

Preface

Every new release of iPhone or Android smart phone spurs new applications and services, with advanced display screens to deliver an exceptional quality of experience to the enduser. However, this comes at a cost placing stringent demands on mobile battery consumption and lifetime. Indeed, this trend is set to continue with the advent of 5G services, and the need to be always connected at any place at any time. If we do not adopt a proactive stance, the enduser will be constrained to the nearest available electricity socket which is a stark irony to the philosophy behind 5G communications.

Although 5G systems are still in their infancy, it is widely accepted among the research community and the key stake holders that the evolution toward 5G is believed to be the convergence of Internet services with legacy mobile networking standards leading to the commonly used term “mobile Internet” over heterogeneous networks (HetNets), with very high connectivity speeds. Moreover, green communications will probably play a pivotal role in this evolutionary path with key mobile stake holders driving momentum toward a greener society. Another aspect that can be deduced based on the current trends of emerging services is the continuous rise in the traffic demand.¹ Based on such vision, it is safe to conclude that energy and cost per bit reduction, service ubiquity, and high-speed connectivity are among the main design drivers for next generation networks.

Toward this end, this book aims to address technology trends and challenges leading toward the next era in mobile communications on the terminal side, namely 5G-ready handsets. The book adopts a multidisciplinary and interdisciplinary stance toward handset design, a necessary ingredient if such handsets are to really takeoff in next generation mobile systems. In this context, the scope of this book covers a wide range of research areas spanning from RF design, mobile cooperation, context awareness, to seamless roaming among multiple technologies, all of which working in synergy toward providing energy efficient seamless ubiquitous mobility and

¹ Demestichas, P., Georgakopoulos, A., et al.: 5G on the horizon: key challenges for the radio-access network. *IEEE Veh. Technol. Mag.* 8(3), 47–53 (2013).

high-speed connectivity within a HetNet environment. The book also addresses potential business models to secure the adoption of the proposed technologies by the key mobile stake holders.

In more detail, the book is organized in a well-defined structure, starting with Chap. 1 which defines prospective green and smart scenarios that will potentially exist in future generations of networking. It is worth mentioning here that the 5G research roadmap is still in its infancy, with commercial deployment only foreseen around 2020. Despite this fact, the majority of the research community agrees on the key design requirements that will drive technology solutions under the 5G umbrella. On one hand, there will be a heterogeneity of communication systems where stakeholders aim to capitalize on existing deployments for providing voice and low data rate services. However, it is expected that this will be complemented by new overlay tiers based on small cells. By reducing the communication distance between the base station and the mobile handsets, small cells are able to provide significant energy saving and high-speed data comparable to the indoor femto cell paradigm available in the market. On the other hand, device-to-device communications are also expected to be a prominent feature of 5G to support the demand for proximity based services while also acting as a vehicle for off-loading traffic from the core network(see Footnote 1). These widely accepted design requirements and technology paradigms provide the inspiration for Chap. 1, that suggests not only candidate networking scenarios for next generation mobile systems based on current roadmaps, but tailor-made to provide high-speed and energy-efficient connectivity to the mobile handset based on the notion of cooperation. These scenarios provide the framework for the technology solutions developed throughout this book and aim to paint a gradual picture of a 5G handset, in terms of requirements, technology features, and capabilities.

Exploiting cooperation and intelligent networking is one piece of the energy saving jigsaw, since a large chunk of the power consumption on the mobile handset is attributable to the radio frequency (RF) circuitry. In fact, if there are no energy saving strategies in place, future mobile handsets could become too hot to handle requiring fan cooling systems; therefore, next generation handsets will unavoidably need to be energy conscious, smart, and multimode in nature to support seamless operation over legacy/future emerging technologies (LTE, LTE+, HSDPA, 3G) in HetNet environments. This vision gives way to stringent design requirements on the RF system design. Addressing the RF perspective to handset design, Chaps. 2 and 3 focus on studying new hardware design concepts that can provide flexible and energy efficient multistandard transceivers. Chapter 2 addresses the global transceiver architecture design and the antenna frontend unit, which is bridged to the RF frontend via a tunable matching network; the latter alleviating the effect of perturbations caused by the user's head or hand. Moreover, Chap. 3 tackles the critical issue of power amplifier design in future mobile handsets. Power amplifiers are considered a key consumer of power in handheld devices. The effect is expected to multiply when ubiquitous broadband connectivity becomes the standard. Chapter 3 hence presents three innovative energy efficient power amplifier designs that aim to

reduce the energy consumption in next generation handsets, leading to longer battery lifetime and stronger market penetration.

