The Next-Generation 6G: Trends, Applications, Technologies, Challenges, and Use Cases

Ayoub Bourbah, Bouchra Meliani, Zhour Madini, and Younes Zouine

Abstract While the 5G generation of mobile communications system has delimited its focus on Internet of Things (IoT) connection and industrial automation systems. The 6G generation will offer an extrasensory experiences through the fusion of the digital, physical, and human world. It will redefine the way we live, work, and manage the world, and it will make us more efficient thanks to the combination of intelligence and vigorous computation capabilities. The sixth generation of mobile communications is still under investigation. Several projects and research have been launched. 6G promises a specific type of communication with very high data rate and capacity, very low latency, maximum coverage, very high reliability, extremely massive connectivity, and very low cost and power. The current article provides an overview of what has been discussed about the future of 6G so far. The major goal of this paper is to present a comprehensive picture of 6G based on the research and projects that have been launched. We describe the potential architectural characteristics of 6G that will give users the experience they expect. We present an important list of technologies that will be the critical element in the rollout of 6G such as artificial intelligence, VLC communications, 3D beamforming, massive MIMO aircraft, and drones. We also exhibit scenarios and use cases that might be lived in this next-generation networks. Finally, we identify the challenges that could be faced by the 6G in different sides …

Keywords 5G · 6G · AI · MIMO · Data rate · Capacity · Massive connectivity · Maximum coverage · VLC · 3D · Beamforming

1 Introduction

Research related to 6G has already started; several entities have taken sides in this marathon, while the dream of 5G is still far from being global. This new generation of mobile telecommunication will be a revolution technology; it will bring new

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type of communication (holographic, intelligent, and multidimensional) and exceed diverse fields of industry (telemedicine, robotics, marine communication …) [1]. In addition, the sixth generation will certainly deal with the shortcomings of the fifth generation (traffic issues, security, energy …). This paper represents a review article, which summarizes the various articles and white papers published under the 6G flag. In this article, in the first section, we will discuss the trends that spurred the emergence of the sixth generation. The second section presents the architecture of 6G characteristics and the possible technologies to ensure these characteristics. Sixth generation requirements and scenarios are described in Section III. At the end, we will present a variety of challenges facing the sixth generation.

2 Trends

The next generation of mobile communication (6G) receives starter cores from a variety of trends, we illustrate the most important:

2.1 Trafic

The world is moving to a fully connected and intelligent frame. The integration of diversified applications, such as artificial intelligence (AI), 3D services, Internet of Everything (IoE), and virtual reality, contributes to a massive quantity of information in whole the network [2]. In 2030, the traffic volume is estimated to reach 5016 EB/month [3], which it was just about 7.462 EB/month in 2010 [4] the massive production of data made the creation of a next generation of mobile communication system an essential goal [4].

2.2 AI

Finance, health care, manufacturing, industry, and wireless communication networks are just a few of the areas where AI is now being used [1]. The incorporation of artificial intelligence (AI) into wireless communication networks will increase the system's performance [1]. AI, for example, might: Enhance performance of handover operation [1] Improve network planning through location determination of the base station [1]. Reduce the consumption of energy—Permit self-healing of network anomalies (prediction and detection …) [1]. In the previous generations and specially the 5G generation, AI was not considered in the developing stage of the system. However, AI can be embedded in the initial phase of 6G conception [1].

3 6G Use Cases and Technical Requirements

6G will enable innovative, futuristic use cases that when deployed on a massive scale, will transform the way we live and work in remarkable ways.

3.1 Holographic Communications

Holographic displays, which provide three-dimensional images from one or many points to one or many points, are the coming step in the multimedia experience [5]. As a result, network interactive holographic capabilities will require a combination of extremely high data rates and extremely low latency [5]. The first is because a hologram is made up of numerous 3D pictures [5], whereas the second is because parallax is employed to allow the consumers to interact with the image as it varies according to his location [6].

3.2 Tactile and Haptic Internet Applications

This category contains various application examples:
Robotic and industrial automation The 6G arrival will usher in a manufacturing revolution, driven by networks that enable human–machine communication in cyber-physical systems (CPSs) [7], a vision known as Industry 4.0. This type of application necessitates communications between large connected systems without human intervention. As a result, robotics will need to be controlled in real time. A communication link with a maximum latency of 100s and a round-trip response time of 1 ms is required for advanced robotics scenarios in manufacturing [6].
Autonomous driving: (V2V or V2I) This sort of application has the potential to significantly reduce traffic accidents and congestion [8]. For collision detection and remote driving, however, delay on the range of a few milliseconds will most certainly be required [8]. The primary areas that 6G wants to enable are improved driver assistance, vehicle platooning, and completely autonomous driving [6].

