Comparing the Gap-To Capacity in Convolution Encoder and Decoder for 1/3 Code Rate

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Abstract - Convolutional codes are applied in applications that require good performance with low implementation cost. They operate on data stream, not static block. Convolutional encoder is a finite state machine (FSM), processing information bits in a serial manner. It is denoted by (n, k, L), where L is code memory depth. We have used MATLAB to perform the convolution encoder/ decoder algorithm presented in this report. More importantly, we should note that because of the exponential increase in complexity with regards to the number of memory elements used and unoptimized MATLAB code, a major drawback is the computational speed. However, from previous experiences that involve a search based type of algorithm, one could invoke a kd-tree to perform fast searches. We also note the generality of the framework and refer the reader to the documented version of the MATLAB code used to implement the convolutional encoder/decoder. In this paper, we present the basic concepts associated with convolution codes, specific encoding and decoding schemes used in this project, and results comparing the gap-to-capacity of the algorithm implemented with respect to Shannon's optimal code.

Keywords - *finite state machine (FSM), convolution encoder/ decoder, gap-to-capacity.*

I. INTRODUCTION

Convolutional encoding is a method of adding redundancy to a data stream in a controlled manner to give the destination the ability to correct bit errors without asking the source to retransmit. Convolutional codes, and other codes which can correct bit errors at the receiver, are called forward error correcting (FEC). The ever increasing use of wireless digital communication has led to a lot of effort invested in FEC (Forward Error Correction).Convolutional codes are introduced in 1955 by Elias. Convolutional codes are one of the powerful and widely used class of codes, These codes are having many applications, that are used in deep-space communications, voice band modems, wireless standards(such as 802.11) and in satellite communications. Convolutional codes are plays a role in low-latency applications such as speech transmission. The convolutional encoder maps a continuous information bit stream into a continuous bit stream of encoder output. The convolutional encoder is a finite state machine, which is a machine having memory of past inputs and also having a finite number of different states. Convolutional codes are commonly specified by three parameters; (n, k, and L) Where n = number of output bits, k = number of input bits, and L = number of memory registers

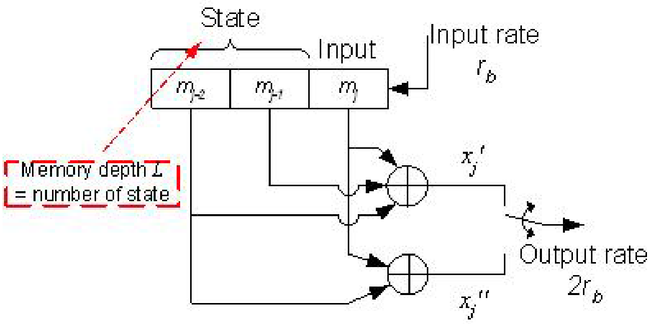

Fig.1: (N, k, L) = (2, 1, 2) encoder

$$x_j' = m_{j-2} \oplus m_{j-1} \oplus m_j$$
$$x_j'' = m_{j-2} \oplus m_j$$

The quantity *k/n* called the code rate, is a measure of the efficiency of the code. Commonly *k* and *n* parameters range from 1 to 8, *m* from 2 to 10 and the code rate from 1/8 to 7/8 except for deep space applications where code rates as low as 1/100 or even longer have been employed. Often the manufacturers of convolutional code chips specify the code by parameters (*n*, *k*, L), the quantity L is called the constraint length of the code and is defined by Constraint Length, L = *k* (*m*-1). The constraint length L represents the number of bits in the encoder memory that affect the generation of the *n* output bits. The constraint length L is also referred to by the capital letter K, which can be confusing with the lower case *k*, which represents the number of input bits. In some books K is defined as equal to product the of *k* and *m*. Often in commercial spec, the codes are specified by (r, K), where r = the code rate *k/n* and K is the constraint length. The constraint length K however is equal to L – 1, as defined in this paper. I will be referring to convolutional codes as (*n*, *k*, *L*) and not as (*r*, K).

