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IEEE Access Special Section Editorial: Optimization for Emerging Wireless Networks: IoT, 5G, and Smart Grid Communication Networks

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EDITORIAL

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The ever-increasing demand for wireless services and the continual improvements in wireless technology has led to the emergence of different types of wireless networks. These emerging networks include 5G networks [item 4) in the Appendix], Internet-of-Things (IoT) [item 5) in the Appendix], communication networks for smart grid, etc. 5G networks are envisioned to adopt a number of emerging concepts and technologies such as dense small cells and heterogeneous networks, device-to-device (D2D) communications, energy-efficient algorithms and protocols, multiband and full duplex transmission, and new multiple access techniques like non-orthogonal multiple access (NOMA) technique, etc. The IoT is an emerging concept in which a variety of intelligent objects or things around us such as mobile phones, sensors, actuators, and radio frequency identification tags, etc., will be seamlessly integrated and will communicate and interact with each other to achieve common goals [item 5) in the Appendix]. In general, these networks aim at providing wireless services to all network users with good quality-of-service, and ubiquitous and high data rate connectivity. Along with their envisioned benefits, these emerging network bring numerous challenges, such as allocation and management of radio spectrum, co-existence of different networks, and explosively increased energy consumption, etc. The effective deployment of these networks and coping with the associated challenges rely on the optimal modeling and design of the networks as well as on optimization method and algorithms for optimal management and utilization of radio spectrum and consumption of energy resource.

This Special Section in IEEE Access builds upon previous IEEE Access Special Sections, including [items 1)–3) in the Appendix]. This Special Section is intended to provide a platform for researcher and practitioners from both academia and industry in the area of optimization and algorithms for emerging wireless networks. We invited original papers with novel contributions in all aspects of optimization for emerging wireless networks.

In this Special Section, we have included 12 high-quality articles from leading research groups around the world working on different research aspects of emerging wireless networks. Among these articles, the invited paper by Ali *et al.* [Dynamic User Clustering and Power Allocation for Uplink and Downlink Non-Orthogonal Multiple Access (NOMA) Systems] focuses on NOMA, while the remaining papers present novel ideas on small cell networks, IoT, D2D communication, multiband transmission, full-duplex systems, gray code for distributing video coding, and the underground communication and localization.

Recently, NOMA has been revealed as a promising multiple access techniques for 5G and beyond 5G wireless networks [item 6) in the Appendix]. The basic idea of NOMA lies in the simultaneous usage of the same radio spectrum by multiple users at the cost of small interference among the users. Networks employing NOMA can serve more number of users than the number of available spectrum bands and can serve the individual users with higher bandwidth. One of the key ideas for successful NOMA operation is to form clusters/groups of users (by exploiting the differences in their channel gains) and allow them to transmit on the same radio resource with appropriate power, and then use successive interference cancellation (SIC) at the receiver(s) to decode the message signal of different users. In the invited paper, Ali, *et al.* [Dynamic User Clustering and Power Allocation for Uplink and Downlink Non-Orthogonal Multiple Access (NOMA) Systems] investigates efficient user clustering and power allocation for both uplink and downlink NOMA systems to maximize the sum-throughput while guaranteeing the minimum rate requirement of the users and satisfying the transmit power budget as well as the SIC receiver's operation constraints. This work illustrates that NOMA performs significantly better than the conventional orthogonal multiple access techniques in various network scenarios.

Dense heterogeneous networks deployment can significantly improve the spectral efficiency in areas with high data traffic and is therefore foreseen as an enabling technology for 5G networks [item 7) in the Appendix]. However, dense deployment of small cells faces a number of challenges such as high energy consumption, inter-cell interference, etc.

Employing sleep mode concept joint with efficient power allocation can help in realizing energy-efficient communication in densely deployed small cells networks. The work of Wu, *et al*. (Cooperative Sleep and Power Allocation for Energy Saving in Dense Small Cell Networks) proposed a cooperative network architecture to reduce energy consumption. In this architecture, the macro base-station is always active to provide coverage of control signals and the small cell base-stations are allowed to sleep in some sub-frames called the sleep sub-frames. Apart from this, the power transmission of small cells base-stations in the active sub-frames is also optimized. This joint cooperative sleep and optimal power allocation can significantly reduce the energy consumption. The article of Yao *et al*. (Distributed ABS-Slot Access in Dense Heterogeneous Networks: A Potential Game Approach With Generalized Interference Model) considers the problem of almost blank sub-frame (ABS)-slot problem in dense heterogeneous networks and investigates that the minimization of aggregate interference is equivalent to network throughput maximization.

