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Sensor's Data Transmission over QAM Using LDPC Over MIMO Channel to enhance the Channel capacity: Performance analysis over RMSE and BER

Charanarur Panem[1], VinayaR.Gad[2], Rajendra S. Gad[1]

[1]Altera SoC Lab., Electronics Department, Goa University, Taleigao, Goa, India
[2]Department of Information Technology, GVM's College Ponda, Goa,India

Abstract. Modern communications systems utilize effective encoding plans, multiple-input multiple-output (MIMO) and high-order QAM-constellations for improves spectral efficiency. However, as the dimensions of the system grow, the design of efficient and low-complexity MIMO receivers possesses technical difficulties. Here in this paper, we have demonstrated data reduction method using Principal Component Analysis (PCA) to fuse the data at sensor level at the transmitter and regress the same at the receiver for improvising the channel capacity of the system. We have fused 45 signals sensor data having a bandwidth from 100Hz - 3000Hz which is sampled at 6000 Hz each. The regression is measured using the RMSE of the transmitted and received signals. Also, the communication system has demonstrated the performance of the 2,4,8QAM modulation technique with and without LDPC decoder(log-domain) for 2x2,3x3,4x4 Multiple Input Multiple Output(MIMO) channel for Bit Error Rate (BER). The performance parameters for data regression and communication error is evaluated over AWGN channel ranging from -15dB to 40dB SNR. The proposed system useful for the next generation low bandwidth communication system such as wireless systems developments, i.e., WiMAX and 4G, 5G, 6G.

Keywords: PCA, LDPC codes, Log-Domain Algorithm, SNR, BER, RMSE, QAM modulation,AWGN.

1. Introduction

In recent time wireless communication system are implemented with Multiple Input Multiple Output(MIMO) system[1].MIMO system enhances capacity(throughput) and reliability(decreases symbol error rate), which is proportional to the dimension of MIMO system i.e. the number of transmit-receive antennas. There are limitations at higher-dimensional MIMO, specifically spatial restriction for antenna deployment and complexity in signal processing at transceiver[2].

Low Density Parity-Check (LDPC) codes are perceived as the most dominant forward error correction codes, whose bit-error-rate (BER) execution is extremely close Shannon limit. LDPC-codes are demonstrated to have better performance and a considerable amount of points of interest other error correction codes such as Hamming codes, Turbo codes, Reed-Solomon and Reed-Muller codes. LDPC codes are broadly utilized in numerous applications for example ,Terrestrial television broadcasting system, digital satellite and Digital Video Broadcasting. Despite the fact that the decoding algorithm in LDPC is modest, but increasing the block length LDPC matrix becomes larger, and it is time consuming to physically connect and test the connections. The challenging parameter in designing of a fully parallel LDPC decoder is its complexity between its nodes inside the decoder. As continue expanding the square length it turns out to be practically troublesome and time taking to physically associate and check the interconnections.

Given the expanding number of applications require high-speed transmission without increasing the BW of the transmission channel,it is the explanation behind the utilization of high-order constellations. The Quadrature Amplitude Modulation (QAM), is exceptionally recommended as a high order constellation. In any case, communication-systems utilizing QAM require a high SNR. To overcome thedrawback, it is motivating to combine high error correction codes. such as LDPC-codes with QAM[3].

In this paper an data reduction method to enhance the channel efficiency using PCA is introduced. We are using MATLAB Simulink(2018B) for modeling the system proposed in Fig. 1.The designing and testing of LDPC decoder is done using high-level modeling tool. The paper is organized as follows. Section II presents the earlier work done in Log-Domain algorithm. Section III explains theory of Log-Domain algorithm. Design methodology for developing LDPC decoder in MATLAB Simulink is given in section IV. Simulation results are covered in Section V and VI draws conclusion to the paper.

1.1 Motivation

The fundamental objective in designing a communication system is to accomplish reliable data transmission for the power effectiveness having the lowest error probability (bit error rate). In addition, a higher data rate with a constraint on available bandwidth is another target. LDPC codes can be chosen as an excellent coding scheme to achieve the highest quality transmission in noisy channels.On the other hand, in terms of efficient use of bandwidth while having a high data rate to achieve good channel capacity should be explored. Therefore, motivated by the development of low power and enhance channel capacity over low bandwidth for various SNR is a challenge. We tried to address this problem using sensor level, data reduction method over MIMO system to improvise the channel capacity by some factor in a wireless communication system.

