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Editorial:

The proliferation of new applications, e.g., mobile TV, Internet gaming, large file transfer, and the development of user terminals, e.g., smart phones and notebooks, has dramatically increased user traffic and network load. Moreover, with the number of wireless subscribers expected to triple over the next 5 years, it is obvious that current networks will not be able to satisfy customer demands in the near future. In order to meet this traffic growth and provide service to their users, vendors and operators are working on the development of new technologies and cellular standards. Within them, heterogeneity in network deployment has been heralded as the most promising way of increasing both coverage and capacity of future wireless systems. Thus, it is expected that new elements such as remote radio heads, picocells, femtocells, and relay nodes will be deployed overlying macrocells. In this way, networks will

be closer to users, and system capacity will be enhanced through a better spatial spectrum reuse.

However, although heterogeneous networks are envisioned to support the increasing data traffic demand and meet the requirements imposed for the fourth generation of mobile networks, they also lead to new technical challenges never faced before. For example, due to the larger number of cells and thus of cell boundaries, the management of interference becomes an intricate problem. Since centralized network planning and optimization cannot deal with the individualistic nature of user-deployed cells, e.g., femtocells, a key to the success of heterogeneous networks is the cooperation between nodes in a decentralized and distributed manner. Such cooperation is the only way to ensure a proper network operation. However, cooperation is not easy to achieve due to different issues and threats imposed by the network itself, e.g., limited back-haul capabilities, dynamics of traffic and radio channel, energy consumption, operational costs, etc.

This special issue features six selected papers with high quality:

The first article, “**Managing Femto to Macro Interference without X2 Interface Support through POMDP**”, co-authored by *Ana Galindo-Serrano* and *Lorenza Giupponi*, presents a self-organized downlink power control for interference management in macrocell-femtocells co-channel deployments. The authors provide a completely autonomous framework, considering 3GPP LTE Release 11 and the non-availability of X2 interfaces between evolved NodeBs (eNBs) and HeNBs. In this situation, HeNBs make autonomous decisions without receiving any feedback from the macrocell network. The network is modeled as a multi-agent system where each node is an independent agent able to learn downlink power allocation policies for different interference situations through Reinforcement Learning techniques. In order to deal with the lack of information in the scenario,

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the authors rely on the theory of Partially Observable Markov Decision Process (POMDP), which works on the basis of a set of beliefs that HeNBs build considering the impact they have on the macrocell system. Moreover, in order to gather this system performance information, the authors propose that HeNBs use spatial interpolation techniques, such as ordinary Kriging. Results show that the proposed approach allows HeNBs to autonomously learn a good power allocation policy that allows them to coexist with the macrocell network without introducing extra signaling overhead.

The second article titled **“McPAO: A Distributed Multi-Channel Power Allocation and Optimization Algorithm for Femtocells”**, from *Yang Yang, Xiaojin Zheng, Jing Xu, Jiang Wang, Xiaoying Zheng, Yong Teng and Kari Horneman*, formulates a multi-channel transmit power allocation problem that allows to maximize the overall system throughput under complex transmit power constraints. The authors apply Lagrangian duality techniques to make the problem decomposable and propose a distributed iterative sub-gradient algorithm, namely Multi-channel Power Allocation and Optimization (McPAO), to solve it. Numerical results show that McPAO can improve the overall system throughput by 18 %, comparing to fixed transmit power allocation schemes. In addition, the authors study the impact of errors in gradient direction estimation, which are caused by limited or delayed information exchange among femtocells in realistic situations. These errors will be propagated into the sub-gradient algorithm and, subsequently, affect the overall performance of McPAO. A rigorous analytical approach is developed to prove that McPAO can always achieve a bounded overall throughput performance very close to the global optimum.

The next article **“Traffic and Mobility Management in Networks of Femtocells”** investigates a new system architecture conceived for efficiently deploying femtocell networks, in which groups of femtocells in the same administrative domain cooperate towards a global performance improvement. The authors (*Jaime Ferragut, Josep Mangués-Bafalluy, José Núñez-Martínez and Frank Zdarsky*) propose femtocell modifications together with a new network entity called Local Femto Gateway (LFGW), which allows offloading a high volume of control and data traffic from the core network to functional entities in the femtocell network. The authors focus on building blocks related to traffic and mobility management where a two-level routing approach is discussed. The high-level routing is carried out by the mobile network layer, and solutions for efficient handover, local breakout, and local location management are presented. The low-level routing is carried out by the transport network layer, and distributed routing solution

for a large-scale, all-wireless femtocell network is presented. Overall, these architectural improvements render the proposed architecture a promising approach for efficient traffic management in large-scale femtocell deployments, hence making them a scalable solution.

