International Journal of Aquatic Science
ISSN: 2008-8019
Vol 12, Issue 02, 2021

Performance Analysis Of Product Code Using TLDPC And SCCI-Turbo Codes Over Fading Channels

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Abstract: In this modern information era, network size and users are increasing day by day. The development of communication systems evolved to digital format from analog format became part of life and caters to various applications like basic voice services, video broadcasting, HD video calling, Home automation, and artificial intelligence. So that data traffic, user density increases exponentially. This needs a data system with more capacity to handle this high volume data communication without error. This makes it a necessity to optimize Error Detection and Correction (EDC) coding as per the present scenario. The error detection and correction code is a method that adds redundant data to empower the robustness of information over the noisy communication channel. This motivates to find a coding scheme to succeed in the channel having high error probability. In this proposed scheme, the Turbo code is combined with TLDPC code as the product code system. The turbo codes are good at handling burst error since it has interleaver in its usual coding process. This is designed with an algorithm of single-column constraint interleaver which exchanges data from a single row to a different column. The performance of the proposed technique is observed over the AWGN channel and Rayleigh channel with the metrics like Bit Error Rate, Signal to Noise ratio, E_b/N_o. The product of TLDPC and Turbo code reduced the BER to $0.8*10^{-6}$atthe Eb/No of 5.5 dB for addressing the Rayleigh channel. Also, it reduces the BER to $0.6*10^{-6}$ for the SNR of 2.6 dB for addressing the AWGN and Rayleigh channel.In the AWGN channel, it reduces the BER from 10^{-4} to 10^{-5}.

Keywords: Bit error rate; Low-Density Parity-Check codes; Turbo code; SCC interleaver; Rayleigh fading channels.

1. INTRODUCTION

One Of The Main Innovations In The Development Of Each Generation Of Information Systems Is Channel Coding, Which Involves Applying Redundancy To Information To Minimize The Bit Error Rate. Turbo Code Is A New Type Of Error Control Code That Was Incorporated In 1993 By A Group Of Researchers From France, Along With A Practical Decoding Algorithm. Ilcev,2018 Said The Major Importance Of These Codes Is That They Can Facilitate Reliable Data Transmission With Power Efficiency Improvement Closer To The Lower Limit Prescribed By Shannon’s Theory. For Low-Power Applications Such As Deep Space And Satellite Communications, Turbo Codes Have Been Proposed, As Well As

For Interference-Limited Applications Such As Broadband Or Personal Telecommunication Networks Of The Third Century. Turbo Codes Appear Randomly On The Channel Due To The Use Of A Pseudo-Random Interleaver. Random Errors And Burst Error Correction Coding Have Moved From Simple Convolutional / Block Codes To More Efficient Turbo Codes And Ldpc Codes As Primary Information Communications Technology. For Architecture-Aware Ldpc Codes, Mansour And Shanbhag, 2003 Implement A Powerful Turbo Message Passing Algorithm. The Basic Turbo Code Consists Of A Decoder And An Encoder. The Turbo Encoder Architecture Consists Of At Least Two Parallel Linked Segment Encoders And An Interleaver Put In Between To Separate Them. Lee Sh Et Al., 2005 Also Have Given The Concatenated Ldpc And Turbo Code As A Scheme For Optimizing Performance In Ber.Marwa Et Al., 2009 Also Provided Serial Concatenation Of Ldpc And Turbo Codes For The General Packet Radio Service (Gprs) Method.Anghelet Al., 2017 Enumerate That The Turbo Decoders Process The Bits Of Data Using Soft Determination By Incorporating Single Row Constraint Interleaver. In The Proposed System, The Single-Column Restricted Interleavers Have Beenintroduced In Turbo Codesand Combined To Tldpc Along With Padding To Help The Coding With Different Code Lengths. The Restricted Interleaver Offers A Near-Uniform Interleaving By Using An Interleaver Which Exchanges Row Data To The Different Column To Scatter The Errors In The Channel.