1.2Paper contributions

This paper is devoted to the study of sensor level fused data transmission over QAM modulation using LDPC Log Domain Error Corrections over MIMO Channel. The appear contributions are the following:

- Present the sensor level data fusion of signals originating from 45 signals for efficient transmission and reception over the communication channel for performance parameters like RMSE.
- The same system analyzed and evaluated for LDPC decoder algorithm for error-free data transmission over noisy channel using QAM Modulation for performance parameters like BER.
- The System is further analyzed for the wireless communication system for data transmission with and without 2x2,3x3,4x4 MIMO channel respectively in AWGN channel.

2. Previous Work

LDPC decoder uses various Message passing algorithm for decoding information, among them Log-Domain algorithm is broadly categorized. The bits to be sent are generated as k×G where the message of k bits gets multiplied by G-matrix also called as generator matrix. LDPC codes have code rate which is represented by k/n. Here k-is the number of original bits in the message and n is the total encoded information. The n bits are directed by a transmitter over an AWGN channel, at receiving end decoder decodes the n-bits using message passing algorithm to obtain original k bits. The LDPC Codes are represented by Tanner Graphs.

LDPC codes can be represented by H-matrix ,that M x N. It contains generally zeros and a small number of 1’s [4], [5] and also called tanner or bipartite graph. LDPC codes are comprehensively used in standards such as 10Gigabit Ethernet, Wi-MAX, Digital video broadcasting (DVB-S2) and anticipated to be part of many upcoming applications[6]. Several messages passing decoding algorithms were introduced along with low-density-parity-check codes[4].once achieve the capacity with AWGN channel with regular binary LDPC codes decoded with the sum-product algorithm(SPA)[5].Conventional LDPC removing certain constraints on the parity check matrix and are known as irregular LDPC codes which outperform regular LDPC -odes[6].Superior performance can be achieved burst errors by allowing coding and decoding through Galois fields[7][8]. Mackay et.al.demonstrated that best performing LDPC codes for BER Vs SNR are unequal non-binary LDPC-codes. Decoding-algorithm for binary-codes using probability domain(SPA) has several drawbacks as compared to implementation here i.e. log-SPA, which is based on the log-likelihood ratio(LLR)[9]. The direct implementation is sensitive to quantization level which are large in number[10][11]. One may note that the SPA requires message multiplications, where the log-SPA use message additions.SPA additions are implemented by Jacobi logarithm[12], resulting in max-log-SPA, and finally, log-SPA implementation does not require normalization step[13].

As shown in Fig.1 the simulation of LDPC decoder is done in MATLAB Simulink using MATLAB script. Simulink model of LDPC decoder can be analyzed using MATLAB script.

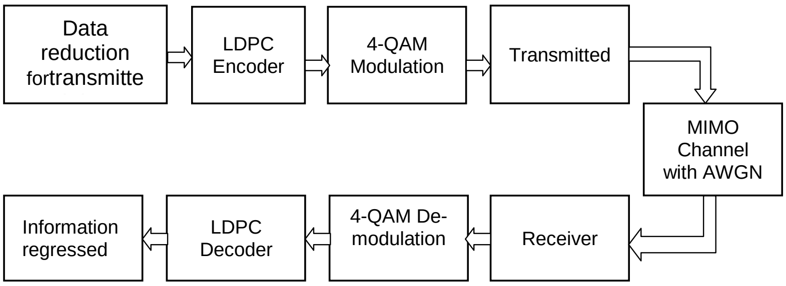

Figure 1. The proposed Sensor's Data Transmission over 2,4,8-QAM Using LDPC Error Corrections Over MIMO Channel

3. Log-Domain Decoding of LDPC Codes

LDPC-codes are linear-block codes. They are characterized by a very parity-check matrix in a finite Galois-field GF(q). This matrix'H' comprises of 'M' commonly autonomous rows and 'N' columns. From H, a methodical NxK(with K=N-M) generator matrix G^T can be developed with the end goal that the lines of create the invalid space of H produces the invalid space G^T ie.$HG^T=0$[14].

