Guest Editorial for the Special Issue on Self-optimizing Cognitive Radio Technologies

Conventional static spectrum allocation policy faces spectrum paucity to gratify the ever-increasing demand for higher data rates at an ever-decreasing cost per unit datum in future-generation wireless communication systems. Cognitive radio (CR) is emerging as the dominant solution for the scarce spectrum in the near future since CR has the ability to provide high bandwidth to wireless users via heterogeneous wireless networks and dynamic spectrum access techniques. Since in CR systems, unlicensed users hunt for spare spectrum intermittently used by licensed users in an opportunistic manner, there exists ample space for self-optimization with the advent of large-scale heterogeneous networks (HetNets). However, the biggest challenges awaiting for CR networks are generated by factors like the ever-increasing complexity of network architecture, configuration and management, large-scale dynamicity, the unstable nature of the available spectrum, dissimilar quality-of-service (QoS) requirements of various users, and the escalating complications of centralized control for cognitive users from diverse networks. Hence extensive measures have to be developed to deal with the aforementioned challenges in order to maximize the '*take home pay*' of CR technologies. Self-optimizing technologies for cognitive users are of paramount interest in this context.

The goal of this PHYCOM special issue is to present original research contributions to address the aforementioned challenges and advance the design of self-optimizing CR technologies.

Cooperative sensing is seen as a way to improve the performance of wireless devices by improving the radio bandwidth utilization and minimizing interference among wireless devices. In cooperative spectrum sensing, several nodes sense the spectrum and share this information to achieve a better understanding of the spectrum usage. The contribution by Andrea Abrardo, Marco Martalò, and Gianluigi Ferrari offers cognitive cooperative schemes to sense the frequency spectrum and estimate the idle subchannels which can be used by the cognitive users without interfering the primary network. The sensing correlation among the cognitive users is exploited to improve the reliability of the decision, taken by a secondary fusion centre (FC), on the occupation status (by a node of the primary network) of each subchannel. In this context, an expression is derived for the mutual information between the occupation status and the observations at the FC. Then, optimal fusion rules, with and without the knowledge of the positions of the nodes, are derived and the missed detection and false alarm probabilities are computed to obtain system receiver operating characteristic curves. Both approaches indicate a significant performance improvement in terms of the network-wise probabilities of missed detection and false alarm at the secondary FC when knowledge of the nodes' positions is available at the secondary FC.

Further on cooperative sensing, the contribution by Tahir Akram, Tim Esemann, and Horst Hellbrück, titled "Cooperative Spectrum Sensing Protocols and Evaluation with IEEE 802.15.4 Devices", provides cooperative sensing results from a system point of view covering protocols to collect sensing results and select cooperative nodes in dynamic radio environment of the unlicensed 2.4 GHz ISM band. The authors present and implement protocols and applications for primary, secondary and cooperative users with a dedicated control channel. Thereby, the secondary user receiver serves as a first cooperative node in the system, which reduces collisions between primary and secondary users. The system performance is evaluated with receiver sensing and additional cooperative nodes. In addition, a mechanism to extend the protocol for multiple secondary users sharing the same control channel has also been proposed. Based on the evaluations, recommendations are made for the usage of cooperative sensing with primary focus on IEEE 802.15.4.

On the algorithmic side of self-optimizing networks, the paper by Ahsan Adeel, Hadi Larijani, and Ali Ahmadinia presents a novel decision making framework for CR networks. The traditional continuous process of sensing, analysis, reasoning, and adaptation in a cognitive cycle has been divided into two levels. In the first level, the process of sensing and adaptation runs over the radio transmission hardware during run-time. In the second level, the process of analysis and reasoning runs in the background in offline mode. This arrangement offloads the convergence time and complexity problem of reasoning process during run-time. For implementation of the first level, a random neural network (RNN) based controller trained on an open loop case based database on the cloud has been designed. For the second level, a genetic algorithm based reasoning and an RNN based learning has been developed. The proposed framework is used to address the uplink power control problem of long-term evolution systems. It has been shown that the RNN based scheme can achieve comparable results with faster adaptation compared to the artificial neural network based and existing fractional power control based schemes, even subject to severe environment changes without the need of retraining.

Finally, the routing problem in multihop CR ad hoc networks (CRAHNs) has been addressed in the contribution by Surajit Basak and Tamaghna Acharya. The goal is to protect the primary user's interest by minimizing the interference it experiences due to imperfect spectrum sensing at the secondary users, which may lead to possible missed detection of the primary user's presence and subsequent transmissions by the secondary users for supporting any on-going routing session in the network. A second objective is to maximize end-to-end secondary user data rate in an integrated framework. Unlike many popular interference management solutions in CR networks, focusing only on transmit power control, the authors adopt a cross-layer approach. The cross-layer approaches are expected to find important applications in wireless networks, especially for supporting multimedia applications. It is shown that an efficient interference minimizing opportunistic path selection scheme in CRAHNs can be designed by adapting the route selection metric with the spectrum sensing statistics (of the available primary user channels) at the secondary users and variation of the secondary users' transmission power requirement to meet some predefined QoS constraint of the secondary users in the network.

In the long run, we expect that these papers would provide constructive thoughts on forthcoming research and developments focused on self-optimizing CR technologies as well as help to curve progressive paths on future wireless communications technologies.

