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Editorial

Physical-Layer Network Coding for Wireless Cooperative Networks

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Cooperative communication is an intriguing topic that has aroused a frenzy of heat in the wireless networking research. The notion of cooperative communication is to enable transmit and receive cooperation at the user level by exploiting the broadcast nature of wireless radio waveform so that the overall system performance including power efficiency and communication reliability can be significantly improved. However, due to the half-duplex constraint in practical wireless relay systems, cooperative communication generally suffers from loss in spectral efficiency. The inception of network coding provides a powerful remedy for improving the spectral efficiency and opens new possibilities for achieving the end-to-end throughput optimality by allowing intermediate network nodes to mix, demix, and remix the signals received from multiple links for subsequent transmissions. In addition, network coding fits naturally for the wireless cooperative networks. Network coding may be implemented in the network layer, media/multiple access (MAC) layer, or the physical layer. Specifically, physical-layer network coding (PLNC) encompasses a rich variety of signal processing and coding techniques and may be exploited in combination with multiple antennas, orthogonal frequency-division multiplexing (OFDM), channel coding, signal detection, and resource allocation. Its excellent performance has been demonstrated in various relay-based communication scenarios, including two-way communication, multiway relaying, multiple-access relaying, multicasting, and broadcasting, and active research is continuing to explore new potentials.

This special issue aims to consolidate the latest research advances in physical-layer network coding in wireless cooperative networks. The purpose is to seek new and original contributions addressing various aspects of PLNC, including, for example, fundamental limits, protocol design, code design, practical implementation issues, joint synchronization, modulation, channel coding and PLNC, combined PLNC and diversity and multiplexing techniques, and cross-layer design and optimization.

In this special issue, we have received a total of 32 original submissions, out of which 11 (34%) papers are accepted for publication after peer review. We regret that we had to reject many good papers due to the limited number of papers that can be published in this special issue. The accepted papers cover a broad area of PLNC-related topics, including channel estimation, protocol design, scheduling, resource allocation, and channel code design for network coded schemes.

To effectively decode a network code would inevitably require the knowledge of at least partial channel information of present channel estimation algorithms for two-way relay channels. Both exploit the nature of reciprocal channels and both consider OFDM transmission strategies, but approach the problem from different aspects. In the paper entitled "*Superimposed training-based joint CFO and channel estimation for CP-OFDM modulated two-way relay networks*", the authors introduce superimposed pilots at the relay to enable the estimation of channels and carrier frequency offset (CFO) parameters. Three different estimators are proposed,

as well as an iterative estimator, and the estimation error is compared to the Cramer-Rao bound. In comparison, the paper "*Channel estimation for two-way relay OFDM networks*" studies the condition and method for designing optimal block training sequences with explicit consideration of the peak-to-average power ratio (PAPR).

To design an effective network coding protocol is an essential issue of implementing signal mixing in the intermediate network nodes and signal detection in the destinations. We have included three papers discussing network coding protocols in this special issue. The paper "*Design criteria for hierarchical exclusive code with parameter-invariant decision regions for wireless 2-way relay channel*" focuses on the design of a new PLNC scheme termed "the hierarchical exclusive code," including the design criterion, the decision region, and the achievable performance. The paper "*The performance of network coding at the physical layer with imperfect self-information removal*" discusses PLNC with denoising and evaluates the impact of residual self-information. The paper "*MIMO network coding-based PHY/MAC protocol for replacement of CSMA/CA in efficient two-way multihop relay networks*" exploits PLNC with the multiple antenna technology to achieve efficient multiple access. The paper by Gacanin and Adachi considers the scenario of broadband two-way relaying with orthogonal frequency division multiplexing (OFDM) and single carrier with frequency domain equalization (SC-FDE) by using analog network coding (ANC) in frequency selective channels. The authors investigate the effects of imperfect removal of self-information on the system performance.

The authors study the resource management issue in the context multiway relay and/or multicast PLNC. "*Beamforming-based physical layer network coding for non-regenerative multi-way relaying*" presents new beamforming relaying strategies for multiway relaying that allow achieving high spectrum utilization with low interference. "*Joint power allocation for multicast systems with physical-layer network coding*" discusses the allocation and optimization of the transmit power. "*Joint NC-ARQ and AMC for QoS-guaranteed mobile multicast*" investigates incremental network coding through automatic repeat request (ARQ) to ensure desired quality of service (QoS).

Joint design of LDPC coding and network coding can further improve the reliability of networks. There are two papers devoted to the design of network codes by leveraging the ideas and tools from channel coding. As the (sparse) mixing operation of network coding finds natural connection to low-density parity-check (LDPC) codes, both make essential use of the LDPC coding structure. Specifically, the paper by Cocco et al. exploits LDPC schemes in high-order Galois fields, while the paper by Duyck et al. considers joint channel-network coding through a unified graph structure and proposes the construction of an LDPC code that achieves full diversity for multiple-access relaying.

Finally, Ma et al.'s work in this PLNC special issue investigates network modulation through linear algebra.

The topics covered in these papers reveal only the tip of the iceberg, but they are certainly demonstrating exciting and diverse perspectives and methodologies in the study of physical-layer network coding. We sincerely hope that the collection of papers in this special issue will help enlighten more and better research in this fruitful area of wireless networks.

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