Comparison Analysis of LDPC Decoding Techniques

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***Abstract*— LDPC codes were first introduced by Gallanger in his phD thesis in 1960. An LDPC code is a linear error correcting code that has a parity check matrix H with small number of nonzero elements in each row and column. There are so many decoding techniques for LDPC codes. In this paper, the deciding criteria for the performance analysis is to compare the BER performance of these codes under the sum product and the bit flip decoding algorithms.**

I. INTRODUCTION

LDPC stands for low density parity check codes. It is the type of forward error correction codes, where the channel decoder estimates a codeword from the received codeword. It is the main concern for result analysis. An error correction/detection scheme can be evaluated by three important properties; the reliability of the scheme, the complexity of the scheme, and the efficiency of the scheme. The reliability of the scheme stands for the reliability of the decoded words in the receiver, which can be measured by Bit Error Rate (BER) or Frame Error Rate (FER). The complexity of the scheme is measured by the number of operations that is required by the system and the complexity of these operations. The efficiency of the scheme is measured by the ratio of the information sent for error correction/detection and the information sent from the source. The main trade-off in the error correction/detection technique is between these three properties. LDPC decoding techniques such as the hard decision decoding like the bit-flip as well as the soft decision decoding such as Sum Product Algorithm (SPA) are used for comparison.

II. Result Analysis

The deciding criteria for the performance analysis is to compare the BER performance of these codes under the sum-product and the bit-flip decoding algorithms. In order to compare these two codes, the standard way to represent the BER vs. SNR is E_b/N_O where N_O is the single-sided noise power spectral density, and E_b is the average energy per message bit (not symbol bit). This scheme takes into account the added requirement of transmitting additional parity bits.

This relationship can be computed as:

$$\frac{E_b}{N_o}(dB) = 10log_{10}\frac{E_s}{RN_o}(dB) \quad \text{................(2.1)}$$

Or,

$$\frac{E_b}{N_o}(dB) = 10log_{10}\frac{E_s}{N_o} + 10log_{10}\frac{1}{R} \quad \text{.......(2.2)}$$

For a code rate of 1/2

$$\frac{E_b}{N_o}(dB) = 10log_{10}\frac{E_s}{N_o} + 10log_{10}2 \quad \text{...........(2.3)}$$

$$\frac{E_b}{N_o}(dB) = 10log_{10}\frac{E_s}{N_o} + 3.01dB \quad \text{.........(2.4)}$$

The bit-flip decoding algorithm operates on hard decisions. It is computationally simple compared to the sum-product algorithm. When dealing with continuous-output channels this algorithm is inferior to the sum-product algorithm because it throws away valuable information coming from the channel. The sum-product is a more complex algorithm than the bit-flip algorithm. It makes use of the soft received signal, which is vital when continuous-output channels are used.

The performance of the SPA for number of iteration =5 gave the following result:

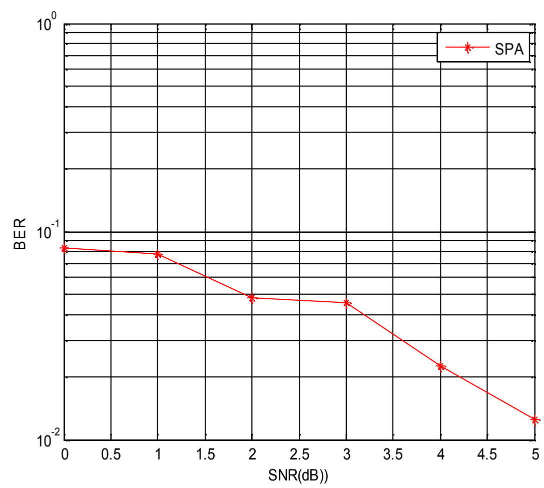

Figure 2.1 Performance of SPA for number of iterations =5

The performance of the SPA decoder improved significantly by keeping the other parameters such as the block length and the column weight the same.

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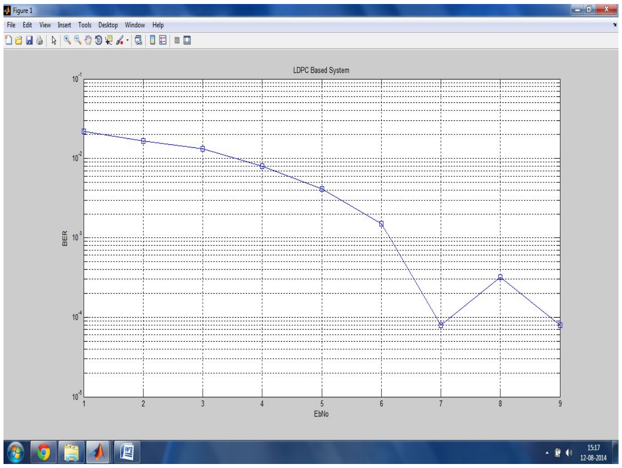