2. EXISTING SYSTEM – CONCATENATION OF LDPC AND TURBO CODE

Moatazand Ashraf, 2015 enumerated a concatenated system using LDPC with the Turbo code for wireless sensor networks. In this system, recursive systematicconvolution codes are used for turbo code. Compared to classical non-recursive non-systematic convolution codes, RSC codes give many benefits. The main advantage is it can correct burst error. Furthermore, at low signal to noise levels, it can do better than classical convolutional codes. Zummoet al., 2005 elaborated that the remarkable property of RSC code is that a small proportion of finite weight information sequences emit finite weight coded sequences at the output of the encoder. These basic sequences mostly in literature are referred to as Return To Zero (RTZ) sequences and play a fundamental role in the asymptotic output of the Turbo Code. Unlike serial concatenation, parallel concatenation requires the encoders to operate on the same clock. This is one of the challenges that make the configuration of the turbo encoder circuit multifaceted. RSC codes are convolution codes, but turbo code works as a block by block. So the interleaver is used to break the stream of input into blocks. From limited memory convolutional code, the interleaver shapes functional lines code and the decoder has to look for the interleaved sequence from the interleaver.

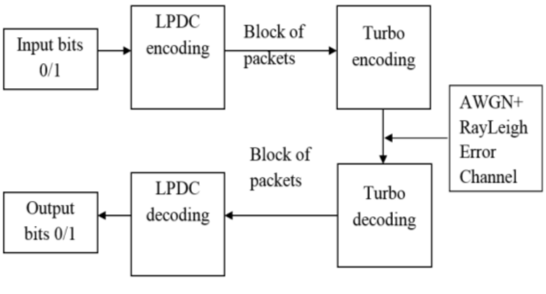

Figure.1Concatenation of LDPC and Turbo code

Interleavers are important to build a strong turbo code. The general use of interleavers is to randomize the positions of errors. Interleavers are customarily used for handling channel burst errors. The output of the component decoder in any concatenated decoding system can exhibit burst errors. Therefore, using the interleaver, the burst errors are distributed at isolated locations. The interleavers are used in turbo coding to encode and decode between two-part RSC/SISO coders. It is used to decrease the contrast between the initial and interleaved data frame parity bits. P_1 and P_2 is the encoded data stream by two RSC encoders. X_k is the uncoded data stream.

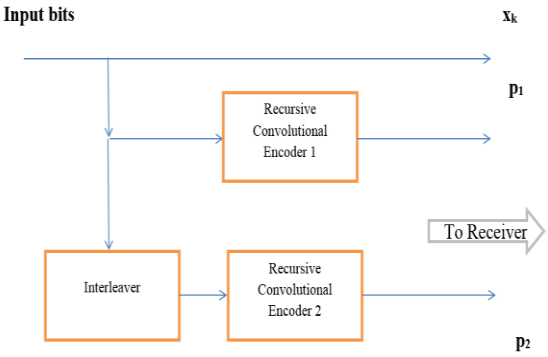

Figure.2Turbo Encoder

Two fundamentals of turbo encoder are:

- A component encoder is named an RSC encoder.
- An interleaver distinguishes the two-part encoders.

Ahmad et al, 2008 with relatively simple part codes and large interleavers, achieves error correction efficiency. The data block length is selected to be very long to obtain output similar to the Shannon limit, typically at least several thousand bits. Systematic feedback encoders produce RSC codes that provide much better output than non-recursive systematic convolution codes. This is known as the feed-forward encoder. The sequence entering the second RSC encoder has the same weight as the ‘L’ sequence entering the first encoder since only the arrangement of the bits is modified by the interleaver.

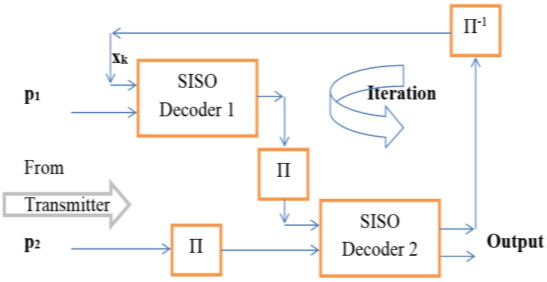

Figure.3Turbo Iterative Decoder

The turbo encoder is composed of two similar recursive systematic convolutions part codes of rate 1⁄2 that are divided by an interleaver. The same sequence of information is encoded twice, but that in different combinations. From the upper encoder, the output sequence is multiplexed and optionally punctured. The two-component decoders consist of an iterative SISO decoder, serially concatenated by an interleaver, as seen in Figure3. These two-component decoders are Soft Input Soft Output (SISO) decoders. The SISO decoder considers the soft input and gives the decoded sequence soft outputs.

