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Editorial

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1. BACKGROUND

Future-generation wireless systems aim to support a spectrum of services over a variety of networks in a way transparent to the user. Flexibility and adaptivity are key ingredients of such future-generation wireless systems in order to deliver optimal quality of service (QoS) for different applications over diverse communication environments. Rather than relying on the traditional horizontal communication model, consisting of a single wireless access system, these future 4G systems will employ a vertical communication model, which integrates different existing and new evolving wireless access systems on a common IP-based platform, to complement each other for different service requirements and radio environments. To enable seamless and transparent interworking between these different wireless access systems, or communication modes, through horizontal (intrasystem) and vertical (intersystem) handovers, multimode functionality is needed to support the different existing air interfaces and the newly emerging ones.

It is expected that multimode capabilities will be ultimately focussed on the terminal side to target a larger market base. New challenges then appear in terms of minimizing the terminal cost, size, and power consumption, while at the same time maximizing its flexibility with respect to communication standards as well as its adaptivity with respect to varying user requirements and changing communication conditions. The conventional approach to the design of a multimode terminal is the provision of a custom baseband processor for every communication mode. However, with the growing number of standards and communication modes, this approach is becoming increasingly infeasible and economically unacceptable. A more efficient approach towards this design is to adopt a reconfigurable (as opposed to fixed) radio concept, such that the terminal can adapt to the best-suited communication mode under the control of a QoS manager. A high degree of flexibility is required not only for the digital baseband processing but also for the analog radio frequency (RF) front end, which should accept a large range of carrier frequencies, possess a flexible bandwidth, and deal with a wide variety of operational conditions. Likewise, the same high degree of flexibility is called for not only at the physical layer but also at the medium access control (MAC) (and possibly higher) layer(s), to be compatible with the protocols of the different standards.

2. OVERVIEW OF THE SPECIAL ISSUE

This special issue, which has been conceptualized within the framework of the IST-FP6 Network of Excellence in Wireless COMmunications (NEWCOM), and, more specifically, within the context of NEWCOM Project D on "Flexible Radio," contains 3 invited papers and 9 regular papers.

The first (invited) paper "Software-defined radio—Basics and evolution to cognitive radio," by F. K. Jondral, reviews the basic concepts and terminology of software-defined radio (SDR) and discusses its future evolution towards cognitive radio. The author further emphasizes the importance of standardization and introduces the so-called software communications architecture (SCA) as an example framework that allows an object-oriented development of SDRs.

2.1. Flexible baseband processing

The second (invited) paper "Flexible radio: A framework for optimized multimodal operation via dynamic signal design," by I. Dagres et al., introduces a general framework for the study and design of flexible/reconfigurable radio systems, with a special focus on the baseband portion of the physical layer and its interactions with procedures taking place in the higher layers. Furthermore, the authors describe specific tools and fundamentals that underpin such flexible transceiver architectures to provide multistandard capabilities, channel adaptivity, and user/service personalization.

The third (invited) paper "Adaptive transmitter optimization in multiuser multiantenna systems: Theoretical limits, effect of delays, and performance enhancements," by D. Samardzija et al., considers optimum linear precoders for multiantenna, multiuser systems. Optimality is considered in terms of maximizing the sum rate capacity subject to an average transmitter power constraint. Performance limits of the proposed schemes under channel prediction and delayed feedback are presented.

The fourth paper "Flexible MIMO transmission scheme for 4G wireless systems with multiple antennas," by F. Horlin et al., presents a generic transmission scheme that allows to instantiate combinations of OFDM and cyclic-prefixed single-carrier modulation schemes with DS-CDMA. Additionally, space-division multiplexing (SDM) and orthogonal space-time block coding (STBC) have been integrated in the generic transmission scheme. For each resulting mode, the optimal linear MMSE multiuser receiver has been derived. A mode selection strategy has also been proposed that trades off efficiently the communication performance in a typical suburban dynamic outdoor environment with the complexity and PAPR at the mobile terminal.

