

Technologies on Fourth-Generation Mobile Communications

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Fourth-generation mobile communications involves a mix of concepts and technologies in the making. Some can be recognized as deriving from 3G, and are called evolutionary (e.g., evolutions of WCDMA and cdma2000), while others involve new approaches to wireless mobile, and are sometimes labeled revolutionary. What is important, though, is the common understanding that technologies beyond 3G are of fundamental relevance in the movement toward a wireless world, a term introduced by the Wireless Strategic Initiative, later renamed the Wireless World Research Forum (WWRF). All of these terms are meant to signify fundamentally better wireless mobile communications in the future.

Fourth-generation mobile includes concepts and technologies for innovations in spectrum allocation and utilization, radio communications, networks, and services and applications. These four major areas are intertwined, and innovations in one will inevitably call for changes in the others. In all cases, it is the interplay of these approaches, technologies, and services/applications with the market, user needs and desires, and even unrecognized future uses that could drive a major technological movement and provides the potential for revolutionary, or very rapid and profound change. It is the belief of these editors that we are at the beginning of that process, and that the rest of the first decade of the 21st century will provide the underlying basis for making wireless as useful and ubiquitous in the future as computers are today. These four major areas are providing innovations that will drive this process.

Spectrum allocation and utilization are just at the beginning of a possible paradigm change. Research in adaptive spectrum and bandwidth allocation is underway, as is research in dynamic utilization of spectral resources. The idea of having a spectral resource allocated, assigned, or used in a way that is not fixed is under investigation in Europe, Asia, and the United States, and is beginning to be considered as a possibility by regulators. Spectrum is too precious a resource for us not to do the best we can. Advances in understanding spectral needs and usage, along with physical, MAC/link, and network layer approaches to optimize the use of that spectrum, and also including the processing resources to control them, can be used to provide the right services and QoS. Regulatory and system changes will also be necessary.

Radio communications technology innovations will truly be the engine of any major change. The ability to provide large data rates, up to 100 Mb/s or 1 Gb/s, have been mentioned. This is largely determined by the ability of the multiple access, modulation and coding, and radio resource technologies to provide these data rates efficiently in a mobile wireless environment. Going to higher speeds

means that the channels are truly wideband, and the waveform processing must thus account for the larger number of resolvable, but random, multiple paths. Improved multiple access and channel coding are also needed. MC-CDMA and OFDM are under investigation as are improved coding schemes, as well as combinations of various multiple access multi-user modulations and coding schemes. Also included are space-division multiple access, smart antennas, and space-time coding techniques. In all cases, fast adaptation to the channel and traffic conditions is key to providing the needed QoS.

Two additional aspects of the radio access area are also critical, as is the network area. One is reconfigurable radio access points and technologies. Those are needed to allow the hardware and software to adopt the best radio access technique suited to each case (i.e., to adapt to the available spectrum, channel conditions, and network). Fortunately, there are software reconfigurable radio technologies under investigation, and in some cases, in very rudimentary form, deployed. More will be needed. But more than reconfigurable radios are needed; reconfigurable networks are also required, since the convergence of the various access technologies will require the networks to provide access to a number of radio technologies, and in fact to be a part of the adaptation process.

The network changes will be apparent in two major aspects. One is the almost certain evolution toward more of an IP, or packet switch, approach, and away from circuit switching, or even a packet switch overlay on circuit switch technology as is the case in 3G. Thus, physical layer techniques for fast acquisition and other needs of burst-type communications will be needed. Also needed are the MAC/link and network layer technologies to implement all-IP networks, and to control and optimize radio and network operation in a highly variable environment. A second and related aspect, requiring major network changes, involves the possible convergence of various technologies and services, such as WLAN and mobile. As these strive toward serving users who wish to communicate data, voice, and possibly video and other applications for a variety of services, there will be both a drive for convergence as well as a need for new technologies.

In the end it will be whether these, and possibly other technologies, can meet the challenge of providing new and effective services and applications to a future wireless market that wants more, but is not quite sure what it wants, that will determine what the wireless world will look like. Research in fourth-generation mobile is one key toward this. The editors are happy to be able to bring nine outstanding articles on various technologies in fourth-generation mobile communications.

Future fourth-generation mobile systems, whether evolutionary or based on technology such as OFDM applied to a wide-area environment, can achieve very large average user throughputs by using adaptive modulation and coding (AMC) instead of fixed modulation and power control. The first article, by [Brian Classon et al.](#) from Motorola, discusses the impact of the underlying channel coding in fourth-generation mobile systems with AMC as well as an improved solution.

Convergence of wireless mobile and wireless access will reshape the wireless industry. Even with evolved WCDMA, there is a need for another public wireless access solution that could cover the demand for data-intensive applications and enable smooth online access to corporate data services in hot spots. This need could be fulfilled by WLAN together with a high-data-rate mobile WCDMA system. [Harri Honkasalo et al.](#) from Nokia give us a new picture of this converged fourth-generation system.

