6G - SIXTH GENERATION MOBILE NETWORKS

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Summary

In this paper, we will present mobile networks of the sixth generation, popularly called 6G. It is expected that this generation of mobile networks will cause a complete revolution in the world of technology but also the daily life of the people who use it. The 6G mobile network will not only be a continuation of the 5G mobile network, but will represent a completely new concept of integration of all existing and future segments of the idea of global networking. 6G networks are expected to reach significantly higher levels of heterogeneity than their predecessors and to support applications that are far more advanced than current mobile usage scenarios, such as virtual and augmented reality (VR/AR), ubiquitous instant communications, ubiquitous intelligence and Internet of Things (IoT). 6G should enable the full integration of wireless networks based on different technologies. A significant advantage of the 6G mobile network that will enable this is certainly the data rate, which will reach speeds of even 1TB/s. In addition, 6G mobile networks will enable extremely high coverage, negligible delay, high reliability and availability in almost all rural areas.

Keywords*: Augmented reality, heterogeneity, data transfer speed, low latency*

1 INTRODUCTION

The development of mobile networks from their inception to the present days has taken place through generations, which include the installation of new advanced technologies and the use of their advantages for the introduction of completely new generations of user services. Each new generation was accompanied by raising the existing way of human life to a completely new level. The 1G mobile network enabled wireless voice calling, the 2G mobile network introduced digitization and wireless messaging services, and simpler variants of global network access through 2.5 and 2.75 enhancements. The 3G mobile network was powerful enough for fast Internet browsing using mobile devices. The 4G mobile network has enabled the flow of multimedia media at high speeds. 5G networks integrate mobile networks with other wireless networks at much higher speeds.

The 6G mobile network is currently in the researching and initial standardization phase. To the uninitiated, the activities carried out around 6G may seem excessive, bearing in mind all the controversies that follow the introduction of 5G and the relatively slow implementation. However, the growing needs of users make these efforts necessary. Technology must serve the needs of future humanity, and possible abuses are not the domain of technology, but of human morality and legal regulations.

2 MIGRATION FROM 5G TO 6G MOBILE NETWORK

The term migration in information technologies implies a process in which data processing and information systems are convert from one technology to another. The system components that are subject to migration can be software, data, hardware and applications.

2.1 Basic features

6G (sixth generation network) is the successor of 5G mobile technology. It will enable the use of higher frequency bands than those used by 5G, which will ensure the delivery of significantly higher data rate and significantly lower transmission delay.

It is assumed that the 6G mobile network will be introduced in the early 2030s. The evolution of digital mobile technologies will enable an increase in speed, capacity and reliability compared to 5G. The 5G network is still developing, and in most countries it is still in the implementation phase or has not even started yet. The development of 6G networks is taking place in the direction of eliminating the shortcomings that 5G and previous generations of mobile networks showed in their exploitation. The upgrade is carried out in such a way as to respect compatibility with a whole range of other advanced technologies, setting itself as a prerequisite for their successful implementation. 5G network is widely used in the most developed countries such as: USA, Great Britain, China, Japan, etc. In addition to expanding the capabilities of 5G, the new 6G network will increasingly support innovative applications in wireless connectivity, communications, multimedia services, the application of artificial intelligence and the Internet of Things.

Just as the 5G mobile network did not put its predecessors out of use, the 6G mobile network will not replace the generations of networks that preceded it either. Each network competes with its infrastructure requirements and those of the previous network to further improve the overall connectivity and quality of services offered to users.

The 6G architecture should be flexible and efficient so that all systems can be easily integrated. Networks with different technologies and generations, common or different communication technologies,

wireless sensor networks, as well as local and distributed computing capacities are just some examples. Applying artificial intelligence anywhere in the network where it can be useful will lead to significant improvements in network performance.

5G provides support for advanced services such as eMBB (Enhanced Mobile Broadband Network), MMTC (Mass Data Communication) and URLLC (Extremely Reliable and Low Latency Communication). However, 6G networks are expected to handle far more demanding applications, for example:

- Increased device and traffic density
- Extreme energy efficiency
- Very low energy consumption
- Very high security
- Localization with centimeter-level accuracy

Some of these challenges can be addressed by using the higher parts of the electromagnetic spectrum in the Terahertz (THz), sub-THz, infrared and visible light bands.

Waveform, modulation and coding, non-orthogonal multiple access, full duplex, massive MIMO (Multiple Input Multiple Output) as technologies currently used in various applications need to be further developed to meet the stringent 6G requirements ("Mobilfunknetz der nächsten Generation", 2021.).

2.2 Smart health service

6G technology represents great potential for the entire healthcare sector. 6G will enable a transmission speed of 1Tb/s and a delay of the order of μs, which will have a very large impact on the application of new technologies in medicine. Intelligent health services 6G will enable complete virtual access to a remote area and eliminate the problem of access to allocated patients. The vision of smart healthcare in the future is to meet quality of service (QoS) requirements that include seamless high-speed connectivity and physician availability for continuous patient monitoring.

