GUEST EDITORIAL

TECHNOLOGIES FOR GREEN RADIO COMMUNICATION NETWORKS





PETER HAN JOO CHONG   CYRIL LEUNG   ZHISHENG NIU   TAPANI RISTANIEMI   BOON-CHONG SEET

Since the introduction of cellular communications in the early '80s, the demand for two-way mobile communication services has increased tremendously. Today there are over 4 billion mobile users and 4.6 million radio base station sites worldwide [1]. This rapid growth of the cellular mobile industry has been at the price of increased energy consumption and a sizable carbon footprint. In 2007, the whole information and communications technology (ICT) industry accounted for about 3 percent of the worldwide energy consumption and contributed about 2 percent of the CO_2 emissions. It is expected that the growth of the ICT footprint will be less than double between 2007 and 2020, whereas that of mobile communications will nearly triple in the same period. Therefore, there is an urgent need to improve the energy efficiency of cellular mobile systems. Along with many countries' aggressive efforts to reduce energy consumption and control greenhouse gases (GHGs), major telecommunication companies have voluntarily committed to lower their CO_2 emissions by 10 percent to 80 percent from 2010 to 2020 as compared to 2006–2007.

Nowadays, we are facing a number of serious energy related problems, including energy shortages, energy price hikes, and global warming; these problems have a significant negative impact in terms of the environment, global health, and social and economic well being. However, today's mobile communication architectures are not specifically designed to be energy efficient. Due to growing public concerns, the concept of a green radio communication network (GRCN) is quickly attracting a lot of interest from industry and university research communities. A number of techniques have been claimed as low-power solutions for future GRCNs, including cognitive radio, multihop relaying, and cooperative communications and multiple-input multiple-output (MIMO) systems; however, some of these techniques may even consume more energy due to their algorithmic complexity. To date, the topic of GRCNs has not been a focus of practical work, and there is no conclusive evidence of any general technique for reducing the overall system energy consumption.

This feature topic covers a variety of recent research articles and comprehensive surveys on recent technological advances in the field of GRCNs. We received over 40 submissions from authors around the world. Papers (including the invited articles) that passed our preliminary screening were subject to a rigorous review process involving experts in this field. Eventually, five articles from the call for papers were accepted for this issue, along with three invited articles. We hope that this issue will serve as a valuable reference and trend indicator for researchers and engineers in both industry and academia.

The first (invited) article, "Techniques for Improving Cellular Radio Base Station Energy Efficiency" by Steve McLaughlin *et al.*, investigates three specific approaches to achieve high energy efficiency gains in future mobile radio networks. The three approaches are base station (BS) sleep mode, femtocell and relaying technique, and multiple antennas. Based on the experiences of their commercial mobile operator research sponsors, those approaches are considered to be the most promising energy saving techniques for future mobile radio networks.

The second (invited) article, "Energy- and Cost-Efficient Ultra-High-Capacity Wireless Access" by Sibel Tombaz *et al.*, emphasizes that future mobile system deployment must balance among infrastructure deployment, spectrum, and energy components. The authors propose a high-level framework for a total cost analysis taking into account new spectrum opportunities, energy-efficient physical layers, and novel deployment and backhauling strategies to minimize the overall system cost. The goal is to provide an overview of the main trade-offs among infrastructure, spectrum, and energy costs for future mobile broadband systems.

The third (invited) article, "TANGO: Traffic-Aware Network Planning and Green Operation" by Zhisheng Niu, claims that future network planning and operation should be more energy efficiency oriented. The author proposes a new framework called TANGO to increase the energy efficiency from the system point of view. TANGO consists of three techniques: BS sleep control, dynamic cell planning, and soft real-time service. Results show that TANGO can significantly improve the energy efficiency of cellular networks with reasonable quality of service levels.

The fourth article, "Network Energy Saving Technologies for Green Wireless Access Networks" by Tao Chen *et al.*, provides an overview of current network energy saving techniques that have been studied by the Third Generation Partnership Project (3GPP) Long Term Evolution (LTE) standards body, which can be broadly classified by the time, frequency, and spatial domains. Even though most existing solutions focus on a single BS, the authors believe that network solutions involving multiple networks are promising for GRCNs.

The fifth article, "How Much Energy Is Needed to Run a Wireless Network?" by Gunther Auer *et al.*, presents the EARTH energy efficiency evaluation framework (E3F), which focuses on BS power consumption. The E3F proposes a sophisticated power model for various BS types and a large-scale long-term traffic model. The E3F is applied to assess the BS energy efficiency on the downlink of a 3GPP LTE radio network.

The sixth article, "Cell Wilting and Blossoming for Energy Efficiency" by Alberto Conte *et al.*, aims to reduce the BS power consumption in a cellular network using a BS sleep mode to serve users in periods of low traffic. The article focuses on the design of BS sleep and wake-up transients. A realistic case study is used to evaluate the performance of the proposed technique.

The seventh article, "Dimensioning Network Deployment and Resource Management in Green Mesh Networks" by Lin X. Cai *et al.*, points out that the main design criterion and the performance measurement is energy sustainability under the green radio network powered by renewable energy. Thus, the authors propose solutions that can allow dynamically harvested energy to sustain the traffic demands in the network. Two issues, network deployment and resource management, are studied to meet the objective of network sustainability.

Finally, the feature topic concludes with "Green Last Mile: How Fiber-Connected Massively Distributed Antenna Systems Can Save Energy" by Alireza Attar *et al.* This article presents a last-mile architecture to carry radio signals over optical fibers in the last mile to a distributed antenna system. The idea behind the proposed technique is that shortening the communication link over the last mile will significantly reduce the energy consumption of the network. Simulation results show that their proposed architecture outperforms two other last-mile solutions, micro BS and femtocells.

