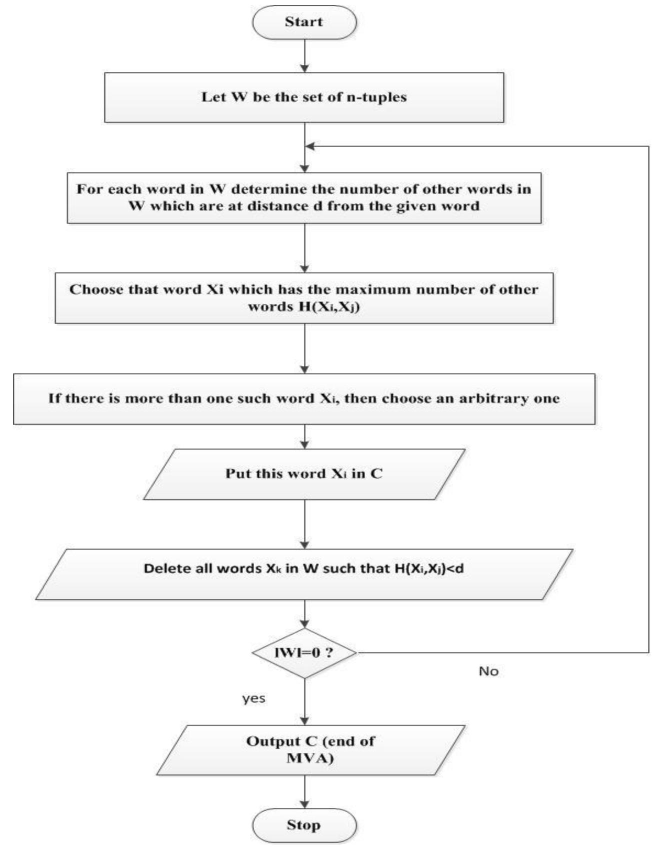

Fig.2 Flow chart of the MVA.

Step 2: Specify a set of W that contains all L_1-tuples having at least a distance d_{min} from eachcodeword in C. If the set of W is not empty, an additional bit at the end of all its words is affixed. This new set which is obtained after addition of bits makes twice number of words and it replaces the previous set W.

***Step 3*:** In the set W, delete all words that do not have at least a distance c_{min} from all codewords of C in this way, minimum distance requirements, (the d_{min} and c_{min}) are satisfied in the set W.

***Step 4*:** The words with the same length must have at least b_{min} distance, again by using two fixed length algorithm the GA or the MVA. Then the chosen codewords are added to set C.

Repeat the procedure of Algorithm, till getting the required number of codewords or there are no more choices. This implies that there is no codeword that justifies the required properties, or if the maximum codeword length is reached, delete the shorter code words to find enough codewords of VLEC code structure.

Step 5: Terminate this procedure, when no extra passable words pointed or else when the required number of codewords is reached.

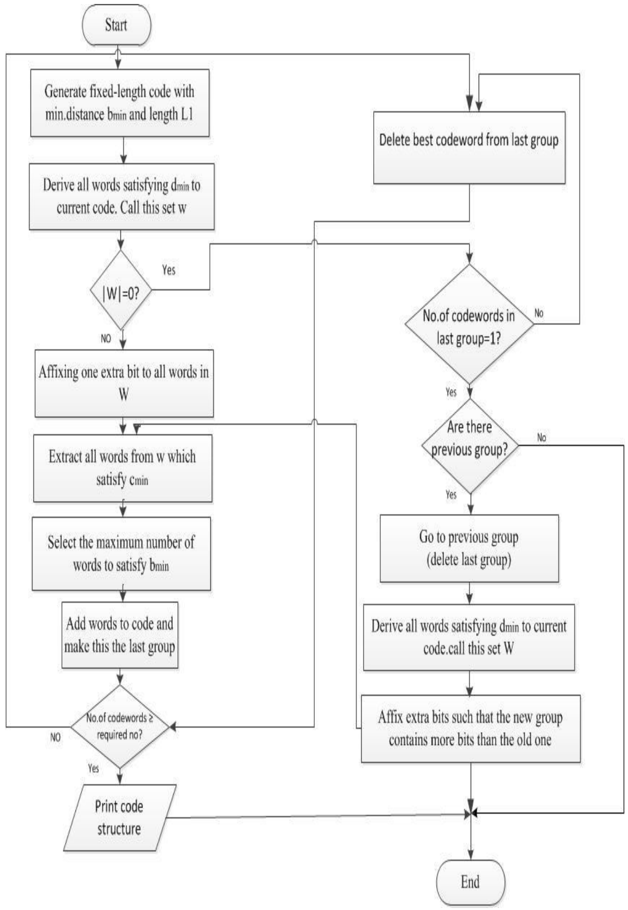

Fig .3: Flowchart of Heuristic algorithm

Modified Viterbi Algorithm with Hamming Metrics

Basic decoding procedures are listed below: Initialization: assign M_0=0, and $M_1 = \infty, \forall$ i> 0. Assume the current state and take initial value i=0

1. Metrical computation of branch: $c_j \in$ c for all codewords, evaluate the branch metric m_j=h(c_j, y_{i+1},y_{i+lj},).
2. Flag, compare and store: Mark Si+*lj* as a visited state. If *mj + Mi*<*Mi+lj*, then store this codeword 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)
4. Increment i to the next visited state and until i> N–l_1
5. Decoding symbols.

