2D LDPC CODES AND JOINT DETECTION AND DECODING FOR TWO-DIMENSIONAL MAGNETIC RECORDING

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I. INTRODUCTION

Two-dimensional magnetic recording (TDMR) is a promising technology for boosting areal densities using sophisticated signal processing algorithms within a systems framework. The read/write channel architectures have to effectively tackle the 2D inter-symbol interference (ISI), 2D synchronization errors, media and electronic noise sources as well as thermal asperities resulting in burst erasures. 1D low-density parity check (LDPC) codes are well studied to correct large 1D burst errors/erasures. However, such 1D LDPC codes are not suitable to correct 2D burst errors/erasures due to the 2D span of the errors. In this paper, we propose the construction of a true 2D LDPC code to effectively correct 2D burst erasures. We also propose a joint detection-decoding algorithm based on the generalized belief propagation (GBP) algorithm to simultaneously handle 2D ISI as well as correct bit/burst errors for TDMR channels. Our work is novel in two aspects: (a) We propose construction of true 2D LDPC code to correct large 2D burst erasures, (b) We develop a 2D joint signal detection-decoder engine that incorporates 2D ISI constraints and modulation code constrains along with LDPC decoding. The proposed 2D LDPC code gives burst erasure correction capability of greater than 22% than the 1D LDPC codes reported earlier. Further performance improvement can be achieved by code optimization. The proposed joint detection-decoding algorithm is observed to achieve a signal-to-noise ratio (SNR) gain of > 0.2 dB in bit error rate (BER) performance (~ 5% increase in areal densities around the 1 Tb/in^2 regime with grain sizes of 10 nm) as compared to a decoupled detector-decoder system configuration. The efficacy of our proposed algorithm and system architecture is evaluated by assessing areal density (AD) gains via simulations for a TDMR configuration comprising of a 2D generalized partial response (GPR) over the Voronoi media model assuming perfect 2D synchronization.

II. RESULTS

Figure 1 shows the architecture of the proposed joint detection-decoding scheme in TDMR. In this architecture, a GBP based joint detection-decoding algorithm is used to equalize as well as decode the readback samples from a Voronoi based TDMR channel model. Figure 2 shows the region graph used by the joint detection-decoding algorithm. The algorithm minimizes the Kikuchi approximation of the Gibbs free-energy defined based on the region graph under the parity check constraints defined by the LDPC code. The regions in the region graph are defined based on the 2D ISI as well as the LDPC code constraints.

For burst erasure correction in TDMR, a defect detector [1] estimates the location of burst erasure using the output of 2D soft-output Viterbi algorithm (SOVA). LDPC code is used to correct the burst erasures as well as the random errors seen at the output of the 2D SOVA. The identified defect location is indicated to the LDPC decoder to effectively correct the burst erasure.

We simulate the TDMR channel using a Voronoi based media model with CTC = 10 nm, bit size = 25x25 nm achieving channel bit density of 1 Tb/in^2. Figure 3 shows the performance of the proposed 2D LDPC as against a traditional 1D quasi-cyclic LDPC code with the same code rate (0.87) and length of 32k corresponding to a sector of data. The proposed construction of 2D LDPC code could correct 42x42 bursts with similar performance as the 1D LDPC code with 38x38 bursts. Figure 4 shows that the proposed joint detection and decoding algorithm performs with > 0.2 dB gain in SNR corresponding to ~ 5% gain in areal density.

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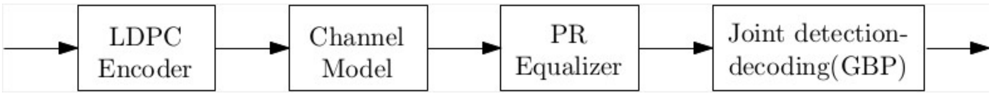

Fig. 1 The samples from the Voronoi based media model are partial response (PR equalized) before the samples are jointly detected and decoded by GBP algorithm.

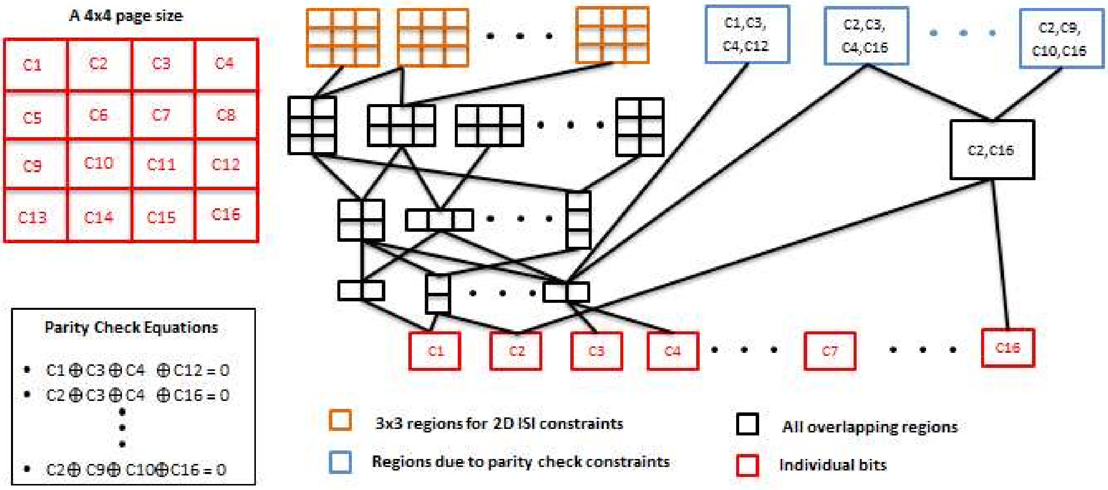

Fig. 2 An example of a region graph used by the GBP algorithm for joint-detection decoding is shown. The regions are chosen based on 2D ISI as well as LDPC code parity check constraints.

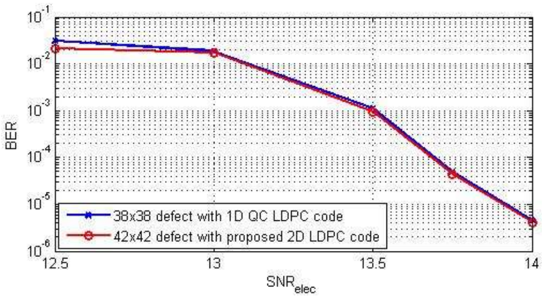

Fig. 3 The proposed 2D LDPC code is able to correct 42x42 burst erasures with the same performance as 1D LDPC codes correcting 38x38 burst erasures under identical channel conditions.

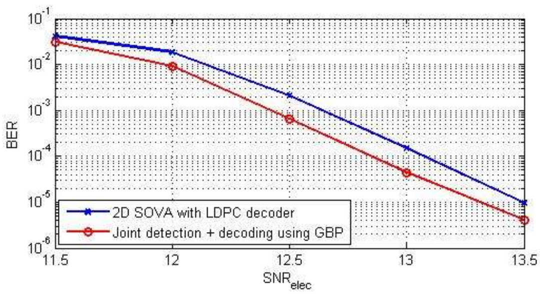

Fig. 4 The proposed joint detection and decoding scheme using GBP performs 0.2 dB better than the separate detection and decoding using 2D SOVA and belief propagation (BP) algorithm.

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