For LDPC codes, the message passing calculations comprises of the accompanying steps: With each check-node($m, 1 \leq m \leq M$) and variable-node ($n, 1 \leq n \leq N$),its partner two kinds of messages[14].

The Log-Likelihood random variables (LLRV) messages from check node m to variable node n:F ($m \longrightarrow n$) signifying the LLRV all factors tested by the m-th check, apart from the n-th variable itself. When LLRV messages from variable node n to check node m:F($n \longrightarrow m$) presents the LLRV of the n-th variable, specified the LLRV of all checks including variable n, with the exemption of check m itself.

Then further indicate by M(n) , the set of check-nodes associated with variable-node n. Similarly, itsdenote by N(m) the set of variable-nodes associated to check-node m. For each check node m, order$N(m): n_{m,0} < n_{m,1} \ldots < n_{m,end-1}$[14].

(1).Demapping and intialization : First, chose the LLRV involving to unpredictable node n, as indicated by the channel and modulation signaling the i-th component is given

$$F_{ch}(c_n)_i = \sum_{j:\phi^{-1}(a_i)} \frac{2x_{nb+j}}{\sigma^2}$$

Wher x, output vector,'c' pdf ,n are the independent white Gaussian noise vectorsfor $1 \leq m \leq M$ and $1 \leq n \leq N$with $H_{m,n} \neq 0$,the LLRV messages as

$$\mathrm{F}\,(m \longrightarrow n) = 0$$

$$\mathrm{F}\,(m \longleftarrow n) = \mathrm{L_{ch}}\,(\mathrm{c_n})$$

(2) *Tentative decoding:* Now calculate the a posterior LLRV for every variable, given by $F_{post}\,(\mathrm{c_n}), 1 \leq n \leq N$

$$F_{post}\,(\mathrm{c_n}) = \mathrm{F_{ch}}\,(\mathrm{c_n}) + \textstyle\sum_{j\,:M(n)} F(j \longrightarrow n) \qquad (1)$$

(3) *Horizontal step:* The message from variable node to check node is just given by (for $1 \leq n \leq N$ and $m\epsilon M(n)$):

$$\mathrm{F}\,(m \longleftarrow n) = \mathrm{F_{ch}}\,(\mathrm{c_n}) + \sum_{j\,:M(n)\backslash m} F(j \longrightarrow n)$$

(4) *Vertical step:* For each test node and nearest variable node $n_{m,k,}$initiate to the new RVs in $GF(q)$: $\sigma_{m,n_{m,i}} = \sum_{j\leq l} H_{m,n_{m,j}} c_{n_{m,j}}$ and $\rho_{m,n_{m,i}} = \sum_{j\leq l} H_{m,n_{m,j}} c_{n_{m,j}}$.It can easily be established that the conveyanceof $\sigma_{m,n_{m,i}}$and $\rho_{m,n_{m,i}}$can be figured recursively accord[14].

$$\begin{cases} F\left(\sigma_{m,n_{m,i}}\right) = F(\sigma_{m,n_{m,i-1}} + H_{m,n_{m,l}} c_{n_{m,l}}) \\ F\left(\rho_{m,n_{m,i}}\right) = F(\rho_{m,n_{m,i-1}} + H_{m,n_{m,l}} c_{n_{m,l}}) \end{cases}$$

where the LLRV of $c_{n_{m,l}}$is specified by $\mathrm{F}\left(m \longleftarrow n_{m,l}\right)$. The information from trial node to unpredictable node $n_{m,l}$is then set by (for $1 \leq m \leq M$ and $n\epsilon N(m)$):

$$\mathrm{F}\left(m \longleftarrow n_{m,k}\right) = \mathrm{F}({H^{-1}}_{m,n_{m,k}} c_{n_{m,k}} \sigma_{m,n_{m,k-1}} + {H^{-1}}_{m,n_{m,k}} c_{n_{m,k}} \rho_{m,n_{m,k-1}}) \qquad (2)$$

The messages (2) are used to refresh the posterior LLRV (1)[14].