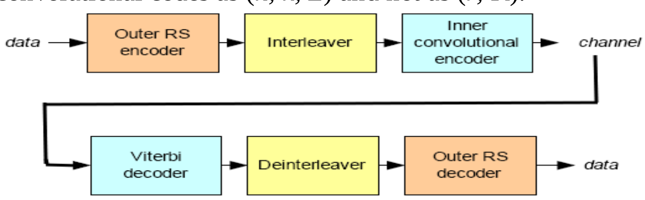

Fig.2: General block diagram for encoder and decoder

II. EXPERIMENT STEP

Generator Polynomial is defined by-

$$g^{(i)}(D)=g_0^{(i)}+g_1^{(i)}(D)+ g_2^{(i)}(D^2)+\ldots\ldots+g_M^{(i)}(D^M)$$

Where, D = unit delay variable M = number of stages of shift registers.
The power series associated with the data sequence u = (u0, u1, u2, . . .) is defined as

$$u(D) = u_0 + u_1\, D + u_2\, D^2 + \ldots = \sum_{i=0}^{\infty} u_i\, D^i\ ,$$

Where u(D) is called the data power series. Similarly, the code power series c (D) associated with the code sequence c = (c0, c1, c2 . . .) is defined as

$$c(D) = c_0 + c_1\, D + c_2\, D^2 + \ldots = \sum_{i=0}^{\infty} c_i\, D^i\ .$$

The indeterminate D has the meaning of delay, similar to z^{-1} in the z transform, and D is sometimes called the delay operator

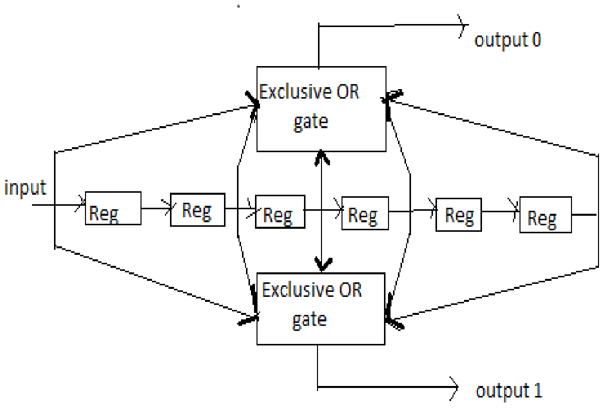

Fig.3: General Structure of shift register

The convolutional code structure is easy to draw from its parameters. First draw *m* boxes representing the *m* memory register. Then draw *n* modulo-2 adders to represent the *n* output bits. Now connect the memory registers to the adders using the generator polynomial as shown in the Fig.1. Convolutional code contains several redundant bits within its sequence that provide the characteristic error-correction property. These bits are generated using the property of sequential arrangement of the bits. [6] Construction of a sequence-storing device is implemented using an *m*-bit wide binary shift register. As a convention a preset value of binary 0 is assigned to each flip-flop. The input bit stream operates at *k* bits per second, and with each clock input method, as transmitting circuits waste little power during switch-on/switch-off [4][5]. There are some research activity examine along 5G mobile broadband first half of 2014 and outline regarding 5G was not defined under by key stakeholders. On the recommendation and requirement for next generation system relaying technology is key feature. Path-loss is the attenuation suffered by the signal when it travels from the transmitter to the receiver.

This paper evaluates the path loss for different relay position & examines different environment condition. In this work we introduce various channel models depending upon surrounding condition and calculate performance of the network. A general rate R = k/n convolutional encoder converts k data sequences into n code sequences using a k × n transfer function matrix G(D) as shown in the following figure