Chapter 4 shifts the perspective to handset mobility given a rich heterogeneous networking environment. Although this was partially achieved in 4G systems, the handover use-cases are limited and lack coordination in terms of energy efficient mobility. In an attempt to push further the boundaries on network mobility to provide tighter integration between diverse networking standards, we investigate energy efficient handovers that include macro-femto use-cases. In the first instance, this chapter studies specific handover algorithms between cellular networks and WiFi, in addition to handover between macro and femto cells in LTE-A, complemented by emphasizing the network functionalities of both IEEE 802.11 and LTE-A that enable mobility between these networks. Based on this platform, we then go beyond by taking energy efficiency to the forefront and propose energy efficient handover algorithms for integrated WiFi-LTE Femto networks using context information to reduce the overall energy consumption of mobile devices, while maintaining the required QoS.

In addition to heterogeneity, cooperation is extensively used in legacy mobile networks for improving link reliability and coverage through approaches such as relaying. These are proven technologies that are showing promising potential for energy saving through cooperation with proxy mobile devices. In Chap. 5, we tackle the topic of cooperative communications by investigating how cooperation may be used for energy saving by exploiting short-range cooperation in synergy with long-range. The chapter proposes a new cooperative approach based on coalitional game theory that uses this as a tool to increase the overall energy saving gain of the network, rather than solely of the mobile user. The game is also used to fairly distribute the gains among players hence motivating players to cooperate; additionally, the game identifies selfish users and free riders and forces them to be excluded from the cooperation process making this technique attractive for use in real operating scenarios.

Next generation mobile systems are expected to be intelligent in nature, enabling attractive business models such as targeted advertisement, as well as providing a platform for operators to effectively exploit their network resources in an era where spectral resources are at a premium. In this book, we exploit the notion of cognition in the sense of smart networks to gather useful context both in the network and the terminal side in order to promote effective use of battery resources. Toward this end, Chap. 6 elaborates on context information and architecture based on legacy mobile networking standards to deliver the notion of a smart 5G mobile phone, and indeed provides the framework for many of the innovative smart building blocks that are elaborated throughout this book. The chapter then concludes by proposing two discovery algorithms which exploit context information to discover available networks and mobile devices in the vicinity, again the key driver being that the discovery approaches in legacy devices are key consumers of power since they are blind in nature.

Following the footsteps of the previous chapter, Chap. 7 reinforces the notion of smartphones, and how this can be exploited for enhancing network operation.

The chapter elaborates on how mobile devices and networks can use positioning context for enhancing network performance in terms of community-based sequential paging and location-aided scheduling for fractional frequency reuse in LTE-A relay network.

Having proposed multiple energy efficient solutions for mobile handsets, Chap. 8 represents the venue for showcasing the proofs of concept on exploiting cooperation and cognition for energy saving in next generation handsets. Chapter 8 presents three showcases to demonstrate the gains achieved by the proposed solutions in a practical networking environment. The showcases constitute an energy efficient short-range cooperation testbed, vertical handover platform for quantifying energy savings, and a horizontal showcase demonstrating the benefits of the RF hardware building blocks proposed (including envelope tracking power amplifier, Doherty power amplifier, tunable matching network integrated circuit, and a miniature multiband antenna). The details of each showcase are described, along with the scenario to be demonstrated.

Having discussed numerous energy saving solutions at the technical level, it would be difficult to observe the take-up of such technologies in the marketplace without the support of viable business models that highlight the potential benefits in terms of revenue. Therefore, the final chapter of this book discusses the business potential for driving the technology solutions based on cooperation and femto cell integration, as part of the 5G paradigm. We present a number of existing business models, which can be adopted and tailored to the proposed cooperation solutions, alongside new business use-cases for the cooperation scenario as well as the Femto cell scenario. The different players in each business model are defined and the interactions among them are clearly shown through elaborative diagrams.

The motivation for this book is to address energy efficient handsets for next generation networks, which is looming toward the so-called 5G paradigm. It is widely accepted that next generation networks will not only evolve from legacy architectures to preserve market acceptance, but will also include disruptive approaches to ensure innovation and the high-speed and energy-efficient targets that are sought after. In this respect, the scenarios suggested in this book are based on cooperation and cognition that indeed drive the proposed technology solutions and may be considered as pieces of the 5G jigsaw. However, it is true to say that 5G is still in its infancy and the final 5G scenario could somewhat take a different path. However, the solutions we propose are technology agnostic and in fact could coexist with a plethora of underlying technologies.

The editors believe that this book represents a significant step forward on the way toward 5G handsets, and built based on commonly agreed design drivers that are still valid for future generations of mobile networks.

Ayman Radwan
Jonathan Rodriguez

Energy Efficient Smart Phones for 5G Networks

Radwan, A.; Rodriguez, J. (Eds.)

2015, XIII, 267 p. 170 illus., 132 illus. in color.,

Hardcover

ISBN: 978-3-319-10313-6