Another issue for a fourth-generation mobile system is reconfigurable wireless terminals. The article by [Markus Dillinger et al.](#) from Siemens describes a novel approach for downloading software modules in fourth-generation mobile networks.

The motivation for a decentralized approach is to cut down the overall download time for all relevant terminals, thereby considering more than over-the-air distribution of software modules.

Dynamic bandwidth allocation (DBA) will play an important role in fourth-generation mobile networks including enhanced WCDMA systems. It can be used to ensure that bandwidth is used where it is most needed, and can help lower blockage probabilities and improve QoS. A code-division generalized processor sharing (CDGPS) fair scheduling DBA scheme is proposed by [Xuemin Shen et al.](#) from the University of Waterloo. Simulation results show that this scheme is effective in supporting differentiated QoS while achieving efficient utilization of radio resources.

Another characteristic of fourth-generation mobile is new transceiver technology using adaptive antenna arrays. The article by [Mr. Taoka from NTT DoCoMo](#) presents a new transmitter antenna weight generation method in this array that focuses on the calibrations in WCDMA and broadband packet wireless access.

The emerging applications for fourth-generation mobile systems typically require highly heterogeneous and time-varying QoS from the underlying protocol layers. [The sixth article](#), from the Technical University of Berlin, identifies the emerging IP-based applications for fourth-generation mobile systems and categorizes their QoS requirements.

China's mobile market has become the largest in the world, and the number of mobile subscribers will be over 300 million by 2005. In [the seventh article](#), the authors address China's perspectives on its 3G/4G communications based on its TD-SCDMA technology as well as the potential marketing survey for the next-generation 4G mobile systems.

[The next article](#), from the University of Illinois, proposes a lightweight, component-based, reconfigurable security mechanism to enhance the security abilities of fourth-generation mobile devices. The final article, by [Dacheng Yang et al.](#) from BUPT China, studies variability and additivity for fourth-generation mobile communications,

The guest editors would like to thank the authors and reviewers who have given so generously of their time to make this issue a reality. Thanks are also given to the [Delson Group](#) and its 3Gwireless 2001 Conference for full support in promoting education, research, and academic advancements. It is the intention of these editors to bring articles on fourth-generation mobile (4Gmobile) on a regular basis to this magazine.

Biographies



[Willie W. Lu](#) [M], is senior principal wireless architect at Siemens-Infineon and a member of the Technological Advisory Council of the U.S. Federal Communications Commission (FCC). He is also an internationally recognized expert in emerging wireless technologies and has been a technical advisor for over 15 telecommunications authorities in more than 10 countries. He is an independent technical examiner for lots of high-tech venture capitals in Silicon Valley, and listed in major Who's Whos in the world. He has guest edited around 20 special issues on emerging wireless communications in IEEE, IEICE, ACM, and other major publications, and over 120 papers published in major professional publications. He is chair of numerous IEEE conferences including GLOBECOM, WCNC, VTC, and featured wireless editor of IEEE Communications Magazine, IEEE Transactions on Wireless Communications (formerly JSAC Wireless), and others. He is a frequent keynote and featured speaker in lots of global technical fora, and a well-known wireless pioneer in Silicon Valley. He is a member of ACM, IEICE, CIC, and Sigma XI, and adjunct professor of many universities in the world.



[Robert Berezdivin](#) [M] is chief scientist at Raytheon's Information and Advanced Systems, northern Virginia. As such he oversees and coordinates its technology strategies and research and development, including those in wireless communications. He also leads its work in fourth-generation mobile and wireless, including innovative developments in high performance radio and access technologies and networks, and in software-defined radio technologies and applications. In addition, he oversees new business activities with advanced technology customers, and has been instrumental in creating new business and technologies for the company. He received his B.S. and M.S. degrees from the University of Florida, and his Ph.D. from the University of California at Berkeley. He has worked in advanced signal processing, radars, and communications systems for over 25 years, and has specifically been involved in mobile wireless systems for over 10 years, including recent work in adaptive multiple access techniques, advanced modulation and coding, adaptive and ad hoc networks with QoS, and flexible and reconfigurable systems including wideband software-defined radios, and distributed systems. His interests include both advanced technologies as well as the systems to implement them. He has numerous publications, has been a speaker, reviewer, and chair or co-chair of various IEEE and other sponsored conference sessions or committees, such as 3GWireless, Globecom, WCNC, AIAA, NDIA, and the Software Defined Radio Forum. He is a participant in the World Wide Research Forum, and speaks on next-generation wireless concepts and technologies. He is listed in various Who's Whos. He is a member of Sigma Xi.