OIDMA System Performance: Role of Convolutional Encoding and Avalanche Photodetectors

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ABSTRACT

IDMA (Interleave Division Multiple Access) is a prominent technology used in the 4G and 5G communication system. IDMA is a recent multiple access technique through which multiple access interference (MAI) and inter symbol interference (ISI) can be minimized in the communication network. The optical fiber channel provides the efficient bandwidth utilization for improving the performance of O-IDMA system. In this article, the impression of low code rate (1/2) convolutional codes with high constraint length (L = 7 and L = 9) has been analyzed on optical coded OIDMA system. The code rate depends on number of Ex-OR gates and constraint length depends on number of memory elements new algorithm for convolutional encoder which satisfies above condition of code rate and constraint length. Tree inter-leavers having larger memory, less power consumption and simplified design features, makes it useful to improve the quality of O-IDMA system. In present article various architecture of convolutional encoders are designed by varying the feedback connections and are tested for observing the BER performance of O-IDMA system implemented on MATLAB. Tree inter-leavers in taken into account for analysis purpose and BER with increasing number of users is plotted in graphical and tabular manner.

***Keywords**: O-IDMA, Ex-OR, Code Rate, Constraint Length, Tree Inter-Leaver, BER*5

I. INTRODUCTION

A very motivating methods has been developed by L. Ping to combine coding and spreading, and it uses dissimilar inter-leavers to separate users known as Interleave division multiple access (IDMA). The major challenge with CDMA multiple access system is to reduce the ISI and MAI because as number of user increases ISI and MAI also increases and BER increases.The advantage of IDMA can be utilized in optical fiber communication known as OIDMA. It deals large band width for larger number of users at minimum cost. Higher capacity optical networks are required to achieve the growth of internet services and new digitized schemes. Interleaver is usually working a key component in turbo codes, due to the fact that iterative method of the turbo coding will use interleaved version of information iteratively to produce high coding gain [1-2].

A very powerful and widely used a variety of codes, called convolutional codes, which are used in a variety of system including todays standard wireless, optical and in satellite communication. Convolutional error correcting or channel coding is used to improve the efficiency and accuracy of information transmitted. Convolutional codes are beautiful because they are intuitive, one can know them in many different ways, and there is a way to decode them so as to recover the mathematically most possible message from among the set of all possible transmitted message. Other major reason for this is the possibility of achieving real time decoding without visible information losses thanks to the well-known soft input Viterbi Algorithm.In present paper, the convolutional coder of fixed code rate and different constraint lengths is designed and connected in the OIDMA system. Code rate and constraint length specifies that different possible combinations of shift registers and adders are used in encoder generates more number of uncorrelated code words and produces larger hamming distance means increasing the error detection and correction ability of codes. Constraint length and network topology are the important parameter of the convolutional encoder [3-4].

The longer the constraint length, the larger the number of parity bits that are subjective by any given message bit. Because the parity bits are the only bits sent over the channel, a larger constraint length generally implies a greater flexibility to bit errors. The trade – off, though, is that it will take significantly larger to decode codes of long constraint length. So one cannot increase the constraint length at random and expect fast decoding.In the present work for analysis purpose tree inter-leaver is selected and their qualitative comparison of fix code rate with different constraint length has been evaluated. In block diagram of OIDMA system the coding section embedded the convolutional encoder. Design of convolutional encoder is based on memory elements and combinational circuits. Basically we are using D flip flops as memory elements and adders (Ex-OR) gates as a combinational circuit. By increasing the memory elements or by increasing the adder will change the code rate and hamming distance. Hamming distance is inversely proportional to bit error rate. So as design topology of encoder changes by either varying adder or memory element the quality of transmission is affected [5].

In this paper, Section 2define the block diagram of optical interleave division multiple access (O-IDMA). Section 3 described the process of interleaving. Convolutional coding, an architecture of convolutional encoder by varying memory elements and Ex-OR Gates are explained in Section 4. Section 5 shows the simulation result and their discussion. Conclusion and future scope drawn in Section 6.

II. OPTICAL IDMA SYSTEM

The block diagram of optical IDMA system shown in Fig.1, having k different users, proposing single path of optical window 1550 nm. All users having converted in fixed code length, which is assumed to be low rate. The chip is interleaved by a chip level inter-leaver. After transmitting through the channel, the bits are reached at the receiver side.

