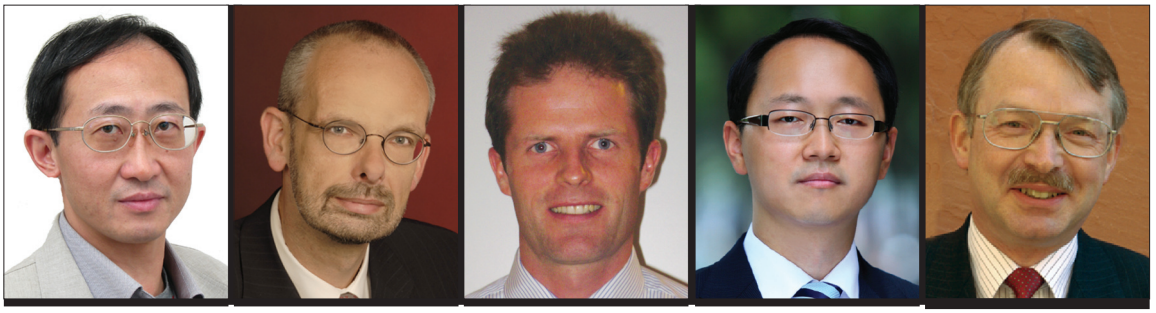
ENERGY EFFICIENCY IN COMMUNICATIONS



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The telecommunications and information community today is facing daunting challenges but also embracing great opportunities. The unprecedented expansion of wireline and wireless networks has resulted in a tremendous increase in energy consumption and left a significant environmental footprint. Recently, it has been reported that energy costs can account for as much as half of a mobile service provider's annual operating expenses. If the aggregate energy consumption of networking devices were to follow the growth trajectories of Internet traffic (i.e., about 50 percent per year), the environmental and financial consequences would be dire. Thus, making information and communications technology (ICT) equipment and applications energy-efficient could not only have a tangible positive impact on the environment, but also help telecommunications operators attain long-term profitability. Moreover, energy-efficient communications can help the world reduce its dependence on fossil fuel, enable demand response and distributed energy resources, and ultimately achieve sustainable prosperity. Accordingly, a myriad of communications and information technologies have already been exploited by the global smart grid initiatives to empower the conventional power grid to support two-way energy and information flow.

To meet the challenges of increasing the energy efficiency in communications, it is necessary to resort to a plethora of paradigm-shifting technologies, such as energy-efficient network architecture and protocols, energy-efficient wireless transmission techniques, energy-efficient home networking, energy-aware backbone networks, smart grid, and opportunistic spectrum sharing without causing harmful interference pollution.

Accordingly, there are two reoccurring Feature Topic issues (November 2010 and June 2011) in sequence devoted to energy efficiency improvement, which aim to provide a comprehensive overview of the state of the art in technology, regulation, and standardization for energy-efficient communications in the coming sustainable development era. The first issue (this one) presents a holistic view of the relevant fundamental technique challenges and essential frameworks for increasing energy efficiency in communications, and includes four specific articles.

The first article, "IEEE 802.3az: The Road to Energy Efficient Ethernet" by Ken Christensen *et al.*, provides an overview of the IEEE 802.3az Energy Efficient Ethernet (EEE), based on utilizing low-power idle mode to reduce the energy consumption of a link when no packets are being sent, and describes the development of the IEEE 802.3az EEE standard and how packet coalescing can be used to improve the energy efficiency of EEE.

The second article, "A Secure Decentralized Data-Centric Information Infrastructure for Smart Grid" by Young-Jin Kim *et al.*, thoroughly depicts an IP-based decentralized and data-centric information infrastructure for supporting the innovative operations and applications of the next-generation smart power grid, which differs from a conventional power distributed system by addressing the specific requirements of power applications such as security, distributed data sources, latency-sensitive data transactions, and real-time event updates.

The third article, "Challenges and Enabling Technologies for Energy Aware Mobile Radio Networks" by Luis M. Correia *et al.*, presents an ensemble approach to characterizing energy-efficient mobile radio networks. It provides appropriate metrics and methods that allow evaluating the energy efficiency of the entire mobile radio system comprising various component, link, and network levels. Moreover, advanced power management methods, taking into account discontinuous transmission at the base stations, slowly changing daily load patterns, and highly dynamic traffic fluctuations at the network level have been investigated as well.