Turbo codes rely on two constraints:

1. Due to the long block lengths, several decoding iterations are needed for near-capacity efficiency which results in a long decoding delay.
2. Good signal to noise ratio efficiency in the waterfall region and poor nonlinear performance in BERat the error floor region.

3. PROPOSED SYSTEM – THE PRODUCT CODE OF TLDPC WITH SCCI-TURBO CODE

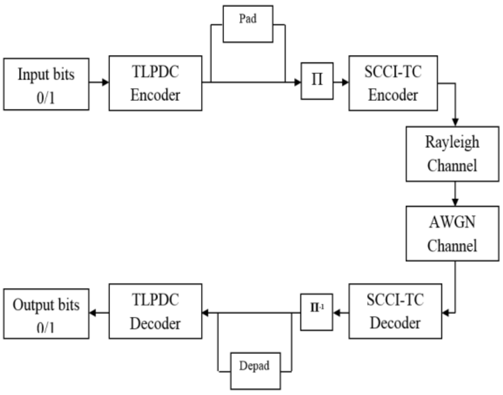

Figure. 4 Proposed system of the product codeof TLPDC and SCCI-TC with padding

In this segment, to overcome the disadvantage of the turbo code; the Single Column Constrained Interleaver (SCCI)which exchanges row data to the different column is used in turbo code and the turbo code is combined with TLDPC with padding. The random zero / one input bits are passed into the TLDPC encoding technique; this adds the parity bits in the row. Then data is fed through padding which adds zeros based on the requirement of the next outer blocks codes. The packet blocks with padding bits are forwarded to the SCCI-TC encoding as an input. The two encoded information is transmitted through the two Error model channel. AWGN channel adds random errors to data and Rayleigh adds the burst error to the data. The data with errors are received by the receiver. Here the bust error is handled by the SCCI-Turbo code which has SCC Interleaver. Then, the data block is de-padded, interleaved, andtransferred into the decoding of TLDPC. TLDPC corrects random errors that SCCI turbo missed to correct them. The output of TLDPC gives the original message data. By adding global iterations between the two decoders as well as local iterations at each decoder, the output of serially concatenated LDPC and turbo codes has been investigated and analysed.

This systemanalysed under various conditions the actions of the proposed scheme.Here, the BPSK modulation is used in all the test conditions. Hence, the turbo codeusually achieves near-Shannon-limit error. But, when it is combined with the proposed TLDPC system, it shows a better linear performance at 2.5 dB SNR.

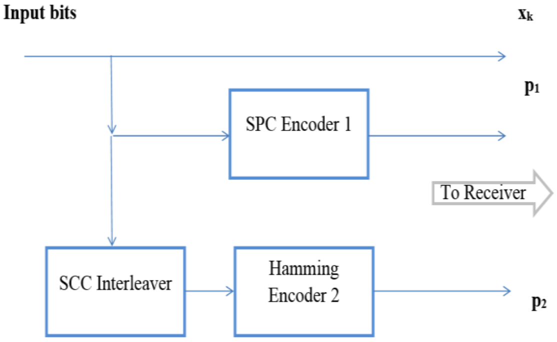

Figure. 5Single Column Constrained Interleaver Turbo (SCCI-TC) encoder

3.1 Single Column Constrained Interleaver Turbo Code

Sang et al., 2014 identified the shortcomings of convolution codes in optical transmissions. Here, the single interleaver restriction isused.Any two coded bits of any input block cannot be inserted in the same output block.