In receiver section, after chip matched filtering, the received signal from the k users are observed. In the receiver side for multiuser detection we have used elementary signal estimator, APP and SDECs having variable iterative mechanisms. The produced LLR are further classified in two ways, one which is produced by PSE and another which is generated by DEC. The function of ESEB and APP decoders are based on users [6-7].

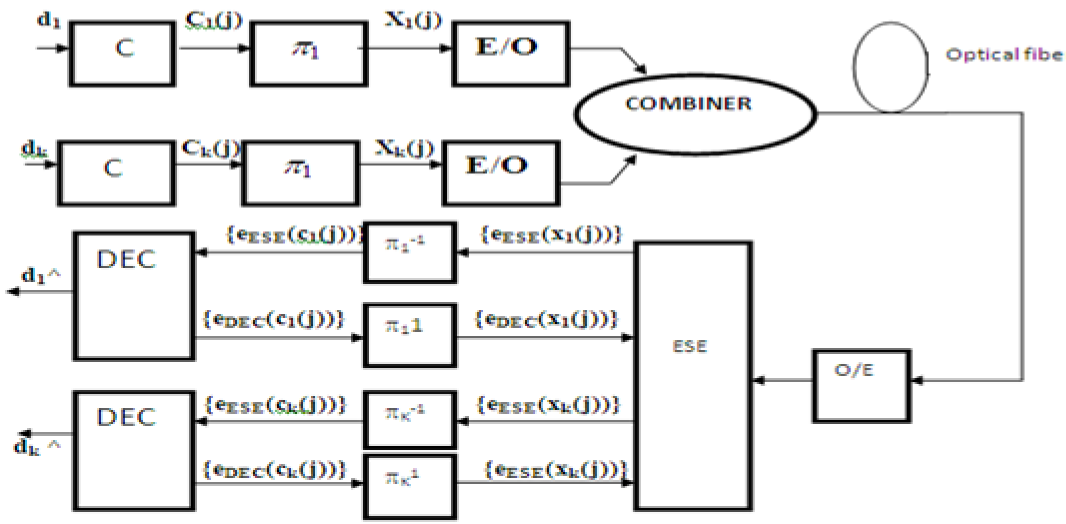

Fig. 1:Optical IDMA Transmitter and Receiver Structure

III. TREE INTERLEAVER

The interleaver design plays very essential part in the efficacy of IDMA system. It produces large number of uncorrelated adjacent bits that produces large free distance d_{free}. For distinguishing the users uncorrelated bits play important part and lesser interaction is required in multiuser detection, if larger number of uncorrelated bits are produced by interleavers. The interleavers are also used for reduction in MAI produced by many users in OIDMA systems. It also reduces collision between user bits since its orthogonality properly implies that no collision. Larger the size of interleaver having larger orthogonality produced by them. Input interleaving is process of arranging bits in an alternative manner to speed up the communication. It fills the bits in row wise and send it in column wise to break the burst errors in random errors [6-7].

In case of tree interleaver method, two randomly selected master interleavers are taken. These inter-leavers possess orthogonally property. The first correlation between two possess selected inter-leavers ensures the minimal cross correlation between other generated user-specific inter-leavers, using tree interleaver generation algorithm. Depending upon data length initially two master interleaver are selected randomly. According the number of users, the level of tree is decided for sake to simplicity we have taken only 14 users which gives the level as 2L where L=2 is the various combination of user separated by 4 on odd and even branches of tree are arranged shown in figure. Upper branch is choosed for odd number that is 1, 3, 5…. etc. of users while 2, 4, 6……. etc that is even users are counted on lower branches of tree [8-9].

