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Editorial

Advances in Error Control Coding Techniques

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In the past decade, a significant progresshas been reported in the field of error control coding. In particular, the innovation ofturbo codes and rediscovery of LDPC codes have been recognized as two significant breakthroughs in this field. The distinct features of these capacity approaching codes have enabled them to be widely proposed and/or adopted in existing wireless standards. Furthermore, the invention of space time coding significantly increased the capacity of wireless systems and these codes have been widely applied in broadband communication systems. Recently, new coding concepts, exploiting the distributed nature of networks, have been developed, such as network coding and distributed coding techniques. They have great potential applications in wireless, sensor, and ad hoc networks. Despite recent advances, many challenging problems still remain. This special issue is intended to present the state-of-the-art results in the theory and applications of coding techniques.

The special issue has received twenty six submissions, and among them, thirteen papers have been finally selected after a rigorous review process. They reflect recent advances in the area of error control coding.

In the first paper, "Structured LDPC codes over integer residue rings," Mo and Armand designed a new class of low-density parity-check (LDPC) codes over integer residue rings. The codes are constructed based on regular Tanner graphs by using Latin squares over a multiplicative group of a Galois ring, rather than a finite field. The proposed approach is suitable for the design of codes with a wide range of rates. One feature of this type of codes is that their minimum pseudocodeword weights are equal to their minimum Hamming distances.

The next two-part series of papers "Differentially encoded LDPC codes—Part I: special case of product accumulate codes" and "Differentially encoded LDPC codes—Part II: general case and code optimization," by J. Tiffany Li, study the theory and practice of differentially encoded low-density parity-check (DE-LDPC) codes in the context of noncoherent detection. Part I studies a special class of DE-LDPC codes, product accumulate codes. The more general case of DE-LDPC codes, where the LDPC part may take arbitrary-degree profiles, is studied in Part II. The analysis reveals that a conventional LDPC code is not fitful for differential coding, and does not in general deliver a desirable performance when detected noncoherently. Through extrinsic information transfer (EXIT) analysis and a modified "convergence constraint" density evolution (DE) method, a characterization of the type of LDPC degree profiles is provided. The convergence-constraint method provides a useful extension to the conventional "threshold-constraint" method, and can match an outer LDPC code to any given inner code with the imperfectness of the inner decoder taken into consideration.

In the fourth paper, "Construction and iterative decoding of LDPC codes over rings for phase-noisy channels," by Karuppasami and Cowley, a design and decoding method for LDPC codes for channels with phase noise is proposed. The new code applies blind or turbo estimators to provide signal phase estimates over each observation interval. It is resilient to phase rotations of $2\pi/M$, where M is the number of phase symmetries in the signal set and estimates phase ambiguities in each observation interval.

A novel approach for enhancing decoder performance in presence of trapping sets by introducing a new concept called trapping set neutralization is proposed in the fifth paper "New technique for improving performance of LDPC codes in the presence of trapping sets" by E. Alghonaim et al. The effect of a trapping set can be eliminated by setting its variable nodes intrinsic and extrinsic values to zero. After a trapping set is neutralized, the estimated values of variable nodes are affected only by external messages from nodes outside the trapping set. Most harmful trapping sets are identified by means of simulation. To be able to neutralize identified trapping sets, a simple algorithm is introduced to store trapping sets configuration information in variable and check nodes.

Design of efficient distributed coding schemes for cooperative communications networks has recently attracted significant attention. A distributed generalized low-density (GLD) coding scheme for multiple relay cooperative communications is developed by Han and Wu in the sixth paper "Distributed generalized low-density codes for multiple relay cooperative communications." By using partial error detecting and error correcting capabilities of the GLD code, each relay node decodes and forwards some of the constituent codes of the GLD code to cooperatively form a distributed GLD code. It can work effectively and keep a fixed overall code rate when the number of relay nodes varies. Furthermore, the partial decoding at relays is allowed and a progressive processing procedure is proposed to reduce the complexity and adapt to the source-relay channel variations. Simulation results verify that distributed GLD codes with various number of relay nodes can obtain significant performance gains in quasistatic fading channels compared with the strategy without cooperation.

