

# A Wireless Communications Laboratory on Cellular Network Planning

Zaher Dawy, Senior Member, IEEE, Ahmad Hussein, Elias Yacoub, and Lina Al-Kanj

**Abstract**—The field of radio network planning and optimization (RNPO) is central for wireless cellular network design, deployment, and enhancement. Wireless cellular operators invest huge sums of capital on deploying, launching, and maintaining their networks in order to ensure competitive performance and high user satisfaction. This work presents a lab course composed of 10 experiments that cover the different phases of RNPO for various state-of-the-art wireless technologies such as GSM, UMTS, and WiMAX. Each experiment constitutes a complete entity including the necessary theoretical background and references, the lab tasks based on real-world scenarios, and a research component consisting of general questions. The proposed lab course represents a novel initiative to increase interactive learning by integrating communications theory fundamental knowledge with state-of-the-art wireless communications software tools and measurement equipment. The experiments are carefully designed to enhance the analytical skills and to advance the academic and practical knowledge of the students.

**Index Terms**—Cellular network planning, drive testing, GSM, UMTS, WiMAX, wireless communications.

## I. INTRODUCTION

**W**IRELESS cellular technologies are continuously evolving to meet the increasing demands for high data rate mobile services. GSM (Global System for Mobile Communications) is currently the most widely deployed cellular system with more than three billion subscribers in more than 200 countries [1]. GSM is based on a hybrid time division/frequency division multiple accessing (TDMA/FDMA) air interface. The allocated spectrum for a given GSM network is divided into multiple frequency channels that are distributed among cells in the network based on a frequency plan in order to control the level of interference. In each frequency channel, time is divided into eight time slots. The proliferation of the Internet and the continuously escalating market demand for mobile data services necessitated the evolution of GSM by developing new technologies such as GPRS (General Packet Radio Service), EDGE (Enhanced Data rates for GSM Evolution), UMTS (Universal Mobile Telecommunication System), and HSPA (High-Speed Packet Access) [2]. GPRS and EDGE are direct

enhancements to GSM networks that are capable of supporting packet switched mobile services and providing peak data rates of 128 kb/s with GPRS and 384 kb/s with EDGE. The enhanced data rates offered by GPRS and EDGE are based on various advanced techniques that include adaptive modulation and coding.

In order to meet the forecasted growth of cellular subscribers and the need for faster and more reliable data services, the third-generation UMTS system was developed and standardized in 1999, based on a code division multiple accessing (CDMA) air interface. In a UMTS network, the frequency reuse factor is one, and thus all users in the network share the same frequency band at the same time by using different spreading codes in order to limit the level of interference. The wideband CDMA (WCDMA) mode of UMTS is currently being widely deployed by cellular operators all over the world (more than 400 million subscribers in more than 130 countries) [3]. WCDMA provides higher spectral efficiency than GSM/GPRS/EDGE, with peak data rates of 2 Mb/s. HSPA is a direct enhancement to UMTS networks that can provide an uplink peak data rate of 3.7 Mb/s and a downlink peak data rate of 14.4 Mb/s. The enhanced data rates offered by HSPA are based on various advanced techniques that include intelligent scheduling, fast link adaptation, and fast retransmission. Long-Term Evolution (LTE) is currently being developed and standardized as the next step after UMTS/HSPA on the evolution track [2]. LTE is based on an orthogonal frequency division multiple accessing (OFDMA) air interface and is capable of providing considerably high peak data rates of 50 Mb/s in the uplink and 100 Mb/s in the downlink. At the same time, the WiMAX (Wireless Interoperability for Microwave Access) wireless technology is being further developed as an all-IP network with an OFDMA air interface to provide high data rate broadband wireless mobile access [4]. WiMAX evolved from a last-mile wireless access technology to a broadband wireless access technology, with nomadic and mobile connectivity as standardized in IEEE 802.16d and IEEE 802.16e, respectively.

In academia, teaching wireless communications is normally oriented toward providing students with the necessary theoretical background. Usually students do not have the opportunity to work with wireless communications tools and equipment related to state-of-the-art wireless technologies. At the Electrical and Computer Engineering (ECE) Department at the American University of Beirut (AUB), Lebanon, there are several courses that are offered in the area of wireless communications, but a wireless communications lab to complement the course material was lacking. Hence, the idea of developing a wireless communications lab course evolved in order to provide students with

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