The development and deployment of IoT is challenged by its large scale, resource constrained and heterogeneous environment. Firstly, most of the existing IoT applications consist of overlaid deployments of wireless sensor and actuator networks where the applications cannot interact with each other and cannot share and reuse the limited available resources. Secondly, the efficient sensing and dissemination of information and the rapid response to changes in the physical world are challenging requirements of IoT. In the article by Zhao, *et al*. [An Event-Driven Service Provisioning Mechanism for IoT (Internet of Things) System Interaction], a multilevel and multidimensional service provision platform is proposed for IoT that addresses both the above described challenging issues. The practicability of this platform is demonstrated via a District Heating Control and Information Service System (DHCISS). In the article by Park, *et al*. (Learning How to Communicate in the Internet of Things: Finite Resources and Heterogeneity), the use, advantages, limitations, performance and computational complexities of innovative learning frameworks, e.g., machine learning, reinforcement learning and sequential learning for IoT applications are presented in a comprehensive way. This work also introduces a cognitive hierarchy theory based framework for handling the heterogeneity of IoT and present the key results on the use of cognitive hierarchy theory in IoT.

D2D communication is a potential solution to provide high throughput, improved energy and spectral efficiencies, and small end-to-end delay in 5G networks. However, the successful deployment of D2D needs interference management and efficient radio resource allocation. The work of Huynh, *et al*. (Joint Downlink and Uplink Interference Management for Device to Device Communication Underlying Cellular Networks) considers the interference management to maximize the sum throughput of D2D pairs while guaranteeing the performance of both uplink as well as downlink cellular communication. This work also demonstrates the trade-off between the throughput and fairness of D2D communication. In the article by Mishra, *et al*. (Efficient Resource Management by Exploiting D2D Communication for 5G Networks), by exploiting D2D communication and relaying, an efficient resource allocation is proposed for cell-edge users who wants to upload contents towards the eNodeB. In this scheme, D2D communication is employed between the cell-edge user and the selected relay while cellular communication is employed between the relay and the eNodeB. In the first phase of this scheme, a relay is selected efficiently from the available relays between the eNodeB and the cell-edge user while in the second phase, resources are efficiently allocated to reduce the uploading time and the number of resource blocks. 5G networks will require high bandwidth and multiple wireless supporting capabilities to provide seamless coverage with high data rates. The utilization of large bandwidth in the millimeter-wave (mmWave) frequency band and the deployment of dense heterogeneous networks are expected to help in addressing the high data rate requirements. However, the high path loss and shadowing characteristics of mmWave band and the severe interference in heterogeneous networks pose challenges. In the article by Niknam, *et al*. (A Multiband OFDMA Heterogeneous Network for Millimeter Wave 5G Wireless Applications), relay-based multiband orthogonal frequency division multiple access (OFDMA) heterogeneous network is considered that consists of mmWave small cells deployed in the service area of macro cell. The authors propose a resource allocation scheme that exploits the distinct propagation characteristics of two mmWave bands (i.e., 60 GHz - the V-band, and 70-80 GHz - the E-band) and the LTE band to maximize the sum data rate of the network while guaranteeing the minimum rate requirement of each user. This work demonstrates the potential role of V- and E-bands in overcoming the propagation challenges at mmWave frequencies.

Full-duplex system enables transmission and reception at the same time in the same frequency band and has therefore attracted researchers' attention as a key technology for improving the spectral efficiency of the next generation wireless networks [item 8) in the Appendix]. However, the deployment of full-duplex base-station introduces self-interference at the base-station and co-channel interference from uplink users to downlink users. The work of Cirik, *et al*. (Linear Transceiver Design for Full-Duplex Multi-Cell MIMO Systems) considers a multi-cell multiple-input multiple-output (MIMO) full-duplex system where multiple base-stations with full-duplex capability serve multiple users operating in full-duplex mode. This work while accounting for self-inference at the users and base-station and co-channel interference among base-stations and users, considers the design of transmit and receive filters for sum-rate maximization under base-station sum-power and user individual power constraints. This work demonstrates that the full-duplex scheme can achieve significantly higher sum-rate rate compared to the conventional half-duplex schemes.

