3GPP LTE and LTE-Advanced

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Bruno Clerckx,[Aff1]
Corresponding Affiliation: Aff1
Email: bruno.clerckx@gmail.com

Angel Lozano,[Aff2]
Email: lozano@stanfordalumni.org

Stefania Sesia,[Aff3]
Email: stefania.sesia@etsi.org

Cornelius van Rensburg,[Aff4]
Email: cvanrensburg@huawei.com

Constantinos B Papadias,[Aff5]
Email: papadias@ait.edu.gr

Aff1 Communication Laboratory, Samsung Advanced Institute of Technology, Samsung Electronics, Yongin-Si 446-712, South Korea

Aff2 Department of Information and Communication Technologies, Universitat Pompeu Fabra, 08002 Barcelona, Spain

Aff3 ST-NXPWireless - SW/FW/Algorithm Group, European Telecommunications Standard Institute (ETSI), Mobile Competence Center, 06921 Sophia Antipolis Cedex, France

Aff4 Wireless R&D Laboratory, Huawei Technologies, Plano, TX 75075, USA

Aff5 Broadband Wireless and Sensor Networks, Athens Information Technology, P.O. Box 68, Markopoulo Avenue, Peania, 19002 Athens, Greece

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A new cellular standard, termed Long-Term Evolution (LTE), also referred to as Evolved UMTS Terrestrial Radio Access (E-UTRA), is currently being defined to replace the UMTS third-generation system. LTE-Advanced, in turn, refers to the most advanced version of LTE that was initiated about one year ago.

LTE represents a radical new step forward for the wireless industry, targeting order-of-magnitude increases in bit rates with respect to its predecessors by means of wider bandwidths and improved spectral efficiency. Beyond the improvement in bit rates, LTE aims to provide a highly efficient, low-latency, packet-optimized radio access technology offering enhanced spectrum flexibility.

The LTE design presents radical differences at every layer. Like many other communication technologies (e.g., digital video and audio broadcasting, DSL, wireless LANs), the physical layer uses OFDM waveforms in order to avoid the intersymbol interference that typically arises in high bandwidth systems. In terms of radio access, CDMA has given away to time and frequency multiple access. One differentiating aspect of the LTE standard is that from the onset, MIMO is an integral component, and not an add-on feature. At the network layer, a flatter architecture is being defined that represents the transition from the existing UTRA network, which combines circuit- and packet-switching, to an all-IP system.

The objective of this special issue is to disseminate new advances in both the physical and medium access control layers that are applicable to the LTE and LTE-Advanced technologies. Out of 23 submissions, we selected 13 papers for inclusion in this special issue. Papers have been classified in 6 categories. The first category (papers 1 and 2) consists of two tutorials and provides an introduction to the LTE system. The second category (papers 3 to 5) focuses on MIMO issues including Single-User MIMO (SU-MIMO) and Multi-User MIMO (MU-MIMO). The third category (paper 6) addresses the design of a practical scheduler for LTE. The fourth category (papers 7 to 10) focuses on multiple access (uplink) and specifically on Single-Carrier FDMA (SC-FDMA). The fifth category (papers 11 and 12) opens the way to LTE-Advanced and on relay architectures. The last category investigates the applicability of the 3GPP LTE interface to satellite transmission.

We hope that this excellent collection of papers will help the interested readers to identify a number of key challenges and opportunities that lie within the LTE and LTE-Advanced cellular standards, contributing not only to a better understanding of these systems but eventually also to the incorporation of techniques that will further boost the performance of the corresponding deployed networks.

A more detailed description of each category and the corresponding papers is as follows.

Two tutorial papers introduce the LTE system. The paper by Martin-Sacristan et al. provides a broad introduction to LTE, describing the core functionalities and the system requirements. It briefly introduces LTE-Advanced requirements and technologies currently under study. Lee et al. provide in their invited paper a tutorial on MIMO technologies. Being active players in the standardization of LTE and LTE-Advanced, they go beyond a simple description of MIMO and provide insightful explanations as to why these features have been adopted.

Three papers address MIMO issues. The first two papers focus on MU-MIMO while the last one focuses on SU-MIMO.

The paper by Shu et al. proposes an optimal MU-MIMO linear precoding scheme with linear (MMSE) detection based on particle swarm optimization. It shows that such a scheme significantly outperforms other well-known approaches (e.g., precoding schemes based on channel block diagonalization). Combined with the use of demodulation reference signals, the proposed scheme may be a good candidate for MU-MIMO in 3GPP LTE-Advanced.

