Guest Editorial Spectrum and Energy Efficient Design of Wireless Communication Networks: Part I

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SPECTRUM efficiency (SE) and energy efficiency (EE) are among the most important venues for technological advances in current and emerging wireless communication networks. The past decade has witnessed tremendous efforts and progress made by both the industry and academia for improving SE. We foresee that the emerging cognitive and self-organizing networks will further increase SE. In recent years, energy and power efficiencies of wireless networks have become more crucial because of the steadily rising energy cost and environmental concerns. While there has been a paradigm shift from improving SE to reducing energy consumption, a dilemma also arises as some EE criteria are in conflict with the SE objectives. Thus, there is an urgent need to address key challenges and state-of-the-art solutions for joint spectrum and energy efficient design (SEED) and optimization of wireless communication networks.

With the above vision, a Call for Papers for a special issue in the IEEE JOURNAL ON SELECTED AREAS IN COMMUNICATIONS, was published in October 2011. The invited topics included system modeling, spectrum and energy efficient architectures and topologies for wireless networks, self-organization and self-optimization techniques for spectrum and energy efficient wireless networks, spectrum and energy efficient link adaptation and resource allocation, multiuser/single-user MIMO techniques for spectrum and energy efficiencies, and signal processing challenges for spectrum and energy efficient wireless networks. By the deadline in April 2012, we received 82 manuscripts, out of which 26 were accepted after a thorough and rigorous review process and 4 were suggested to accept if room.[1] Unfortunately, due to space constraints, several high-quality manuscripts could not be accommodated in this JSAC issue. Further, due to the page limit, we will publish two JSAC volumes (May 2013 and Dec 2014) each containing 15 papers.

The first volume published in May 2013 covers three subfields: (i) Spectrum and energy efficient architectures and topologies for wireless networks, (ii) Multiuser/single-user multiple input multiple output (MIMO) techniques for spectrum and energy efficiencies, and (iii) Cross-layer protocols and algorithms for joint spectrum and energy efficiencies.

The first six papers are on spectrum and energy efficient architectures and topologies for wireless networks. The paper by Ni and Collings, entitled, "A New Adaptive Small-Cell Architecture," proposes a new small-cell architecture which reconfigures topologies and frequency bands, adapting to changing traffic demands and interference-mitigating requirements. The new architecture consists of distributed small-cell nodes (SCN) and co-located baseband units (BBU), and adaptively switches the connections between the SCNs and BBUs. The BBUs can even be shared among multiple SCNs that use different frequency bands. The architecture requires fewer BBUs, and the spectrum and energy utilization is significantly more efficient compared with current architectures.

The paper by Soh, Quek, Kountouris and Shin, entitled, "Energy Efficient Heterogeneous Cellular Networks," investigates the design of energy efficient cellular networks through the deployment of sleeping strategies and small cells, as well as the associated tradeoff issues. The authors also formulate optimization problems in the form of power consumption minimization and energy efficiency maximization, and determine the optimal operating regimes for macrocell base stations.

The paper by Guo and O'Farrell, entitled, "Dynamic Cell Expansion with Self-Organizing Cooperation," proposes a novel cell expansion technique, where the coverage area of cells can expand and contract based on the traffic load. This is accomplished by switching off low load cell-sites and compensating for the coverage loss by expanding the neighbouring cells through antenna beam tilting. The multi-cell coordination is resolved by using either a centralized controller or a distributed self-organizing-network (SON) algorithm.

The paper by Tao, Xu, Rehman, Xu and Li, entitled, "A Generic Mathematical Model Based on Fuzzy Set Theory for Frequency Reuse in Cellular Networks," proposes a fuzzy set theory based generic mathematical model for deriving various Soft Fractional FR (SFFR) schemes. The authors use various parameters such as average throughput, spectral and power efficiency to evaluate the derived schemes.

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Digital Object Identifier 10.1109/JSAC.2013.130501

[1]Papers coauthored by Guest Editors were handled independently by Senior Editors.

The paper by Cho and Choi, entitled, "Energy-efficient Repulsive Cell Activation for Heterogeneous Cellular Networks," considers a two-tier heterogeneous cellular network (HCN) where macrocells and distributed low power cells, namely daughtercells, are operated in a common spectrum. The authors employ repulsive cell activation in the interfering daughtercell network and see the impact of a minimum separation distance between the daughtercell BSs in terms of coverage under open access and power efficiency.

The paper by Yue, Pan, Fang, and Glisic, entitled, "Spectrum and Energy Efficient Relay Station Placement in Cognitive Radio Networks," proposes a new architecture, which is called the Cognitive Capacity Harvesting network (CCH) to enhance the spectrum and energy efficiencies of CRNs. In CCH, a collection of relay stations (RSs) with cognitive capability are deployed to facilitate the accessing of secondary users (SUs). In this way, the architecture not only removes the requirement of cognitive radios from SUs and reduces their energy consumption, but also increases frequency reuse and enhances spectrum efficiency. The authors study the RS placement strategy in CCH. Considering the NP-hardness of the problem, they also design a framework of heuristic algorithms to compute the near-optimal solutions.

The next four papers are related to multiuser/single-user MIMO techniques for spectrum and energy efficiencies. The paper by He, Sheng, Zhu, You, and Li, entitled, "Energy- and Spectral-Efficiency Tradeoff for Distributed Antenna Systems with Proportional Fairness," proposes an EE scheme with proportional fairness for the downlink multiuser distributed antenna systems (DAS), and exploits multi-criteria optimization method to systematically investigate the relationship between EE and SE, the authors also develop an optimal algorithm to allocate the available power to balance the tradeoff between EE and SE.