Widespread and customized healthcare services and free overcoming of geographical restrictions are part of the vision of smart healthcare in the future. The 6G mobile network will enable the emergence of a variety of new use cases, including dynamic personal health monitoring, telediagnosis and pathology inference, holographic medicine, patient recovery training, and telesurgery, especially with new sensors and AI (Artificial Intelligence) capabilities in 6G ("What is 6G Mobile" 2022.).

2.3 Industry 4.0 and robotics

The concept of Industry 4.0 envisages the digital transformation of production processes through the integration of cyber-physical systems, (IoT) networks, cloud computing and AI, in order to enable high precision and efficiency of production. Within industrial processes, automatic control systems and advanced communication technologies are used. In addition to very low latency and high-resolution data transmission in real time, the standard will establish prerequisites for maximum reliability and data security that was not possible until now.

The 5G mobile network enabled the first implementations of Industry 4.0 concepts, and in the future it is expected that only with 6G this concept will produce the results expected from it. Networking of autonomous vehicle systems requires extreme levels of reliability and low latency, even in extremely fast mobility scenarios (up to 1000 km/h), to enable security that is impossible to satisfy with existing technologies.

The large number of different types of in-vehicle sensors require data rates that can support the terabytes of data generated per hour of driving, which is far beyond current

network capacity. In addition, flying vehicles, for example unmanned aerial vehicles, represent huge potential for different scenarios (eg construction, first aid etc.). 6G will build on the infrastructure that was put in place for 5G and improve connectivity – on land, under the sea or even in space.

4G latency is around 50 milliseconds. In the 5G mobile network, it is 5 milliseconds, which is about 10 times less. 6G latency is estimated at a maximum of 1 millisecond, five times less than 5G. That near-instantaneous speed will help enable mass transmission.

Downloading a long video in a 6G mobile network will take only 1 second without losing the original quality. 6G will support a large number of innovative applications in the field of connectivity and communication. Giordani M. et al (2020) state the expectation that 6G networks will use higher frequencies than 5G networks, and this will enable the achievement of higher data transfer speeds and greater overall capacity.

Most of the new applications of 5G networks are connected to IoT (Internet of Things), for communication of autonomous vehicles and the like. The key element of the 6G mobile network is TeraHerz communication.

The THz range is too high for electronic devices used to generate microwave signals and too low for devices used to generate optical signals. As such, existing THz signals are generated from either frequency-based electronic devices multiplexing or from photovoltaic devices based on photomixing.

The generated THz signals can be divided into two categories:
• Impulse signals
• Continuous signals

THz signals have high losses when propagating in free space. Propagation loss is caused by the propagation of an electromagnetic wave in free space and is proportional to the square of the distance from the transmitter.

Millimeter waves (MMW) are extremely high-frequency electromagnetic waves in the frequency range of 30 GHz to 300 GHz (10 mm–1 mm wavelength). They lie between microwaves and infrared waves. Millimeter waves have the potential to meet the growing need for bandwidth and high-speed communications.

The advantages of millimeter waves are high bandwidth, with speeds of around 10 Gbps or more which is at least 10 times faster than 1 Gbit/s when using microwave frequencies. This enables high-quality streaming of videos, video games in real time, as well as professional applications of various purposes. Components and antennas for millimeter wavelengths are very small compared to those for lower frequencies.

3 VISION OF 6G MOBILE NETWORK

The demands placed on 6G can be achieved by using new advanced and intelligent communication techniques. Some of them can be satisfied by the use of reconfigurable intelligent surfaces, extremely large MIMO, new spectral bands, holographic radio communication, full-duplex wireless communication, multiple access and advanced modulation techniques. These are necessary techniques that need to be integrated into the system in order to maximize data transfer speed. In addition, energy harvesting and backscatter communication techniques are useful and necessary to improve energy efficiency.

6G should enable the full integration of wireless networks based on different technologies. This includes the integration

of terrestrial and other non-terrestrial wireless networks, underwater links and those using satellite communication systems. Having such complete network integration provides the necessary fully connected communications platform with full coverage.
Unlike previous networks, 6G wireless communication networks are expected to support many latency-sensitive applications such as tactile Internet, holographic teleportation (telepresence), Internet of Smart Things (IoST) and multi-sensory augmented reality (XR), which includes augmented reality.

IoT applications can be divided into smart cities, smart radio environments, smart healthcare, smart grid, smart transportation, smart factories, smart agriculture and smart home. All these smart applications are expected to be supported by the 6G wireless communication network.

