SMART-DEVICE-TO-SMART-DEVICE COMMUNICATIONS: PART I


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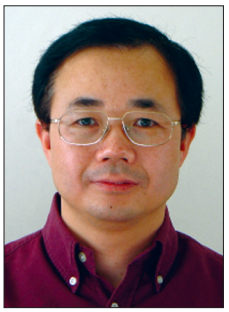
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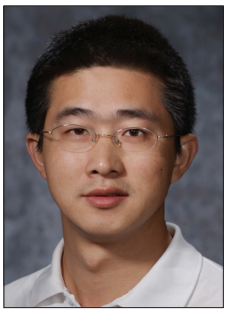
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As telecom operators are struggling to accommodate the existing demands of mobile users, new data consuming applications are emerging in the daily routines of mobile users (e.g., proximity-aware services). Moreover, 4G cellular technologies (WiMAX and LTE-A), which have extremely efficient physical and MAC layer performance, are still lagging behind mobile users' booming data demand. One of the most promising approaches to boost mobile capacity is to reuse efficiently existing frequency bands. This can be accomplished by several options, such as densification of the base stations and deployment of small cells underlying the conventional cellular networks, and using cognitive radio and spectrum sharing. Device to-device (D2D) communication is one such paradigm that appears to be a promising component in the next generation cellular technologies. In fact, a Third Generation Partnership Project (3GPP) study group is investigating D2D communications in cellular networks.

D2D communication uses cellular spectrum (license band) supported by a cellular infrastructure and promises three types of gain: the proximity of user equipment (UE) may allow extremely high bit rates, low delays, and low energy consumption; the reuse gain implies that radio resources may be simultaneously used by cellular as well as D2D links, tightening the reuse factor, even on reuse-1 system; finally, the hop gain refers to using both uplink and downlink resources when communicating via the access point in the cellular mode. Moreover, D2D communication may extend the cellular coverage and facilitate new types of wireless peer-to-peer services and at the same time increase the energy efficiency of communication. It is clear that D2D can offer a palette of interesting colors to paint new business opportunities for mobile stakeholders, promoting its candidacy for a next generation wireless communication system.

This Feature Topic of *IEEE Communications Magazine* includes different aspects on smart D2D communication ranging from smart radio protocols to energy-efficient networking topologies, including deployment strategies and lightweight security. This topic intends to bring together all mobile stakeholders, academic and industry, to identify and promote technical challenges and recent results related to D2D communication. This theme reflected in the very large number of papers (37 were submitted, out of which we have selected top 14 research articles); therefore, this Feature Topic is divided into two parts.

In the first article of Part I, "Cellular Traffic Offloading onto Network-Assisted Device-to-Device Connections" by Andreev Sergey *et al.*, the authors detail the vision of integrating managed D2D communications into current cellular technology to overcome the limitations of WiFi. The authors also quantify the estimated network performance gains from offloading cellular traffic onto D2D connections. The authors' analyses are based on an advanced system-level simulation toolkit that captures the relevant details of the network environment, and on a detailed characterization of dynamic D2D communications based on stochastic geometry. The authors conclude that D2D communications provide a significant boost to network capacity as well as user energy efficiency and quality of service perception.

In the second article, "Novel Concepts for Device-to-Device Communication Using Network Coding" by Daniel Lucani *et al.*, the authors discuss the potential and shortcomings of D2D communication as proposed today, advocating for the use of network coding as an enabling technology for enhanced security and communication efficiency, allowing for smarter D2D systems.

In the third article, "An Overview of 3GPP Device-to-Device Proximity Services" by Xingqin Lin *et al.*, the authors provide an overview of D2D standardization activities in 3GPP, identify outstanding technical challenges, draw lessons from initial evaluation studies, and summarize best practices in the design of a D2D-enabled air interface for LTE-based cellular networks.