3.3 Network and Computing Convergence

Similar to the 5G networks, edge computing architecture is expected to be used in 6G networks as well. When an user requests a service with low latency, the network directs the request to the closest edge computing point [5]. For computation-intensive applications and load balancing, a number of edge computing units could be engaged, but the computing resources must be deployed in a coordinated manner [5]. Edge

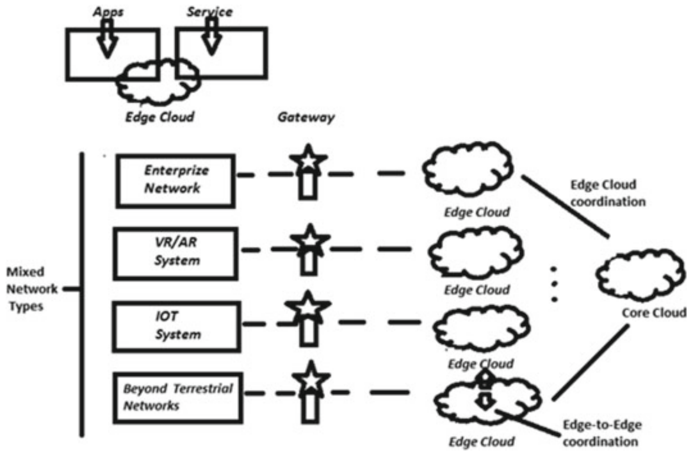

Fig. 1 Edge-to-edge coordination through local edge clouds [6]

cloud coordination is a good fit for AR, VR, autonomous driving, and holographic communications [6]. The major network requirements for this are computing awareness of constituent edge facilities, coupled network and computing resource scheduling (centralized or distributed), flexible addressing (any network node can become a resource provider), and rapid routing and rerouting (traffic should be able to route or reroute in response to load conditions) [6].

Figure 1 shows edge-to-edge coordination all over local edge clouds of various network and service categories, along with edge coordination with the core cloud architecture [5], to exemplify this concept [6].

3.4 Connectivity for Everything

We may discuss a variety of situations throughout this part, such as real-time monitoring of towns, the environment, transportation, and streets … [5]. As a result, the Internet of bio-things, enabled by smart wearable devices, and intra-body communications enabled by implanted sensors [5], will boost connection demand far beyond mMTC [9]. The most essential network needs for such situations are large aggregated data rates owing to vast amounts of sensory data, high security and privacy, especially when medical data are being transferred, and perhaps low latency when a speedy intervention (e.g., heart attack) is required. There are no mechanisms or models in place to evaluate these data requirements right now [6].

3.5 Chip-to-Chip Communications

Today, cable connections are used for on-chip, interchip, and interboard communication, so when data rates exceed 100–1000 Gb/s, those links become useless (bottlenecks). As a result, they must replace the cable connections with optical or THz wireless connections. Another attractive area for 6G is the development of such "nano-networks." Specific KPIs for nano-networks are dependent on chip implementations and applications [5] that will become apparent once they advance during the coming decade [6].

3.6 Space-Terrestrial-Integrated Networks

The concept of offering the Internet from space via enormous constellations of LEO satellites has gained popularity in recent years the connection to satellites instead of depending on existing terrestrial infrastructure become possible for mobile devices in this scenario [6].

4 Technologies

To ensure the good deployment of the network, 6G will be based on different and enhanced technologies:

4.1 Artificial Intelligence: AI

Artificial intelligence is one of the most essential technologies in 6G. In order to construct intelligent networks and real-time communication, this new generation will focus on machine learning technologies so that real-time data transit will be easier with the introduction of this technology, which will also boost efficiency and decrease data processing delay. For example, time-consuming steps (handover, network selection phase, etc.) can be executed quickly using AI [10].

4.2 Terahertz Communications

Because the RF band is currently not enough to fulfill the huge demands of 6G, this generation will be based on sub-THz communication and advanced mMIMO in order to increase bandwidth and spectral efficiency. The THz will play a key part in 6G communication [4], which is intended as the next stage in high data rate transmission. The frequency band of THz communication is between 0.1 and 10 THz, which corresponds to the range 0.03–3 mm of wavelengths [4] but the frequency band recommended by ITU-R between 275 GHz and 3 THz, it is the main part for cellular communications [4]. As a result, by combining the THz and mmWave bands, the capacity of 6G cellular communication will be increased. At its smallest, the capacity is 11.11 times that of the mmWaves. We can get high data rates by employing the THz band [4]. THz band is define between 275 and 3 THz; it is composed from the mmWave 275–300 GHz and the far infrared 300 GHz to 3 THz. The important characteristics of using THz communication: The THz band can provide a large available bandwidth to deal with very high data rates. Due to the elevated frequency, the path loss will arise. So, in the 6G, the directional antennas will be needful because these antennas can reduce the interference. The devices and BS using the THz band will have a large number of antenna components [5], due to the wavelength of the THz waves [4].

