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Multi-non-binary turbo codes

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Abstract

This paper presents a new family of turbo codes called multi-non-binary turbo codes (MNBTCs) that generalizes the concept of turbo codes to multi-non-binary (MNB) parallel concatenated convolutional codes (PCCC). An MNBTC incorporates, as component encoders, recursive and systematic multi-non-binary convolutional encoders. The more compact data structure for these encoders confers some advantages on MNBTCs over other types of turbo codes, such as better asymptotic behavior, better convergence, and reduced latency. This paper presents in detail the structure and operation of an MNBTC: MNB encoding, trellis termination, Max-Log-MAP decoding adapted to the MNB case. It also shows an example of MNBTC whose performance is compared with the state-of-the-art turbo code adopted in the DVB-RCS2 standard.

Keywords: Turbo codes; Non-binary code; Multi-non-binary recursive systematic convolutional code; Galois field

1 Introduction

Two decades after their introduction in [1], turbo codes (TCs) have found their utility in numerous communication systems. TCs can be found in LTE, DVB or in deep space communications standards [2-4]. This TC success was possible because of the numerous studies in the past years, leading to the diversification of TC families and to the emergence of new codes, whose decoding is based on the principle of iterative or turbo decoding. Thus, the evolution of TC in terms of component convolutional encoder after the now classic single binary turbo codes (SBTC) [1], was followed by double/multibinary turbo codes (D/MBTCs) [5,6] and non-binary turbo codes (NBTCs) [7-9]. These new TC families aim to improve SBTC performance, especially by lowering the error floor. Proposing a new family of multi-non-binary turbo codes (MNBTCs), this paper may be seen as a continuation of these concerns. The MNBTC was firstly introduced in [10], but this paper presents a more complete description of MNBTCs and also an example of more efficient MNBTCs. An MNBTC has recursive and systematic convolutional component encoders, with several non-binary inputs. This evolution from single-binary to (multi-)non-binary is found at low-density parity-check (LDPC) codes [11], but it happened much earlier [12].

The first benefit brought forth by the new family of MNBTCs is latency reduction, the data block being more compact. Another benefit, argued by practical results, is a lower error floor. Basically, simulations show that the waterfall region extends below 10^{-8} of frame error rate (FER). Furthermore, MNB turbo decoders have a better convergence at high SNRs.

In addition, MNBTCs as non-binary LDPCs (NB-LDPCs) can be easily combined with high-order modulations, yielding increased bandwidth efficiency. The price for these benefits is the increased complexity of the component code trellis and, therefore, of the computational effort of the decoder. But, due to the evolution of the processing capacity, it is expected that the complexity of non-binary codes to no longer pose a disadvantage in relation to binary codes. This is confirmed by the extensive studies of NB-LDPC codes, [13-17].

The structure of the paper is as follows: in Section 2, we describe the MNBTC encoder and decoder, as well as component codes, the MNBTC structure, the encoding process and trellis termination, the Max-Log-MAP algorithm adjusted to the MNB case, and details of interleaving. In Section 3, we propose a memory-3 MNBTC with two inputs offering a good trade-off between performance and complexity. The process of component encoder selection is explained and performance is assessed through simulations in both the AWGN and the Rayleigh fading channels, in conjunction with BPSK and 16-QAM modulations. Performance is compared with the DBTC of the DVB-RCS2 standard [3] and also with some NB-LDPC from literature. Section 4 concludes the paper.

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