"Implementation of Channel Coder for LDPC (Low Density Parity Check) Linear Block Code using Neural Network"

Dimpal Thakor[1], Prof. Dharmeshkumar Patel[2]

[1]*Department of Electronics and Communication Engineering, GEC, Surat, Gujarat, India;*
[2]*Professor, Government Engineering College, Surat, Gujarat, India;*

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Abstract*: The Problem of using channel decoding of linear codes with short to moderate block length is considered. The Deep Learning based algorithms can be used to improve decoding capability. The Deep Learning algorithms also shown that tying the parameter of the decoders across the iteration, so as to form a recurrent neural network architecture, which can be implemented with the comparable results. The main advantage is that to use the Deep Learning algorithms for less number of parameter has been significantly used. This Deep Learning algorithms generalize the belief propagation algorithm by assigning weights to the edges of the Tanner graph and then these edges are trained using Deep Learning algorithms. The Proposed work is on DNN (Deep Neural Network) decoders for LDPC (Low Density Parity Check) codes is considered. The use of LDPC codes provide the best performance for medium to higher block length but it also provide better performance for small block length. The use of this iterative Deep Learning based decoder converge faster and thus achieve higher throughput at the cost of trivial additional decoding complexity.*

Key Words**: Decoding of LDPC codes, Deep Neural network, Feed forward neural network.**

1. INTRODUCTION:

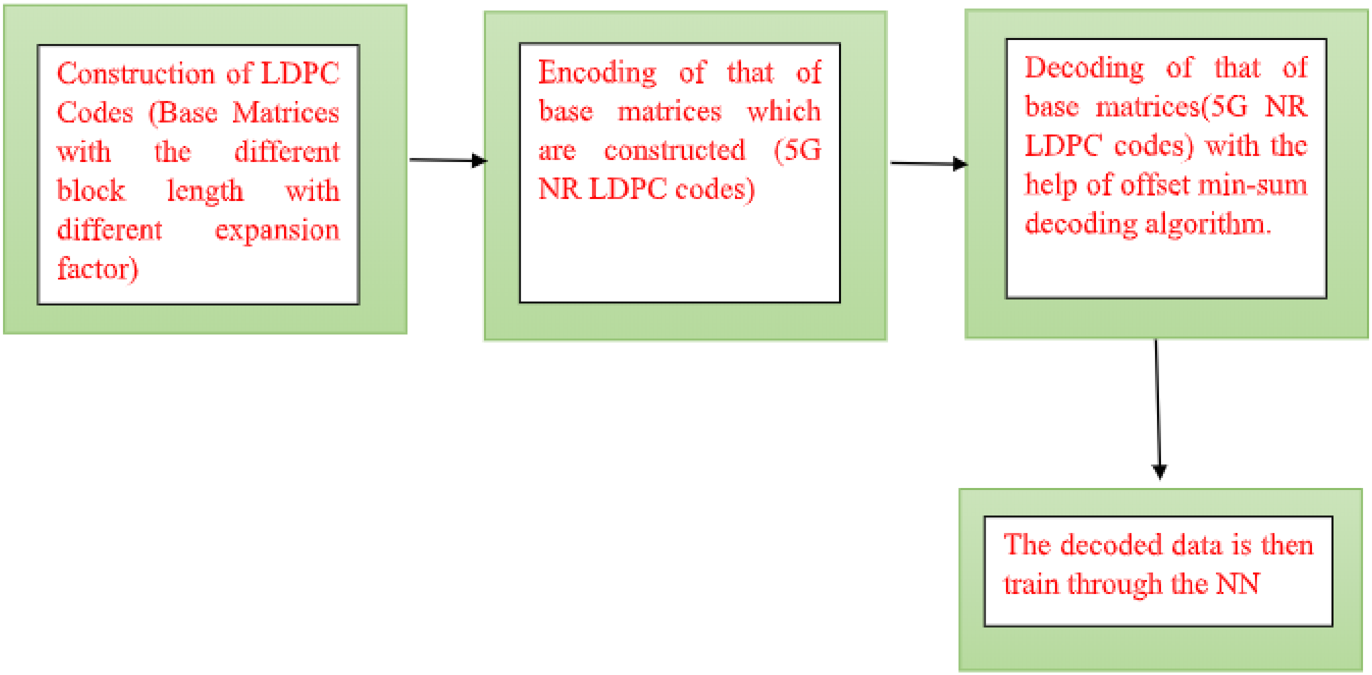
When transmission of digital signals takes place between two systems such as two computers as shown in fig. 1.1, the signal gets contaminated due to the addition of **'noise'** to it. The noise can introduce an error in the travelling binary bits from one system to another system, which changes '0' to '1'. This error can become serious threat to the accuracy of the digital system. So therefore it is necessary to detect and correct the errors. The reliability of the data transmission will be severely affected due to these errors. In order to improve reliability, will have to increase the signal power or to reduce the spectral density N_0 so as to maximize SNR E_b / N_0. But practically there is a limitation on the maximum value of the SNR. We cannot increase beyond its limit. Hence for a fixed value of SNR , we have to use some kind of **"CODING"** in order to improve the quality of the signal. LDPC is a Linear error correcting code, a method of transmitting a message over a noisy transmission channel.LDPC codes are defined by a sparse parity-check matrix.For example it contains only a small number of 1s per row or column, then the code is known as low parity check codes. Decoding of LDPC codes Much number of decoding algorithms has been developed for both binary and non-binary LDPC codes based on soft decision decoding and hard decision decoding schemes. The generic block diagram for decoding algorithm is as shown below. The basic procedure for decoding of the LDPC codes includes the following metrics. Check nodes issue some constraints to the variable nodes. If the variable nodes satisfy those constraints, the input code to the decoder is assumed to be true and transmits that data to the output. Else the error is detected with the help of Syndrome and corrected the Received code word then passed to the output node. The decoding of LDPC codes is an iterative process.

