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Toward 5G Emerging Technologies: Selected Papers from IEEE PIMRC 2014

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Preface The fifth generation of wireless access technology (5G) is facing a daunting task of meeting constant demands for higher data rates and system capacity, as well as wide range of applications and users' quality of experience (QoE) requirements. Although not standardized yet, 5G technology is expected to offer significantly higher throughput than long-term evolution (LTE), have a latency in the low milliseconds and be able to accommodate and support the anticipated explosion in the Internet of Things (IoT) devices. New device types (e.g. probes, meters, sensors, actuators) will significantly contribute to traffic increase and new market sectors will bring new priorities (e.g. critical infrastructures).

Tentative timeline for 5G standardization is around 2018–2019 (i.e. release 14 or 15 of the 3GPP standards) with anticipated roll-outs in 2020 time frame. Use of millimeter wave (mmWave) technology is expected to be a significant part of the 5G innovations; and according to its advocates, the spectrum has the potential to initiate new businesses and use cases once appropriate regulatory agencies makes it available. Massive multiple-input multiple output (MIMO), Software Defined/Cognitive Radios, Cloud-based Networks, Self-Organized Cells, Device to Device Communications are among other technologies that could potentially be used in 5G systems. Breakthrough energy-efficient hardware and software will most likely be employed to make 5G systems "green".

Wireless technology has enormous potential to change the way we live, work, and behave. 5G is envisioned to extend traditional services from enhanced mobile broadband to vertical markets such as connected cars, industry automation, smart metering and health care. However, there are still many technical challenges that must be overcome in order to make this vision a reality. Although the exact pathways to 5G systems, devices, and architectures is still under development, massive growth in applications and data consumption by mobile consumers will be a strong driver to push the industry toward that technology.

The papers which appear in this special issue have been carefully selected from the best IEEE PIMRC 2014 conference papers addressing some of the challenging issues related to the emerging 5G technologies. The invited authors have been asked to provide a significantly extended version of their respective conference papers, which have subsequently undergone a rigorous review process according to the IJWIN publication standards prior to acceptance. The final set of papers address various challenging issues such as user cooperation in 5G radio access networks, cost effective deployment addressing on-demand capacity, beamforming in mmWave MIMO transceivers, coexistence and efficient multi-carrier resource allocation. Our objective is to give the reader a perspective on current technical achievements and also future challenges and possible development in this exciting area. We sincerely hope that you enjoy reading the interesting and high-quality research works presented here.

The authors of the first paper ''User Cooperation for 5G Wireless Access Networks" address device-to-device (D2D) connectivity as one of the main enablers of future 5G radio access networks. Specifically, they introduce a

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new model for user cooperation in 5G radio access networks termed frequency selective soft forwarding (SF). SF exploits the inherent frequency selectivity and broadcast nature of the downlink radio access channel for the sake of enabling efficient user cooperation and seamless integration of D2D connectivity into cellular radio access networks. The authors Amine Maaref and Yu Cao investigate several variants of SF including centralized and distributed approaches, and provide various tradeoffs of performance versus signaling overhead cost. They also propose a hybrid cooperation mode selection strategy which leverages the performance benefits of SF and the low overhead cost of decode-and-forward (DF) relaying to enhance the performance of 5G radio access networks. Using a state-of-the-art LTE-compliant link-level simulator, the authors show that their proposed user cooperation strategies greatly outperform baseline cooperation schemes relying on conventional DF and approach the performance of optimal joint reception with significantly lower cost in terms of D2D resource utilization and signaling overhead.

To support anywhere and anytime services of Beyond 4G (B4G) networks, new deployment solutions are required that can cost-effectively address the increasing capacity demand of the future and offer consistently high bit rates as well as acceptable quality of service (QoS) throughout the network coverage area. The second paper ''Techno-economical Comparison of Dynamic DAS and Legacy Macrocellular Densification: Capacity and Cost-efficiency Analysis of Alternative Deployment Solutions for Outdoor Service Provisioning" by Syed Fahad Yunas, Mikko Valkama, and Jarno Niemel presents an advanced outdoor distributed antenna system (DAS) concept (i.e. Dynamic DAS) that offers on-demand outdoor capacity in urban areas by dynamically configuring the remote antenna units to either act as individual small cells or distributed nodes of a common central cell. The authors study the technical and economic aspects of two different deployment strategies based on pure macrocellular deployment and a novel dynamic DAS solution. They consider four key performance metrics for their analysis; Coverage, SINR, Network Capacity- and Cost efficiency. Their results indicate that the dynamic outdoor DAS concept offers an efficient and capacity-adaptive solution to provide outdoor capacity, on-demand, in urban areas. Furthermore, from the deployment point of view, the extreme tilt configuration offered higher cell level throughputs compared to macrocellular and dynamic DAS with Omni-directional antenna configuration, due to better interference management in urban canyon.