Algorithm of SCCI Turbo code

```
1. Input:blocks of n1 coded bits, G-matrix
   Output: interleaved blocks
2. Start
   Assign: $\gamma = L\gamma'$
3. $g_j = (g_{j0}, g_{j1}, g_j 2, \ldots g_{j(k-1)}))$ ;
   $b_j = g_j[G] = (b_{j0}, b_{j1}, b_{j2} \ldots b_{j(n-1)}))$;
   $j = 0,1,2,..,\gamma - 1$;
4. Single coded bit is formed as $t(i) = b_j \gamma$,
   where $i = 0,1,\ldots,(\gamma_{n-1})$, $j = [i/n_1]$, $\gamma = i - n_{1j}$;
5. SCC interleaver is $t(i), 0 \le i \le \gamma_{n-1}$
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Consider a single frame of an SCCI consisting of the (n1,k1) outer block code p-code words.

L is the columns of the block, then

$\gamma = L\gamma'$, (1)

where γ' is the number of code-words on each of L.

Let $g_j = (g_{j0}, g_{j1}, g_{j2}, \ldots g_{j(k-1)})$ (2)

$b_j = g_j[G] = (b_{j0}, b_{j1}, b_{j2} \ldots b_{j(n-1)})$, (3)

$j = 0,1,2,..,\gamma - 1$, (4)

Denote the set of γ independent information blocks and the respectivecodeword in the frame, where G is the matrix of the outer block code.

Let b be the sequence of coded bits formed as

$t(i) = b_j\gamma$ (5)

where $i = 0,1,\ldots,(\gamma_{n-1})$, $j = [i/n_1]$, $\gamma = i - n_{1j}$.

The SCCI interleaver places;$t(i), 0 \leq i \leq \gamma_{n-1}$ at an interleaved position on the interleaved sequence (u).

$u(\pi(i)) = t(i)$ (6)

The sequence u is passed into the inner code. Divide the interleaver input (b) into n_1-coded bit blocks each, and its u-coded output sequence into k_2 interleaved bit blocks each. The restriction in SCCI-TC is difficult to place any two coded bits of any input block into the same output block.Single parity check (SPC) encoder improves the performance of turbo code. Turbo codes usually having an error-rate floor problem. This can code can be improved using the SPC code. At BER of 10^{-5}, performances of about 0.5 dB from the theoretical limit is observed for turbo-SPC codes at moderate to high code rates.

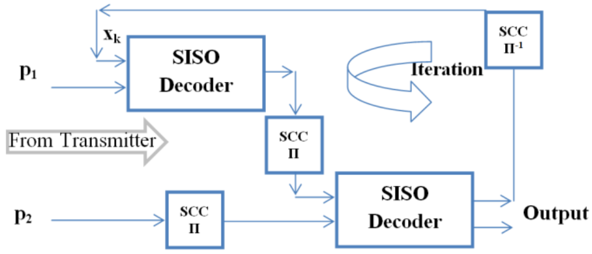
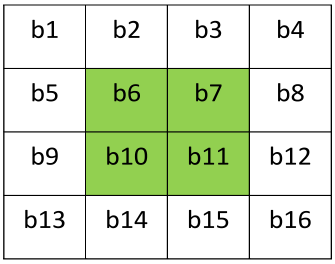
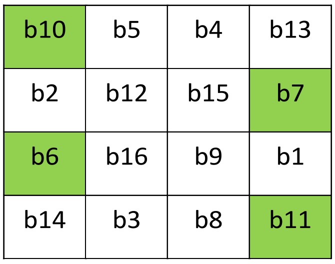


Figure.6Single Column ConstrainedInterleaver Turbo (SCCI-TC) decoder

By using the SCC Interleaver in the Turbo decoder, the errors are spread over the full matrix. The SISO decoder getsdata that has errors in a random position. This makes the turbo code correct the burst error created by the Rayleigh channel. TLDPC decoder gets the data with reduced errors, which helps the TLDPC to correct random errors effectively. Usually, turbo codes cannot produce a low error floor even when increasing SNR. Through the proposed system, the BER can be further reduced by increasing SNR. The turbo code consists of convolutional code like RSC coder in its parallel coding algorithm. In product codes, the various codes can be used in the coding system based on the application requirement.The Soft In Soft Out (SISO) algorithm is having a simple architecture than the soft-output Viterbi, the max-log-MAP, and log-MAP algorithms, When the SISO algorithm is used, turbo code which is having the block length of 150 bits can outperform convolutional codes with comparably equal decoder complexity.



