

Preface

It has been just over three decades since the brick-size, heavyweight, vehicle-mounted, voice-oriented wireless terminal has been replaced by its lightweight, flexible, wearable, multimedia-oriented version. Whereas in the beginning the use of mobile phone was restricted to those few who could afford to buy equipment and services, today its widespread use has made it unconceivable for anyone to live without it. The number of wireless services subscriptions has long surpassed those of the fixed telephone lines with users eager to make use of and demanding new wireless features. It is now reasonably correct to say that new generations of wireless systems appear in every ten years although equipment and services evolve in a much faster pace.

First-Generation (1G) wireless networks appeared in the late 1970s. The aim was to provide voice services to mobile subscribers. The systems had as their main features voice transmission over analogue frequency modulation (FM) channels and frequency division multiple access (FDMA) as multiple access architecture. They operated over the 800–900 MHz, although one or another could be found in the 450 MHz band. Capacity expansion was rather limited and privacy was inexistent. The best representatives of these systems are: advanced mobile phone service (AMPS) in North America; total access communication system (TACS), European TACS (ETACS), and nordic mobile telephony (NMT) in Europe; Japanese TACS (JTACS) in Japan. Soon, there was the need for more spectrum-efficient and more advanced wireless networks.

As early as in the 1980s, the buzzwords “personal”, “anywhere, anytime” permeated talks, speeches, papers, and all things concerning wireless communications. Researchers and engineers alike freed their imagination to conceive a wireless system that would fulfil the requirements of a personal communication, available to anyone, anywhere, anytime. That would constitute the Second-Generation (2G) wireless networks, available in the early 1990s. Of course, the expectations for the predicted services were only partially attained. The 2G systems were indeed able to increase spectral efficiency as well as introduce some kind of privacy but were far from what everyone thought it would really be. They provided robust communications, authentication capability, low-speed data in

addition to voice services. The systems used digital transmission techniques and time division multiple access (TDMA) or code division multiple access (CDMA) as multiple access architectures. The best representatives of these systems were: Global System for Mobile communications (GSM) with its data service aggregate general packet radio service (GPRS)¹, and Digital AMPS—IS-136 (D-AMPS), using TDMA, and CDMA-One (IS-95), using CDMA. In addition to the 800–900 MHz band, GSM inaugurated the use of the 1.8 GHz band. GSM soon became a universally adopted 2G network.

The widespread use of the Internet boosted the development of wireless systems able to provide better data-transmission capability for mobile applications. The Third-Generation (3G) networks were then envisaged by the international mobile telecommunications-2000 (IMT-2000), with standards and specifications developed by several organizations under the auspices of the international telecommunications union (ITU). The aim of a 3G system was to deliver a data rate of 2 Mbps for stationary or walking users and 384 kbps for moving vehicles. In fact, ITU did not clearly specify the minimum required data rate. Hence, different data rates have been sold as 3G and the systems went commercially in the early 2000s. Two major systems are commonly branded 3G: universal mobile telecommunications systems (UMTS) and CDMA2000. UMTS, designed for networks based on GSM, was developed by the 3rd generation partnership project (3GPP). It uses different terrestrial interfaces, named UMTS terrestrial radio access (UTRA), the most popular being wideband CDMA (WCDMA). UMTS networks have been improving their data-transmission capability through high-speed downlink (uplink) packet access (HSD(U)PA) technologies. CDMA2000, designed for networks based on CDMA-One, was developed by 3GPP2. It includes the 1xEV-DO technology for broadband Internet access. A combination of CDMA and TDMA is applied as a means to achieve the desired data-rate transmission. Undoubtedly, UMTS is the predominant 3G system worldwide.

Clearly, communications systems have moved drastically from voice towards data applications. Such applications are increasingly demanding higher data rates, which current wireless systems have not been able to provide. A Fourth-Generation (4G) network was necessary. In this sense, the ITU-radio communication sector (ITU-R) established the requirements for 4G standards, the IMT-Advanced. Some of these requirements include: (i) be an all-IP packet switched network; (ii) provide peak data rates of 100 Mbps for high mobility and 1 Gbps for low mobility; (iii) use scalable channel bandwidths of 5–20 MHz; be able to provide smooth handover through heterogeneous networks; etc. Mobile WiMAX and long term evolution (LTE), already in use (early 2010s), but which did not fully comply with the required standards yet are recognized as 4G systems. In 2009, the LTE-Advanced, standardized by the 3GPP, was formally submitted as a candidate 4G system.