The fourth article, **“Energy Efficient Networking with IEEE 802.16 m Femtocell Low Duty Mode”**, co-authored by *Hung-Yu Wei, Ching-Chun Kuan and Guan-Yu Lin*, studies low duty mode femtocell operation in order to efficiently mitigate interference between macrocells and femtocells. The authors propose a new mechanism for integrating the low duty mode in femtocells and the sleep mode in user equipment to achieve a higher power-saving efficiency. Based on the IEEE 802.16 m system architecture, the authors build a practical system model and analyze the performance of the proposed mechanisms. Result shows that with simple modifications of the sleep-cycle operation, the proposed mechanisms can significantly reduce the power consumption of femtocells, leading to energy efficient operation of femtocells.

The fifth article titled **“Energy Conservation via Antenna Scheduling in Fiber-Connected Femto Base Stations”**, from *Haoming Li, Alireza Attar and Victor C. M. Leung*, formulates the energy consumption of broadband wireless access with fiber connected massively distributed antennas (BWA-FMDA) architecture under a generalized framework. Moreover, the authors propose an optimization tool based on coordinated multipoint transmission (femto-CoMP) for femtocell clustered networks to maximize energy efficiency by adjusting the number of transmit antennas and controlling transmit power in zero-forcing beamforming. Based on the analytical results, the authors group every two neighboring antennas in multiple femto-CoMP configurations, and propose a new network configuration scheme that uses antenna scheduling to jointly improve spectral and energy efficiency. Compared with standalone femtocells, the proposed scheme is shown to increase energy efficiency in a typical office building by 64 %~160 % and spectral efficiency by 2 %~36 %. Compared with previous BWA-FMDA configurations, the new scheme is able to improve energy efficiency by 6 %~68 % and spectral efficiency by 15 %~55 %. The exact gains depend on network configurations and transmit power levels.

The last article **“Flexible UL-DL Switching Point in TDD Cellular Local Area Wireless Networks”** investigates uplink-downlink switching techniques for time division duplex wireless networks. An advantage of time division duplex wireless networks over frequency division duplex is that uplink-downlink switching points may be flexibly adapted to asymmetric traffic loads. This enables more efficient spectrum use, but may lead to harmful cross-link interference between cells.

As a result, the net gain (or loss) from flexible uplink-downlink switching depends on the traffic characteristics and network scenarios. The authors (*Pekka Jänis, Cássio B. Ribeiro* and *Visa Koivunen*) analyze the uplink-downlink switching problem in femtocell networks where high fluctuations in short-term traffic loads occur. The authors show through theoretical analysis and system-level simulations that in such a scenario significant gains in effective user throughput and packet delays may be achieved under low traffic loads. The gains become smaller at high traffic loads where packets accumulate in queues and there are both uplink and downlink traffics to transmit with high probabilities. When the uplink and downlink transmit powers are not balanced and uplink-downlink switching point adaptation is applied, the link direction with lower transmit power may suffer from degraded performance. The authors show that an interference-aware scheduler provides a better performance and lowers the packet delays further.

The guest editors are thankful to our reviewers for their efforts in reviewing the received manuscripts. We also thank the Edit-in-Chief, Imrich Chlamtac, Ronila Gamatero, Leonora Panday and Sara Fruner for their supportive guidance during the entire process.

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Dr. Guillaume de la Roche is a Wireless System Engineer at Mindspeed Technologies, a leading provider of system on chips (SoCs) for small cells. Prior to that he was with Infineon (2001–2002, Germany), Sygnum (2003–2004, France), CITI Laboratory (2004–2007, France) and Centre for Wireless Network Design (2007–2011, United Kingdom). He has been a part time lecturer at Lyon 1 University since 2005. He was also a visiting researcher at DOCOMO-Labs (2010, USA) and Axis

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