Millimeter Wave MIMO systems will be a significant part of the emerging 5G technologies. This important issue has been addressed in the third paper ''Robust RF Beamforming for Millimeter Wave MIMO-OFDM Systems" by Yahia Ramadan, Ahmed Ibrahim, and Mohamed Khairy. Due to the small wavelength of mmWave, tens of antennas can be packed in mmWave transceivers. However, implementing an RF chain for each antenna is impractical due to the high cost and power of mixed signal devices. To reduce this cost, an analog RF beamformer using variable gain amplifiers and analog phase shifters is typically implemented. In this paper, the authors propose a novel spatial diversity scheme for mmWave RF beamforming. They formulate the spatial diversity as an optimization problem that tries to maximize the geometric mean of the projections of the RF precoder on the transmit steering vectors and the geometric mean of the projections of the RF combiner on the receive steering vectors. Two algorithms have been provided as the solution to this optimization problem. Simulation results show that the proposed spatial diversity scheme outperforms the conventional schemes in case of no blockage as well as cases with blockage to any propagation path regardless of the number of paths. This is due to the fact the proposed spatial diversity scheme distributes the energy efficiently over all propagation paths.

Recently, the possibility of LTE systems using the unlicensed spectrum has drawn significant interests from mobile operators. Using this technology, the unlicensed spectrum is directly utilized by LTE without the need to offload traffic to an alternative radio access technology such as Wi-Fi. However, the deployment of LTE networks in the unlicensed band could pose significant challenges to the performance of current and future Wi-Fi networks. This is the topic of the fourth paper "On the Impact of LTE-U on Wi-Fi Performance" by Alireza Babaei, Jennifer Andreoli-Fang, Yimin Pang, and Belal Hamzeh. In this paper, the authors discuss the LTE and Wi-Fi coexistence challenges and present analysis on performance degradation of the Wi-Fi networks at the presence of LTE operation. Their probabilistic and numerical analyses show that when Wi-Fi and LTE networks operate together in the unlicensed band without modifications to existing protocols, Wi-Fi transmissions are significantly affected by the presence of LTE transmissions. Specifically, given the two potential modes of operations currently proposed for LTE-U in the unlicensed spectrum, the amount of "quiet" period presented by the LTE protocol for Wi-Fi users is too short to allow access to the channel. As a result, Wi-Fi is at risk of spending a significant amount of time in the "listening" mode when LTE transmission is present in the same channel. The results of this paper indicate that further research needs to be done to achieve a "fair" coexistence mechanism.

The fifth paper "An Efficient Multi-Carrier Resource Allocation with User Discrimination Framework for 5G Wireless Systems" by Haya Shajaiah, Ahmed Abdelhadi and Charles Clancy provides an efficient resource

allocation with user discrimination framework for 5G Wireless Systems to allocate multiple carriers resources among users with elastic and inelastic traffic. Considering different classes of user groups where users are partitioned into different groups based on their carriers' coverage area, the objective is to allocate multiple carriers resources optimally among users that belong to different classes. The authors use a utility proportional fairness approach in the utility percentage of the application running on the user equipment (UE). Each user is guaranteed a minimum QoS with a priority criterion that is based on user's class and the type of application running on the UE. Given the assumptions, the results of this paper prove the existence of a tractable global optimal solution for the proposed resource allocation optimization problem and present a multicarrier resource allocation with user discrimination algorithm. The proposed algorithm ensures fairness in the utility percentage, gives priority to VIP users and within a VIP or a regular user group it gives priority to adaptive real-time applications while providing a minimum QoS for all users. Simulation results highlighting the performance of the proposed algorithm are also presented.

In conclusion, we would like to express our appreciation to all authors in this special issue. Their excellent contribution and work on extending the conference version of their papers on this emerging technology will undoubtedly make this special issue a successful and informative technical resource. We also extend our gratitude to the reviewers whose meticulous reviews and thoughtful comments have enhanced the innovative ideas presented here. Finally, we would like to sincerely thank the devoted staff of Springer for their high level of professionalism and assistance during the preparation of this special issue.

Kamran Sayrafian is a Senior Scientist at the Information Technology Laboratory of the National Institute of Standards and Technology (NIST) located in Gaithersburg, Maryland. He is leading a strategic program related to the application of Pervasive Technology in Healthcare Information Systems. Prior to this, he was the cofounder of Zagros Networks, Inc. a fabless semiconductor company based in Rockville, Maryland where he served as President and senior member of the architecture team. Dr. Sayrafian has been an adjunct faculty of the University of Maryland since 2003. He has served as an invited member of the technical program committee of several international conferences. He has also been the Technical Program Committee and Executive co-chair of the IEEE PIMRC 2014 and organizer of several other IEEE ComSoc Conferences and workshops focused on the applications of wireless communication in healthcare. His research interests include medical body area networks, mobile sensor networks and RF-based indoor positioning. He has published over 100 conference and journal papers, and book chapters in these areas. He was the recipient of the IEEE PIMRC 2009 and SENSORCOMM 2011 best paper awards, and has been a Guest Editor for a number of journal special issues focusing on the pervasive healthcare technologies and sensor networks. Dr. Sayrafian was the US Embassy Science Fellow in Croatia in 2014. He was a contributing member of the European COST Action IC1004 "Cooperative Radio Communications for Green Smart Environments"; and, his research results have been included in the final report of this Action. He was also a contributing member and the co-editor of the channel modeling document of the IEEE802.15.6 international standard on body area networks. He is the co-inventor/inventor of four US patents; a senior member of IEEE; and, the recipient of the 2015 US Department of Commerce Bronze Medal for his contribution to the field of body area networks. Dr. Sayrafian holds Ph.D., M.S. and B.S. degrees in Electrical and Computer Engineering from University of Maryland, Villanova University and Sharif University of Technology, respectively.

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