2. Proposed Method:

The basic flow for fulfilling the objectives is to decode the codes through the Neural Network.

Step1 : Construction of LDPC code:
Step2 : Encoding LDPC code:
Step3 : Decoding LDPC code using the offset min-sum algorithm then train the data through the NN.

Fig-1 Encoding and Decoding System in LDPC code using NN.



Once the Construction of LDPC code are getting ready the encoding of the LDPC codes takes and the decoding is done by the offset minsum decoding .

2.1 Offset Min-sum Decoding: The foundation of work is based on the improvement in error performance of normalized min sum algorithm . From descriptions in previous sections, we have seen that the sum product decoding has been reduced to different forms to reduce the complexity and through some compromise in performance. Min sum decoding algorithm is one of them. Different works have been done on min sum decoding to improve its performance to get closer to sum product algorithm performance like normalized min sum decoding algorithm, adaptive min sum decoding algorithm, self-corrected min sum decoding algorithm etc. The proposed different factors which modifies and improves the error performance in different ways. In the normalized min-sum algorithm, a normalizing factor was proposed to be multiplied in check node. But, the error performance using normalized min-sum algorithm can be further modified to get closer to the error performance of sum product algorithm.

- **Optimization Factor.**

The value of optimization factor varies for different Signal to Noise Ratio (SNR). For a particular SNR, we took the value of that causes the minimum Bit Error Rate (BER).
Where,