In the fourth article, "Device-to-Device Communications in Cellular Networks" by Daquan Feng *et al.*, the authors discuss the basic concepts of D2D communications, existing fundamental works on D2D communications, and some potential research topics and challenges.

In the fifth article, "Relay-by-Smartphone: Realizing Multihop Device-to-Device Communications" by Masaya Ito *et al.*, the authors propose the concept of multihop D2D communication network systems, which is applicable to different wireless technologies, and clarify the requirements for open issues in such systems.

In the sixth article, "Secure Device-to-Device Communication in LTE-A" by Muhammad Alam *et al.*, the authors intend to provide an overview of the security architecture, threads, and requirements. Based on these requirements, the authors propose several potential solutions by reusing the existing

security mechanisms. Promising topics for future research are also discussed.

In the seventh article, "A Survey of Access Management Techniques in Machine Type Communications" by Muhammad Islam *et al.*, the authors survey the existing access management approaches for M2M communication, aiming at a novel classification scheme that will serve as a guide and motivation toward further research in this area.

In the last article of Part I, "Smart Management of D2D Constructs: An Experiment-Based Approach " by Dimitrios Karvounas *et al.*, the authors consider the concept of D2D communications for the resolution of persistent issues of mobile networks. Specifically, two scenarios are described: the opportunistic coverage expansion of the infrastructure, where an access point (AP) transits to offline mode, and hence its terminals shall exploit the presence of neighboring devices in order to reroute their traffic to alternative APs, as well as the opportunistic capacity expansion scenario where an AP faces congestion issues due to the excessive traffic of its terminals or the use of an obsolete RAT with low capacity.

The articles included in this Feature Topic consider different aspects of device-to-device communication. We hope that you enjoy reading this issue and find the articles useful. We would like to thank all the authors for submitting their work and the reviewers for their time in reviewing the articles. Thanks to EUREKA CELTIC Green-T, Marie Curie GREENET, and FCT SMARTVISION projects, ideas from which were our motivation to organize this Feature Topic. We acknowledge the support of Sean Moore, Editor-in-Chief, who has guided us in this endeavor, and Jennifer Porcello for her editorial support.

BIOGRAPHIES

SHAHID MUMTAZ [M] (smumtaz@av.it.pt) is currently working as a senior researcher and technical manager at the Institute of Telecommunication, Aveiro, Portugal, under the 4Tell group. Prior to his current position, he worked as a research intern at Ericsson Research Labs, Karlskrona, Sweden, in 2005. From March 2002 to August 2002, he worked as a system engineer at Pakistan Telecommunication (PTCL). He received his M.Sc. and Ph.D. degrees in electrical and electronic engineering from Blekinge Institute of Technology (BTH), Karlskrona, Sweden, and the University of Aveiro in 2006 and 2011, respectively. He is funded by the Swedish government and FCT Portugal. He has been involved in several EC R&D Projects (CoDIV, FUTON, C2POWER, GREENET, GREEN-T ORCALE, ROMEO, FP6, FP7) in the field of green communication and next generation wireless systems. In an EC project, he holds the position of technical manager, where he oversees the project from the scientific and technical sides, managing all details of each work package to ensure the maximum impact of the project's results on further development of commercial solutions. He has also been involved in two Portuguese funded projects (SmartVision & Mobilia) in the area of networking coding and development of a system-level simulator for 5G wireless systems. His research interests lie in the field of architectural enhancements to 3GPP networks (i.e., LTE-A, user plane and control plane protocol stack, NAS, and EPC), green communications, cognitive radio, cooperative networking, radio resource management, cross-layer design, heterogeneous networks, M2M and D2D communication, and baseband digital signal processing. He has more than 45 publications in international conferences, journal papers, and book chapters. He is also an Editor of two books and a Guest Editor for *IEEE Wireless Communications* and *IEEE Communications Magazine*. He has been on the Technical Program Committees of IEEE conferences, including GLOBECOM, ICC, and VTC, and chaired some of their symposia. He was Workshop Chair of IEEE ISWCS '13 in Germany and a recipient of the 2006 IITA Scholarship, South Korea.

