The Design of Protograph LDPC Codes for Two-dimensional Magnetic Recording channels.

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This paper investigates the performance of the protograph based low-density parity-check (LDPC) codes for two dimensional (2D) inter symbol interference (ISI) channels with magnetic recording density. The protograph LDPC codes have been shown to possess excellent error performance over AWGN channel [1] and over partial response channel [2]. Moreover, the protograph structure that realizes linear encoding and decoding allows high-speed encoding and decoding implementations. We further proposes a protograph LDPC code for 2D ISI channel with the help of extrinsic information transfer (EXIT) chart fitting and asymptotic ensemble weight enumerators. Analysis and simulation results show that the proposed code has performance gain both in low- and high-SNR regions over previously optimized irregular LDPC codes for 2D ISI channels [3].

I. System Model.

Let $x(i,j) \in \{-1, 1\}$ denote the binary data distributed in an array with M rows and N columns, $i = 1,2,\ldots, M$, and $j = 1,2,\ldots, N$. L_M and L_N denote the interference lengths in horizontal and vertical directions, respectively. The 2-D channel response before equalization is represented by and $L_M \times L_N$ channel response matrix $H_{2\text{-D}}$. The additive white Gaussian noise (AWGN) with zero mean and variance σ^2 is assumed. Moreover, this paper considers the optimal symbol-based BCJR 2D-detector [3]. A protograph contains a relatively small number of nodes and can be represented by a base matrix. A larger derived LDPC protograph code can be further obtained by performing a "copy-and-permute" operation on the base matrix [1]. Based on some observations (not shown in this abstract), from Monte Carlo simulation, without introducing degree-2 node in the protograph, we propose a protograph suitable for 2-D ISI channel, and its corresponding base matrix, as shown in Fig. 1 (a). The code rate R of the proposed code is $(n+1)/(n+2)$.

II. Exit Analysis and Asymptotic Ensemble Weight Enumerators for Proposed Protograph.

We can evaluate thresholds of LDPC codes by finding the minimum channel E_b/N_0 to ensure EXIT curves of the inner channel detector and the outer LDPC decoder as closely as possible, but do not cross over. With code rate 8/9 (n=8 in Fig. 1 (a)) and over a 4Tb/in^2 2D ISI channel [2], Fig. 1 (b) shows the EXIT curves of channel detector and LDPC decoder. The proposed code has decoding tunnels larger than the irregular LDPC code, providing faster convergence speed and lower decoding threshold value, for symbol-based BCJR detector. Specifically, the decoding threshold of the proposed code are 3.93 dB, slightly lower than that of irregular code, 4.0 dB with BCJR detector.

Now we turn to computing the normalized logarithmic asymptotic weight distribution $r(\delta)$ for the scalar normalized total codeword weight δ in the proposed protograph LDPC code [1]. Fig. 2 (a) shows asymptotic weight distribution of the proposed code. Since the first zero crossing at δ_{min} of value 0.031, the typical minimum distance ratio, is greater than zero, the minimum distance of the proposed code increases linearly with block length with proportionality constant δ_{min}. That is, the error floor of the proposed code lowers with the increase of block length.

III. Simulation Results.

Fig. 2(b) compares the decoding performance of the proposed protograph code and irregular LDPC code that was optimized for 2-D ISI channel. The code rate is 8/9 and code lengths are 4608 and 13824, respectively. The number of outer iteration between channel detector and LDPC decoder is 10, and the number of iterations in LDPC decoder is 30. The 2D ISI channel with magnetic recording density of 4Tb/in^2 is assumed [3]. We can see that the proposed code has lower decoding threshold and exhibit a lower error floor than the irregular LDPC code. At BER rate of 10^{-5}, the proposed code of length 13824 bits is less than 0.3 dB away from the symmetric information rate of 2D ISI channels.

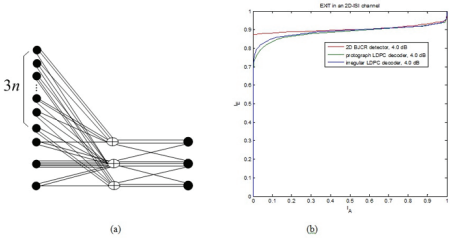

Fig. 1. (a) A proposed protograph, and (b) EXIT curves of the irregular code and the proposed protograph code.

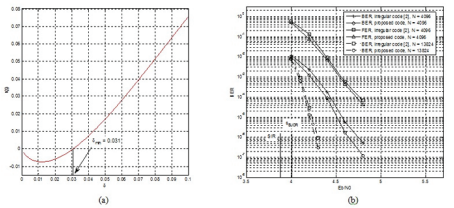

Fig. 2. (a) Asymptotic weight distributions for the proposed protograph. (b) Performance comparison of the proposed code and irregular code in 4Tb/in2 magnetic recording channel

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