4.3 Optical Wireless Technology

OWC technologies such as light fidelity, visible light communication (VLC), and FSO communication based on the optical band will be used in the future generation 6G [4]. Communication with optical wireless technology has a number of advantages, including increased data rates, reduced latencies, and provide secure communications [4].

4.4 FSO Backhaul Network

The data transmission in the FSO system is similar to that of optical fiber because the trans and receiver properties are identical to those of optical fiber [4], As a result, this technology is a good fit for delivering backhaul connectivity in 6G [5]. It is feasible to have quite long surface of communications with FSO, well over 10,000 km away. FSO provides high-capacity backhaul connectivity to far and non-remote locations including the all parts of the universe [5], as well as cellular BS connectivity [4]

4.5 Unmanned Aerial Vehicle

In 6G, BSs will be deployed in unmanned aerial vehicles (UAVs) or drones to enable high data rate wireless communication [5]; this technology has many advantages, like easy deployment and strong degrees of freedom with controlled mobility [4]. For example, in the case of natural disasters, or in unstable environments, drones can easily manage these situations [4]. It can also serve to satisfying the requirements of three use cases: eMBB, uRLLC, and mMTC [4]. Furthermore, UAVs will help to improve network connectivity, detect incidents and disasters, and transfer information to emergency services.

4.6 Holographic Beamforming

Beamforming or channelforming is a signal processing technique used in antenna and sensor arrays for the directional transmission or reception of signals [4]. This procedure has many advantages, but the main property is the high signal-to-noise ratio and the high network efficiency [5]. Holographic beamforming is a new technique of beamforming for 6G that uses software-defined antennas [4]. This type of technology has more advantage compared to beamforming; HBF is able to transmit and receive signals in a more efficient and flexible way in multi-antenna communication [4].

5 The 6G's Architecture

As the generation of the 6G network is supposed to be a pure revolution in the field of communication, the targeted architecture should be able to meet the challenge. The services offered will be both diverse (XR, holographic communication, 3D communication, telepresence, etc.) and provided to an extremely dense population in different places in the universe (earth, ocean, air, space) which will need a strong management and dissemination capacity. To cope with these cases, the architecture of the 6G network should be characterized as follows (Fig. 2).

5.1 Global Architecture

The interconnection in the network will completely change with the 6G generation. We will move from a two-dimensional network to a multidimensional one. The coverage will be a global issue that is supposed to cover all parts of the universe (land, ocean, air, space, the micro world, and outer space) [11]. The 6G ground mobile communication system and the satellite communication system will form a network that gathers different type of communication (terrestrial/satellite/marine wireless communication) [11]. The 6G network will cover all of the areas of human activity: remote areas with no human living, deep oceans, and even the stratosphere [11]. Through different technologies such as visible light communication (VLC), free space optics communication (FSO Comm), and unmanned aerial vehicles (AUVs), the feature of global architecture can be assured.

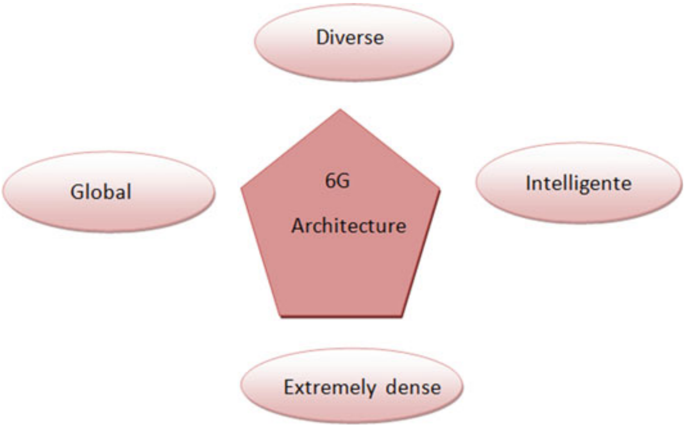

Fig. 2 The characteristics of 6G architecture

5.2 Diverse Architecture

The 6G was presented as an extra multi-service provider; the network should handle very diverse list of services at the same time for different users [12]. The services will be divided into large different categories as described in the use case section, depending on the capacity and the speed of the communication, the coverage extension, the energy consumption, and latency ….