The flowchart of modified Viterbi decoding algorithm is shown in Fig .4

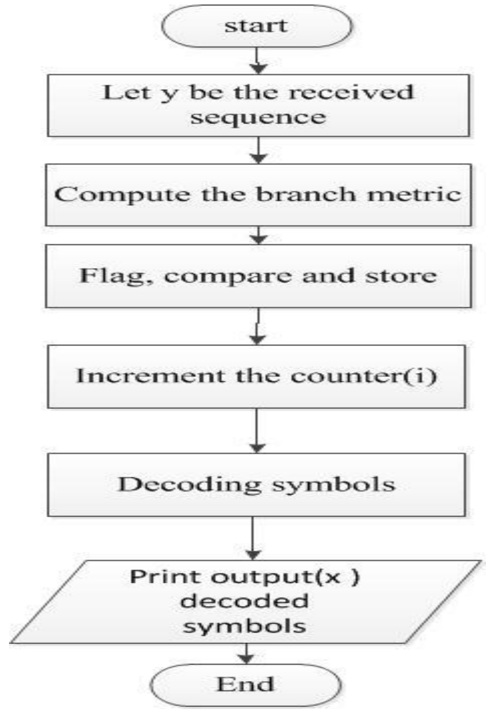

Fig.4 The flow chart of modified viterbi decoding algorithm.

In order to assess the performance of VLEC as a joint source code with channel code, cascaded system is built which consists of Huffman code as a source encoder followed by BCH (7, 4) code as a channel encoder; also the cascaded block is connected to the 16-QAM OFDM modulation technique.

Turbo encoder is built for compression purpose as a type of error correction code used with OFDM system which encodes a binary input signal using a parallel concatenated blocks which consist of two identical convolution encoders and one internal interleaver.

III. Results

Figure 5 shows the performance curves of source encoded using a cascade of Huffman cod followed by (7,4) BCH code as the channel code with 16-QAM OFDM modulation technique and a code rate of the cascade system about (0.57). This figure also refers to the comparison between the cascade system and the VLEC with 16-QAM OFDM modulation technique with free distance=2 and a code rate about (0.53) for symbol English source. This VLEC has the same code rate as the standard cascade of Huffman and BCH.

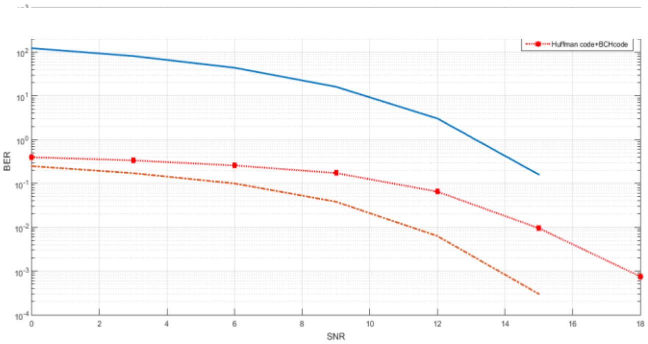

Fig.5: Performance of standard code with VLEC Codes.

Comparing the Performance of VLEC Codes With turbo code:

In recent years, turbo code was widely used by LTE system as channel coding technique. Figure 6 shows the performance curve, which is a comparison between Turbo code with 1-iteration and code rate about 1/3 and Variable length error correcting code with d_{free} =2, and code rate about 0.369

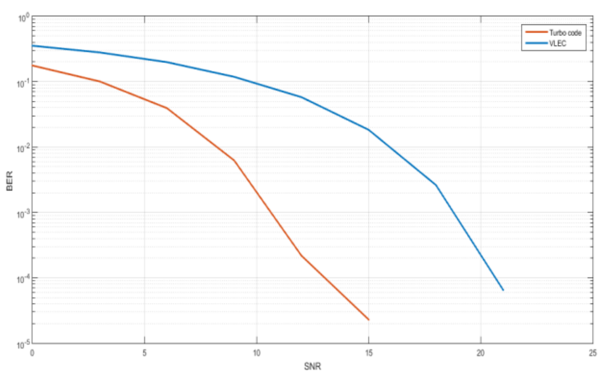

Fig. 6 : comparing performance curve of turbo encoder and VLEC.

IV. Conclusion

Fast and flexible VLEC generation can be obtained in this paper in order d_{free} starts from 2 this means that at minimum diverge distance and converge distance ($d_{free}=d_{min}+c_{min}$), one can get acceptable system performance. VLEC shows better performance than the turbo code and VLEC has coding gain about (8dB) at probability of error about (10^{-3}).also VLAC shows better performance than cascade scheme at high signal to noise ratio.

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