¹GPRS was known as a 2.5G system.

As usual and ever, a generation is not fully available yet and a vivid discussion on the requirements for the next generation is under way. Fifth-Generation (5G) wireless networks aim: (i) to support tens of Mbps for tens of thousands of users; (ii) to support connections for massive sensor deployments; (iii) to meet new use-cases such as internet of things (IoT); and others. It is predicted that 5G networks should be rolled out by 2020.

It is certain that what is expected for a given wireless generation is only accomplished two or three generations later...

CPqD has been involved with wireless communications since the very beginning. It has been conducting research and development in a wide range of aspects of the system. In addition, it has been actively participating in the Regulatory and Standardization agencies national and internationally. More recently, CPqD has led the move in order to standardize the introduction of the use of 450 MHz in 3GPP, which was officially established in 2013. Also a Radio Access Network, RAN, both in 450 and 700 MHz have been fully developed and tested in laboratory and also in the field with operators.

This book gathers a little of the latest works in the wireless communications field at CPqD. Chapter [“LTE and Beyond”](#) traces a thorough overview of the current Long Term Evolution systems and their future. Issues such as fundamentals of LTE (e.g. architecture, control and user plane protocols, physical layer), advanced features (e.g., spectrum usage, efficiency, capacity), interference management, advanced services, and others are nicely covered in the text. Chapter [“Brazilian Telecommunications Regulatory Framework and the Impacts on the Development of Broadband Radio Access Systems”](#) the Brazilian Regulatory Framework for telecommunications services is adopted as the basis for an analysis on the impact of introduction of new technological scenarios and the new opportunities that can be envisaged. Chapter [“Dual-Polarized Crossed Dipole Antenna Array for LTE Base Station”](#) presents a solution for a dual-polarized antenna array for LTE base station applications operating in the 450 MHz band. In particular, the antenna operates with a $\pm 45^\circ$ slanted polarization diversity with a horizontal beamwidth of 65° . Chapter [“Evaluation of the LTE 450 MHz System Performance with Different Terminal Antennas”](#) conducts simulation analysis in order to evaluate the performance of commercial antennas for LTE systems at 450 MHz. The environment, a rural area, is chosen to comply with the ANATEL and 3GPP standards. The results show that the use of directional antennas may improve the cell throughput up to 90 % and terminal throughput up to 10 times as compared to the same scenario using omnidirectional antennas. Chapter [“Wavelet-Based Narrowband Interference Suppression in Long Term Evolution Physical Channels”](#) describes a wavelet-approach in order to mitigate narrowband interference in LTE physical channels. Simulations are used that suggest that an optimized a suppression process calls for different wavelet type depending on the physical channel considered. Chapter [“Link Adaptation in LTE Systems”](#) details how link adaptation (selection of modulation schemes and code rate) is performed in both downlink and uplink in LTE systems. Chapter [“Method and Test Environment for the Validation of Random](#)

[Access Channel for Long Term Evolution Systems in 450 MHz](#)” proposes a laboratory method to validate Physical Random Access CHannel (PRACH) procedure implemented in the LTE 450 MHz. The method avoids the costly and time-consuming procedures of field tests. Chapter “[Experimental Assessment of Voice Over IP in LTE Systems Under Different Cell Conditions](#)” depicts a measurement-based performance assessment of VoIP in LTE networks for suburban and rural applications when different LTE configurations of QoS and cell conditions are considered. Chapter “[Integration Between LTE and Satellite Networks](#)” investigates the viability of introducing satellite-based backhaul connectivity to LTE networks. Both laboratory-simulated link as well as real-world link in a LTE 450 MHz system is tested. The results show that the introduction of a satellite link does not limit the quality of the services provided.

We cordially invite you to enjoy the book.

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Long Term Evolution

4G and Beyond

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