5.3 Extremely Dense Architecture

As the number of connected devices is expected to reach 500 billion by 2030 [1], the 6G network architecture should be able to handle this high number of users; there will be different types of equipment (augmented reality (AR) glasses, virtual reality (VR) headsets, and holographic devices) with different quality of service criteria to be served at the same time. The 6G architecture must be prepared to serve this dense area of devices with sufficient throughput, acceptable speed, and an intelligent management unit [1].

5.4 Intelligent Architecture

Artificial intelligence (AI) will be included into 6G communication networks [5]. AI will be used to encompass all network sensors, control, physical layer signal processing, system administration, service-based communications, and so on [5].

The integration of AI during the development stage of communication systems will offer a super smart architecture, which will give more opportunities to take advantage of AI for improvement of overall network operation in terms of performance, cost, and ability to provide various services [1].

6 The Challenges Facing the Next Generation

As the 6G will bring a new vision in diverse sides (technologies, applications, and architecture …), this coming network will face multiple challenges in different levels.

6.1 The Terahertz Signal

THz frequency band will be the transmission features in 6G. However, it is difficult to work with such frequency range because: The generation of a continuous terahertz signals is tough due to the complexity of antenna/transmitter design. Thus, the generation cost will be high. The THz signals are characterized by a high energy loss. A Thz wave can be attenuated after a few meters. The presence of more moisture in the air make the loss energy much higher, consequently the 6G promises cannot be achieved [13]. The THz technology is still under investigations, and many researches are lunched to find an economical solution for these shortcomings.

6.2 The Energy

Energy is an important issue in the 6G. 6G will implement many technologies, which require high energy such as AI, edge computing, and big data. Consequently, it should find a solution for harvesting, charging, and conservation of energy. Signal processing mechanisms and data transmission required high power consumption too. In order to settle this energy issue, the 6G should offer new waveform and modulation mechanisms. The embedded AI in the 6G initial phase of development can efficiently reduce the quantity of energy consumed [13].

6.3 The Global Coverage

The global coverage goal, fixed by the 6G network, will be achieved through the low-earth orbit (LEO) satellite, having a height of 500–2000 km from the orbit. Its general purpose will be providing a global coverage with less path loss, lower transmission delay. Nevertheless, the LEO satellite has many problems related to Doppler variation, Doppler shift, long transmission delay, and more path loss. As a result, many issues regarding synchronization, signal detection, and signal measurement may arise [13].

7 Conclusion

Given the expected increase in traffic by 2030, the 5G network will no longer be able to handle the big data transmitted. 6G will be the unique solution to deal with this problem and other expected challenges. Through this article, we have visualized the basic keys to 6G technology. We presented architecture and technologies, then requirements and scenarios, and concluded with the challenges that the sixth generation might deal with.

References

1. Samsung 6g Vision: research.samsung.com
2. Mathew A (2021) Chapter 10 sixth-gen wireless tech with optical wireless communication. Springer Science and Business Media LLC
3. Prakash V, Garg L, Azzopardi J, Camilleri T (2022) Chapter 5 High-speed connectivity. IGI Global
4. Chowdhury MZ, Shahjalal Md., Ahmed S, Jang YM (2020) 6G Wireless communication systems: applications, requirements, technologies, challenges, and research directions
5. arxiv.org
6. Tataria H, Shafi M, Molisch AF, Dohler M, Sjöland H, Tufvesson F (2021) 6G wireless systems: vision, requirements, challenges, insights, and opportunities
7. Li T, Khandaker MRA, Tariq F, Wong K, Khan RT (2019) Learning the wireless V2I channels using deep neural networks. In: IEEE 90th vehicular technology conference (VTC2019-Fall)
8. deepai.org
9. Tang F, Fadlullah ZM, Mao B, Kato N (2018) An intelligent traffic load prediction-based adaptive channel assignment algorithm in SDN-IoT: a deep learning approach. IEEE Internet Things J 5(6):5141–5154
10. DOCOMO White Paper 5G Evolution and 6G https://doi.org/10.1007/11823285_121
11. Lua Y, Zheng X (2020) 6G: a survey on technologies, scenarios, challenges, and the related issues
12. Zhao J (1907) A survey of reconfigurable intelligent surfaces: towards 6G wirelesscommunication networks with massive MIMO 2.0. arXiv:1907.04789
13. Nayak S, Patgiri R (2020) 6G communication: envisioning the KeyIssues and challenges. http://export.arxiv.org/pdf/2004.04024