α= Optimization factor
Range = $0 \leq \alpha \leq 1$

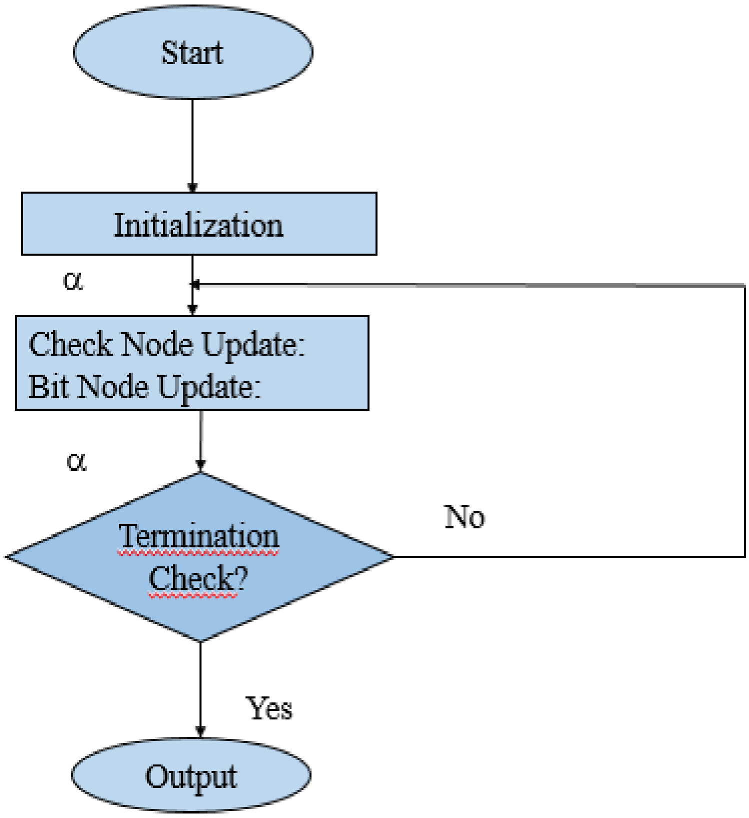


Fig-2 Flow chart of offset minsum decoding

The machine learning uses a neural network with only more hidden layers, which is fed by a database of LLRs for training. In the first layer, called the input layer, the received LLRs of the neural network are assigned to the next layer like the message passing from variable nodes to check nodes. In the second layer which is generally known as the hidden layer, the LLRs are calculated and being passed or forward to the last layer, where the procedure is like the check node updating by Equation in the OMS algorithm.

In the last layer known as the output layer, the LLRs are finally updated according to Equation. Similar with one iteration of the LDPC decoding, the neural network controls the flow of LLRs and optimizes the four factors in the hidden and output layer.

With large amounts of the LLR data, the neural network can train the factors in the i th iteration to minimize the gap between the output and the target codes by the stochastic gradient descent. When the optimization of the factors is finished, the four optimized factors are saved and used to calculate the LLRs for the next iteration by the OMS decoder described in Algorithm. Then, the LLRs are sent back as the training data to start the optimization for the next iteration, where the neural network should have been initialized.

Since the LDPC codes in 5G new radio (NR) belong to the family of PB-LDPC codes with QC structures, an operation unit of the neural network can deal with a set of Z bits simultaneously, where Z is the lifting factor of a QC matrix. That makes the number of operation units equal to the number of edges or nodes in a protograph. The protograph is usually considered as a small bipartite graph containing n variable nodes and M check nodes which are interconnected.