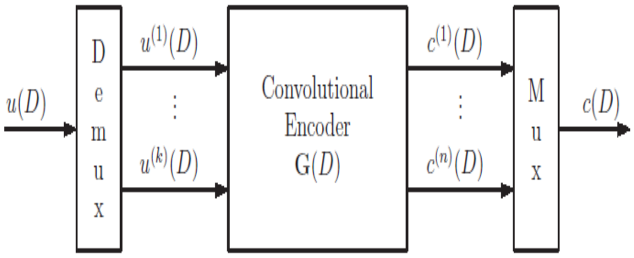

Fig.4: General Structure of Convolution encoder

A. Rate 1/2 Convolutional Encoder

From the above diagram it shows 3 shift-registers where the first one takes the incoming data bit and the rest, form the memory of the encoder. When we perform Exclusive ORing we get the generator polynomials as- G1=111=7 and G2=101=5, it shows

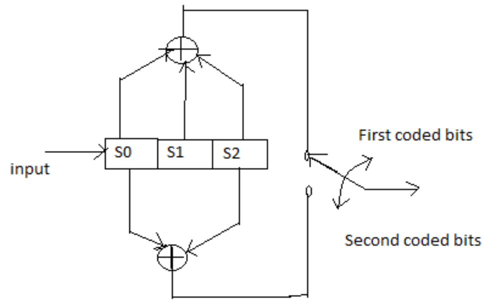

Fig.5: Rate 1/2 Convolutional Encoder

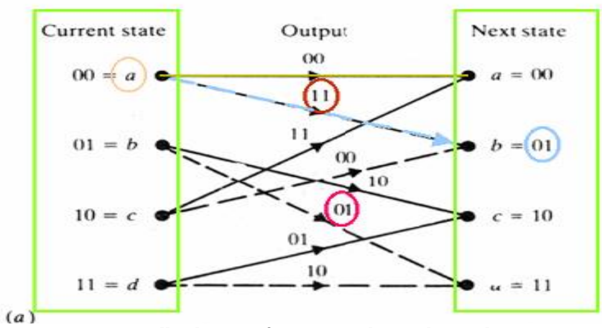

Fig.6: Trellis diagram for ½ Convolutional Encoder

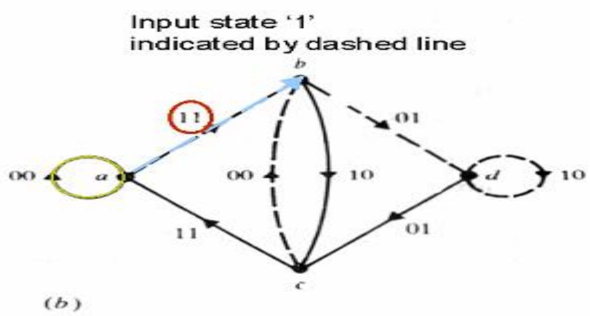

