Preface

The innovative and effective use of Information and Communication Technologies (ICT) is becoming increasingly important to improve the economy of the world. Wireless communication networks are perhaps the most critical element in the global ICT strategy, underpinning many other industries. It is one of the fastest growing and most dynamic sectors in the world.

The development of wireless technologies has greatly improved people's ability to communicate and live in both business operations and social functions. The phenomenal success of wireless mobile communications is mirrored by a rapid pace of technology innovation. From the second generation (2G) mobile communication system debuted in 1991 to the 3G system first launched in 2001, the wireless mobile network has transformed from a pure telephony system to a network that can transport rich multimedia contents. The 4G wireless systems were designed to fulfill the requirements of International Mobile Telecommunications-Advanced (IMT-A) using IP for all services. In 4G systems, an advanced radio interface is used with Orthogonal Frequency-Division Multiplexing (OFDM), Multiple-Input Multiple-Output (MIMO), and link adaptation technologies. 4G wireless networks can support data rates of up to 1 Gb/s for low mobility, such as nomadic/local wireless access, and up to 100 Mb/s for high mobility, such as mobile access.

Long-Term Evolution (LTE) and its extension, LTE-Advanced systems, as practical 4G systems, have recently been deployed or soon will be deployed around the globe. However, there is still a dramatic increase in the number of users who subscribe to mobile broadband systems every year. More and more people crave faster Internet access on the move, trendier mobiles, and in general instant communication with others or access to information.

More powerful smartphones and laptops are becoming more popular nowadays, demanding advanced multimedia capabilities. This has resulted in an explosion of wireless mobile devices and services. As more and more devices go wireless, many research challenges need to be addressed. One of the most crucial challenges is the physical scarcity of Radio Frequency (RF) spectra allocated for cellular communications. Cellular frequencies use ultra-high-frequency bands for cellular phones, normally ranging from several hundred megahertz to several gigahertz. These frequency spectra have been used heavily, making it difficult for operators to acquire more.

Another challenge is that the deployment of advanced wireless technologies comes at the cost of high energy consumption. The increase of energy consumption in wireless communication systems causes an increase of (CO_2) emission indirectly, which currently is considered as a major threat for the environment. Other challenges are, for example, average spectral efficiency, high data rate and high mobility, seamless coverage, diverse Quality of Service (QoS) requirements, and fragmented user experience (incompatibility of different wireless devices/interfaces and heterogeneous networks), to mention only a few.

All the above issues are putting more pressure on cellular service providers, who are facing continuously increasing demand for higher data rates, larger network capacity, higher spectral efficiency, higher energy efficiency, and higher mobility required by new wireless applications. On the other hand, 4G networks have just about reached the theoretical limit on the data rate with current technologies and therefore are not sufficient to accommodate the above challenges.

As a result, 5G is the next step in the evolution of mobile communication. It will be a key component of the Networked Society and will help realize the vision of essentially unlimited access to information and sharing of data anywhere and anytime for anyone and anything. 5G will therefore not only be about mobile connectivity for people. Rather, the aim of 5G is to provide ubiquitous connectivity for any kind of device and any kind of application that may benefit from being connected.

Mobile broadband will continue to be important and will drive the need for higher system capacity and higher data rates. But 5G will also provide wireless connectivity for a wide range of new applications and use cases, including wearable, smart homes, traffic safety/control, and critical infrastructure and industry applications, as well as for very-high-speed media delivery.

In contrast to earlier generations, 5G wireless access should not be seen as a specific radio access technology. Rather, it is an overall wireless-access solution addressing the demands and requirements of mobile communications.

LTE will continue to develop in a backwards-compatible way and will be an important part of the 5G wireless-access solution for frequency bands below 6GHz. There will be massive deployments of LTE providing services to an enormous number of devices in these bands. For operators with limited spectrum resources, the possibility to introduce 5G capabilities in a backwards-compatible way, thereby allowing legacy devices to continue to be served on the same carrier, is highly beneficial and, in some cases, even vital.

In parallel, new Radio Access Technology (RAT) without backwards-compatibility requirements will emerge, at least initially targeting new spectrum for which backwards compatibility is not relevant. In the longer-term perspective, the new non-backwards-compatible technology may also migrate into existing spectrum.

THE CHALLENGES

In 5G cellular networks, the challenges are to enable connectivity for a very wide range of applications with vastly different characteristics and requirements. The capabilities of 5G wireless access must extend far beyond those of previous generations of mobile communication.