The fourth article, "Cell Zooming for Cost-Efficient Green Cellular Networks" by Zhisheng Niu *et al.*, details a novel concept and architecture of cell zooming in mobile cellular networks, which adaptively adjusts the cell size according to traffic load, user requirements, and channel conditions. The proposed centralized and distributed cell zooming algorithms effectively leverage the trade-off between energy saving and blocking probability, which not only solve the problem of traffic imbalance but also reduce the total energy consumption in cellular networks.

In particular, we would like to thank Dr. Steve Gorshe for his kind encouragement and valuable comments on improving energy efficiency in communications. We hope that the articles in this issue and the forthcoming recurring issue (June 2011) will stimulate the readers of *IEEE Communications Magazine* to actively take part in this significant emerging area of research.

BIOGRAPHIES

HONGGANG ZHANG (honggangzhang@zju.edu.cn) is a full professor at the Department of Information Science and Electronic Engineering, as well as co-director of the York-Zhejiang Laboratory for Cognitive Radio and Green Communications, Zhejiang University, China. He received a Ph.D. degree in electrical engineering from Kagoshima University, Japan, in 1999. Prior to that, he received his Bachelor and Master of Engineering degrees, both in electrical engineering, from Huazhong University of Science and Technology (HUST), China, in 1989, and Lanzhou University of Technology, China, in 1992, respectively. From October 1999 to March 2002 he was with the Telecommunications Advancement Organization (TAO) of Japan as a TAO research fellow. From April 2002 to November 2002 he was at the Toyota IT Center. From December 2002 to August 2004 he was with the UWB Research Consortium, the Communications Research Laboratory (CRL), and the National Institute of Information and Communications Technology (NICT) of Japan, focused on UWB wireless communications, IEEE 802.15 WPAN standardizations, and Wireless 1394 smart home networks. He was the principal author and contributor for proposing DS-UWB in the IEEE 802.15 WPAN standardization task group. From September 2004 to February 2008 he was with CREATE-NET, where he led its wireless group in participating in a number of European FP6 & FP7 projects (EUWB, PULSERS 2). He is founding Vice-Chair of the Technical Committee on Cognitive Networks (TCCN) of the IEEE Communications Society. He was the Co-Chair of the IEEE GLOBECOM 2008 Symposium on Selected Areas in Communications. He is the founding Technical Program Committee (TPC) Co-Chair of CrownCom 2006 as well as a Steering Committee Member of CrownCom 2006–2009. He has served as Guest Editor for an ACM/Springer *Mobile Networks and Applications* (MONET) *Journal* special issue on "Cognitive Radio Oriented Wireless Networks and Communications" in 2007, an Elsevier *PHYCOM* special issue on "Cognitive Radio: Algorithms & System Design" in 2008, an *IEEE Transactions on Vehicular Technology* special issue on "Achievements and the Road Ahead: The First Decade of Cognitive Radio" in 2009, and an *IET Communications Journal* special issue on 'Cognitive Communications" in 2010. He is an Honorary Visiting Professor of the University of York, United Kingdom.

ANDREAS GLADISCH [M] (andreas.gladisch@telekom.de) received a Dipl.Ing. degree in theory of electro techniques from the Technical University of Ilmenau, Germany, in 1986 and a Ph.D. degree in optical communications from Humboldt University of Berlin, Germany, in 1990, where he was engaged in research on coherent optical communication and optical frequency control. He joined the Research Institute of Deutsche Telekom in 1991, where he was involved in projects with coherent optics, wavelength-division multiplexing (WDM) systems, wavelength control, and frequency stabilization. From 1996 to 1998, he was leading a research group working in the field of design and management of optical networks, and in 1999, he became the Director of the Department on Network Architecture and System Concepts of T-Systems. Since 2009 he is responsible for the research field Broadband Network Architecture and Economics of Deutsche Telekom Laboratories. He has participated in several European funded research projects, such as DEMON, MOON, LION, NOBEL, OASE, and SPARC. His research interests are network architecture and how optical technologies could change the overall network architecture. In 2002 he was a guest editor of *IEEE JSAC* on WDM-Based Network Architectures. He was responsible for projects developing the mid-term strategy of the Deutsche Telekom transport network, especially the concepts for the further development of synchronous digital hierarchy (SDH), WDM, and OTN. His current research activities are in the field of broadband access network architecture, techno-economics, and green communication. He has been a TPC member for numerous conferences on optical communication and network architecture. During the last years, he has organized workshops and sessions about green communication and energy-efficient ICT at various conferences (e.g., ICC, ECOC). He has authored or coauthored more than 100 national and international technical conference or journal papers He is a member of Informationstechnische Gesellschaft (ITG)

