Chapter 31
Key Microwave and Millimeter Wave Technologies for 5G Radio

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ABSTRACT

This chapter presents an overview on the drivers behind the 5G evolution and explains technological breakthroughs in the microwave and millimeter wave domain that will create the 5G backbone. Extensions to millimeter wave frequency bands, advanced multi-antenna systems and antenna beamforming and simultaneous transmission and reception are some of the prospects that could lead to both architectural and component disruptive design changes in the future 5G. 5G is expected to include an innovative set of technologies that will radically change our private and professional lives, though applications of novel services, such as remote healthcare, driverless cars, wireless robots and connected homes, which will alter boundaries between the real and the cyber world.

INTRODUCTION

The fifth generation (5G) is the next major step in the development of mobile networks, which is expected to be implemented from 2020 and beyond. Apart from the empirically observed fact that every generation is succeeded after about 10 years, the motivation behind 5G is that current networks, despite their continued evolution, are approaching fundamental limits of their performance. Table 1 sums up key parameters of 4G networks (based on IMT-Advanced standard, not yet achieved) and what is ex-

DOI: 10.4018/978-1-7998-7708-0.ch031

Table 1. Comparison between the key requirements for 4G and 5G

	Fourth Generation (4G)	Fifth Generation (5G)
Data rate for stationary users	1 Gbps	50 Gbps
Data rate for moving users (pedestrians, vehicles)	100 Mbps	5 Gbps
Latency	10 ms	1 ms

pected for 5G (there is no official standard yet, but the given values are widely cited in the literature, e.g. (Boric-Lubecke, et al., 2015)). In addition to that, 5G is expected to improve reliability (up to 99.999%), coverage and capacity, support advanced machine-type communication (MTC), and to improve battery life of devices up to 10 times.

The demand for the stated goals of 5G has two main drivers; the first is evolution of existing services. Mobile data rates are going ever higher, driven by applications such as 4K video streaming. However 5G is about much more than just that speed, capacity and reliability are aimed to be significantly improved, compared to the current networks. The ultimate goal in this respect is to provide users with the perception of "infinite capacity", i.e. that any service can be run without delay wherever the user might be.

Second driver behind 5G are the emerging new applications. For example, virtual and augmented reality systems have received a lot of attention in recent years, as well as lots of investments from the industry and venture capitalists. It is envisioned that the users will be able to connect with others to participate in shared virtual environment, with the purpose of either gaming or business applications like smart office. In any case, along with high data rate, very low latencies are needed to provide realistic experience – less than 10 ms for visual and aural senses. If touch interaction is transmitted through network – the goal of the so-called Tactile internet – latency of less than 1 ms is required for users not to perceive delay (Simsek, et al., 2016).

Internet of Things (IoT) is another area which is seeing huge growth (more than 20 billion devices are predicted by 2020), and it could greatly benefit from 5G connectivity. Currently, there is significant fragmentation in IoT communication standards, with technologies like RFID, Bluetooth, WiFi and proprietary systems being used simultaneously. 5G networks, due to their scalability, have the potential to provide unified framework to integrate various IoT systems, paving the way for large-scale diverse applications like smart city. For some IoT applications, like autonomous vehicles, latency is critical parameter. The high data-rates of 5G could help improve battery life of sensors, as their duty cycles can be shorter.

The aforementioned goals present a huge challenge, and there is a wide consensus in the research community that they cannot be met by simple evolution of the current technology (Boccardi, Heath, Lozano, Marzetta, & Popovski, 2014). There is a necessity for radical new solutions, and in the authors' view the key enablers for 5G will be the following:

- Utilization of millimeter wave (mm-wave) spectrum;
- Advanced multi-antenna (MIMO) techniques;
- In-band full duplex;
- Innovative network architecture.