Type-II HARQ Using Split Block-Type LDPC Codes

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Abstract

By using splitting, we construct rate-compatible block-type low-density parity-check (B-LDPC) codes having a wide range of code rates. A strong motivation for proposing splitting scheme comes from the observation that the quality of the initial transmission is the most important factor to achieve high throughput of type-II HARQ. By building low-rate codes from high-rate codes by splitting rows of the parity-check matrix, rate-compatible LDPC codes are obtained having good FER (Frame Error Rate) performance in the first transmission. The splitting algorithm not only needs smaller number of operations but also shows faster decoding convergence speed than other rate-control methods such as puncturing and shortening, since more efficient Tanner graph is used for the decoding.

I. Introduction

Recently, low-density parity-check (LDPC) codes [1],[2] have been actively studied since they provide better performance than turbo codes with lower decoding complexity. Also, to solve the high encoding complexity problem of LDPC codes, many fast-encodable LDPC codes are proposed such as block-type LDPC (B-LDPC) codes [3].

Rate compatible (RC) codes are a family of nested codes where the codeword bits of the high-rate code are contained in the codeword of low-rate code. Therefore, they can be encoded and decoded using a single encoder/decoder pair. To construct RC LDPC codes, many schemes such as data puncturing and puncturing have been proposed.

Puncturing is widely used to design high-rate codes from good low-rate mother code. Rate-compatible puncturing patterns [4] are constructed by selecting the punctured parity bits from the unpunctured parity bits from low-rate code. Through proper puncturing, a series of higher-rate codes are obtained from the low-rate mother code. The encoder generates full set of parity bits, but some are not transmitted (punctured). The decoder assigns neutral value to the punctured positions and performs the decoding. However, puncturing is efficient only when the amount of puncturing is not large since punctured LDPC codes are decoded by giving 0 LLR values to the punctured positions, and this causes slow decoding convergence speed. Also, punctured LDPC codes have larger decoding complexity than the unpunctured LDPC codes of the same code rate due to the complicated Tanner graph.

In this paper, we propos new rate-control scheme called splitting in order to solve the above problems. The proposed scheme comes from the observation that the quality of the initial transmission is the most important factor to achieve high HARQ throughput. For RC-LDPC codes built from splitting, the initial transmission has a good FER in the first transmission since for the splitting mother code rate is the highest rate in desired rate coverage. Contrary to alternative methods that generate codes of different rates by puncturing or shortening, our method separates a high degree check node to two low degree nodes to produce lower-rate codes. Compared to the alternative methods, proposed scheme guarantees good performance since the number of distinct check node degrees can be as small as possible after splitting and they can be distributed as uniformly as possible. Especially, the splitting guarantees that to ensure the performance of lower rate codes check node degree should be uniformly reduced and avoid parallel edges.

This paper is organized as follows. In Section II, B-LDPC codes are reviewed. Section III provide split B-LDPC codes and type-II HARQ. Performance comparison for various rate-compatible B-LDPC codes is presented in Section IV and Section V provides some concluding remarks.

II. Overview of B-LDPC Codes

B-LDPC codes are proposed in [3], which can support various lengths by using scaling and modulo methods.

$$H=\begin{bmatrix} P_{0,0} & P_{0,1} & P_{0,0} & \cdots & P_{0,n_b-2} & P_{0,n_b-1} \\ P_{1,0} & P_{1,1} & P_{1,2} & \cdots & P_{1,n_b-2} & P_{1,n_b-1} \\ P_{2,0} & P_{2,1} & P_{2,2} & \cdots & P_{2,n_b-2} & P_{2,n_b-1} \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ P_{m_b-1,0} & P_{m_b-1,1} & P_{m_b-1,2} & \cdots & P_{m_b-1,n_b-2} & P_{m_b-1,n_b-1} \end{bmatrix}$$

Fig. 1. Parity-check matrix of B-LDPC code.

A B-LDPC code can be defined by the parity-check matrix H of size m by n given in Fig. 1 where $P_{i,j}$ 뷁 are chosen from $z\times z$ circulant permutation matrices and $z\times z$ all-zero matrix. Note that $n=n_b\times z$ and $m=m_b\times z$ denote the numbers of codeword bits and parity bits, respectively.

H can also be considered of being obtained by expanding an $m_b\times n_b$ binary base matrix H_b where $(H_b)_{i,j}=1$ if $P_{i,j}$ is a circulant permutation matrix and 0, otherwise. H_b can be partitioned into two parts such as $H_b=[(H_{b1})_{m_b\times(n_b-m_b)} \mid (H_{b_2})_{m_b\times m_b}]$ where H_{b_1} and

This work was supported by grant No. (R01-2005-000-11064-0) from the Basic Research Program of the Korea Science &Engineering Foundation and supported by ITRC program of the Korean Ministry of Information and Communications.