The currently available predictive video coding techniques have high encoding complexity and are not suitable for emerging applications which requires low complexity and low power consumption such as sensor networks and wireless video surveillance. In the literature, gray code is claimed to improve the performance of distributed video coding (DVC). However, these claims are questionable as they do not account for factors like log-likelihood computation and robustness to wrongly decoded bits. The article by Song, *et al*. (Can Gray Code Improve the Performance of Distributed Video Coding?) comprehensively evaluates the performance of gray code and concludes that the performance improvement of gray code varies for different DVC schemes and it does not perform well in all aspects for all types of DVC schemes.

The deployment of underground wireless sensor networks for magneto-induction (MI) communication and MI localization is an emerging field [item 9) in the Appendix]. However, the sensor networks use frequencies in MHz range [item 10) in the Appendix] and these higher frequencies may experience much higher attenuation in conductive material due to skin effect. Therefore, it is crucial to understand the nature of the underground medium in order to choose appropriate frequency for each specific application. The article of Abrudan, *et al*. (Impact of Rocks and Minerals on Underground Magneto-Inductive Communication and Localization) provides attenuation figures for the common underground materials at three different frequencies (i.e., 1 kHz, 100 kHz, and 10 MHz) typically used in communication and localization. This article will provide guidelines for researchers working on underground communication and localization to find answers to the various fundamental questions related to this research area. In Jiang, *et al*. (A Cuckoo Search-Support Vector Machine Model for Predicting Dynamic Measurement Errors of Sensors), a hybrid Cuckoo search- support vector machine is investigated that effectively and quite accurately predicts the dynamic measurement error of sensors.

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APPENDIX
RELATED WORK

1) M. Peng, T. Huang, Y. R. Yu, and J. Pan, "IEEE access special section editorial: Recent advances in software defined networking for 5G networks," *IEEE Access*, vol. 3, pp. 3076–3078, 2015.
2) W. Wang, C.-H. Lee, L. Chen, F. R. Yu, and H.-J. Su, "IEEE access special section editorial: Emerging cloud-based wireless communications and networks," *IEEE Access*, vol. 3, pp. 3122–3124, 2015.
3) M. Peng, C.-L. I, C.-W. Tan, and C. Huang, "IEEE ACCESS special section editorial: Recent advances in cloud radio access networks," *IEEE Access*, vol. 2, pp. 1683–1685, 2014.
4) C.-X. Wang *et al.*, "Cellular architecture and key technologies for 5G wireless communication networks," *IEEE Commun. Mag.*, vol. 52, no. 2, pp. 122–130, Feb. 2014.
5) L. Atzori, I. Antonio, and G. Morabito, "The Internet of Things: A survey," *Comput. Netw.*, vol. 54, no. 15, pp. 2787–2805, Oct. 2010.
6) Y. Saito, Y. Kishiyama, A. Benjebbour, and T. Nakamura, "Non-orthogonal multiple access (NOMA) for cellular future radio access," in *Proc. IEEE VTC Spring*, Jun. 2013, pp. 1–5.
7) N. Bhushan *et al.*, "Network densification: The dominant theme for wireless evolution into 5G," *IEEE Commun. Mag.*, vol. 52, no. 2, pp. 82–89, Feb. 2014.
8) M. Duarte, C. Dick, and A. Sabharwal, "Experiment-driven characterization of full-duplex wireless systems," *IEEE Trans. Wireless Commun.*, vol. 11, no. 12, pp. 4296–4307, Dec. 2012.
9) X. Tan, Z. Sun, and I. F. Akyldiz, "Wireless underground sensor networks," *IEEE Antennas Propag. Mag.*, vol. 57, no. 4, pp. 74–87, Aug. 2015.
10) A. Ahmad, S. Ahmad, M. H. Rehmani, and N. Ul Hassan, "A survey on radio resource allocation in cognitive radio sensor networks," *IEEE Commun. Surveys Tuts.*, vol. 17, no. 2, pp. 888–917, 2nd Quart., 2015.

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