The paper by Komulainen proposes some linear uplink (UL) MU-MIMO beamforming schemes for cellular TDD systems. The UL scheme is designed to coexist with downlink (DL) MU-MIMO block zero-forcing by coordinated transmit-receive processing. It relies on the channel state information of the zero-forced DL channels to precode UL transmission. The proposed scheme is shown to outperform SU-MIMO transmission combined with user selection as well as UL antenna selection. The proposed concept may be a promising candidate for 3GPP LTE-Advanced.

The paper by Yang examines the performance of various kinds of antenna selection schemes in MIMO systems with limited size antenna arrays and nonnegligible mutual coupling. It is shown that the performance of antenna selection is closely related to the antenna spacing and that appropriate selection schemes are required when mutual coupling is taken into account. Results indicate that soft selection always outperforms hard selection. This study provides novel insight into the deployment of antenna selection in both 3GPP LTE and LTE-Advanced.

One paper addresses the design of a scheduler for 3GPP LTE downlink. In particular, the paper by Sadiq et al. proposes a complete and practical scheduler with low computational complexity by integrating state-of-the-art techniques regarding resource allocation, fast algorithms, and scheduling. Simulations covering both PHY and MAC layers are performed and demonstrate the various design tradeoffs to be made in the selection of the queue-and-channel-aware QoS scheduling policies to cope with the diverse mix of traffic of an LTE downlink.

Performance of 3GPP LTE uplink multiple access based on SC-FDMA is discussed in the following four papers. Wu et al. compares the information rate achieved by SC-FDMA and OFDMA with linear frequency-domain equalizers. Based on some geometrical interpretation, it is shown that the loss incurred by SC-FDMA can be mitigated by exploiting multiuser diversity and spatial diversity. 3GPP LTE uplink performance evaluations confirm those findings.

The paper by Svensson et al. proposes a novel uplink multiple access scheme denoted as B-IFDMA (Block Interleaved Frequency Division Multiple Access). In the presence of realistic channel estimation at the receiver and imperfect channel state information at the transmitter, B-IFDMA is shown to outperform the currently adopted SC-FDMA method. Additional benefits in terms of amplifier and energy efficiency, robustness to frequency offsets, and Doppler spreads are detailed.

The paper by Assimi et al. investigates the design of Hybrid Automatic Repeat reQuest (HARQ) for single-carrier transmission as in 3GPP LTE UL. Here, transmit diversity techniques are introduced for HARQ retransmissions; this is because in slow fading environments, retransmitting identically the same packet does not provide additional diversity gain. The authors investigate the performance of both cyclic-frequency-shift-diversity and bit-interleaving-diversity using theoretical analysis and simulations. The choice of a specific diversity scheme is shown to depend on the desired performance/complexity tradeoff and the system parameters.

Karakaya et al. further address the problem of sensitivity of SC-FDMA to frequency offsets. A novel Kalman filter-based method is introduced, enabling the tracking of the channel taps in the time domain, to mitigate the intercarrier interference under high Doppler spreads. This method is evaluated under various scenarios to assess the impact of the design parameters on the performance.

The following two papers introduce new technologies based on relay for LTE-Advanced.

The paper by Teyeb et al. proposes to enhance the LTE architecture by performing dynamic relaying while maintaining backward compatibility with LTE Release 8. A flexible, efficient, and self-organizing multihop architecture is introduced where relays can be linked to base stations on an "as need" basis rather than in a fixed manner.

The paper by Peters et al. focuses on the problem of the extra interference added by the presence of relays, which is currently mostly overlooked. They also analyze the performance of various kinds of half-duplex relay strategies in interference-limited environments. The performance benefits of those strategies are discussed as a function of deployment scenarios and the system parameters.

The last paper by Bastia et al. studies the applicability of 3GPP LTE to satellite transmissions. With the introduction of several new features such as inter-TTI interleaving techniques that exploit the existing HARQ structure of LTE, Peak-to-Average Power Ratio (PAPR) reduction techniques, and preamble sequence design for random access, it is shown that the existing terrestrial air interface can be adopted for transmission over satellite links.

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Bruno ClerckxAngel LozanoStefania SesiaCornelius van RensburgConstantinos B. Papadias