Fig.7: State diagram for ½ Convolutional Encoder

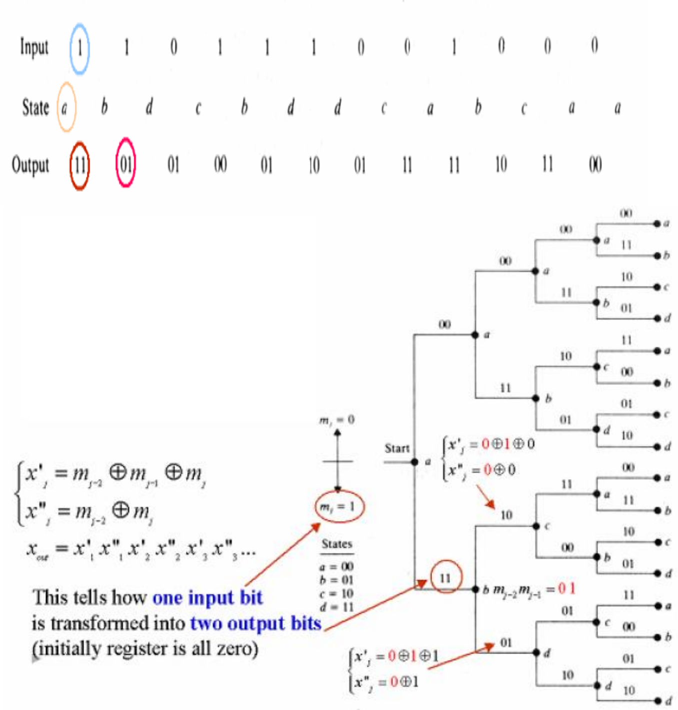

Fig.8: Tree diagram for ½ Convolutional Encoder

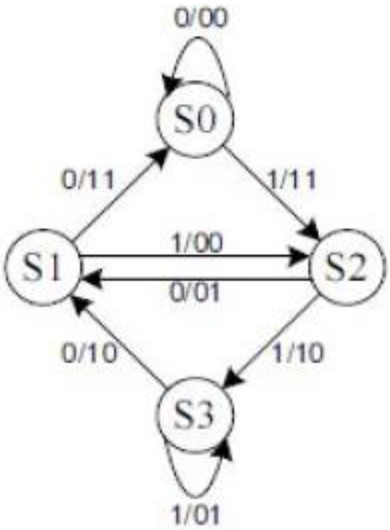

Fig.9: Finite State machine

B. Rate 1/3 Convolutional Encoder

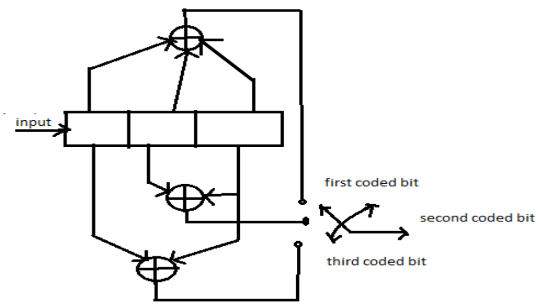

Fig.10: Rate 1/3 Convolutional Encoder

G1 = 111, G2 = 011, G3=101

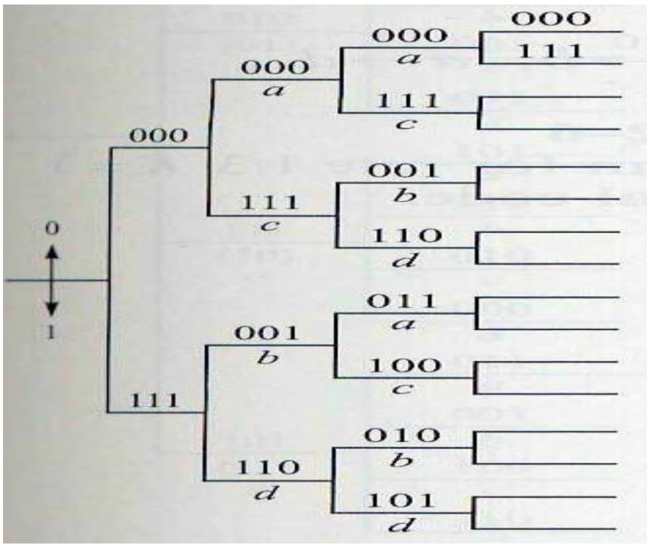

Fig.11: Tree diagram for rate 1/3, *K*=3 convolutional code.

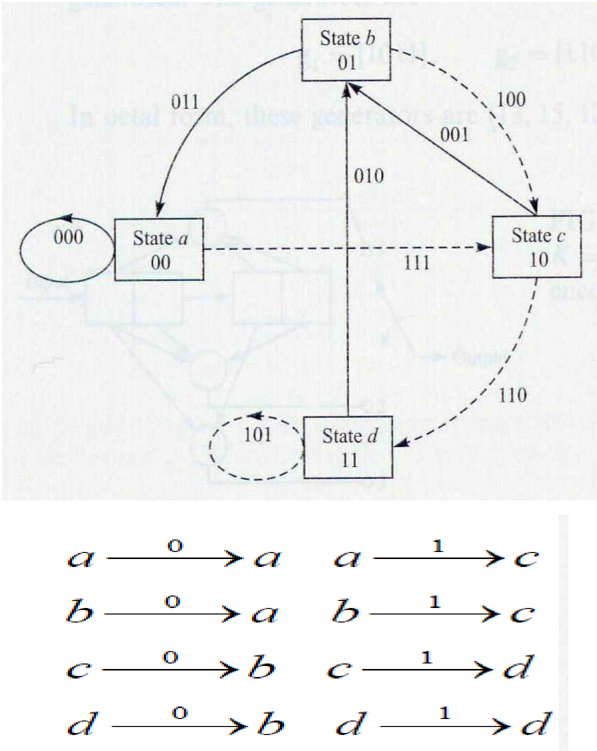

Fig.12: State diagram for rate 1/3, *K*=3 convolutional code.

