Special Issue on Improving the Energy Efficiency of Cellular Communications

Guest Editorial

With 5 billion mobile phone subscribers already in the world today and the projected rapid increase in wireless data consumption, the energy efficiency of cellular networks has now become an urgent issue –in terms of both a network operator's energy cost (hence profit margin) and the perspective of environmental impacts. This is particularly the case for base stations, which can account for more than half of a network's energy consumption. While much research in this area is already under way, many significant challenges at all levels still remain to be investigated. These issues range from fair metrics and the corresponding fundamental trade-offs to traffic patterns and user behaviours, and from circuit design and baseband processing to network deployment and dynamic reconfiguration.

While base station design (e.g. power amplifier and remote radio head) still plays a key role in increasing the energy efficiency at a link level, the ultimate improvement of energy efficiency in cellular networks is likely to require a network approach based on dynamic cell reconfiguration and inter-level joint optimisation.

One powerful network approach to improving the energy efficiency is heterogeneous networking. This can be achieved either by densification of cells overlaid by a macro-cell network or by deployment of relay stations at the boundary of macro cells. A critical question is: which structure is better in network performance and energy efficiency? This is studied in the 1st paper of this special issue: "*Small-net vs. relays in a heterogeneous low energy LTE architecture*" by W. Guo and T. O'Farrel. By using a multi-cell multi-user dynamic LTE simulator, the paper shows that a key parameter in deciding which structure to employ is the percentage of high-mobility users.

Another network oriented strategy to increase the energy efficiency, which has lately received much attention, is to impose a sleep mode on certain base stations or sectors under certain traffic loads. While this makes obvious sense from the view point of energy consumption, many outstanding issues still exist. One challenge is: under which traffic condition(s) a base station should be "switched off"(i.e. entering sleep mode) while avoiding over-frequent mode switching. This is the topic of the 2nd paper: "*Two teletraffic-based schemes for energy saving in cellular networks with micro-cells*" by Z. Haq and F.Y. Li. By using a simplified 3-cell network, the authors propose both a deterministic switching scheme based on a channel occupancy threshold and a probabilistic scheme based on a finite Markov decision process, while suggesting the possibilities for future extension.

The sleep mode strategy also faces some practical challenges, and these have not been addressed in great detail in the existing literature. The 3rd paper of this special issue, "*Realistic energy saving potential of sleep mode for existing and future mobile networks*" by G. Micallef, L. Saker, S. E. Elayoubi, and H.-O. Scheck, deals with exactly some of these practical factors, and shows how much gain in energy efficiency can potentially be realised when some realistic conditions or limitations are taken into account (such as user experience and the type of equipment and networks).

The three papers included here are the results of a rigorous peer review and selection process, but we would like to express our gratitude to all the authors who have responded to our call for papers as well as all the reviewers for their constructive comments. Finally, we must also thank Dr. Haohong Wang, the Editor-in-Chief of Journal of Communications, for giving us the opportunity to guest edit this special issue.

Guest Editors

Fu-Chun Zheng
The University of Reading, UK

Luís Correia
Technical University of Lisbon, Portugal

Y. Jay Guo
CSIRO, Australia

Tim O'Farrell
The University of Sheffield, UK

Ritesh Madan,
Accelera MB, USA

Fu-Chun Zheng obtained the BEng (1985) and MEng (1988) degrees in radio engineering from Harbin Institute of Technology, China, and the PhD degree in Electrical Engineering from the University of Edinburgh, UK, in 1992.

From 1992 to 1995, he was a post-doctoral research associate with the University of Bradford, UK, Between May 1995 and August 2007, he was with Victoria University, Melbourne, Australia, first as a lecturer and then as an associate professor in mobile communications. He joined the University of Reading, UK, in September 2007 as Professor (Chair) of Signal Processing. He has been awarded two UK EPSRC Visiting Fellowships - both hosted by the University of York (UK): first from August 2002 to July 2003 and then from August 2006 to July 2007. Over the past 15 years, Dr Zheng has also carried out and managed many industry-sponsored projects. He has been both a short term visiting fellow and a long term visiting research fellow with British Telecom, UK. Dr Zheng's current research interests include signal processing for communications, multiple antenna systems, and green communications.

