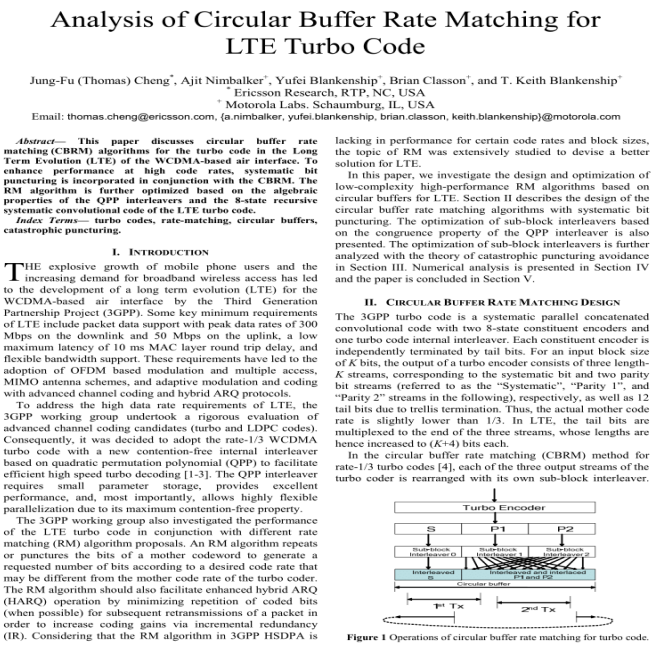
Evaluation Of HSDPA And LTE: From Testbed Measurements To System Level Performance



Analysis of Circular Buffer Rate Matching for LTE Turbo Code

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***Abstract*— This paper discusses circular buffer rate matching (CBRM) algorithms for the turbo code in the Long Term Evolution (LTE) of the WCDMA-based air interface. To enhance performance at high code rates, systematic bit puncturing is incorporated in conjunction with the CBRM. The RM algorithm is further optimized based on the algebraic properties of the QPP interleavers and the 8-state recursive systematic convolutional code of the LTE turbo code.**

***Index Terms*— turbo codes, rate-matching, circular buffers, catastrophic puncturing.**

I. Introduction

THE explosive growth of mobile phone users and the increasing demand for broadband wireless access has led to the development of a long term evolution (LTE) for the WCDMA-based air interface by the Third Generation Partnership Project (3GPP). Some key minimum requirements of LTE include packet data support with peak data rates of 300 Mbps on the downlink and 50 Mbps on the uplink, a low maximum latency of 10 ms MAC layer round trip delay, and flexible bandwidth support. These requirements have led to the adoption of OFDM based modulation and multiple access, MIMO antenna schemes, and adaptive modulation and coding with advanced channel coding and hybrid ARQ protocols.

To address the high data rate requirements of LTE, the 3GPP working group undertook a rigorous evaluation of advanced channel coding candidates (turbo and LDPC codes). Consequently, it was decided to adopt the rate-1/3 WCDMA turbo code with a new contention-free internal interleaver based on quadratic permutation polynomial (QPP) to facilitate efficient high speed turbo decoding [1-3]. The QPP interleaver requires small parameter storage, provides excellent performance, and, most importantly, allows highly flexible parallelization due to its maximum contention-free property.

The 3GPP working group also investigated the performance of the LTE turbo code in conjunction with different rate matching (RM) algorithm proposals. An RM algorithm repeats or punctures the bits of a mother codeword to generate a requested number of bits according to a desired code rate that may be different from the mother code rate of the turbo coder. The RM algorithm should also facilitate enhanced hybrid ARQ (HARQ) operation by minimizing repetition of coded bits (when possible) for subsequent retransmissions of a packet in order to increase coding gains via incremental redundancy (IR). Considering that the RM algorithm in 3GPP HSDPA is lacking in performance for certain code rates and block sizes, the topic of RM was extensively studied to devise a better solution for LTE.

In this paper, we investigate the design and optimization of low-complexity high-performance RM algorithms based on circular buffers for LTE. Section II describes the design of the circular buffer rate matching algorithms with systematic bit puncturing. The optimization of sub-block interleavers based on the congruence property of the QPP interleaver is also presented. The optimization of sub-block interleavers is further analyzed with the theory of catastrophic puncturing avoidance in Section III. Numerical analysis is presented in Section IV and the paper is concluded in Section V.

II. Circular Buffer Rate Matching Design

The 3GPP turbo code is a systematic parallel concatenated convolutional code with two 8-state constituent encoders and one turbo code internal interleaver. Each constituent encoder is independently terminated by tail bits. For an input block size of K bits, the output of a turbo encoder consists of three length-K streams, corresponding to the systematic bit and two parity bit streams (referred to as the "Systematic", "Parity 1", and "Parity 2" streams in the following), respectively, as well as 12 tail bits due to trellis termination. Thus, the actual mother code rate is slightly lower than 1/3. In LTE, the tail bits are multiplexed to the end of the three streams, whose lengths are hence increased to $(K+4)$ bits each.

In the circular buffer rate matching (CBRM) method for rate-1/3 turbo codes [4], each of the three output streams of the turbo coder is rearranged with its own sub-block interleaver.

Figure 1 Operations of circular buffer rate matching for turbo code.

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