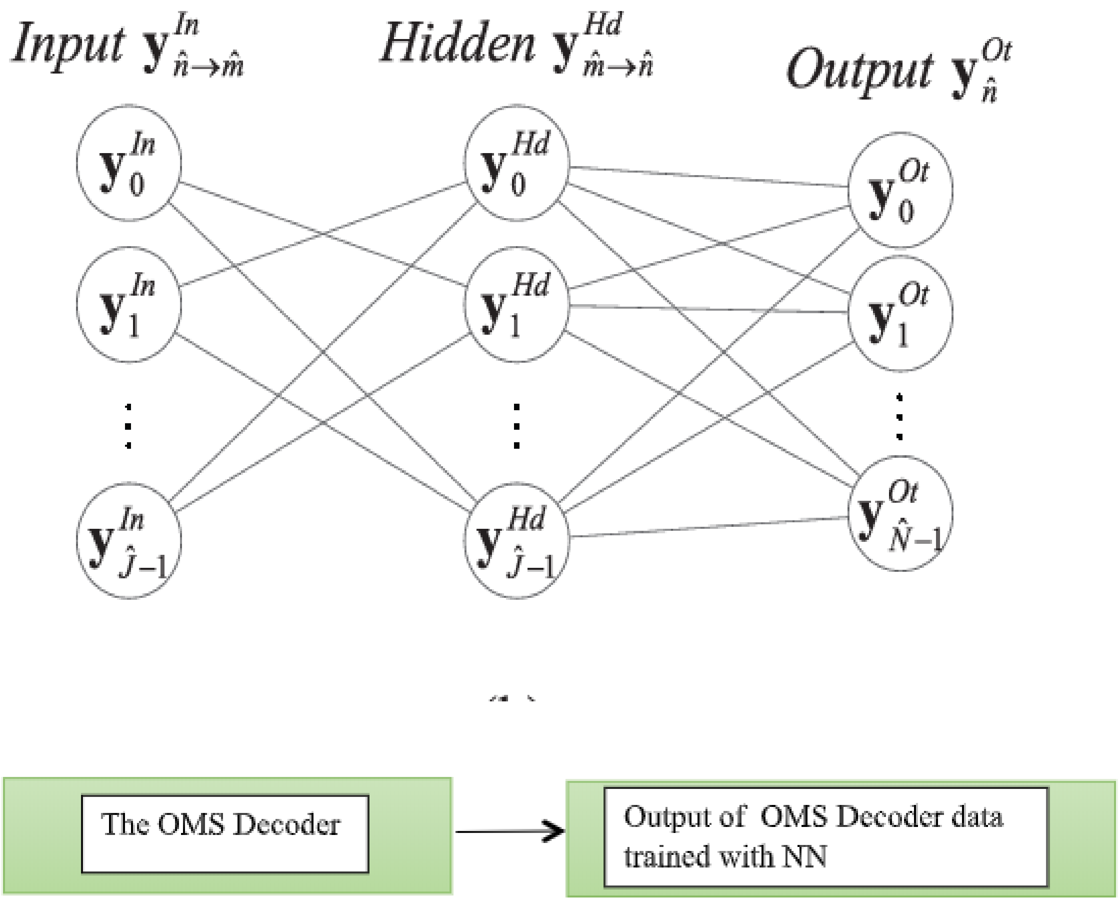


Fig.-3 OMS decoder with NN Operation

3. ADVANTAGES OF DECODING USING ITERATIVELY:

(1).Instead of trellis, the decoding takes place on TANNER graph.
(2). Messages are exchanged between v- nodes and c- nodes.
(3).Edges of the graph act as information pathways.
(4).The LDPC decoding provide the less per- iteration complexity than that of Turbo codes.
(5). Randomly generated LDPC codes has higher efficiency and fewer cycles then structurally or pattern wise generated code.

4. LIMITATION:

In order to retrieve error less transmission data we need to perform the different error correcting codes with the different decoding algorithms with help of deep neural network .The LDPC linear codes provides the best performance for short to moderate block length , but provide the more computational complexity for the large block length. At the time of construction, due to Improper Design of Parity check matrix of LDPC code Short cycle increases which intern create Error floor , water fall region.

5. CONCLUSION:

In order to retrieve error less transmission data we need to perform the different error correcting codes with the different decoding algorithms .The LDPC linear codes provides the best performance for short to moderate block length , but provide the more computational complexity for the large block length. At the time of construction, due to Improper Design of Parity check matrix of LDPC code Short cycle increases which intern create Error floor, water fall region. Nowadays as we know the LDPC codes are used in everywhere so we need to provide perfect decoding algorithm to reduce some of the parameters such as the signal to noise ratio, Bit error rate etc. This can be achieved by using the DNN architecture. Also the neural decoders provide the all advantages over all of the algorithms. So our task is to provide the errorless communication over the channel with use of deep neural networking. Main feature of this thesis is to provide accurate performance with less computational complexity with high SNR, high BER with the use of less iteration, with less process time, with the reduction in Delay. Also, provide the best throughput with less complexity.

6. REFERENCES

[1] Andrew Jiang. "Machine Learning and Algorithmic Techniques for Error Detection". Computer Science and Engineering Depatment Texas A&M University.

[2] Tobias Gruber, Sebastian Cammerer , Jakob Hoydis and Stephan ten Brink. "On Deep Learning – Based Channel Decoding".IEEE 2017.

[3] Eliya Nachmani , Yair Br'ery and David Burshtein. "Learning to Decode Linear Codes Using Deep Learning". Fifty-fourth Annual Allerton Conference , UIUC , USA , IEEE September 27 -30,2016

[4] Mingxu Zhang , Qin Huang , Shuai Wang and Zulin Wang . " Constuction Of LDPC Codes Based On Deep Learning Reinforcement Learning". Collabrative Innovation Center of Geospatial Technology, Wuhan , China.