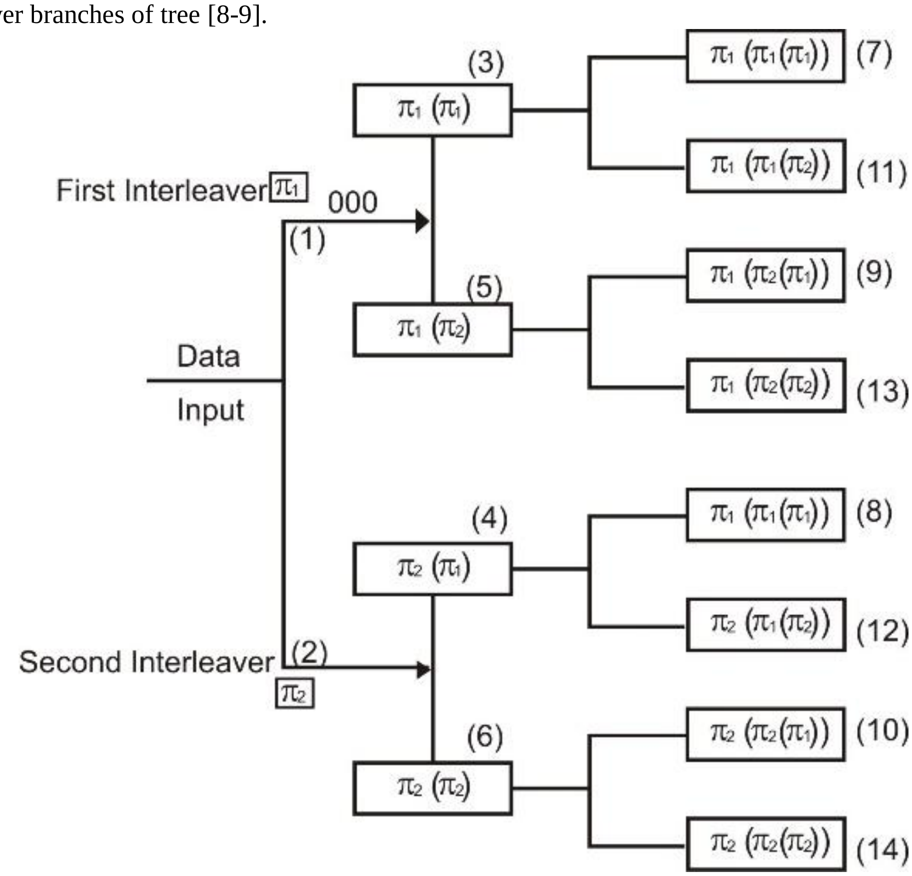

Fig. 2:*Tree Based Interleaving Technique*

IV. CONVOLUTIONAL CODING

Convolutional codes cares for information by adding redundant bits to any binary data. The convolutional encoder calculates each *n*-bit symbol (n > k) of the output sequence from linear operations on the current input k-bit symbol and the contents of the shift register(s). Thus, a rate *k/n* convolutional encoder processes a k-bit input symbol and computes an *n*-bit output symbol with every shift register update. Convolutional codes are commonly specified by three parameters; (n, k, m).

n = number of output bits
k = number of input bits
m = number of memory registers

The amount k/n is called as code rate. It is a measure of the efficiency of the code. Generally, 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 in employment. Here The Quantity L is called the constraint length of the coder. The constraint length L denotes 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 [10-11].

Design of Convolutional Encoder

In designing of convolutional encoder there are two prime constraints. First one is number of shift register and another one is number of Ex-OR gates used in encoder circuit. The constraint length L of an encoder is well-defined as number of shift registers where only one message bit can affect the encoder output, designed as L = m+1, where m represents number of memory elements or shift registers used. As more numbers of shift registers are used in encoder more number of output bits are influenced by single bit, which reduces the chance of error in deciding input bits at receiving side. If we increase the number of adders at output then more number of uncorrelated bits as well as code words produces at output, which increases the dmin (minimum hamming distance) between code wards and increases the error correcting capability of encoder.

In the Figure shown below there are two convolutional encoders are designed for different constraint lengths (L = 7 and L = 9). The encoder is (1,2) having one input and two output bits that is two Ex-OR gates are used. In first case, L=7 shown in Figure 3 that is 6 shift register and two adders are used, the feedback connections are decided by trellis [173, 133] where 173 and 133 are in octal representation.In second case, L = 9 shown in figure 4 that is 8 shift register and two adders are used. Here the optimum trellis is selected as [561, 753] in octal, shows encoder feedback connection. We see from the above discussion that as constraint length is increasing the encoder network topology changes accordingly [12-14].

The effect of increasing constraint length of encoder in OIDMA has been observed. Theoretically result should be improved for increasing L, but using more number of registers in encoder increases, delay as well as circuit design complexity.

From the above, Fig. 3 and 4 represents low code rate and high constraint length of convolutional encoders designed and applied in OIDMA system and is also decoded by Viterbi decoding method.