III. VITERBI DECODER

Viterbi Decoing was developed by Andrew j. Viterbi in 1967 and in the late 1970's become the dominant technique for convolutional codes. The Viterbi algorithm is a dynamic programming algorithm m for finding the most likely sequence of hidden states – called the Viterbi path – that results in a sequence of observed events, especially in the context of Markov information sources and hidden Markov models. The terms Viterbi path and Viterbi algorithm are also applied to related dynamic programming algorithms that discover the single most likely explanation for an observation. For example, in statistical parsing a dynamic programming algorithm can be used to discover the single most likely context-free derivation (parse) of a string, which is sometimes called the Viterbi parse. The Viterbi Algorithm applied to a Finite State Machine traversal of states primarily objectives at creating an optimum state path by successive elimination of possible state traversals.

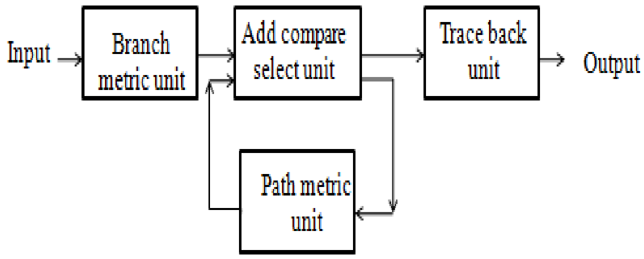

Fig.13: Block Diagram of Viterbi Decoder

It selects the traversal path exhibiting the most likelihood [14], or in the processing of a bit stream, least error metric. The error metric is popularly considered to be the hamming distance11 between the selected bit set and input bit set (for hard decision decoding) and reliability of symbol (for soft decision decoding). The algorithm, hence, outputs the most likely traversal of any Finite State Machine.

TABLE I
STATE TABLE FOR ENCODER IN SECTION IID

Current State	Next State, Output			
	For Input 0		For Input 1	
	Next State	Output Bits	Next State	Output Bits
00	00	00	10	11
01	00	11	10	00
10	01	10	11	01
11	01	01	11	10

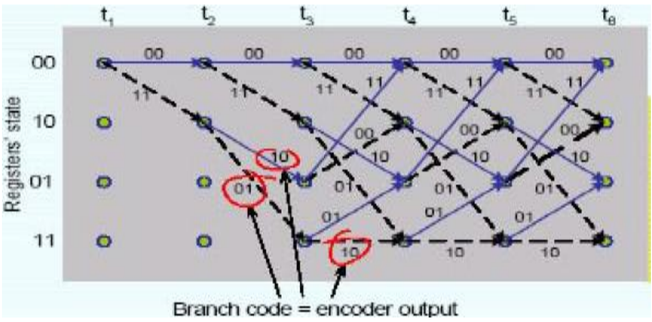

Fig.14: Tree diagram for rate 1/2, *K*=3 convolutional code.

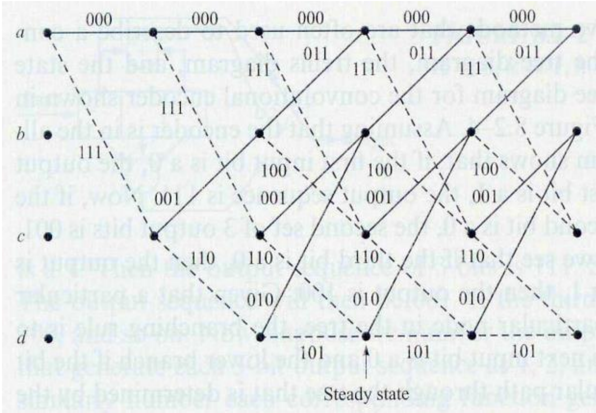

Fig.15: Tree diagram for rate 1/3, *K*=3 convolutional code.