Since the early 1990s, a progressive introduction of inline optical amplifiers and an advent of wavelength division multiplexing (WDM) accelerated the use of FEC in optical fiber communications to reduce the system costs and improve margins against various line impairments, such as beam noise, channel crosstalk, and nonlinear dispersion. In contrast to the first and second generations of FEC codes for optical communications, which are based on Reed-Solomon (RS) codes and the concatenated codes with hard-decision decoding, the third generation FEC codes with soft-decision decoding are attractive to reduce costs by relaxing the requirements on expensive optical devices in high-capacity systems. In this regard, the seventh paper "Reed-Solomon turbo product codes for optical communications: from code optimization to decoder design" by Bidan et al. investigates the use of turbo-product codes with Reed-Solomon codes as the components for 40 Gb/s over optical transport networks and 10 Gb/s over passive optical networks. The issues of code design and novel ultra-high-speed parallel decoding architecture are developed. The complexity and performance trade-off of the scheme is also carefully addressed in this paper.

Recently, there has been renewed interest in decoding Reed-Solomon (RS) codes without using syndromes. In the eighth paper "Complexity analysis of Reed-Solomon decoding over GF(2^m) without using syndromes," Chen and Yan investigated the complexity of a type of syndrome-less decoding for RS codes, and compared it to that of syndrome-based decoding algorithms. The complexity analysis in their paper mainly focuses on RS codes over characteristic-2 fields, for which some multiplicative FFT techniques are not applicable. Their findings show that for high-rate RS codes, syndrome-less decoding algorithms require more field operations and have higher hardware costs and lower throughput, when compared to syndrome-based decoding algorithms. They also derived tighter bounds on the complexities of fast polynomial multiplications based on Cantor's approach and the fast extended Euclidean algorithm.

In the ninth paper "Efficient decoding of turbo codes with nonbinary belief propagation" by Poulliat et al., a new approach of decoding turbo codes by a nonbinary belief propagation algorithm is proposed. The approach consists in representing groups of turbo code binary symbols by a nonbinary Tanner graph and applying a group belief iterative decoding. The parity check matrices of turbo codes need to be preprocessed to ensure the code good topological properties. This preprocessing introduces an additional diversity, which is exploited to improve the decoding performance.

The tenth paper, "Space-time convolutional codes over finite fields and rings for systems with large diversity order" by Uchoa-Filho and Noronha-Neto, propose a convolutional encoder over the finite ring of integers to generate a space-time convolutional code (STCC). Under this structure, the paper has proved three interesting properties related to the generator matrix of the convolutional code that can be used to simplify the code search procedure for STCCs over the finite ring of integers. The properties establish equivalences among STCCs, so that many convolutional codes can be discarded in the code search without loosing anything.

Providing high-quality multimedia service has become an attractive application in wireless communication systems. In the eleventh paper, "Joint decoding of concatenated VLEC and STTC system," Chen and Cao proposed a joint source-channel coding scheme for wireless fading channels, which combines variable length error correcting codes (VLECs) and space time trellis codes (STTCs) to provide bandwidth efficient data compression, as well as coding and diversity gains. At the receiver, an iterative joint source and space time decoding algorithm is developed to utilize redundancy in both STTC and VLEC to improve overall decoding performance. In their paper, various issues, such as the inseparable systematic information in the symbol level, the asymmetric trellis structure of VLEC, information exchange between bit and symbol domains, and a rate allocation between STTC and VLEC, have been investigated.

In the twelfth paper, "Average throughput with linear network coding over finite fields: the combination network case," Al-Bashabsheh and Yongacoglu extend the average coding throughput measure to include linear coding over arbitrary finite fields. They characterize the average linear network coding throughput for the combination network with min-cut 2 over an arbitrary finite field, and provide a network code, which is completely specified by the field size and achieves the average coding throughput for the combination network.

The MacWilliams identity and related identities for linear codes with the rank metric are derived in thethirteenth paper "MacWilliams identity for codes with the rank metric" by Gadouleau and Yan. It is shown that similar to the MacWilliams identity for the Hamming metric, the rank weight distribution of any linear code can be expressed as a functional transformation of that of its dual code, and the rank weight enumerator of the dual of any vector depends only on the rank weight of the vector and is related to the rank weight enumerator of a maximum rank distance code.

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