The fifth paper "Reconfigurable signal processing and hardware architecture for broadband wireless communications," by Y.-C. Liang et al., proposes a flexible baseband transceiver, which can be reconfigured to any type of cyclic-prefix-based communication scheme. In addition, the authors introduce a corresponding reconfigurable hardware architecture, and identify the common blocks that can be reused across the different communication schemes. Finally, they recognize that the major challenge is to have an efficient system configuration and management function that will initiate and control the reconfiguration based on user requirements and channel conditions.

The sixth paper "Modular software-defined radio," by A.-R. Rhiemeier, proposes a model of signal processing software including irregular, connected, directed, acyclic graphs with random node weights and random edges. Several approaches for mapping such software to a given hardware are discussed. Taking into account previous findings as well as new results from system simulations presented, the paper concludes on the utility of pipelining as a general design guideline for modular software-defined radio.

The seventh paper "Adaptive mobile positioning in WCDMA networks," by B. Dong and X. Wang, introduces a technique for mobile tracking in wideband code-division multiple-access (WCDMA) systems employing multiple receive antennas. To achieve a high estimation accuracy, the algorithm utilizes the time difference of arrival (TDOA) measurements in the forward link pilot channel, the angle of arrival (AOA) measurements in the reverse-link pilot channel, as well as the received signal strength. The proposed algorithm jointly tracks the unknown system parameters as well as the mobile position and velocity.

2.2. Flexible analog RF front ends

The eighth paper "Flexible frequency discrimination subsystems for reconfigurable radio front ends," by B. Carey-Smith et al., surveys recent advances in flexible, frequency-selective, circuit components (including bandpass and bandstop filters, and narrowband tunable antennas) applicable to software-defined radio front ends. In this perspective, the authors discuss the filtering requirements in the SDR context and advocate the use of intelligent, adaptive control to provide environment-aware frequency discrimination.

The ninth paper "Flexible analog front ends of reconfigurable radios based on sampling and reconstruction with internal filtering," by Y. Poberezhskiy and G. Poberezhskiy, pursues several ways to overcome the challenges of practical realization and implementation of novel sampling and reconstruction techniques with internal filtering. In this perspective, the impact of these novel techniques on the analog front-end architectures and capabilities of software-defined radios is discussed.

The tenth paper "A reconfigurable spiral antenna for adaptive MIMO systems," by B. Cetiner et al., studies the design of spiral antennas that are reconfigurable in the sense that they can alter antenna characteristics through structural change. In their work, the authors propose a reconfigurable spiral antenna architecture based on RF-MEMS technology. The presented technology allows monolithic integration of RF-MEMS with antenna structures on any microwave laminate substrate, with the capability to change the impedance and radiation characteristics of the antenna. As a reference model, the design, fabrication, and characterization of conventional single-arm rectangular spiral antennas radiating circularly polarized fields along their axes are presented in the paper.

2.3. Flexible MAC and higher-layer protocols

The eleventh paper "Multimode communication protocols enabling reconfigurable radios," by L. Berlemann et al., proposes a generic protocol stack, comprising common protocol functionality for reconfigurable wireless communication systems. More specifically, the proposed generic protocol stack contains parameterizable modules of basic protocol functions that reside in the data link layer and the network layer of the open systems interconnect (OSI) model.

It is demonstrated that the presented parameterizable modules can be regarded as a toolbox for the timely and cost-efficient development of future communication protocols.

The twelfth paper "Towards a fraud-prevention framework for software defined radio devices," by A. Brawerman and J. Copeland, considers a framework for security enhancement in mobile SDR devices through the introduction of new hardware units and protocols. The presented framework offers enhanced security by incorporating features like monitoring against malicious attacks and viruses, authentication, critical information-protection, and anticloning. Proofs and experimental results are also given to validate the presented fraud-prevention framework.