IV. MODEL FOR SIMULATION FOR 1/3 CODE CONVOLUTION CODE

We test the robustness of the rate 1/3 convolution code for memory element sizes of 3; 5; 7. Specifically, we measure the coding efficiency of each respective convolution code over 10,000 trials and assume that our message is of L = 100 bits. Moreover, this simulation is done over several SNR levels. Although one would ideally like to reach the theoretical coding gain given by Shannon's limit, we deem the "success" of encoder/decoder if it is able to achieve roughly 4 dB using a hard decoding scheme. This base line can then be improved by substituting various branch metrics, such as the L2 norm. To this end, we present simulation results of the algorithm for both hard and soft decoding. for information of how to switch between the two by trivial changes to the MATLAB code.

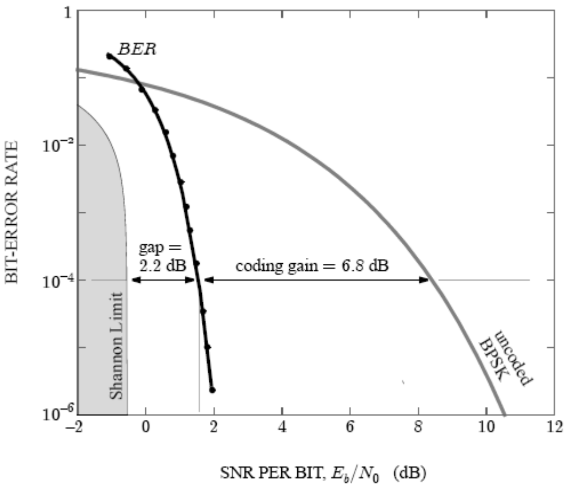

Fig.16: A simulated BER (log scale) versus Eb=No (in dB) curve highlighting both the gap to capacity with respect to Shannon Limit curve of a 1/3 system as well as the coding gain with regards to an un-coded code(Theoretical)

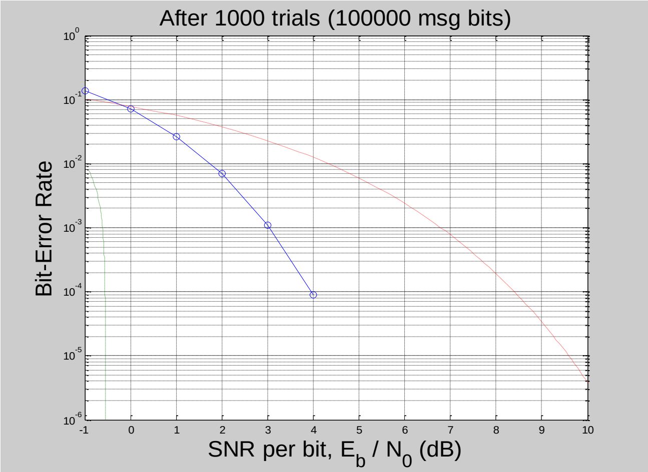

Fig.17: Simulated result for Convolution code for BPSK Modulation scheme.

V. RESULT AND CONCLUSION

We attempt to mitigate the gap to capacity of Shannon's theoretical limit for a rate 1/3 system. In particular, given the generality and flexibility provided with convolution codes, we present several varying convolution encoders for several varying memory element sizes. Using both soft and hard decoding, we then presented experimental results that for the most part fall within the expected theoretical gains.

VI. REFERENCES

[1] Viterbi, A.J., "Error Bounds for Convolutional Codes and an Asymptotically Optimum Decoding Algorithm, IEEE Transactions on Information Theory", April 1967;

[2] J. Geldmacher K. Hueske and J. Gotze. ―Adaptive decoding of convolutional codes.‖ Adv. Radio Sci., 5, pp. 209-214, 2007.

