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Preface

The advent of 5G networks – what do you need to know?

Undoubtedly, the advent of 5G networks will permanently change the future of telecommunications, affecting the professional work of every engineer. In light of the above, a brief outline of the standard's details is presented herein to emphasize the significance of the new concept.

Fifth-generation networks have been, until recently, an unclear future prospect, as no specific details concerning their operation were available. Answers to the "what is 5G?" question were merely speculations.

Although many technical aspects of the 5G architecture and even of the 5G technologies still remain unclear, some technical solutions have been assuming a more specific shape over the past few years. The most probable paths along which the 5G technology will be developing (with some of them not confirmed and subject to potential change) are described below.

From the technical point of view, the type of modulation used is of primary importance, and a lot of attention has been devoted to this specific aspect. Selection of the modulation type was preceded by a detailed analysis of the pros and cons of various techniques. The standardization body finally decided that cyclic prefix orthogonal frequency division multiplexing (CPTD) will be used in fifth generation networks, with QPSK, 16-, 64- or 256-QAM subcarrier modulation. Such a choice was based on the numerous advantages of this particular solution.

The OFDM technique has been known since the 1960s and started to evoke some serious interest in the late 1980s, when research concerning GSM networks was conducted, and later, when the UMTS standard was developed. However, OFDM failed to be implemented in any of the abovementioned cases, as the computing power of processors available at that time was insufficient.

The technical progress in this area has enabled the popularization of OFDM in, inter alia, the following: digital audio and video broadcasting systems (DAB, DVB), asymmetric digital subscriber line data transmission technology (ADSL) and data transmission via power lines (PLC). The popularity of OFDM results from the fact that it provides high data rates, simultaneously eliminating signal distortion caused by the phenomenon of multipath inter-symbol interference (ISI). Doing away with that type of interference is a serious issue in other types of modulation.

In OFDM, a data stream with a high bitrate is split into several slower substreams that are transmitted simultaneously using multiple carriers, which extends the duration of one symbol. As a result, signals that are reflected by multipath phenomena and reach the receiver with a delay, exert a smaller impact on the quality of received signal. In addition, in the CP-OFDM modulation variant, inter-symbol interference is prevented by the interval between consecutive symbols, the so-called cyclic prefix (CP). CP is a copied symbol end inserted at its beginning. Thanks to its application, if the delay between the original signal and the reflected signal does not exceed its length, the transmitted information can be easily retrieved at the receiver.

Thanks to the fact that OFDM is not a new method, solutions have been developed for LTE networks that will now reduce the cost of its adaptation to the needs of the 5G standard. The possibility of implementing multi-antenna transmission systems (MIMO-OFDM) is a considerable advantage as well. Furthermore, the plans assume that the multi-user (MU) version of the multi-antenna MIMO transmission protocol will be implemented in 5G networks. New beamforming techniques that will be introduced in 5G NR networks will additionally maximize the strength of the signal sent towards the receiver, simultaneously reducing, to the minimum, the strength of signals disseminated in other directions. Future NR systems are also expected to rely on the Massive MIMO technology, where the number of antennas is increased to several hundred.

It is worth noting that OFDM has a few drawbacks, too. One its limitations is the high peak-average power ratio (PAPR). At higher values, the operating point of the RF power amplifier shifts to the linear part of the characteristic to avoid signal distortion. This causes a reduction in efficiency. In the case of base stations, higher power consumption is not a big issue, but in the mobile, battery-powered user devices, this is an unfavorable phenomenon. Therefore, in the case of 5G uplink, the DFT-S-OFDM technique is used with the following modulations: $\pi/2$-BPSK (a novelty), as well as 16-, 64- or 256-QAM. The advantage of DFT-S-OFDM is its ability to achieve a low PAPR coefficient, while simultaneously ensuring multipath immunity.

The importance of mmWave

5G networks will operate on numerous frequencies, both higher and lower. The range of below 1 GHz will be used, e.g. 600, 700 and 800 MHz bands. As far as the range between 1 and 6 GHz used in China, Europe, South Korea and Japan is concerned, the 3.3–3.8 GHz section is of particular interest. Great hopes are also related to the millimeter wave (mmWave) band, especially 52.6 GHz, although research is already conducted on relying on 64–71 GHz and 71–76 GHz bands in wireless communication. Examples of bands that have been pre-reserved for 5G NR networks in different parts of the world include: 24.25–27.5 GHz and 40.5–43.5 GHz (Europe), 27.5–28.35 GHz, 37–38.6 GHz and 38.6–40 GHz (USA), 24.75–27.5 GHz and 37–43.5 GHz (China).

The transition to higher operational frequencies will have its consequences. The higher the carrier frequency, the greater the phase noise. The narrower the spacing between subcarriers (subcarrier spacing, SCS), due to phase noise, the higher is error vector magnitude (EVM) which characterizes the quality of modulation. Also, the higher the carrier frequency, the higher the Doppler shift. With the user's speed of several km/h and the frequency of several dozen GHz, it can reach up to several percent of the space between subcarriers.

On the other hand, the larger the SCS, the shorter the OFDM symbol, and, therefore, the CP prefix. This, in turn, results in a greater impact of the multipath phenomenon on the quality of transmission. Therefore, the choice of the width of the gap between the subcarriers requires a compromise solution. That is why a decision has been made that it will be scalable in 5H NR networks. The multiples of 15 kHz are allowed: 15, 30, 60, 120 and 240 kHz. This basic value has been chosen to allow the coexistence of 5G and 4G networks, where SCS equals 15 kHz. With the change of the subcarrier gap, the cyclic CP prefix is also shortened or extended, respectively. This will enable to adjust its length to propagation conditions prevailing in a given communication channel. The scalability of the frame is also a consequence of SCS' flexibility. This feature will ensure compatibility of 5G NR networks.

5G networks will also introduce a completely new concept of dividing the channel into parts, the so-called Bandwidth Parts (BWP). Each BWP will consist of a group of adjacent PRB blocks and will have an SCS and a CP assigned thereto. The individual BWPs will be allocated to different users according to their needs and capabilities, which will ensure energy savings.

Undoubtedly, the 5G technology will be a key factor in creating a commonly available ecosystem of the future. Due to its breakthrough functionality, this subject will certainly be the focal point of numerous research papers, and the findings thereof will also be presented in our Journal.

I would like to take this opportunity to declare the era of next generation telecommunication networks to have officially begun.

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