GUEST EDITORIAL

4G MOBILE COMMUNICATIONS: TOWARD OPEN WIRELESS ARCHITECTURE

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The number of subscribers for mobile communications has increased much faster than predicted, particularly for terrestrial use, and the majority of traffic is changing from speech-oriented communications to multimedia communications. It is generally expected that the number of portable handsets will exceed the number of PCs connected to the Internet. First steps toward the fourth generation (4G) or beyond 3G (B3G) have been taken to support advanced and wideband multimedia services. The International Telecommunication Union—Radiocommunication Standardization Sector (ITU-R) defines 4G to be developed over time as depicted in Fig. 1. Radio-based telecommunications, currently under requirements definition, will be standardized from 2007 on and will be deployed from about 2010 on.

According to the ITU-R visions, a steady and continuous evolution of existing radio access networks will be one of the characteristics of B3G systems, besides the functional fusion of

- Existing, enhanced, and newly developed elements of cellular systems
- Nomadic wireless access systems
- Systems with high commonality and seamless interworking

ITU-R further expects that new radio interface(s) are likely to be used in conjunction with enhanced IMT-2000 wireless access technologies, higher data rates with adaptive interfaces, and seamless services, where the user may not need to be concerned with the underlying technology used at a particular time or location.

ITU is still not clear on the 4G definition, and currently there are two groups defining the 4G: one is on high data rates (up to 100 Mb/s), the other on open architecture.

Since 4G on its introduction will find many predecessor systems operational, interworking between 4G and other radio access systems in terms of horizontal and vertical handover and seamless services with service negotiation, including mobility, security, and quality of service (QoS), will be one key requirement. Therefore, the most important issue in developing future 4G mobile systems is the architecture based on the converged broadband wireless platform and targeted for open wireless architecture.

In addition to ultra-high bit rates, ubiquitous coverage via heterogeneous access, low cost, and machine-to-machine and sensor networks, the Wireless World Research Forum (WWRF) names the following characteristics of B3G systems:

- Users are in control through intuitive interactions with applications, services, and devices.
- Services and applications are personalized, ambient-aware, and adaptive (I-centric); ubiquitous from the point of view of the user.
- Seamless services are provided to users, groups of users, communities, and machines (autonomously communicating devices) irrespective of place and network, and with agreed QoS.
- Users, application developers, service and content providers, network operators, and manufacturers can efficiently and flexibly create new services and business models based on the component-based architecture of the wireless world.

Both ITU-R and WWRF are telecommunications driven, but there are other actors, like IEEE with Project 802, that will impact the future (4G) of wireless and mobile radio communications focusing on a much shorter time axis. It is quite natural to reflect this by taking the progress in all of these domains into account.

This special issue is very timely and valuable for those involved in the research of next-generation mobile communications.

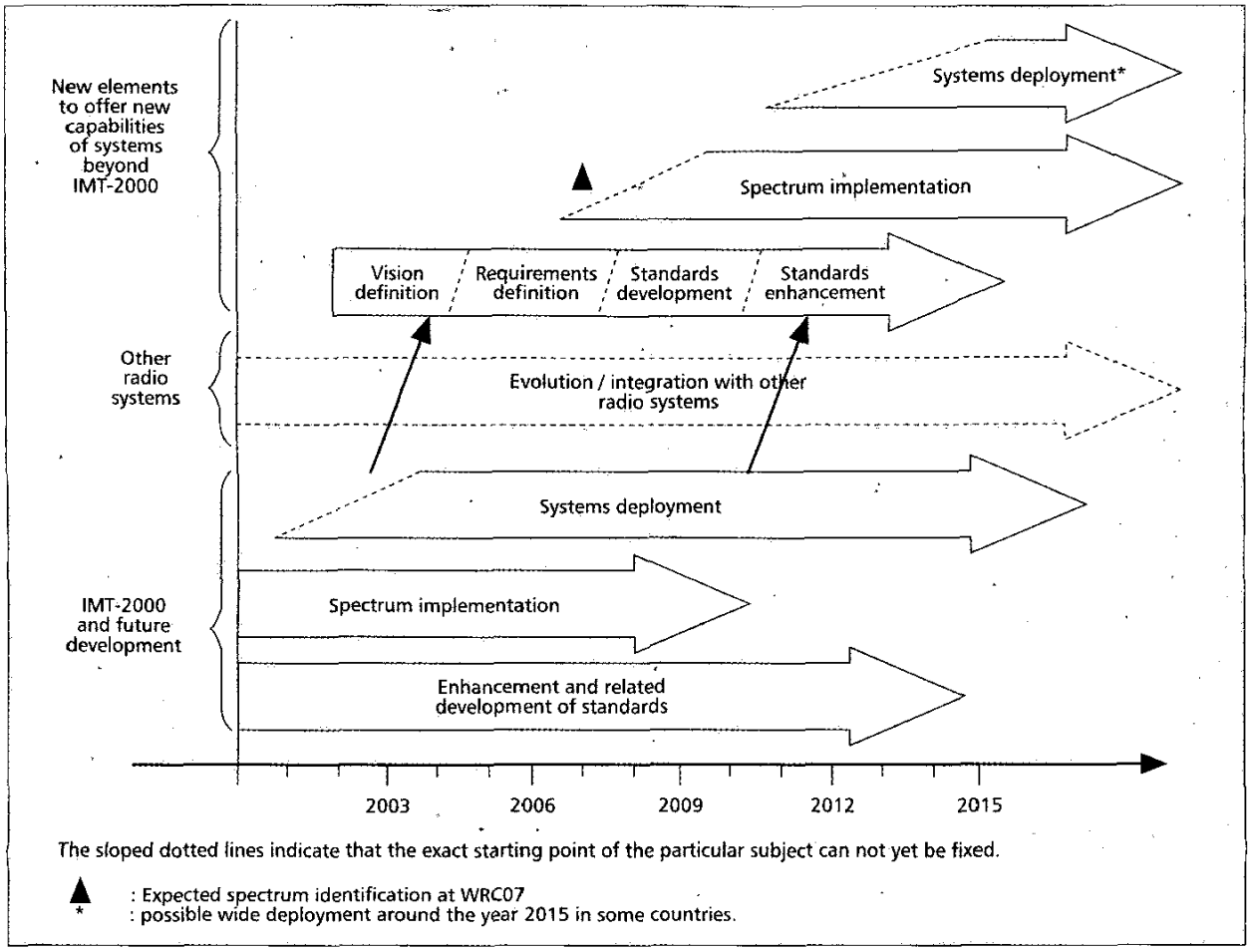
In the first article, "Cross-Layer Design in 4G Networks," Carneiro and Ricardo present an overview of some important problems faced by all-IP wireless mobile terminals and a framework for solving these problems with cross-layer design. The framework classifies known problems in one of four coordination planes: security, QoS, mobility, and wireless link. An interlayer coordination model (a cross-layer manager) is presented to address the problems.