[3] J. Hagenauer and P. Hoeher. A viterbi algorithm with soft-decision outputs and its applications. in Proc., IEEE Globecom Conj, pp. 1680-1686, 1989 .

[4] http://en.wikipedia.org/wiki/History_of_mobile_phones

[5] Claude Berrou. ― A low complexity soft-output viterbi decoder architecture.‖ IEEE Trans. Commun., pp. 737-745, 1996.

[6] M. K. Gupta, Vishwas Sharma, ―To Improve Bit Error Rate Of Turbo Coded Ofdm Transmission Over Noisy

[7] Yonghui Li, Senior Member, IEEE, Md. Shahriar Rahman, Branka Vucetic, Fellow, IEEE "Duality of Channel Encoding and Decoding - Part I: Rate-1 Convolution Codes", IEEE Transactions on Information Theory 33 pages, 19 figures, *Submitted on 12 Jan 2012*

[8] Zheng Yuan ; Int. Sch., Beijing Univ. of Posts & Telecommun., Beijing, China ; Xinchen Zhao "Introduction of forward error correction and its application" Consumer Electronics, Communications and Networks (CECNet), 2012 2nd International Conference 2012. http://ieeexplore.ieee.org/xpl/login.jsp?tp=&arnumber=6201904&url=http%3A%2F%2Fieeexplore.ieee.org%2Fiel5%2F6196279%2F6201368%2F06201904.pdf%3Farnumber%3D6201904

[9] Vijay A Suryavanshi and Aria Nosratinia "Convolutional Coding for Resilient Packet Header Compression," Multimedia Communications Laboratory, The University of Texas at Dallas Richardson, TX 75083-0688, USA *Information Security*, 2014, 7, 19-27

[10] *Jeff Foerster and John Liebetreu*, FEC Performance of Concatenated Reed-Solomon and Convolutional Coding with Interleaving", IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>

[11] Md. Liakot Ali, Mohammad Bozlul Karim, S.M Tofayel Ahmad, Simulation and Design of Parameterized Convolutional Encoder and Viterbi Decoder for Wireless Communication, 2012

[12] Ripple Dhingra1 and Danvir Mandal2, "Convolutional Code Optimization for Various Constraint Lengths using PSO", International Journal of Electronics and Communication Engineering. ISSN 0974-2166 Volume 5, Number 2 (2012), pp. 151-157

[13] Shaina Suresh, Ch. Kranthi Rekha, Faisal Sani Bala , "Performance Analysis of Convolutional Encoder and Viterbi Decoder Using FPGA" International Journal of Engineering and Innovative Technology (IJEIT) Volume 2, Issue 6, December 2012

[14] Umesh Kumar Pandey1 , Prashant Purohit2 ,"Convolution code with Hard Viterbi Decoding For MPSK in AWGN" International Journal of Emerging Technology and Advanced Engineering, Volume 3, Issue 9, September 2013

[15] Sneha Bawane1 , V.V.Gohokar2 "SIMULATION OF CONVOLUTIONAL ENCODER", IJRET: International Journal of Research in Engineering and Technology, eISSN: 2319-1163 | pISSN: 2321-7308

[16] J. G. Proakis, *Digital Communications*, 3rd edition, WCB/McGraw-Hill, Boston, Massachusetts, 2001

[17] S. Haykin, *Communication Systems*, 3rd edition, John Wiley & Sons, New York, 1994.

[18] L. W. Couch, II, *Digital and Analog Communication Systems*, 4th edition, Macmillan Publishing Company, New York, 1993.

[19] T. McDermott, *Wireless Digital Communications: Design and Theory*, Tuscon Amateur Packet Radio Corporation, Tuscon, Arizona, 1996

[20] Salehe I. Mrutu1, Anael Sam2 and Nerey H. Mvungi3, "Forward Error Correction Convolutional Codes for RTAs' Networks: An Overview", *I.J. Computer Network and*

[21] Yang Sun, " Convolutional Encoder and Viterbi Decoder Design for WARP OFDM PHY V15.0" IEEE Transactions on Information Theory 39 pages,

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