4.Design Methodology

Efficient implementation of higher Block length LDPC decoder is a time-consuming process hence to overcome, we have designed LDPC encoder and decoder in MATLAB Simulink (2018B). Using Simulink library in communication system, we have provided streams of data in matrix form of block length (100, 45) of 16-bitwordlength corresponding to 45 sensors signal data. This is reduce to (45,45) of 16-bitwordlength Eigen matrix corresponding to 45 sensors signal data. Thisreduce matrix is mapped to LDPC for the code rate of R = 1/2 to generate the block length of 64800 bits at he LDPC encoder having 32400 message bits. The encoded data from LDPC encoder is further 4-QAM modulatons. Channel selected here is AWGN having SNR values from -15dB to 40 dB. The said system is further tested for the performance over LDPC codes with 2x2,3x3,4x4 MIMO for wireless communication application.

5.Results Analysis

We use a class of irregular pseudo-random LDPC codes which were proposed by Neal [15] to simulate the error performance over an AWGN channel. The block length (32400, 64800), having code rate R = 1/2, the average column weight Wc = 4 or 8 and the average row weight Wr = 8 or 12. The maximum number of iterations decoders are set 50, respectively.

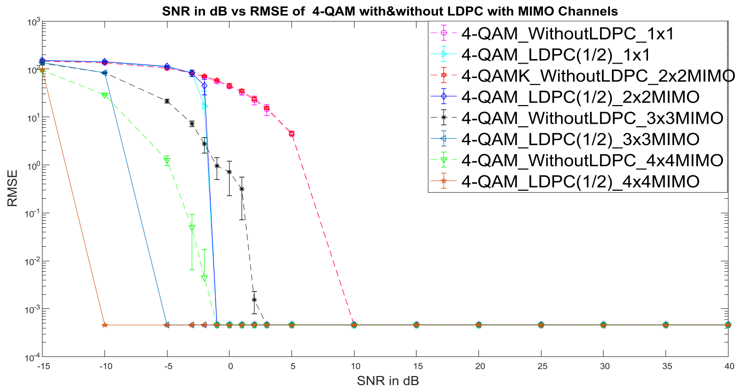

Figure 2. RMSE performance LDPC code with code rate R = 1/2 over an AWGN channel via 4-QAM modulation.

We have presented the RMSE performance in Fig. 2. The performance is for 4-QAM modulation with and without LDPC error correction over AWGN channel having SNR -15dB to 40dB. One can see that he performance of RMSE is better with LDPC algorithm as compared to the without LDPC error corrections for 1x1, 2x2, 3x3 and 4x4 MIMO channel. The RMSE is 0.5e-4 for 1x1 LDPC MIMO at -01 dB SNR value. The RMSE is 0.5e-4 for 4x4 LDPC MIMO at -10 dB SNR value. This state that one can have error-free signals transmission upto -10dB with LDPC error correction coding.

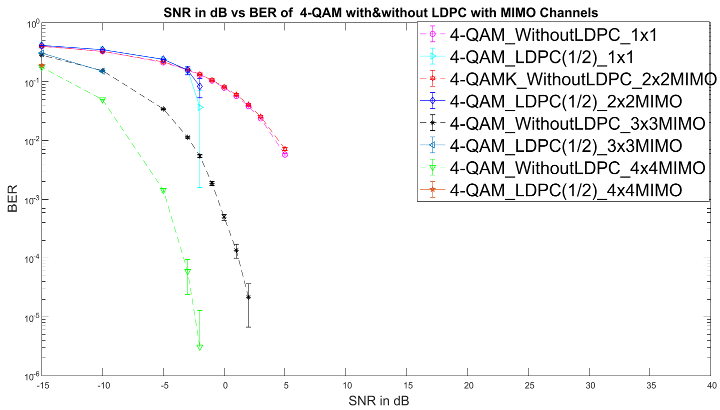

Figure 3. BER performance LDPC code with code rate R = 1/2 over an AWGN channel via 4-QAM modulation.

We have also presented the BER performance in Fig. 3. The performance is for 4-QAM modulation with and without LDPC error correction over AWGN channel having SNR -15dB to 40dB. One can see that the performance of BER is better with LDPC algorithm as compared to the without LDPC error corrections for 1x1, 2x2, 3x3 and 4x4 MIMO channel. The BER value at the e-2 is -5.5 dB, -2dB, 4dB and 5dB respectively for 4x4, 3x3 , 2x2, and 1x1 MIMO. This implies that 4x4 is performing better compared to 1x1 MIMO for error correction. The BER value at the 0.1e-1 is -15 dB, -9dB, -2dB and -1dB respectively for 4x4, 3x3 , 2x2, and 1x1 MIMO. This implies that 4x4 is performing better with LDPC compared to without LDPC.