In the second article, "Ambient Networks: An Architecture for Communication Networks Beyond 3G," by Niebert *et al.*, a novel networking concept (the ambient network) for a future wireless network is described. The approach is to embrace the heterogeneity arising from the different network control technologies and to allow agreement for cooperation between networks on demand.

The third article, "Two-Hop-Relay Architecture for Next-Generation WWAN/WLAN Integration" by Wei and Gitlin, proposes an integrated two-hop-relay architecture that both enhances the system capacity of existing WAN systems and extends the system coverage area of WLAN terminals. The proposed two-hop-relay architecture can be considered as a system-level macrodiversity technique that utilizes temporal channel quality variation to achieve increased system capacity.

In the article "Real-Time Traffic Support in Relayed Wireless Access Networks," Zhao and Todd first discuss some open issues related to real-time QoS support in a relayed wireless access network (RWAN). They propose an RWAN architecture to support real-time packet transmission based on the IEEE 802.11 standard, simplified multihop relaying, and a packet scheduling scheme.

The enhanced role of IP in 4G systems and the assimila-



■ **Figure 1.** *The ITU-R timeline for the evolution to 4G/B3G.*

tion of WLAN technology will enable further advances toward pervasive computing and the pursuit of complete context awareness in state-of-the-art applications and services. 4G services can be smarter and more adaptive by taking advantage of all types of context available to them, within a well-defined context management framework. The article "Context Management for the Provision of Adaptive Services to Roaming Users" by Xynogalas *et al.* brings us closer to the definition of such a flexible framework for the efficient management of context, to support the development of advanced telecommunication services and integrated real-time information provision and processing systems.

In the article "Quality-of-Service Provisioning in 4G CDMA Cellular Networks" by Jiang and Zhuang, a vertically coupled system model (between the transport layer and link layer) is proposed to provide QoS in 4G CDMA cellular networks. A packet switching medium access control (MAC) scheme is provided to achieve efficient multiplexing, based on information from the coupled higher layer. The MAC scheduler uses only per-flow information in packet scheduling, thus significantly reducing the computation complexity and system overhead.

The use of an out-of-band signaling path apart from data paths enables flexibility in developing new services for wireless overlay networks. In the article "Novel Out-of-Band Signaling for Seamless Interworking between Heterogeneous Networks," Inoue presents an out-of-band signaling system based on the tunneled network model. The system enables the handover of connections from one radio access network to another seamlessly.

In the final article, "Flexible Spectrum Use and Better Coexistence at the Physical Layer of Future Wireless Systems via a Multicarrier Platform," Hijazi *et al.* propose a new multicarrier platform to optimize the efficiency of wireless operators' licensed bands and enable flexible sharing of licensed and unlicensed bands (in different spectral regions). This research appears able to also support a recent FCC proposal that goes beyond suggesting improved spectral efficiency, and instead suggests innovative spectrum management regulations.

