

FULL DUPLEX COMMUNICATIONS



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With the rapidly growing demand for mobile applications, future wireless networks are facing considerable challenges in spectral efficiency. To deal with it, many techniques have been developed recently. Among them, in-band full duplex (IBFD), which enables a device to transmit and receive simultaneously at the same frequency, has ignited great interest from both academia and industry. IBFD can potentially double the spectral efficiency in the physical layer and also bring many advantages in high-layer design.

However, to fulfill the minimum performance requirement for the current cellular networks, self-interference cancellation in IBFD communications is still a great challenge to the physical layer design. In addition, some system-level protocols must be redesigned since devices need to send and receive signals at the same frequency simultaneously.

The objective of this Feature Topic is to provide some recent advances and design challenges on IBFD communications. Among a large number of submissions to this Feature Topic, we have carefully selected seven articles that cover various issues from hardware design to system-level protocols.

The first two articles mainly focus on recent advances and challenges related to the hardware design for self-interference cancellation. The article by Mikko Heino *et al.* presents a novel antenna design using resonant wavetraps. It is demonstrated that around 100 dB self-interference cancellation can be achieved by combining the developed antenna design and a digital canceller in a practical system. The article by Leo Laughlin *et al.* discusses how to use electrical balance duplexers to cancel self-interference, where various electrical balance duplexer architectures are compared, and some perspective research opportunities are presented.

The next three articles focus on the medium access control (MAC) layer design of IBFD systems. The article by Karaputugala Madushan Thilina *et al.* first highlights some immediate challenges in both physical-layer and MAC-layer design in IBFD communications, and then provides a thorough survey on the existing full duplex MAC protocols. Some future research directions on this topic are also discussed. The article by Sanjay Goyal *et al.* investigates scheduling in full duplex cellular networks. It is shown that the capacity of the system with IBFD can be almost doubled compared to that with half-duplex by a proposed proportional fairness based scheduler despite self-interference. The energy efficiency of full duplex systems is also addressed in that article. The article by Zhongshan Zhang *et al.* proposes an opportunistic decode-and-forward (DF)-based relay selection scheme for full duplex relay networks, which substantially reduces the outage probability even though there are still some challenges for future research.

The last two articles investigate the applications of IBFD to cognitive radio and device-to-device (D2D) networks. The article by Yun Liao *et al.* introduces a new design approach for full duplex cognitive radio networks, where the secondary user can

simultaneously sense and access the vacant spectrum. The article by Li Wang *et al.* provides a comprehensive overview on how to implement full duplex communications in heterogeneous networks and how to integrate full duplex radios in D2D communications. The article also discusses applications of the full duplex techniques in future 5G networks.

Finally, the Guest Editors would like to thank all authors for their submissions even if we are unable to accommodate all of them in the Featured Topic. We greatly appreciate all the reviewers for their timely and professional reviews. We also acknowledge the support and guidance from the Editor-in-Chief of *IEEE Communications Magazine*.

BIOGRAPHIES

GEOFFREY YE LI [F'06] (liye@ece.gatech.edu) is a professor with the School of Electrical and Computer Engineering at Georgia Institute of Technology. He has also held a Cheung Kong Scholar title at the University of Electronic Science and Technology of China since 2006. He was with AT&T Labs — Research for five years before joining Georgia Tech in 2000. His general research interests include wireless communications and statistical signal processing. In these areas, he has published over 300 referred journal and conference papers in addition to 26 granted patents. His publications have been cited around 20,000 times, and he has been listed as one of the World's Most Influential Scientific Minds, also known as a Highly Cited Researcher, by Thomson Reuters. He received the Stephen O. Rice Prize Paper Award in 2010 and the WTC Wireless Recognition Award in 2013 from the IEEE Communications Society, and the James Evans Avant Garde Award in 2013 and the Jack Neubauer Memorial Award in 2014 from the IEEE Vehicular Technology Society.

MEHDI BENNIS received his M.Sc. degree in electrical engineering jointly from EPFL, Switzerland, and the Eurecom Institute, France, in 2002. From 2002 to 2004, he worked as a research engineer at IMRA-EUROPE investigating adaptive equalization algorithms for mobile digital TV. In 2004, he joined the Centre for Wireless Communications (CWC) at the University of Oulu, Finland, as a research scientist. In 2008, he was a visiting researcher at the Alcatel-Lucent Chair on Flexible Radio, SUPELEC. He obtained his Ph.D. in December 2009 on spectrum sharing for future mobile cellular systems. He is the Principal Investigator of the European CELTIC-SHARING project on multidimensional HetNets. His main research interests are in radio resource management, heterogeneous networks, game theory, and machine learning in the context of heterogeneous and small cell networks. He has published more than 50 research papers in international conference proceedings, journals, and book chapters.

GUANDING YU received B.E. and Ph.D. degrees in communication engineering from Zhejiang University, Hangzhou, China, in 2001 and 2006, respectively. After that, he joined Zhejiang University, where he is an associate professor in the Department of Information and Electronic Engineering. Since July 2013, he has also been a visiting professor with the School of Electrical and Computer Engineering, Georgia Institute of Technology, Atlanta. His research interests include energy-efficient wireless communication system design, device-to-device communications, and small cell techniques. He served as General Co-Chair of the CRNet 2010 Workshop, TPC Co-Chair for the Green Communications and Computing Symposium of Chinacom 2013, and a TPC member for various academic conferences. He is serving as a Guest Editor of the *IEEE Communications Magazine* Feature Topic on Full Duplex Communications and a Guest Editor of the *IEEE JSAC* Series on Green Communications and Networking.