LIE-LIANG YANG (M'98, SM'02) received his B.Eng. degree in communications engineering from Shanghai TieDao University, China, in 1988, and his M.Eng. and Ph.D. degrees in communications and electronics from Northern (Beijing) Jiaotong University, Beijing, China, in 1991 and 1997, respectively. From June 1997 to December 1997 he was a visiting scientist at the Institute of Radio Engineering and Electronics, Academy of Sciences of the Czech Republic. Since December 1997, he has been with the University of Southampton, United Kingdom, where he is a professor of wireless communications in the School of Electronics and Computer Science. His research has covered a wide range of topics in wireless communications, networking, and signal processing. He has published over 300 research papers in journals and conference proceedings, authored/co-authored three books, and also several book chapters. Details on his publications can be found at http://www-mobile.ecs.soton.ac.uk/lly/. He is a Fellow of the IET, served as an Associate Editor of the *IEEE Transactions on Vehicular Technology* and *Journal of Communications and Networks*, and is currently an Associate Editor of the *IEEE Access and the Security and Communication Networks Journal*.

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FUMIYUKI ADACHI [M'79, SM'90, F'00] received his B.S. and Dr. Eng. degrees in electrical engineering from Tohoku University, Sendai, Japan, in 1973 and 1984, respectively. In April 1973, he joined the Electrical Communications Laboratories of Nippon Telegraph & Telephone Corporation (now NTT) and conducted various types of research related to digital cellular mobile communications. From July 1992 to December 1999, he was with NTT Mobile Communications Network, Inc. (now NTT DoCoMo, Inc.), where he led a research group on wideband/broadband CDMA wireless access for IMT-2000 and beyond. Since January 2000, he has been with Tohoku University, where he is a Distinguished Professor of Communications Engineering at the Graduate School of Engineering. His research interest is in the areas of wireless signal processing and networking, including broadband wireless access, equalization, transmit/receive antenna diversity, MIMO, adaptive transmission, channel coding, and others. From October 1984 to September 1985, he was a United Kingdom SERC Visiting Research Fellow in the Department of Electrical Engineering and Electronics at Liverpool University. He was a VTS Distinguished Lecturer for 2011 to 2013. He was a co-recipient of the IEEE Vehicular Technology Transactions Best Paper of the Year Award in 1980 and again in 1990, and also a recipient of an Avant Garde award in 2000. He is a Fellow of the Institute of Electronics, Information and Communication Engineers of Japan (IEICE), and has been a recipient of the IEICE Achievement Award in 2002 and a co-recipient of the IEICE Transactions Best Paper of the Year Award in 1996, 1998, and again in 2009. He is a recipient of the Thomson Scientific Research Front Award 2004, the Ericsson Telecommunications Award 2008, the Telecom System Technology Award 2009, the Prime Minister Invention Prize 2010, a British Royal Academy of Engineering Distinguished Visiting Fellowship 2011, and the KDDI Foundation Research Award 2012.

NAJAH ABU ALI is currently an associate professor at the Faculty of Information Technology of the University of the United Arab Emirates. She got her Ph.D. in computer networks from the Department of Electrical Engineering, Queen's University, Kingston, Canada. Her general research interests include analytical and measurement-based performance evaluation of computer networks and radio resource management in wireless networks. Recently, her focus is on machine-to-machine communication, particularly on designing energy-efficient radio resource management and scheduling schemes. She also has interest in designing localization algorithms and routing protocols for vehicular networks. She has published her work in several journals and conferences, and has delivered several tutorials in her fields of research. She is a Principal Investigator or Co-Principal Investigator of several major research projects that have been funded by several agencies such as QNRF and NRF / UAEU. She is also a co-author of the book *LTE, LTE-Advanced and WiMAX: Toward IMT Advanced Networks* (Wiley).