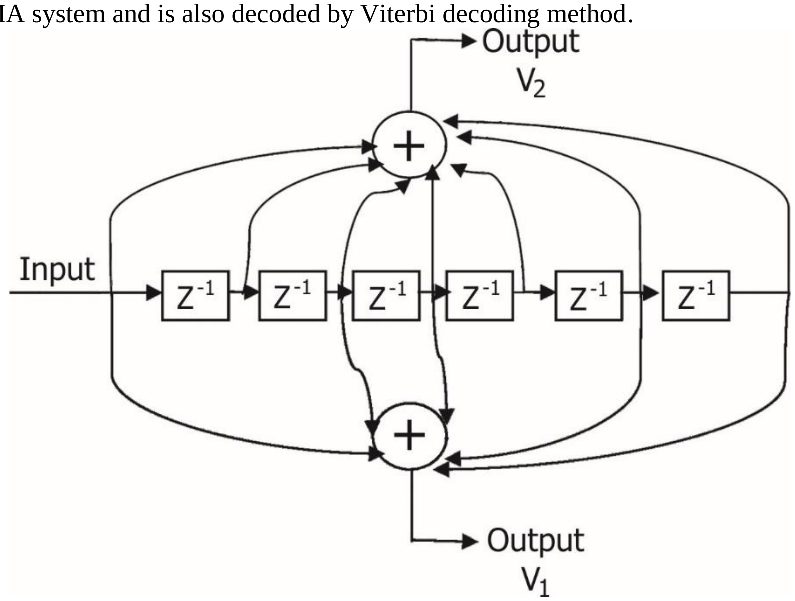

Fig. 3 ***Convolution Encoder for Code Rate (1/2) and Constraint Length L=7***
L = 7 [171, 133], 6 – Shift Register

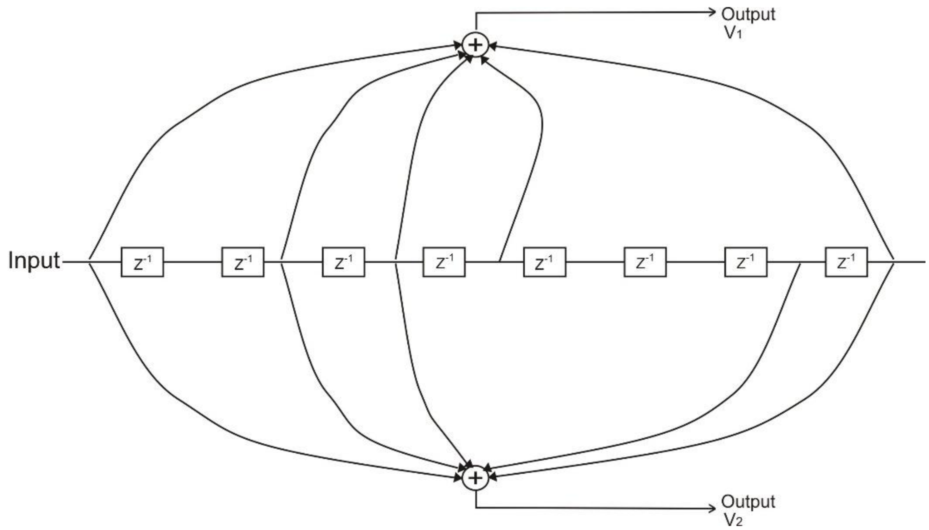

Fig. 4.Convolution Encoder for Code Rate (1/2) and Constraint Length L=9
L = 9 [561, 753], 8 – Shift Register

V. RESULT & DISCUSSION

Here, the BER performance of the convolutional coded OIDMA system has been implemented on MATLAB software. The input parameter is taken as the spreading length is fixed as 16, input block lengths is 100, E_b/N_o is 3, data length is 512 has been fixed. In the optical parameter the optical source wavelength is 1553nm, input power is 1mw, input pulse is Gaussian, fiber losses 0.15db, fiber cross section 8×10^{-11} is fixed. Optical detector having characteristics such as gain 1000, efficiency 0.85 type Avalanche photodiode have been used in receiver section.
BER performance of OIDMA system is calculated by varying the memory element and fixing the Ex-OR gates by using tree inter-leaver. The observed result for bit error rate verses number of users for constraint length (L = 7 and L = 9) and code rate (1/2) has been arranged in tubular and graphical form for tree interleavers.

