


Editorial

Recent Technical Developments in Energy-Efficient 5G Mobile Cells: Present and Future

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1. Introduction

The chapter of 4G (4th Generation) mobile systems is finally coming to an end, with waves of 4G systems having been deployed throughout Europe and worldwide. These systems provide a universal platform for broadband mobile services at any time and anywhere. However, mobile traffic is still growing at an unprecedented rate and the need for more sophisticated broadband services is further pushing the limits of the current standards to provide even tighter integration between wireless technologies and higher speeds [1]. The increasing number of mobile devices and traffic, the change in the nature of service and devices, along with the pressure on the operation, costs, and energy efficiency are all continuously putting stringent limits on the requirements of the designs of mobile networks. It is widely accepted that incremental enhancements of the current networking paradigm will not come close to meeting the requirements of networking by 2020 [2]. This has led to the need for a new generation of mobile communications: so-called 5G. The interests of stakeholders and academic researchers are now focused on the 5G paradigm. Although 5G systems are not expected to penetrate the market until 2020, the evolution towards 5G is widely accepted to manifest in the convergence of internet services with existing mobile networking standards, leading to the commonly used term “mobile internet” over heterogeneous networks (HetNets), with very high connectivity speeds.

The envisaged plan is to narrow the gap between current networking technologies and the foreseen requirements of 2020 networking and beyond, providing higher network capacities, the ability to support more users, lower cost per bit, better energy efficiency, and finally, adaptability to the new nature of services and devices, such as support of smart cities and the Internet of Things (IoT).

Certain technology trends, properties, and offered services have been widely envisioned to form part of the highly anticipated 5G [3,4]. It is almost globally accepted that the densification of mobile networks is the way to go for 5G. It is expected that mobile networks will become hugely densified with the adoption of multitier heterogeneous networks, including macrocells, a huge number of small cells, remote radio units (RRUs), and device-to-device communications [5]. Additionally, cooperation and network virtualization are expected to play the main roles in 5G systems [5]. Small cells are envisaged as the vehicle for ubiquitous densified 5G services, providing cost-effective, energy-efficient, high-speed communication. Small cells were partly adopted in the 4G revolution in the form of the femtocell, and the outdoor version, the picocell; however, femtocells are confined to indoor use, and picocells require radio networking infrastructure and planning, representing a significant cost for operators. Yet, small-cell technology is here to stay, with its desirable energy rating making it a winning candidate for a basic building block upon which the mobile networks of the future will evolve.

2. The Present Issue

This Special Issue features 15 articles which addresses the main aspects of technology trends which are widely accepted to form part of 5G, by providing a virtual cooperative wireless network of small cells. The main aim of these investigations goes beyond the current vision of densification and small-cell 5G through disruptive, new “femtocell”-like paradigms, where end-users play the role of prosumers of wireless connectivity, i.e., “Mobile Small Cells”.

The 15 articles within this special issue illustrate the true innovation in engineering design that can occur by blending models and methodologies from different disciplines. In this special issue, the target was to follow this approach to deliver a new disruptive architecture to deliver next-generation mobile small-cell technologies. According to this design philosophy, the novelty of these articles resides in the intersection of engineering paradigms that include cooperation, network coding, and smart energy-aware frontends. These technologies will not only be considered as individual building blocks, but will be re-engineered according to an interdesign approach, serving as enablers for energy-efficient femtocell-like services on the move.

Next-generation handsets will need to be green, or in other words, “energy-aware”, so as to support emerging smart services that are likely to be bandwidth-hungry, as well as to support multimode operation (5G, LTE, LTE-A, HSDPA, 3G among others) in HetNet environments. This vision gives way to stringent design requirements in the RF system design that, in today’s handset, are the key consumers of power. To address the RF frontend and propose multi-standard flexible transceivers, the power consumption must be considered as a key design metric. This will include investigating RF building blocks such as energy-efficient power amplifiers (PAs) and antenna techniques, and tuneable RF bandpass filters.

Seven articles in this special issue propose novel and efficient antenna designs that employ both single and MIMO synthesis for use in heterogeneous networks [6–12]. Some of these designs operate on fixed single/multiband and radiations, as in [6–10], while some have the feature of reconfigurability that allows them to operate in a tuned manner in which the resonant frequencies and patterns can be shifted/reconfigured even after the designs have been made [11,12]. The other two articles present recent work on a highly efficient power amplifier which will provide hardware solutions to the growing RF front-end integration challenges with additional design requirements towards energy efficiency for Pas [13,14]. A paper presenting the recent progress of 4G/5G reconfigurable filters for multimode operation with potential energy efficiency traits, good linearity, and potentially low-cost manufacturing over a variety of substrates is also included in this issue [15].