Therefore, although some of the basic concepts covered by the 6G vision are already included in 5G, only the implementation of 6G will enable the successful realization of the planned goals („Was ist 6G" 2022.).

3.1 Holographic communication

Holography is a method of creating and reproducing three-dimensional images using coherent light (laser). On the photographic plate, not only the arrangement of the intensity of the light rays is registered as in ordinary photography, but also their directions and phases. Therefore, holography enables the storage of the full three-dimensional structure of the recorded object. In this way, a vision of the image is created that has depth like real objects.

Holographic communication enables the transmission of holographic media through a suitable communication network. The hybrid communication technology used here extracts different physical quantities and distributes them to the desired receiver via a secure 6G quantum internet channel. Future aspects of holographic communication are inevitably linked to the use of 6G.

Holographic communication via 6G infrastructure will create an environment that will facilitate remote diagnosis of diseases, enable recognition of emotions, collection of biological data and remote interaction with the human body. The corona virus pandemic indicated the necessity of mastering holographic technology and virtual presence.

4 APPLICATION OF 6G MOBILE NETWORK

Given that the implementation of 6G can hardly be expected before 2030, it is not yet possible to fully predict which new areas of application could arise from its implementation. However, many visions and ideas already exist, as we mentioned earlier.

Optimization of latency and reliability will enable critical application capabilities such as remote operations with ultra-high resolution images and holographic communication. Chowdhury M.Z., Shahjalal M., Ahmed S. and Jang Y (2020) state that even small improvements in reliability can make the new technology's application areas significantly wider.

Some of the areas that 6G will cover will definitely be:

- Telemedicine
- Applications that require high data rates and low delays at the same time (with 5G only one or the other is possible)
- New, sophisticated applications of mixed or augmented reality;
- 3D holography
- Ultra-high resolution video conferences (eg 16K)

- Demanding online video games with ultra-fast real-time responses (<1 ms);
- Video streaming in very high resolutions (16K or more)
- New applications in the area of smart city, and IoT
- New AI applications

The 6G network is expected to set trends for the further development of intelligent connectivity, deep connectivity, holographic connectivity and ubiquitous connectivity. 5G connectivity, communication capabilities and efficiency cannot satisfy the much-anticipated ubiquitous connectivity, as they focus on the number of bandwidth connections and not on real-time system performance. In general, the 6G network has a vision that requires reliability, high connectivity, real-time requirements and bandwidth to provide an effective solution to new and significant communication network challenges.

Augmented Reality (XR): 6G will support augmented reality, virtual reality and mixed reality in communication systems. These capabilities will combine artificial intelligence and 3D objects to address the perceptual needs of cognition, computing, scalding, physiology and human senses. The technology will generate realistic impressions of reality and recreate real-world environments to create visualizations and atmospheres for real-time interaction.

Robotics and autonomous systems: 6G mobile technology will develop connected robots and autonomous systems that will transform everyday life. A good example is autonomous cars that perceive their own environment using sensors such as GPS, light detection, distance measurement, sonar, radar and odometry.

Intelligent societies: 6G will be used to create an intelligent society that will improve quality of life, environmental monitoring and automation through artificial intelligence communication and efficient energy consumption. Society will adopt the use of smart mobile devices and autonomous cars, controlling the entire system remotely.

Wireless brain-computer interaction: This is the process of direct communication between the brain and external devices by sending brain signals to a digital device that analyzes the signals and converts them into actions. 6G will contribute to the development of these BCI (computer interface) systems to further improve intelligent life.

Intelligent healthcare: 6G will play an essential role in medical healthcare systems to build better healthcare. Innovations such as holography, artificial intelligence and mobile computing are being integrated into healthcare systems to aid in remote operations and the transfer of large amounts of medical information to further improve the quality of treatment.

Automation and manufacturing: 6G will help in automatic control of processes, devices and systems to achieve high reliability and low delays. Automation will also ensure error-free data transmission in various areas and further reduce data loss in transmission and reception (“6G kommt” 2023.)

CONCLUSION

The research we conducted shows that the 6G mobile network will have a huge impact on all spheres of human life. While the 4G mobile network has not yet been fully implemented in Bosnia and Herzegovina, some countries in the world such as China and Japan are already developing 6G technology. In the past, the development of new generations of mobile communications took ten years.

Two very important characteristics that describe a 6G mobile network are data rate and latency. The maximum throughput that a 6G network could theoretically reach is 1Tb/s (terabit per second), which is even 50 times stronger than 5G, with a delay of less than 0.1 millisecond (with 5G, the delay is 1 millisecond).

In addition to many advantages, we believe that every new network carries with it disadvantages. The 6G mobile network will enter people's lives at the cost of less and less contact between people and nature. Therefore, it is necessary to approach the issue of introducing new developed technologies in a multidisciplinary manner so that humanity is ready to enter a completely changed way of life without losing its original identity.

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