An Iterative Detection/Decoding Algorithm of Correlated Sources for the LDPC-Based Relay Systems

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Abstract: An iterative detection/decoding algorithm of correlated sources for the LDPC-based relay systems is presented. The signal from the source-destination (S-D) link is formulated as a highly correlated counterpart from the relay-destination (R-D) link. A special XOR vector is defined using the correlated hard decision information blocks from two decoders and the extrinsic information exchanged between the two decoders is derived by the log-likelihood ratio (LLR) associated with the XOR vector. Such the decoding scheme is different from the traditional turbo-like detection/decoding algorithm, where the extrinsic information is computed by the side information and the soft decoder outputs. Simulations show that the presented algorithm has a slightly better performance than the traditional turbo-like algorithm (Taking the (255,175) EG-LDPC code as an example, it achieves about 0.1dB performance gains around BLER=10^{-4}). Furthermore, the presented algorithm requires fewer computing operations per iteration and has faster convergence rate. For example, the average iteration of the presented algorithm is 33 at SNR=1.8dB, which is about twice faster than that of the turbo-like algorithm, when decoding the (961,721) QC-LDPC code. Therefore, the presented decoding algorithm of correlated sources provides an alternative decoding solution for the LDPC-based relay systems.

Keywords: correlated sources; iterative decoding; LDPC codes; relay channel

I. INTRODUCTION

The basic single relay system was first investigated by Van de Meulen in 1971 [1]. Early research work on the relay system mainly focuses on the capacity analysis under some fundamental coding strategies, such as the decode-and-forward strategy and the estimate-and-forward strategy [2-6]. Parallel with these work, coding/decoding designs of how to approach the relay channel capacity have also been extensively studied [7-11]. The decoding schemes therein commonly adopt the iterative turbo-like strategy, such as the partial factor-graph decoupling in [8] and the cooperative constellation decoding in [9], where the transmitted data can be recovered based on two consecutive received signals at the destination between two detection/decoding systems.

In [12], Daneshgaran *et al.* invented a de-

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Two iterative detection/decoding algorithms, the traditional turbo-like algorithm and the presented algorithm of correlated sources are investigated and compared in this paper.

coding algorithm of correlated sources based on low density parity-check code (LDPC) for a basic communication model with three nodes, where two of which send correlated data blocks to the third destination node. It is shown that, the destination node can use the correlation of the data blocks to obtain coding gains.

Motivated by this work, we will re-formulate the single relay channels as correlated sources in this paper. Suppose that both the source and the relay employ an identical LDPC code with binary phase shift keying (BPSK) modulation. At the destination, two consecutively received blocks can be treated as correlated encoded blocks. One is from the source-destination (S-D) link at the previous time slot, while the other is from the relay-destination (R-D) link at the current time slot, both of which contain highly-correlated data, especially when the channel conditions are good enough. Based on this fact, we then present the iterative detection/decoding algorithm of correlated sources for the relay systems.

Simulation results show that the presented algorithm performs slightly better than the traditional turbo-like algorithm. Besides, the presented algorithm requires fewer computing operations per iteration and has faster decoding convergence rate. Therefore, the presented algorithm of correlated sources provides a candidate for decoding the LDPC-based relay systems.

II. PRELIMINARIES

2.1 Relay structure

A single relay channel can be simply described in figure 1(a) with three nodes: the source (S), the relay (R) and the destination (D) nodes. The authors in [11] presented a corresponding physical model, as shown in figure 1(b). In this physical description, the R-node is positioned in the same line with the S-node and the D-node. Besides, the physical communication distance of the S-D link is normalized to 1. Consequently, the distance of S-R link is d and the distance of R-D link is $1-d$. Similar to the large-scale path loss model in [8], the channel coefficients of the three links are defined as $h_{SD}=1$, $h_{SR}=\sqrt{1/d^{\alpha}}$ and $h_{RD}=\sqrt{1/(1-d)^{\alpha}}$, where the parameters h_{SD}, h_{SR} and h_{RD} represent the channel gains of the S-D, the S-R and the R-D links, respectively. The parameter α is the pathloss-exponent, whose value is typically chosen from 2 to 5, depending on different channel conditions [13].

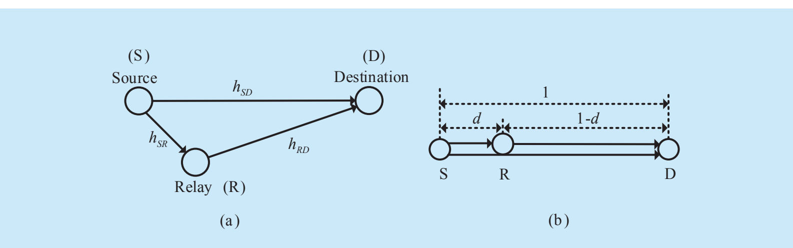

Fig. 1 *(a) Relay system (b) Distance-oriented relay model*

2.2 System model

Transmitting: 1) S-node:Let $\mathbf{u}^t=(u_0^t,u_1^t,\cdots,u_{k-1}^t)$ be the k-bit information block at time t. The block $\mathbf{u}^t$ is encoded into a codeword $\mathbf{w}^t$ with length n. For simplicity, we only consider the BPSK modulation here. The modulated signal vector with respect to $\mathbf{w}^t$ can be denoted as $\mathbf{x}_S^t=(x_{S,0}^t,x_{S,1}^t,\cdots,x_{S,n-1}^t)$, where $\mathbf{x}_{S,i}^t=1-2w_i^t$, for $0\leqslant i\leqslant n-1$. Then the S-node sends the modulated signal $\mathbf{x_S^t}$ to the S-R and S-D channels. **2)** R-node: During time t, the R-node re-encodes the hard-decision result $\hat{\mathbf{u}}^{\mathbf{t-1}}$ of the previous information block $\mathbf{u}^{\mathbf{t-1}}$, resulting a codeword $\hat{\mathbf{w}}^{\mathbf{t-1}}$. Similarly, the modulated vector of $\hat{\mathbf{w}}^{\mathbf{t-1}}$ is $\mathbf{x_R^t}=(x_{R,0}^t,x_{R,1}^t,\cdots,x_{R,n-1}^t)$, where $x_{R,i}^t=1-2\hat{w}_i^{t-1}$, for $0\leqslant i\leqslant n-1$. Then the R-node transmits the modulated signal x_R^t to the D-node.

Receiving: 1) R-node: the R-node receives the noised version of $\mathbf{x}_S^t$ from the S-node at time t, as follows

$$\mathbf{y}_R^t=\sqrt{P_s}\,h_{SR}\mathbf{x_S^t}+\mathbf{n_R^t} \tag{1}$$

where $\mathbf{n_R^t}\sim N(0,\ \sigma_R^2)$ is the additive white Gaussian noise (AWGN) at the R-node and P_S