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ABSTRACT

Modern information and communication systems are based on the reliable and efficient transmission of information. For practical applications the coding scheme used by the transmission system not only needs to have good coding characteristics, but also needs to be efficiently implemented.

Different efficient coding schemes exist for q-ary fields, but in the real world communications the noise model is usually not in a q-ary field, instead they exist in the real domain. A coding scheme that can exploit the real algebra of the channel which is a more natural approach for data transmission.

Lattice codes have potential to become an efficient and practical coding scheme for the AWGN channel and particularly for multi-terminal Gaussian networks because the encoder and the channel use the same real algebra.

Recently, a variety of lattices called low density lattices codes (LDLC) have been studied because they can be seen as a Euclidean space code analogue to low density parity check codes (LDPC). Has been reported that LDLC lattices can attain 0.6dB to the unconstraint capacity for dimension 100,000. In addition, they can be decoded efficiently using iterative decoders. Previous constructions for LDLC lattices, such as the latin square design, are based on high-complexity computer search algorithms to eliminate 4-cycles.

On the other hand, finite fields codes based on array codes have been widely studied, these codes have a deterministic (no pseudorandom) and low computational complexity construction. In addition, a triangular-structured parity check matrix based on array codes can be easily constructed, which add benefits for encoding.

In the iterative LDLC decoder the messages consist of infinite Gaussian mixtures, and for any implementation, the Gaussian mixtures must be approximated. Different authors had introduced various ways to overcome the Gaussian mixtures approximation, but these methods are not a good approximation and/or have a high computational complexity.

The focus of this dissertation is to describe an efficient construction and iterative decoding algorithm for LDLC lattices. In this dissertation there are two main contributions:

1. The first main contribution is the design of LDLC lattices based on array codes. The proposed lattices are called “array LDLC lattices”. The inverse generator matrices for array LDLC lattices can be defined by four parameters, And has the following properties: a 4-cycle free matrix to improve the performance of the belief propagation (BP) decoding, triangular structure to aid encoding and shaping operations, sparseness for low storage and has a deterministic construction, i.e. no pseudorandom construction.

   The benefit of the structure of the array LDLC lattices is that the generator matrix can be obtained by doing block

matrix inversion. And the generator matrix can be used to derivate an upper bound for the minimum distance. By numerical results the derivate upper bound is a good approximation for most of the array LDLC lattices. In addition having a triangular structure some elements less protected than others. A method to balance the protection of the elements is given. These methods also can be used as a guide for LDLC lattice design.

Finally, for all cases considered, the array LDLC lattices have a better performance than the latin square construction.

2. The second main contribution is a new parametric LDLC lattice decoding algorithm, the new decoding algorithm is called the ``three/two Gaussian parametric decoder'', the proposed decoding algorithm approximate the infinite mixture of Gaussian with a finite number of Gaussians either two or three. The major advantage of the proposed LDLC decoding algorithm is a favorable performance-complexity tradeoff as compared to previous parametric decoding algorithms. Another advantage of the proposed algorithm is that it is nearly parameter-free; the only parameter selection of interest is the number of Gaussians in the approximation, two or three Gaussians. This is in contrast to other LDLC decoders that have algorithmic parameters.

   Strengths of the algorithm include its simplicity and suitability for analysis. Analysis is performed by evaluating the Kullback-Leibler divergence between the true messages and the three/two Gaussian approximation. The approximation using three or two Gaussians is more accurate than previously proposed approximations.

   Also, noise thresholds for the three/two Gaussian parametric decoding algorithm are presented, the proposed decoder reduces the noise thresholds 0.05dB compared to previous parametric decoders. The numerical results show that for n = 1,000 the two-Gaussian approximation is the same as the best known decoding algorithm. But when the dimension is n = 10,000, a three-Gaussian approximation is needed. Finally the results presented are a guideline on how to choose different parameters for LDLC lattice design.

The array LDLC lattices and three/two Gaussian parametric decoding algorithm are a step forward to a more practical algorithms for LDLC lattices.

Keywords: Lattice codes, LDLC lattices, deterministic construction, parametric decoder