In closing, we would like to thank all authors for their valuable contributions to this feature topic. We are also grateful to the more than 100 experts who participated in the review process and completed their reviews within a very tight schedule. Last but not least, we wish to thank the Editor-in-Chief, Professor Michael Fang, and the publication staff for the constant support they provided during the preparation of this feature topic.

REFERENCES

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BIOGRAPHIES

PETER H. J. CHONG (EHJChong@ntu.edu.sg) received his B.Eng. (with distinction) in electrical engineering from the Technical University of Nova Scotia, Halifax, Canada, in 1993, and M.A.Sc. and Ph.D. degrees in electrical engineering from the University of British Columbia, Vancouver, Canada, in 1996 and 2000, respectively. Between July 2000 and January 2001 he worked in the Advanced Networks Division at Agilent Technologies Canada Inc., Vancouver. From February 2001 to May 2002 he was with the Radio Communications Laboratory at Nokia Research Center, Helsinki, Finland, and was involved in research on WCDMA and standardization for HSDPA. During his stay in Finland, he taught part of a graduate course in WCDMA at the Helsinki University of Technology. Since May 2002 he has been with the School of Electrical and Electronic Engineering, Nanyang Technological University (NTU), Singapore, where he is now an associate professor. He was Technical Program Committee Chair for Mobility Conference 2005 and 2006, and General Chair of Mobility Conference 2007 and 2008. He served as a Guest Editor of the *Journal of Internet Technology* in 2006, *International Journal of Ad Hoc and Ubiquitous Computing* in 2007, and lead Guest Editor of *IEEE Communications Magazine* for the Feature Topic on Technologies in Multihop Cellular Network in 2007 and *IEEE Wireless Communications* for the Special Issue on Technologies for Green Radio Communication Networks in 2011. He is an Editorial Board Member of *Security and Communication Networks*, *International Journal of Wireless Communications and Networking*, and *Wireless Sensor Network*, and an Editor of the *Far East Journal of Electronics and Communications*. His research interests are in the areas of mobile communications systems, including channel assignment schemes, radio resource management and multiple access, MANETs ,and multihop cellular networks.

CYRIL LEUNG (cleung@ece.ubc.ca) received his B.Sc.(First Class Honours) degree from Imperial College, University of London, England, in 1973, and M.S. and Ph.D. degrees in electrical engineering from Stanford University in 1974 and 1976, respectively. From 1976 to 1979 he was an assistant professor in the Department of Electrical Engineering and Computer Science, Massachusetts Institute of Technology. During 1979–1980 he was with the Department of Systems Engineering and Computing Science, Carleton University, Ottawa, Canada. Since July 1980 he has been with the Department of Electrical and Computer Engineering, University of British Columbia where he is a professor and currently holds the PMC-Sierra Professorship in Networking and Communications. His current research interests are in wireless communications systems. He is a member of the Association of Professional Engineers and Geoscientists of British Columbia.

ZHISHENG NIU [M] (niuzhs@tsinghua.edu.cn) graduated from Northern Jiaotong University (currently Beijing Jiaotong University), China, in 1985, and got his M.E. and D.E. degrees from Toyohashi University of Technology, Japan, in 1989 and 1992, respectively. After spending two years at Fujitsu Laboratories Ltd., Kawasaki, Japan, he joined Tsinghua University, Beijing, China, in 1994, where he is now a professor in the Department of Electronic Engineering and deputy dean of the School of Information Science and Technology. He received Best Paper Awards from the 13th and 15th Asia-Pacific Conference on Communication (APCC) in 2007 and 2009, respectively, and the Outstanding Young Researcher Award from the Natural Science Foundation of China in 2009. His current research interests include teletraffic theory, mobile Internet, radio resource management of wireless networks, and green communication and networks. Currently, He is a Fellow and Councilor of the IEICE, Director for Conference Publications of IEEE Communication Society, council member of the Chinese Institute of Electronics (CIE), and Vice Chair of the Information and Communication Network Committee of the Chinese Institute of Communications (CIC).

TAPANI RISTANIEMI [SM] (tapani.e.ristaniemi@jyu.fi) received his M.Sc. in mathematics (1995), Ph.Lic. in applied mathematics (1997), and Ph.D. in wireless communications (2000) from the University of Jyväskylä, Finland. During 2001–2003 he was a professor of wireless communications at the Department of Mathematical Information Technology, University of Jyvaskylä, and during 2003–2006 a professor of wireless data communications, Institute of Communications Engineering, Tampere University of Technology, Finland. In 2006 he joined the University of Jyvaskylä, where he holds a professorship of computer science. His research interests include signal processing for wireless communications and self-organizing wireless communication systems.

BOON-CHONG SEET [M] (boon-chong.seet@aut.ac.nz) received his Ph.D. degree in computer engineering from Nanyang Technical University, Singapore, in 2005. After graduation he was recruited as a research fellow under the Singapore–MIT Alliance (SMA) Program at the School of Computing, National University of Singapore. In 2007 he was awarded a visiting scholarship by the Technical University of Madrid, Spain, to pursue research under an EU-funded project on multidisciplinary advanced research in user-centric wireless network enabling technologies (MADRINET). Since December 2007 he is with Auckland University of Technology, New Zealand, where he is currently a senior lecturer in the Department of Electrical and Electronic Engineering. He is also currently a visiting faculty member at the University of British Columbia, Canada. His research activities span the fields of mobile and wireless networking, computing, and communications. He is a member of the ACM.