Massive System Capacity

Traffic demands for mobile-communication systems are predicted to increase dramatically. To support such traffic in an affordable way, 5G networks must be able to deliver data with much lower cost per bit compared with the networks of today. Furthermore, in order to be able to operate with the same or preferably even lower overall energy consumption compared with today, 5G must enable radically lower energy consumption per delivered bit.

Another aspect of 5G system capacity is the capability to support a much larger number of devices compared with today. The new use cases envisioned for 5G include, for example, the deployment of billions of wirelessly connected sensors, actuators and similar devices. Each device will typically be associated with very little traffic, implying that, even jointly, they will have a limited impact on the overall traffic volume. However, the sheer number of devices to be connected provides a challenge, for example, in terms of efficient signaling protocols.

High Data Rates

Every generation of mobile communication has been associated with higher data rates compared with the previous generation. In the past, much focus has been on the peak data rate that can be supported by a wireless-access technology under ideal conditions. However, a much more important capability is the data rate that can actually be provided under real-life conditions in different scenarios.

5G should be able to provide data rates exceeding 10Gbps in specific scenarios such as indoor and dense outdoor environments. Data rates of several 100Mbps should be generally achievable in urban and suburban environments. Data rates of at least 10Mbps should be achievable essentially everywhere, including sparsely-populated rural areas in both developed and developing countries.

Low Latency

Lower latency has been a key target for both 4G and the evolution of 3G, driven mainly by the continuous quest for higher achievable data rates. Due to properties of the internet protocols, lower latency over the wireless interface is critical to realize the higher data rates. 5G targets even higher data rates, and this in itself will drive a need for even lower latency.

However, lower latency will also be driven by the support for new applications. Some of the envisioned 5G applications, such as traffic safety and control of critical infrastructure and industry processes, may require much lower latency compared with what is possible with the mobile-communication systems of today. To support such latency-critical applications, 5G should allow for an application end-to-end latency of 1ms or less.

Ultra-High Reliability and Availability

In addition to very low latency, 5G should also enable connectivity with ultra-high reliability and ultra-high availability. For critical services, such as control of critical infrastructure and traffic safety, connectivity with certain characteristics, such as a specific maximum latency, should not only be 'typically available.' Rather, connectivity with the required characteristics has to be always available with essentially no deviation.

Low Energy Consumption

The possibility for low cost and low energy consumption for mobile devices has been a key requirement since the early days of mobile communication. However, in order to enable the vision of billions of wirelessly connected sensors, actuators and similar devices, a further step has to be taken in terms of device cost and energy consumption. It should be possible for such 5G devices to be available at very low cost and with a battery life of several years without recharging.

High Network Energy Performance

While device energy consumption has always been prioritized, high energy performance on the network side has more recently emerged as a Key Performance Indicator (KPI).

- High network energy performance is an important component in reducing operational cost, as well as a driver for better dimensioned nodes, leading to lower total cost of ownership.
- High network energy performance allows for off-grid network deployments relying on decently sized solar panels as power supply, thereby enabling wireless connectivity to even the most remote areas.
- High network energy performance is part of a general operator aim of providing wireless access in a sustainable and more resource-efficient way.

The importance of these factors will increase further in the 5G era, and the possibility of very high network energy performance will therefore be an important requirement in the design of 5G wireless access.

SEARCHING FOR A SOLUTION

Such requirements need special technologies to be deployed. The detailed 5G standards are still work in progress and uncertain yet. Carrier Aggregation, massive Multiple Input – Multiple Output (MIMO), beam forming, cloud computing, millimeter Waves (mmW), Cognitive Radio (CR), Full Duplex (FD), Non-Orthogonal Multiple Access (NOMA), green communication, energy harvesting, Device-to-Device (D2D), wearable antenna, new security techniques and Cloud Radio Access Networks are potential technologies under research to meet 5G needs and be applied on it. In this book, we tend to overview some of these supportive technologies for 5G heterogeneous networks.

ORGANIZATION OF THE BOOK

The book is organized into 12 chapters. A brief description of each of the chapters follows:

Chapter 1 covers the major developments in cellular Communication networks namely Fixed Internet, Mobile internet, Things Internet and the upcoming Tactile Internet. The authors of this chapter present new trends and challenges in adopting 5th Generation of Cellular Communication (5G) for Internet of Things (IoT). Further, they provide an insight about the transformation from infrastructure based internet to opportunities or service based internet design.

Chapter 2 present a study aims to develop a model of information transmission based on discrete event concepts. This methodology aims to increase efficiency in sending and receiving data by reducing the consumption of time during this process. Next, chapter discusses the technological concepts that involve the mobile transmission and that motivated the development of the CBEDE methodology (Coding of Bits for Entities by means of Discrete Events) presented in this chapter.