The other three papers study Non-Orthogonal Multiple Access (NOMA) schemes. The first paper addresses an investigation of two transmission scenarios for the base station (BS) in cellular networks to serve users who are located at the cell-edge area [16]. In this study, it was shown that wireless-powered NOMA and the cell-center user can harvest energy from the BS in such a model. Moreover, the problem of the cell-edge user, i.e., due to the weak received signal, has been solved by fabricating a far NOMA user with multiple antennae to achieve improved performance. A similar work [17] proposes NOMA as a promising technology that could be used in next-generation networks in the near future. Within this work, a multipoints cooperative relay (MPCR) NOMA model, instead of just a relay, as suggested in previous studies, was proposed. The third paper [18] introduces the Power Domain-based Multiple Access (PDMA) scheme as a kind of NOMA that can be used in green communications and which can support energy-limited devices by employing wireless power transfer. Such a technique is known as a lifetime-expanding solution for operations in future access policy, especially in the deployment of power-constrained relays for three-node, dual-hop systems.

To equip the network with small cells, parameters such as cell size, interference in the network, and deployment strategies to maximize the network’s performance gains expected from small cells are important, as stated in reference [19]. Furthermore, the network performance was evaluated for different Pmax values for small-cell uplink. Various deployment scenarios for furnishing the existing macro layer in LTE networks with small cells were considered within this work.

The last work in this special issue presents a theoretical study of electromagnetic propagation in a complex medium suspended multilayer coplanar waveguide (CPW). This work is based on the generalized exponential matrix technique (GEMT) that was joined with Galerkin's spectral method of moments, and then applied to a CPW printed on a bianisotropic medium. The analytical formulation is based on a Full-GEMT, a method that avoids the usual procedure of heavy and tedious mathematical expressions, using matrix-based mathematics instead [20].

3. Future

From a future perspective, to help current mobile standards to move forward a cooperative approach, a more user-network centric approach is desirable, i.e., where all devices are seen as a "pool of resources" to be used by the network as a vehicle, leading to enhanced spectral and energy efficiency. It is essential to break the femto-barrier and reduce the energy consumption in the network by at least a factor of 10, while providing higher data rates, higher capacities, and ubiquitous service through reduced-cost solutions for future 5G systems.

Thus, initially, to support reliability, throughput, coverage, and the coexistence requirements of 5G wireless systems in a cost-effective and energy-efficient manner, some vital issues should be considered, such as analyses, design, and optimization of NCC communications for mobile small cells and of small-cell overlay deployment for HetNets, thereby enabling the potential of 5G systems.

Moreover, in order to accomplish secure network coding for 5G cooperative mobile small cells, we must go beyond the previously proposed mechanisms by using random linear network coding, as well as modifying and adapting the proposed protocols to multihop secret key distribution in highly dynamic wireless networks. The use of random linear network coding is expected to boost performance.

In terms of a frontend that can meet the requirements of 5G systems, it is apparent that reliance on a single technology will no longer have a place in the mobile communication paradigm; rather, the very careful integration of diverse radio technologies in a cost-effective way will be required. Forthcoming 5G systems comprise a truly mobile multimedia platform that constitutes a convergent networking arena, that not only includes legacy heterogeneous mobile networks, but also advanced radio interfaces and the possibility of operating at mm-wave frequencies to capitalize on the large swathe of available bandwidth. This provides the impetus for a new breed of handset designs that, in principle, should be multimode in nature, energy efficient, and above all, able to operate at the mm-wave band, placing new design drivers on antenna design. Therefore, the target in future is to investigate advanced 5G massive array/MIMO antennas for 5G smart future applications that can operate in the mm- range, i.e., above 30 GHz, and meet the essential requirements of 5G systems such as large bandwidth (>1 GHz) and gain and efficiencies up to 15 dBi and 95% respectively. Also, it should extend the current Doherty amplifier implementation towards a three-step approach to promote the concept of efficiency enhancement and linearity compensation in PA design. Also, new reconfigurable switchable 5G filters should be designed using tuning technology with an emphasis on low-loss, low-power consumption, reduced size, and high-Q, which would also give rise to easy integration with the CMOS PA.

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