Table 1: BER Performance for Code Rate ½ and Constraint Length (L = 7 and L = 9)

Code Rate = ½, Data Length (m)=512, block =100, Spread Length (S.L.=316) and E_b/N_o is 3, Tree Interleaver			
S. No.	Number of Users	BER for Const. Length L = 7	BER for Const. Length L = 9
1	340	2.453×10^{-9}	9.345×10^{-10}
2	360	7.346×10^{-9}	6.345×10^{-9}
3	380	1.341×10^{-8}	9.245×10^{-9}
4	400	4.283×10^{-8}	1.345×10^{-8}
5	420	7.103×10^{-8}	4.456×10^{-8}
6	440	1.312×10^{-7}	9.345×10^{-8}

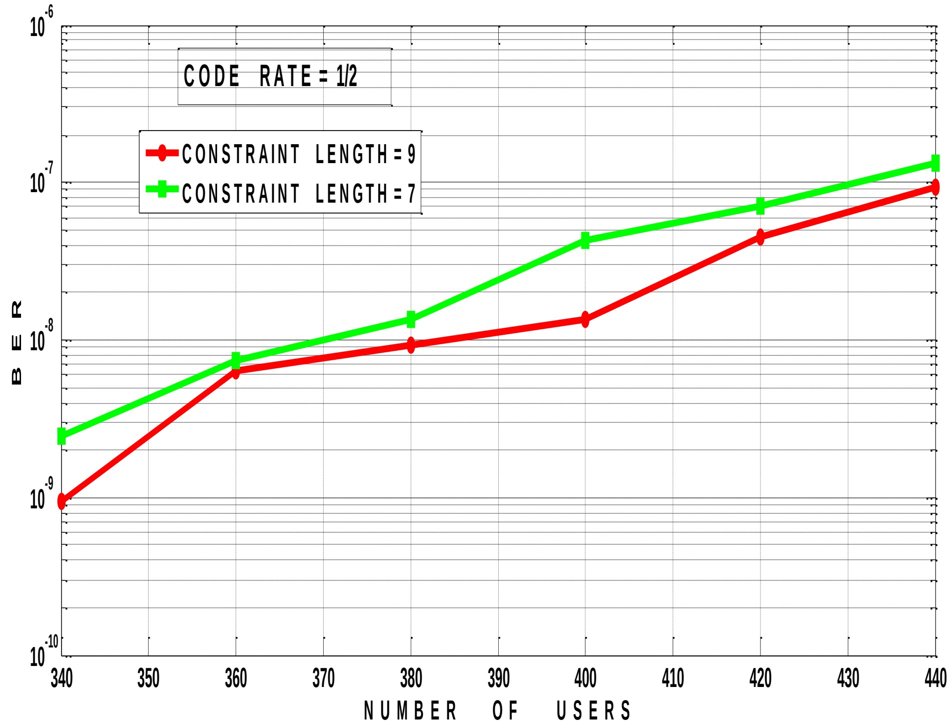

Fig. 5: BER Performance for Code Rate ½ and Constraint Length (L = 7 and L = 9)

For Table-1 and Fig. 5 which is plotted for tree interleaver indicates that BER for code rate (1, 2) and constraint length (L = 7), (340 user) is 2.453×10^{-9} and when constraint length (L = 9), the BER is 9.345×10^{-10}. The observed result (t. e. decreases BER from 10^{-9} to 10^{-10}) clearly emphasis on the theoretical fact that by using more number of memory element in encoder produces more uncorrelated bits and decreases BER. When number of users is increased the errors are increasing as number of users increases in each case t. e. for L = 7 and L = 9 and this also resembles to theoretical aspects. The observed reading also glimpse on the fact that when more number of memory elements are used then readings are improved. For instance, when number of users 440, L = 7 then BER is 1.312×10^{-7} which decreases to 9.345×10^{-8} for (L = 9, 440 users). When number of users 440 for (L = 7), then BER is 1.312×10^{-7} and when L = 9, then BER is 9.345×10^{-8}. From above discussion it shows that high constraint length provides the better performance comparison to low constraint length for fixed code rate.

VI. CONCLUSION

The OIDMA system simulated results of BER using fixed input parameters and fixed optical channel parameters with low rate high constraint length convolutional encoders gives the good expected result clearly resembles the theoretical aspects. We have seen from both the graph (L = 7 and L = 9) that by increasing traffic intensity (number of users) the BER enhance slowly with a continuous manner. In present work since Ex-OR gates are fixed so its effect with increasing constraint length are not considered. In future work both parameters might be varied simultaneously and optimum number of shift register with Ex-OR gates may be calculated easily.

Overall we conclude that effect of variation of constraint length of convolutional encoders on OIDMA improves its performance qualitatively and if we use tree interleaver along with it, system may be a prominent solution for forthcoming 4G and 5G technologies.

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