b1	b2	b3	b4
b5	b6	b7	b8
b9	b10	b11	b12
b13	b14	b15	b16



b10	b5	b4	b13
b2	b12	b15	b7
b6	b16	b9	b1
b14	b3	b8	b11

Figure.7Schematic representation of SCC interleaver

The single-column constrained interleaver exchanges the data from every row to different columns as shown in the Figure 7. For example, b9 to b12 is exchanged to columns 1 to 4. This ensures the error to be scattered to a different location.

4. RESULT AND DISCUSSION

Performance of the TLDPC in product with SCCI-TC is compared with LDPC, Turbo code, and concatenated LDPC with Turbo for various code rate and frame length of 200& 1000 bits.

4.1 Performance of SCCI-Turbo code

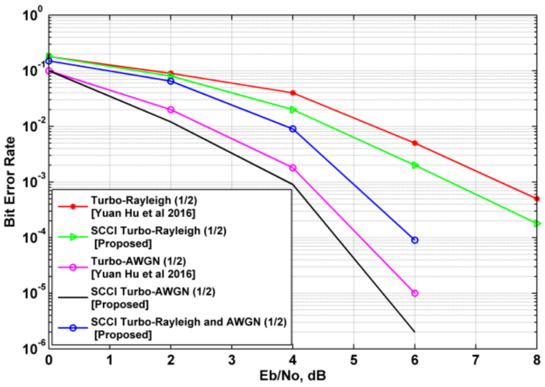


Figure. 8 BER variation of Turbo code, SCCI-Turbo code in AWGN, and Rayleigh channels

Figure8compares the BER performance of the Turbo code and SCCI-Turbo code which shows the simulated BER variation on Gaussian channel and Rayleigh channel whose outer block code is the (8,7) single parity check code and whose inner block code is the (8,4) extended Hamming code as per the 802.16a WiMax standard (2012). The QPSK modulation is used in all variants of this analysis. In the AWGN channel, for Eb/No of 8, The turbo code produced BER of near to 10^{-3} and SCCI-Turbo produced BER near to 10^{-4}. In the Rayleigh channel, for Eb/No of 6, The turbo code produced BER of near to 10^{-5} and SCCI-Turbo produced BER near to 10^{-6}.It indicates that the SCCI-Turbo outperforms the turbo code in both the AWGN channel as well as in Rayleigh channel.

4.2 Product code performance for frame length of 200 bits.

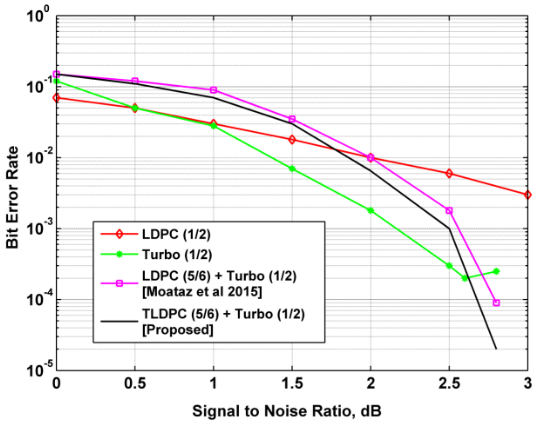


Figure. 9 Performance comparisons of proposed product code for the frame length of 200 bits in AWGN Channel

The simulation results for the 200-bit frame length are seen in Figure 9. When the outer LDPC code rate is 5/6 and the inner turbo code rate is 1/2, it takes around 2.8 dB to get BER 1x10^{-4}. The cumulative code rate, in this case, is 0.42. The Product of TLDPC and SCCI-TC requires about the same 2.8 dB to produce a better BER of2x10^{-5}. Here the outer TLDPC code rate is 5/6 and the inner SCCI- turbo code rate is 1/2. The Product scheme of TLDPC and SCCI-TC showed an improvement with thelinear error floor.

4.3 Product code performance for frame length 1000 bits.

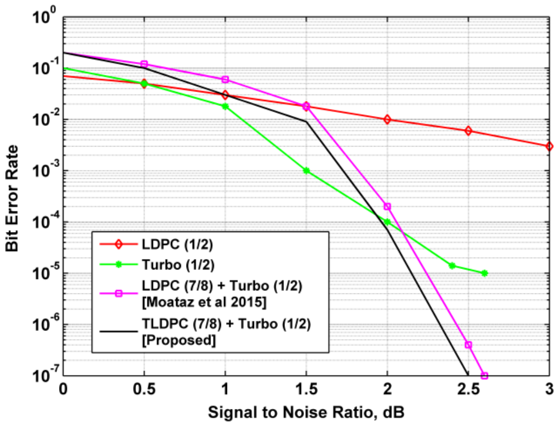


Figure.10Performance comparisons of product code for the frame length of 1000 bits in AWGN Channel.

The simulation results for the 1000-bit frame length are seen in Figure 10. The turbo code output depends on the length of the frame. Low BER achieved when using longer frame lengths for turbo codes. When the outer LDPC code rate is 7/8 and the inner turbo code rate is 1/2, the cumulative code rate, in this case, is 0.44. The BPSK modulation is used in the AWGN channel. At the SNR of 2.5 dB, the system having 200 bits frame length has given the BER of 10^{-3}. But it decreases to 10^{-7} when a frame length of 1000 bits is used. The result indicates that when frame length increases the BER of the proposed system decreases.