MARIO PICKAVET (mario.pickavet@intec.ugent.be) is a full professor at the Department of Information Technology (INTEC) of Ghent University, Belgium. He received an M.Sc. degree in electrical engineering, specialized in telecommunications, in 1996 from Ghent University. His graduation thesis, *Topological Planning of Telecommunication Networks Using Genetic Algorithms*, covered the development of a genetic algorithm enhanced with some deterministic optimization routines for a joint topology-capacity design of telecommunication transport networks. From 1996 until 1999 he was a research fellow of the Flemish Fund for Scientific Research (FWO-V) in the Broadband Communications Networks Group. In 1999 he received a Ph.D. degree in electrical engineering from the same university. His Ph.D. thesis, *Use of Heuristic Techniques for Global Design and Planning of Telecommunication Networks*, covered the design of mesh-based transport networks and the multiperiod planning of survivable networks. Since 2000 he has been a professor at Ghent University where he teaches courses on discrete mathematics, multimedia networks, and network modeling. His current research interests are related to broadband communication networks (WDM, IP, (G-)MPLS, Ethernet, OPS, and OBS) and include design, long-term planning, techno-economical analysis, and energy efficiency of core and access networks. Special attention goes to operations research techniques that can be applied for routing and network design. In this context, he is currently involved in several European and national projects, such as the Network of Excellence "Building the Future Optical Network in Europe" (BONE), DICONET, ECODE, ALPHA, SPARC, TREND, and OASE. He has published about 200 international publications, in both journals and proceedings of various conferences. He has been a TPC member for numerous conferences. During the last years, he has organized several workshops and sessions on energy efficiency at various communication network conferences (e.g., ECOC 2008, OFC 2009). He is co-author of the book *Network Recovery: Protection and Restoration of Optical, SONET-SDH, IP, and MPLS*. He is the holder of a bronze medal at the International Mathematical Olympiad (Sweden, 1991).

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WERNER MOHR [SM] (werner.mohr@nsn.com) graduated from the University of Hannover, Germany, with a Master's degree in electrical engineering in 1981 and a Ph.D. degree in 1987. He joined Siemens AG, Mobile Network Division, Munich, Germany, in 1991. He was involved in several EU funded projects and ETSI standardization groups on UMTS and systems beyond 3G. In December 1996 he became project manager of the European ACTS FRAMES Project until the project finished in August 1999. This project developed the basic concepts of the UMTS radio interface. Since April 2007 he has been with Nokia Siemens Networks GmbH & Co. KG, Munich, Germany, where he is head of Research Alliances. He was the coordinator of the WINNER Project in Framework Program 6 of the European Commission, Chairman of WWI (Wireless World Initiative) and the Eureka Celtic project WINNER+. The WINNER project laid the foundation for the radio interface for IMT-Advanced and provided the starting point for the 3GPP LTE standardization. In addition, he was Vice Chair of the eMobility European Technology Platform in the period 2008–2009 and is now eMobility Chairperson for the period 2010–2011. He was Chair of the Wireless World Research Forum from its launch in August 2001 up to December 2003. He is a member of VDE (Association for Electrical, Electronic & Information Technologies, Germany). In 1990 he received the Award of the ITG (Information Technology Society) in VDE. He was a board member of ITG in VDE for the term 2006–2008 and was re-elected for the term 2009–2011. He is co-author of the books *Third Generation Mobile Communication Systems* and *Radio Technologies and Concepts for IMT-Advanced*.