[5] Enver Cavus , Babak Daneshard. " A PERFORMANCE IMPROVEMENT AND ERROR FLOOR AVOIDANCE TECHNIQUE FOR BELIEF PROPAGATION DECODING OF LDPC CODES". 2005 IEEE 16th International Symposium on Personal , Indoor , Mobile Radio Communications.

[6] Evgeny Likhobabin and Vlamidir Vityazev , Member of IEEE. "Error Floor Reduction for LDPC Codes Using Self-Correction Technique". 24th Telecommunication forum TELFOR 2016.

[7] Shruti Wahane, Sandeep Kakde , Atish Khobragade and Wael Elmedany."A Systematic Approach For Achieving Low Error Bit Rate of LDPC Decoder Using MWD algorithm". IEEE 2017.

[8] R.G. Gallager, "Low-density parity-check codes," Cambridge, MA:M.I.T. Press, 1963.

[9] D.J.C. MacKay, R.M. Neal, "Near Shannon limit performance of low density parity check codes," Electron. Lett., vol. 32, no. 18, pp. 1645-1646, Aug. 1996.

[10] T. Richardson, A. Shokrollahi, R. Urbanke, "Design of capacity approaching irregular low-density parity check codes," IEEE Trans. Inform. Theory, vol. 47, pp. 619637, Feb. 2001.

[11] S. ten Brink, G. Kramer, and A. Ashikhmin, "Design of low-density parity-check codes for modulation and detection," IEEE Trans. Commun., vol. 52, no. 4, pp. 670–678, Apr. 2004.

[12] E. Sharon, A. Ashikhmin, and S. Litsyn, "Analysis of Low-Density Parity-Check Codes Based on EXIT Functions," IEEE Trans. Communications, vol. 54, no. 8, pp. 1407 – 1414, Aug. 2006.

[13] M. El- Hajjar and L. Hanzo, "EXIT Charts for System Design and Analysis," IEEE Communications Surveys & Tutorials, vol. 16, No. 1, First Quarter 2014.

[14] Kakde Sandeep and Atish Khobragade, "Performance analysis of a high throughput LDPC decoder using sum product and min sum algorithm," Int. J. Com. Dig. Sys., vol. 6, no. 2. pp. 89–95, 2017.

[15] Bourichi and Adil El, "A low power parallel sequential decoder for convolutional codes," Int. J. Com. Dig. Sys. vol. 2, no. 2, pp. 95–101,2013.

[16] V. Savin, "Self-corrected min-sum decoding of LDPC codes," IEEE International symposium on Information Theory, 2008. pp. 146-150.

[17] J. Andrade, G. Falcao, V. Silva, J.P. Baretto, N. Goncalves, V.Savin "Near- LSPA Performance at MSA Complexity," IEEE International Conf. on Communications, 2013, pp.3281-3285.

[18] T. Richardson, "Error floors of LDPC codes," in Proc. 41st Allerton Conf. on Communications, Control, and Computing, Allerton House, Monticello, IL, Oct. 2003.

[19] M. Luby, M. Mitzenmacher, M. A. Shokrollahi, and D. Spielman, "Improved low-density parity-check codes using irregular graphs," IEEE Trans. Inf. Theory, vol. 47, pp. 585598, Feb. 2001.

[20] H. Pishro-Nik and F. Fekri, "Improved decoding algorithms for low density parity-check codes," in Proc. 3rd International Conference on Turbo Codes and Related Topics 2003.

[21] T. J. O'Shea, K. Karra, and T. C. Clancy, "Learning to communicate: Channel auto-encoders, domain specific regularizers, and attention," IEEE Int. Symp. Signal Process. Inform. Tech. (ISSPIT), pp. 223–228, 2016.
[22] I. Goodfellow, Y. Bengio, and A. Courville, Deep Learning. MIT Press,2016.
[23] C. E. Shannon, "A mathematical theory of communication," Bell Syst. Tech. Journal, vol. 27, pp. 379–423, 623–656, 1948.
[24] Eliya nachmani, Elad Marciano , Loren Lugosch , Member of IEEE , Warren J. Gross , Senior Member , IEEE. "Deep Learning Methods for Improved Decoding of Linear Codes" IEEE 2017.
[25] Xiaoning WU, MING JIANG , and Chunming zhao."Decoding Optimization for 5G LDPC codes using machine learning " IEEE 2018.