Table 1. Variabeles are using proposed system

Parameter	Value
LDPC code rate	½(32400 /64800)
LDPC Encoder Input Type	Bit
LDPC Decoder output Type	Information Part
LDPC Decoder Decision Input Type	Hard Decision
LDPC Decoder Number of Iterations	50
Modulator Type	4-QAM
Modulator Input Type	Bit
Modulator Symbol Order	Binary
Demodulator Output Type	Bit
LLR Algorithm	LLR
Channels	SISO&2x2,3x3,4x4 MIMO
Channel Noise Factor	SNR

As the model starts simulating, for every received data at the LDPC decoder, BER, channel SNR and PER is continuously updated. We need to go on increasing SNR to get an error-free output signal and less noisy plot.

6.Discussion And Conclusion

Simlar works are discovered like Vinayaet. al.[16] indicated that the consequences of BER execution improve with an increase in square block which can be optimizedfor error correction by setting the number of decoding iterations between 5 to 50 for SNR close to 2dB. Raghuwansiet.al, demonostrated the BER achieve is 10e-6, because of changes in modulation as well as 256-FFT points BPSK modulation the wireless LDPC based MIMO-OFDM [17]. Indira Bestariet.al, demonstrated LDPC encoding having BER of 10e-7 at SNR -6.0 dB.Here,single RF based MIMO OFDM works even at negative value of SNR dB.Here channel estimation generates very small difference within theoretical and estimated value[18].

Madiopet. al. ,researchedabout the unpredictability and BER execution analysis of Maximum likelihood zero forcing and minimum mean square error MIMO receivers by utilizing a small length binary polar code. The performance gain of 3dB at 10e−2 of the optimal maximum likelihood detector[19]. Lamiaet.al., presentedthe at small code rate with high channel efficive ness with low complexity of decoding at low BER LDPC-BCH for MIMO system and also proposed LDPC convolutional codes[20]. A.Z.M. Touhidul Islam et.al., 1/2-code rated LDPC channel for MIMO-OFDM system under changed digital-modulations on a Raleigh-fading channel.It provides the Eb/N0 value of 0.75 dB, the system shownenhancedby 2.7195 dB in the contained of 2-PSK modulation [21].

Ristoet.al., have proposed soft decision decoding with signal combing algorithm of Alamouti and the MRC to orthogonal MIMO codes for 3 and 4 transmit antennas. Here complexity does not exceed that of the Alamouti combiner and hence it can be easily implementable. Here FEC decoders attain the same error rates with 2 to 3dB smaller data bit energy as compared to hard decision MIMO. These novel combiners are more eligible for low mobility environment. This novel MIMO provides the largest gain when integrated to the bitwise soft decision demodulation. Regressing bitwise LLR value is very simple in QPSK and it QAM[22].

Ankitaet.al demonstrated the integration of LDPC codes and space-time block codes on for end image reconstruction offering better visual quality at low data transmission. Here this scheme of soft decision decoding offers a coding gain of 3dB at -2dB channel SNR for eight antenna system simulation studies shows that with an increase in SNR increases coding gain. Coding gain also increases with a number of transmit antennas[23].Ibrahim et. al., the BER performance of LDPC codes in Weibull fading channels were analyzed for different decoding rules by means of comparative computer simulations. An LDPC coded BPSK communication system was designed as a communication infrastructure to perform the analysis. Four different decoding rules and ½ code rate used in simulations[24]

In this paper, a brief overview of Min-Sum algorithm based LDPC decoder is presented. Among various message passing algorithms, one of the vital algorithms is Min-Sum which provides suitability for implementation of Decoder with less hardware implementation area. Also the Bit Error Rate calculated for 4-QAM is from 10e-1 to 10e-6 for SNR -15 to 5dB. The data reduction methodology for enhancing the channel capacity of the channel has helped in designing high performance communication system specially in the low bandwidth wireless networks. Forupcoming work, concentrate on the study of changed Modulation techniques and their performance in terms of BER and RMSE effectiveness versus SNR of received data.

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