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Frederik Petré was born in Tienen, Belgium, on December 12, 1974. He received the E.E. degree and the Ph.D. degree in applied sciences from the Katholieke Universiteit Leuven (KULeuven), Leuven, Belgium, in July 1997 and December 2003, respectively. In September 1997, he joined the Design Technology for Integrated Information and Communication Systems (DESICS) Division at the Interuniversity Micro-Electronics Center (IMEC), Leuven, Belgium. Within the Digital Broadband Terminals (DBATE) Group of DESICS, he first performed predoctoral research on wireline transceiver design for twisted pair, coaxial cable, and power-line communications. During the fall of 1998, he visited the Information Systems Laboratory (ISL), Stanford University, California, USA, working on OFDM-based power-line communications. In January 1999, he joined the Wireless Systems (WISE) Group of DESICS as a Ph.D. researcher, funded by the Institute for Scientific and Technological Research in Flanders (IWT). Since January 2004, he has been a Senior Scientist within the Wireless Research Group of DESICS. He is investigating the baseband signal processing algorithms and architectures for future wireless communication systems, like third-generation (3G) and fourth-generation (4G) cellular networks, and wireless local area networks (WLANs). His main research interests are in modulation theory, multiple access schemes, channel estimation and equalization, smart antenna, and MIMO techniques. He is a Member of the ProRISC Technical Program Committee and the IEEE Benelux Section on Communications and Vehicular Technology (CVT). He is a Member of the Executive Board and Project Leader of the Flexible Radio project of the Network of Excellence in Wireless COMmunications (NEWCOM), established under the sixth framework of the European Commission.

Ahmet Kondoz after receiving his Ph.D. degree in 1987 from the University of Surrey, he became a lecturer in 1988, reader in 1995, and in 1996 he was promoted to Professor in multimedia communication systems. He took part in the formation of the Centre for Communication Systems Research (CCSR) and led the multimedia communication activities within CCSR. He is the Founding Director of I-Lab, the new multidisciplinary media lab. Professor Kondoz's current research interests are in the areas of digital signal, image/video, speech/audio processing and coding, wireless multimedia communications, error resilient media transmission, immersive/virtual/augmented environments, and the related human factors issues including human computer interaction/interface. He has published more than 250 journal and conference papers, two books, and 7 patents. Professor Kondoz has been involved in ETSI, ITU, INMARSAT, and NATO standardizations of low-bit-rate speech communication activities. He is the Managing Director of MulSys Limited, a UniS spin-out company marketing world's first secure voice product over the GSM voice channel which has been pioneered by Professor Kondoz's team in the I-Lab. Professor Kondoz has been awarded several prizes, the most significant of which are the Royal Television Societies' Communications Innovation Award and the IEE Benefactors Premium Award.

Stefan Kaiser received the Dipl.-Ing. and Ph.D. degrees in electrical engineering from the University of Kaiserslautern, Germany, in 1993 and 1998, respectively. From 1993 to 2005, he was with the Institute of Communications and Navigation of the German Aerospace Center (DLR), Oberpfaffenhofen, Germany, where he was Head of the Mobile Radio Transmission Group. He worked on multicarrier communications (OFDM and MC-CDMA) for future wireless systems and digital terrestrial video broadcasting (DVB-T). In 1998, he was a Visiting Researcher at the Telecommunications Research Laboratories (TRLabs), Edmonton, Canada, working in the area of wireless communications. Since 2005, he has been with DoCoMo Communications Laboratories Europe GmbH, Munich, Germany, where he is Head of the Wireless Solution Laboratory. His research interests include among others multicarrier communications, multiple-access schemes, and space-time processing for future mobile radio applications (B3G, 4G).

Ashish Pandharipande was born in India in 1977. He received the B.Eng. degree in electronics and communications engineering from the College of Engineering, Osmania University, Osmania, India, in 1998. He pursued his graduate education at the University of Iowa, Iowa City, where he received the M.S. degrees in electrical and computer engineering and mathematics in 2000 and 2001, respectively, and the Ph.D. degree in electrical and computer engineering in 2002. He was with the Electrical and Computer Engineering Department, University of Florida, Gainesville, as a Postdoctoral Researcher in 2003. He is currently a Senior Researcher in the technical research staff at Samsung Advanced Institute of Technology, Korea. His research interests are in the areas of multicarrier (OFDM) and MIMO wireless communications, reconfigurable and cognitive wireless systems, multirate signal processing, and signal processing techniques in communications.