Chapter 3 introduces an overview of microstrip antenna and MIMO systems for the next 5G band. Also, in this chapter, a novel design of MIMO antenna for the coming generation 5G bands as a solution for the next generation of smartphone antennas is investigated. Moreover, the effect of mutual coupling on closely coupled microstrip antennas in closely MIMO antenna systems is discussed. The anticipated wireless system is size-compact, relatively easy to fabricate and implement in practical mobile applications.

Chapter 4 shows two different types of dual-band flexible wearable antennas design. The first one is a rectangular antenna with six U-slots on the patch. This wearable antenna combines the hardness and flexibility in that, it is printed on a material called "ULTRALAM® 3850HT". The second antenna is a planar inverted-2F wearable antenna pasted on Jeans textile material as a substrate. The two proposed 5G-antennas are applied for founded of a smart watch.

Chapter 5 compares between Bit Error Rate analysis (BER) of Discrete Wavelet Transform (DWT)-OFDM system and conventional Fast Fourier Transform (FFT)-OFDMA system in order to ensure that wavelet transform based OFDMA transmission gives better improvement to combat Inter Carrier Interference (ICI) than FFT based OFDMA transmission and hence improvement in BER. In this chapter, author uses a kalman filter in order to improve BER by minimizing the effect of ICI and noise.

Chapter 6 focuses on adaptive cache management schemes for Cloud Radio Access Networks (CRAN) and Multi-Access Edge Computing (MEC) of 5G mobile technologies. Moreover, this chapter proposes a new cache management algorithm using Zipf distribution to address dynamic input for CRAN and MEC models. This work contributes in the support of 5G for IoT by enhancing CRAN and MEC performance; it also contributes to how novel caching algorithms can resolve the unbalanced input load caused by changing distributions of the input traffic.

Chapter 7 designs new efficient cache management schemes for the BaseBand Unit (BBU) pool in CRAN. It adopts the Exponential-Decay (EXD) scheme to keep recently frequently requested records in cache and enhances it with Analytical Hierarchy Process (AHP) to support multiple levels of mobility and QoS. The other new algorithms include a probability-based scoring scheme, a hierarchical, or tiered, approach, and enhancements to previously existing approaches.

Chapter 8 obtains an overview about Device-to-Device (D2D) communication technology in the existence with cellular network. Some standards have been summarized such as recent 3GPP and D2D WRAN based IEEE 802.22 evaluation. Moreover, current D2D's prototypes have been showed. Also, the importance of attaching D2D technology with different features has been illustrated. Besides that, D2D technology faces a lot of vital challenges; that have been highlighted.

Chapter 9 addresses Cognitive Radio Systems (CRSs) in the 5G network and presents the existing, emerging and potential applications employing CRS capabilities and the related enabling technologies, including the impacts of CRS technology on the use of spectrum from a technical perspective. The description of such technologies, operational elements and their challenges are also presented. Furthermore this chapter provides high level characteristics, operational and technical requirements related to CRS technology, their performances and potential benefits.

Chapter 10 is discussing the role of Cloud Computing centers in 5G networks, and how such integration could be implemented as found in the literature. The benefits of Cloud/5G integration will be explained as well. In addition, some challenges related to the integration is demonstrated.

Chapter 11 proposes a 5G tutorial consisting of the previous Vehicles to anything (V2X) technologies, the improvements over the 4G and IEEE802.11P, the 5G vital requirements, challenges, technologies, security enhancements, and the 5G system structure. In this chapter, authors cover the previous Dedicated Short Range Communication (DSRC)/wave standards, the LTE-V, the cellular V2X, the structure of C-V2X, the evolution of LTE towards 5G, the enhancement of the proposed 5G technologies, and finally the security aspects of the proposed 5G within V2X communications.

Chapter 12 presents a summary and state of art of Machine-to-Machine (M2M) communications characteristics, taxonomy, applications. The authors also show different technologies for deploying of M2M communications, and future challenges.

The purpose of this book is to take a step toward clarifying what '5G' really means in the technological sense, by: introducing 5G fundamental supportive technologies; expanding on some of the use case scenarios and applications that 5G might enable; and discussing conceivable implications for operators in terms of network infrastructure and commercial opportunities. Finally, researchers, academicians, students, faculties, scientists and Information Technology sector industry professionals will find this handbook beneficial for research exposure and new ideas in the field of 5G cellular communication and wireless heterogeneous networks technologies.

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