Figure 2.2 Performance of the LDPC SPA for iteration 50

In the simulations it is observed that the sum-product algorithm has better BER performance compared to the bit-flip algorithm. The following result shows the performance comparison of the two techniques:

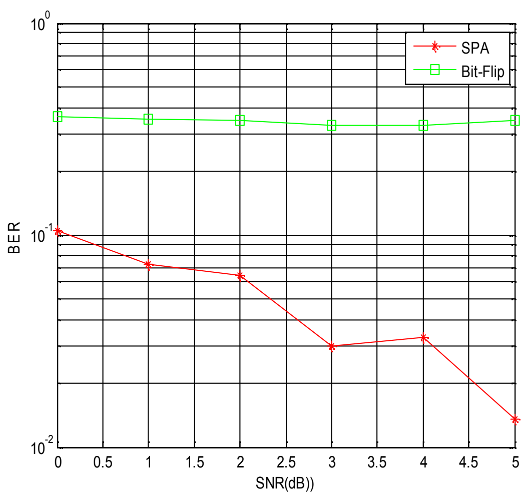

Figure 2.3 Performance comparison of Bit-flip and SPA decoding techniques

It is observed that for both decoding algorithms, the BER performance of LDPC codes increase with increasing the block-length of the code. But for the same block-length, performance of the sum-product decoder is better than the performance of the bit-flip decoder. It is observed that both the sum-product and the bit-flip algorithms are performing better with increasing number of iterations, where the sum-product decoder performs better than the bit-flip decoder for the same number of iterations. The sum-product decoder performs better than the bit-flip decoder. The price we have to pay is the high complexity of the decoder along with the decoding delay. In applications where decoding time is not important but error correction capability is the first priority, like deep space communication, the sum-product decoder should be employed. The bit-flip is a relatively simple algorithm but cannot perform as good as the sum-product algorithm. The comparison dealt with comparing the various LDPC decoding techniques results such as the bit-flip, and variants of SPA. The simulations showed that the performance of the bit flip decoding remained the poorest among the four compared techniques.

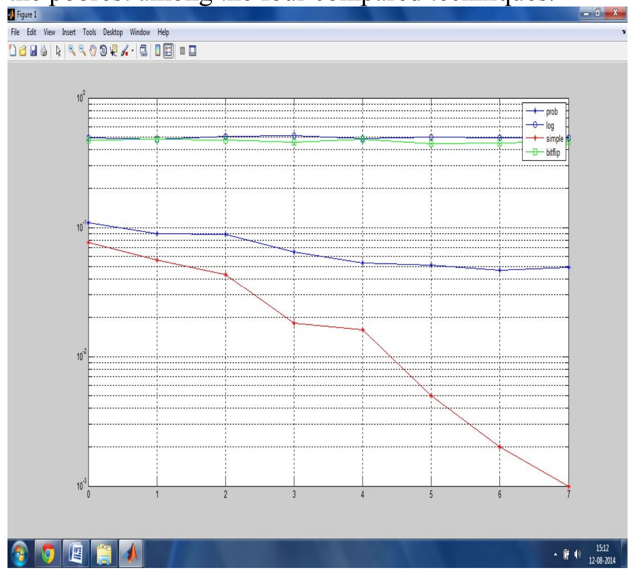

Fig.2.4.Performancecomparison of LDPC Decoding Techniques

The simulation parameters are as follows: QPSK modulation, number of rows are 1000, number of columns are 1000, cycles of girth 4 are eliminated and column weight is 3, number of frames are 10, number of iterations are 5 while the channel used is the AWGN channel.

This work compares the hard and soft decision decoding techniques in general, particularly the Bit-Flip and variants of the Sum-Product decoding techniques. Here we have taken the probability-domain, log-domain and the simplified log-domain SPA techniques for the soft decision decoding techniques for analysis and comparison. Figure 2.4 shows comparison of decoding techniques of LDPC in terms of BER. It can be seen clearly that the bit-flip algorithm is the worst in comparison to other algorithms. The performance of probability-domain algorithm is better than the BF decoding. The BER performance of simple decoding at input SNR 7 is 10^-4 dB. This scheme is best among all the four techniques described in this dissertation. The simple decoding technique is an approximation of the log- domain decoding technique and performs better than the bit-flip and probability domain decoding technique.

Conclusion

The decoding of LDPC has become a very hot topic of research over the past few years as real-time encoding will become the overall goal in terms of application integration. It is also worth nothing that there are hardware implementations that are roughly 103 times faster than current software implementations. In the simulations it has been observed that among the four techniques analyzed and compared, it is the log-domain Sum-Product algorithm that performs best in terms of reliability. In terms of complexity, the bit flip technique, being the simplest of all is considered the best. There is a trade-of between the performance and complexity of the decoding techniques.

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