The guest editors would like to thank the authors of all the articles submitted to this issue. The initiatives of the R&D activities in 4G mobile communications were evident from the large number of submissions we received. The editors would also like to acknowledge the contribution of many experts who participated in the review process for this issue. The

guidance from and discussion with Dr. Michele Zorzi, Editor-in-Chief of *IEEE Wireless Communications*, are greatly appreciated.

BIOGRAPHIES

WILLIE W. LU [SM] is a senior principal wireless architect and vice president at Infineon Technologies (formerly Siemens Microelectronics). He is also an internationally very well recognized and accredited senior expert in emerging wireless technologies, and has been a senior technical advisor for over 22 wireless communication authorities in more than 10 countries. He is an independent technical examiner for lots of high-tech venture capitals in the United States, Europe, Asia, and other places, and is listed in major *Who's Who* editions in the world. He has guest edited around 40 special issues on emerging wireless communications in IEEE, IEICE, ACM, CIC, and other major publications, and has had over 150 papers published in major professional publications. He has been technical chairman of numerous IEEE conferences including GLOBECOM '03, VTC '03, WCNC '02, and WWC, and wireless feature editor of *IEEE Communications Magazine*, *IEEE Transactions on Wireless Communications* (formerly *J-SAC Wireless*), and others. He is a frequent keynote and featured speaker at many global technical fora, and a very well-known wireless pioneer on the worldwide basis. He is a member of ACM, IEICE, CIC, CIE, and Sigma Xi, and an adjunct professor at many world-class universities. He is also the founding chairman of World Wireless Congress and Fourth Generation Mobile Forum (4GMF), and has been a distinguished wireless expert for various Chinese authorities since 1999.

BERNHARD H. WALKE [SM], with more than 35 years of activity in the mobile and telecommunications area, is very well connected to virtually anybody in industry and academia. For the last 13 years he has held the Chair for Communication Networks at Aachen University (RWTH), Germany, where about 35 researchers on average work under his guidance on topics such as air interface design, formal specification of protocols, fixed network planning, development of tools for stochastic event driven simulation, and analytical performance evaluation of services and protocols of XG wireless systems. During this time he has supervised more than 650 Master's theses and 43 Ph.D. theses covering practically all aspects of fixed and mobile communication networks. Most of this work continuously has been funded by third-party grants. He has published more than 110 reviewed conference papers, 25 journal papers, and seven textbooks on the architecture, traffic performance evaluation, and design of future communication systems. He has been a board member of ITG/VDE. He has served for more than a decade as Programme Committee and Steering Committee Chairman of scientific European conference series such as the European Personal Mobile Radio Communications Conference (EPMCC) and the European Wireless (EW), conferences he co-founded. Since 1996 he has been a scientific coordinator for large German research programs including Mobile ATM, Multi-Hop and MOBIKOM. Since 1993 his group has participated in more than 15 large research projects funded by the European Commission and has substantially contributed to the specification of standards including ETSI/GPRS, ETSI/BRAN HiperLAN2, CEN TC 278 DSRC, IEEE 802.11e, 802.16, and 802.15.3. From 2001 to 2003 he was an elected Chair of Working Group 4 (New Technologies) of the Wireless World Research Forum. WG4 defines air interfaces for B3G systems. Prior to joining academia, he worked in various industry positions for AEG Telefunken (now part of EADS AG). He holds a diploma and a doctorate in electrical engineering, both from the University of Stuttgart, Germany.

XUEMIN (SHERMAN) SHEN [SM] (xshen@bbcr.waterloo.ca) received a B.Sc. (1982) degree from Dalian Maritime University, China, and M.Sc. (1987) and Ph.D. (1990) degrees from Rutgers University, New Jersey, all in electrical engineering. From September 1990 to September 1993 he was first with Howard University, Washington D.C., and then the University of Alberta, Edmonton, Canada. Since October 1993 he has been with the Department of Electrical and Computer Engineering, University of Waterloo, Canada, where he is a full professor. His research focuses on mobility and resource management in interconnected wireless/wireline networks, stochastic process, and control. He is a co-author of two books, and has publications in communications networks, control and filtering. He received the Premier's Research Excellence Award (PREA) in 2003 from the Province of Ontario for demonstrated excellence of scientific and academic contributions, and the Distinguished Performance Award from the Faculty of Engineering, University of Waterloo, for outstanding contributions in teaching, scholarship and service. He served as Technical Vice Chair, IEEE GLOBECOM '03 Symposium on Next Generation Networks and Internet, and ISPAN '04; Editor, DCDIS — Series B: Application and Algorithm, and *IEEE Transactions on Wireless Communications*; Associate Editor, WCMC (Wiley), and International Journal of Computer and Applications. He is a registered Professional Engineer of Ontario, Canada.