As a closing note, we would like to thank all the authors for their valuable contributions and considering this special issue as a platform to publish their novel research outcomes in the area of self-optimizing CR technologies. This special issue would have not been possible without the high-quality feedback received from the diligent reviewers whom we wish to thank sincerely for their volunteer effort and devotion. Finally, we would like to express the appreciation of the Guest Editorial team to the Editor-in-Chief and the Staffs supporting PHYCOM for encouraging, reviewing, and facilitating the processing of this special issue.

Dr. Muhammad R. A. Khandaker, *Managing Guest Editor*
Department of Electronic and Electrical Engineering
University College London, United Kingdom.
Email: m.khandaker@ucl.ac.uk

Prof. Kai-Kit Wong, *Guest Editor*
Department of Electronic and Electrical Engineering
University College London, United Kingdom.
Email: kai-kit.wong@ucl.ac.uk

Prof. Haitao Zhao, *Guest Editor*
College of Electronic Science and Engineering
National University of Defense technology, Changsha, China.
Email: haitaozhao@nudt.edu.cn

Prof. Shamik Sengupta, *Guest Editor*
Department of Computer Science and Engineering
University of Nevada, Reno, USA.
Email: ssengupta@unr.edu

Muhammad R. A. Khandaker received the B.Sc. (Hons.) degree in computer science and engineering from Jahangirnagar University, Dhaka, Bangladesh, in 2006, the M.Sc. degree in telecommunications engineering from East West University, Dhaka, in 2007, and the Ph.D. degree in electrical and computer engineering from Curtin University, Bentley, WA, Australia, in 2013.

Since 2013, he has been a Post-Doctoral Research Associate with the Department of Electronic and Electrical Engineering, University College London, United Kingdom. Prior to this, he was a Jr. Hardware Design Engineer with Visual Magic Corporation Ltd., Dhaka, in 2005. He was a Lecturer with the Department of Computer Science and Engineering, IBAIS University, Dhaka, in 2006, the Department of Information and Communication Technology, Mawlana Bhasani Science and Technology University, Tangail, Bangladesh, in 2007, and the Institute of Information Technology, Jahangirnagar University, in 2008. He was a recipient of the Curtin International Postgraduate Research Scholarship for his Ph.D. study in 2009, and the Best Paper Award at the 16th Asia-Pacific Conference on Communications, Auckland, New Zealand, in 2010. He has served as the Managing Guest Editor for ELSEVIER Physical Communication, Special Issue on Self-optimizing Cognitive Radio Technologies, 2015, and as a TPC member of several conferences including IEEE GLOBECOM, IEEE VTC, IEEE ISSPIT, and IEEE ICACCI.

Kai-Kit Wong received the BEng, the MPhil, and the PhD degrees, all in Electrical and Electronic Engineering, from the Hong Kong University of Science and Technology, Hong Kong, in 1996, 1998, and 2001, respectively. He is Professor of Wireless Communications at the Department of Electronic and Electrical Engineering, University College London, United Kingdom. Prior to this, he took appointments at the University of Hull, UK and the University of Hong Kong, and also visiting positions at Alcatel-Lucent, Holmdel, US and the Smart Antenna Research Group at Stanford University. His current research interests center around game-theoretic cognitive radio networks, cooperative communications, physical-layer security, physical-layer caching, full-duplex radio, massive MIMO and energy-harvesting wireless communications.

Dr Wong is Fellow of IEEE and IET, and is Senior Editor of IEEE Communications Letters and IEEE Wireless Communications Letters, and also serves in several other editorial boards.

Haitao Zhao received his M.S. and PhD degree in information and communication engineering both from National University of Defense Technology (NUDT), Changsha, China in 2004 and 2009, respectively. He is currently an associate professor in College of Electronic Science and Engineering, NUDT. Prior to this, he visited the Institute of Electronics, Communications and Information Technology (ECIT), Queen’s University of Belfast, UK from April 2008 to July 2009 and conducted postdoctoral research at Hong Kong Baptist University from August 2014 to February 2015. His main research interests include cognitive radio networks, self-organized networks and cooperative communications. He is now a mentor member for IEEE 1900.1 standard, and a member of World-wide University Network (WUN) Cognitive Communications Consortium. He has served as a TPC members of IEEE ICC (2014-2016) and guest editors for several international journal special issues on cognitive radio networks.

Shamik Sengupta is an Assistant Professor in the Department of Computer Science and Engineering at University of Nevada, Reno (UNR). He received his Ph.D. degree from the School of Electrical Engineering and Computer Science, University of Central Florida in 2007. Before joining University of Nevada, Reno, he worked as a Post-Doctorate Researcher at Stevens Institute of Technology and an Assistant Professor at City University of New York (John Jay College of Criminal Justice). His research interests include cognitive radio and DSA networks, game theory, cybersecurity, network economics and self-configuring wireless mesh networks. He has authored over 65 international conferences and journal publications. He is the recipient of an IEEE GLOBECOM 2008 best paper award and a recipient of NSF CAREER award in 2012. Shamik Sengupta serves on the organizing and technical program committee of several IEEE conferences. He served as Guest Editor in Eurasip Journal on Wireless Communications and Networking, Special Issue on

Advances in 4G Wireless and is now serving as a Lead Guest Editor, Special issue on Cognitive Radio Enabled Wireless Sensor Networks and Survivability Challenges; Editorial board member of Elsevier Computer Communications, Springer Computing Journal, and Guest Editor for ELSEVIER Physical Communication, Special Issue on Self-optimizing Cognitive Radio Technologies, 2015. For more information, visit: http://www.cse.unr.edu/~shamik/.