He has been an active IEEE member since 1995. He was an editor (2001 – 2004) of *IEEE Transactions on Wireless Communications.* In 2006, Dr Zheng served as the general chair of *IEEE VTC 2006-Spring* in Melbourne, Australia (http://ieeevtc.org/vtc2006spring/) - the first ever VTC held in the southern hemisphere. He received a VTC Chair Award from the IEEE VT Society at IEEE VTC 2009-S (Barcelona, Spain) in April 2009.

Luis M. Correia was born in Portugal, on 1958. He received the Ph.D. in Electrical and Computer Engineering from IST (Technical University of Lisbon) in 1991, where he is currently a Professor in Telecommunications, with his work focused in Wireless/Mobile Communications in the areas of propagation, channel characterisation, radio networks, traffic, and applications, with the research activities developed in the INOV-INESC institute. He has acted as a consultant for Portuguese mobile communications operators and the telecommunications regulator, besides other public and private entities. Besides being responsible for research projects at the national level, he has been active in various ones within the European frameworks of RACE, ACTS, IST, ICT and COST (where he also served as evaluator and auditor), having coordinated two COST projects, and taken leadership responsibilities at various levels in many others. He has supervised more than 150 M.Sc. and Ph.D. students, having authored more than 350 papers in international and national journals and conferences, for which he has served also as a reviewer, editor, and board member, and edited 6 books. He was part of the COST Domain Committee on ICT. He was the Chairman of the Technical Programme Committee of several major conferences. He is part of the Expert Advisory Group and of the Steering Board of the European Net!Works platform, and was the Chairman of its Working Group on Applications.

Prof Y. Jay Guo has over twenty years of international experience in industry, academia and the Commonwealth Science and Industry Research Organization (CSIRO) across three continents. Currently, he serves as the Research Director of the Smart and Secure Infrastructure portfolio (Theme) in the Digital Productivity and Services Flagship, which covers broadband networks and services, and cyber-physical security. Prior to joining CSIRO, he worked for eight years in the European wireless industry serving as senior managers of advanced technology development and strategy planning in Fujitsu, Siemens and NEC. In the past seven years, he has led a number of research portfolios at CSIRO with great success, and won numerous prestigious awards from industry and research communities.

Jay is a leading researcher in antennas, gigabit wireless communications systems and wireless positioning. He is Fellow of IET, an Adjunct Professor at UNSW, Macquarie University and University of Canberra, and a Guest Professor at the Chinese Academy of Sciences and Shanghai Jiaotong University. He has served as Guest Editors and Chairs for several top tier research journals and international conferences. He has published over 200 research papers including 82 journal papers and 3 scholarly books, and holds 18 patents.

Professor Tim O'Farrell holds a Chair in Wireless Communication in the Department of Electronic & Electrical Engineering at the University of Sheffield, Sheffield, UK. His research interests encompass physical layer and resource management techniques for wireless communication systems in particular mobile cellular, wireless LAN and wireless optical systems. In his field, Tim has led 17 major research projects, frequently with industry, as principal investigator. He has published over 200 technical papers including 8 granted patents and has participated in standards, consultancies and expert witness activities within the wireless sector. Presently, Tim is the Academic Coordinator of the Green Radio project jointly sponsored by the UK's Virtual Centre of Excellence in Mobile and Personal Communications (Mobile VCE) and the UK's Engineering and Physical Sciences Research Council (EPSRC). Tim is a Chartered Engineer and a member of the IET and IEEE.

Ritesh Madan received a Ph.D. in 2006 and a M.S. in 2003 from Stanford University, and a B.Tech from the Indian Institute of Technology (IIT) Bombay in 2001, all in Electrical Engineering. At Stanford, he was a recipient of the Sequoia Capital Stanford Graduate Fellowship. He is currently an Algorithms Architect at Accelera MB where he develops resource allocation algorithms and system architectures for self-organizing wireless networks. Prior to that he worked at the New Jersey Research Center (NJRC), Qualcomm, NJ, developed technologies for interference management in 4G heterogeneous cellular networks, increasing capacity of WiFi networks by increasing spectral reuse, and proximal data services in LTE via wireless peer to peer connections . His research interests include methods for resource allocation in wireless networks, stochastic control, and optimization.