The paper by Cheng, Zhang and Zhang, entitled, "Joint Spectrum and Power Efficiencies Optimization for Statistical QoS Provisionings Over SISO/MIMO Wireless Networks," proposes an efficient framework to jointly optimize effective spectrum efficiency (ESE) and effective power efficiency (EPE) under different statistical QoS provisionings constraints to support the real-time traffics over wireless networks. And in the mutually beneficial (MB) region, the authors propose a novel strategy to achieve the joint effective spectrum and power efficiencies optimization using the average transmit power control. In the contention-based (CB) region, the authors propose the wireless-relaybased strategy to jointly optimize effective capacity and power efficiency. In both MB and CB regions, the authors develop the dynamic transmit power control strategy and the MIMO-based strategy to jointly maximize the effective spectrum and power efficiencies.

The paper by Nguyen and Krunz, entitled, "Power Minimization in MIMO Cognitive Networks using Beamforming Games," studys the set of precoding matrices (one per frequency channel) at each node, where power, spectrum allocation, and beamformers are optimized to minimize the transmit power. To improve the efficiency of the NE, the authors introduce pricing policies that employ a novel network interference function. The study of the existence and uniqueness of the new NE under pricing are then given. And a sketch of a MAC protocol that implements the above resource allocation and beamforming scheme is also presented.

The paper by Rui, Zhang, Deng, Cheng and Li, entitled, "Mode Selection and Power Optimization for Energy Efficiency in Uplink Virtual MIMO Systems," tackles the EE issue in uplink virtual MIMO systems, which requires the optimization of two interlaced parameters: the number of constituent mobile users in the virtual MIMO and their corresponding power allocation. Then the authors show the existence of a unique globally optimal power allocator for the case without power constraints under the assumption of zero-forcing receivers, and further reveal the impact of power constraints upon power allocation, as compared to its global counterpart, aiming to provide a powerful means for power-constrained EE optimization. Finally, the authors establish theories, for isometric networks, to narrow down the search range for possible transmission modes, leading to a significant reduction of computational complexity in optimization.

The last five papers are related to cross-layer protocols and algorithms for joint spectrum and energy efficiencies. The paper by Hou and Chen, entitled, "An Energy-Aware Protocol for Self-Organizing Heterogeneous LTE Systems," proposes a model that jointly considers several important characteristics of heterogeneous LTE system, including the usage of OFDMA, the frequency-selective fading for each link, the interference among different links, and the different transmission capabilities of different types of base stations. Based on this model, the authors propose a distributed protocol that improves the spectrum efficiency of the system, which is measured in terms of the weighted proportional fairness among the throughputs of clients, and reduces the cost of energy.

The paper by Man-Cho So and Zhang, entitled, "Distributionally Robust Slow Adaptive OFDMA with Soft QoS via Linear Programming," proposes a novel alternative, termed the slow adaptive OFDMA, to drastically reduce the computational and signaling costs. The proposed scheme adapts subcarrier allocation at a much slower timescale than that of channel fading variation, yet achieves similar system capacity and QoS levels as the optimal fast adaptive OFDMA.

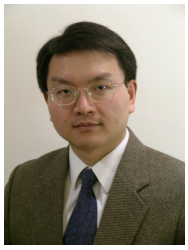
The paper by Chen, Jiang, Xu, and Hu, entitled, "Energy-Efficient Coordinated Scheduling Mechanism for Cellular Communication Systems with Multiple Component Carriers," proposes an energy-efficient coordinated scheduling mechanism to reduce the energy consumption in cellular networks by dynamically switching off component carriers and BSs according to load variations, with special attention on the switching off order and BS transmit power adjustment to maintain service continuity of downlink users.

The paper by Amin, Martin, Deaton, DaSilva, Hussien and Eltawil, entitled, "Balancing Spectral Efficiency, Energy Consumption, and Fairness in Future Heterogeneous Wireless Systems with Reconfigurable Devices," proposes a multi-attribute scheduling algorithm implemented by a central Global Resource Controller (GRC) that manages the resources of several different autonomous wireless systems. To compute the relative importance of each attribute, the authors use the Analytical Hierarchy Process (AHP) that takes interview responses from wireless network providers as input and gener-

ates weight assignments for each attribute in the optimization problem.

The paper by Zhou, Hu, Qian and Chen, entitled, "Energy-Spectrum Efficiency Tradeoff for Video Streaming over Mobile Ad Hoc Networks," investigates the properties of EE and SE for video streaming over mobile ad hoc networks by developing an energy-spectrum-aware scheduling (ESAS) scheme. The authors propose an ESAS scheme with a dynamic transmission range, which significantly outperforms the previous minimum-distortion video scheduling in terms of joint EE and SE performance, and derive an achievable EE-SE tradeoff range and a tight upper/lower bound with respect to energy-spectrum efficiency index for various node velocities. Through simulations, the authors demonstrate the node mobility is beneficial to EE but not to SE.

Finally, the guest editorial team would like to express their appreciation to all the authors of the papers submitted to this special issue. Moreover, we are grateful to all the anonymous reviewers involved in the review process, for delivering high-quality review reports. We would also like to express our gratitude to the JSAC team: the Editor-in-Chief Dr. Martha Steenstrup, the Senior Editor Prof. Wayne Stark, the Executive Editor Laurel Greenidge and the IEEE publications staff (Sue Lange in particular) for their fantastic support and input, which made this issue successful.



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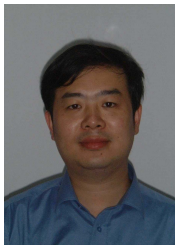

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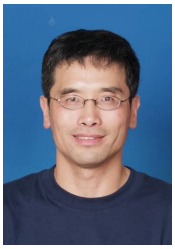

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