4.4 Product code performance in Rayleigh fading channel

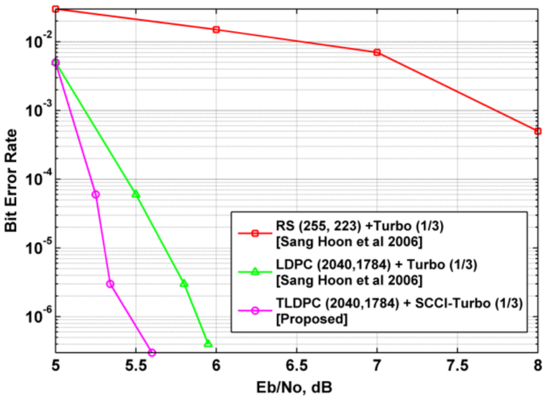


Figure. 11The ratio between Eb/No to BER of proposed product code in Rayleigh channel.

The function of the proposed system is analyzed under the Raleigh fading channel, the code rate of turbo code in all these systems are taken as 1/3. The LDPC and TLDPC are examined in codeword length of 2040 and message length of 1784 with a code rate of 87.4%. The RS code of 255 codeword length and 233 message length with a block interleaver is taken for analysis. BPSK modulation is used in all three systems. The results show that the implementation of trellis layered structure and SCC interleaver helps the product of TLDPC-SCCI turbo code to outperform the product codeofRS-Turbo code and LDPC-Turbo code by reducing BER to $0.8*10^{-6}$ from $0.2*10^{-1}$ and $0.5*10^{-4}$respectivelyat the Eb/No of 5.5 dB.

4.5 Product code performance in AWGN and Rayleigh fading channel

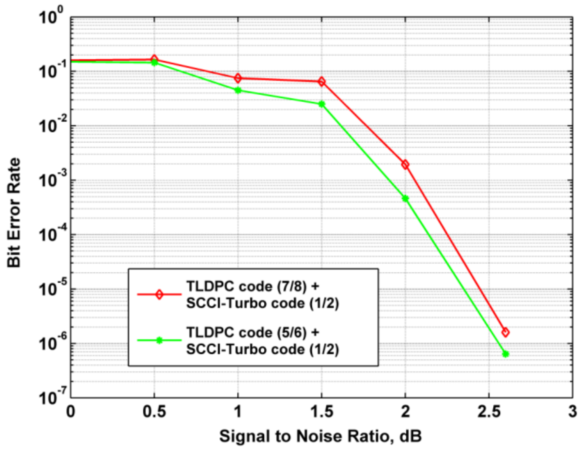


Figure. 12 The ratio between SNR to BER of the proposed system, in AWGN and Rayleigh channel.

The proposed system is analyzed with various code rates in AWGN and Rayleigh channels. Figure 12 shows that the proposed product code with TLDPC in the code rate of 5/6 and SCCI-Turbo code in the code rate of ½ has given $0.6*10^{-6}$ BER for the SNR of 2.6

dB. The combined code rate is 42%. When the code rate of TLDPC changed to 7/8. The combined code rate is 44%. The BER of $0.2*10^{-5}$ is obtained at the same SNR. This shows that the proposed code reduces the BER while using the same code rate of 0.42.

5. CONCLUSION

In this proposed system, the product code using TLDPC with the SCCI-Turbo code is described. Single Column Constrained Interleaver is incorporated to strengthen the turbo code by exchanging row data to a different column. The proposed system also consists of padding which is used to make compatibility between TLDPC and SCCI-Turbo code. Bit error rate performance of the SCC interleaver has been presented and discussed for various E_b/N_o which shows 1 dB performance improvement over turbo code. By constructing the SCCI-Turbo code in a product with TLDPC, the low BER floor is achieved. TLDPC inproduct with SCCI-TC overcomes the drawback of the current turbo code by using the outer TLDPC code rate as 5/6 and the inner SCCI-Turbo code rate as 1/2.Bit error rate performance of the product code systemis analysed for various SNR which shows that the proposed product code outperforms the RS-Turbo code and LDPC-Turbo code by reducing BER to $0.8*10^{-6}$ from $0.2*10^{-1}$ and $0.5*10^{-4}$ respectively at the E_b/N_o of 5.5 dB. Hence, this system can be used as error detection and correction system for deep space communication systems, and wireless sensor networks.

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