Vision, Requirements and Challenges of Sixth Generation (6G) Networks

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***Abstract*— The use of wireless connectivity has increased exponentially in recent years. Fifth generation (5G) communications will soon be deployed worldwide. Six-generation (6G) communications vision and planning have begun, and the use of 6G communications is expected to begin in the 2030s. The 6G system has higher capacity, higher data rates, lower latency, higher security and better quality of service (QoS) compared to the 5G system. This paper presents a brief overview on the vision and requirements of 6G wireless communications and networks. Finally, some of the challenges in launching the 6G are also explained.**

Keywords—wireless networks, 5G, 6G, Terahertz communication.

I. INTRODUCTION

The world is waiting for the global arrival of fifth generation (5G) wireless networks, and everyone wants to see the impact on the economy and the everyday world. However, researchers in the field of communications have taken a step forward and started research on sixth generation networks. The thing about 6G is that it follows 5G and tries to make it more complete.

5G is currently in the early stages of implementation, and it is expected that after its full deployment, we will see the presence of 4G for many years and improve its capabilities. The cost of 5G infrastructure is higher than 4G, and this has prevented operators from investing in 5G, but as the costs decrease, the problem will be solved. With the advancement of edge computing, we will see the presence of more smart devices and the positive performance of 5G in smart factories, automated devices and virtual reality streams will increase. The effect of switching from fourth generation to fifth generation networks is the same as the transition from second generation to third generation, which reduced latency and increased the number of communication channels and speed.

We must first examine what needs fifth-generation networks do not meet and try to place them in the next generation. In the world of cellular networks, the goal is to achieve greater speed and frequency spectrum. Preliminary predictions indicate that 6G is expected to offer a speed of 1 terabyte per second. To achieve this speed, we need to transmit signals above 1 terahertz; Frequencies that are generally in the GHz range for 5G. To use this frequency spectrum requires comprehensive research into the nature of frequency, new computing architectures, chip design, and energy sources. Fortunately, research on these topics has begun a long time ago and several articles have been published in this field.

According to some experts, along with the new generation of communication networks, other technologies will be developed or the way of using them will change. For example, with the advent of 5G, smartphones have become more prominent and have become a more practical device from a mode of entertainment. Smartphones play a key role in the discussion of the Internet of Things, smart homes and remote control equipment. Of course, 6G is the era of the transition from smartphones and will be replaced by other more practical technologies that are becoming more popular with the people.

The way data is used will change. With the arrival of the fifth generation of communication networks, smart glasses, virtual reality and other devices will become more useful. New electronic devices and efficient humanoid robots are being built. According to this hypothesis, instead of buying a smartphone that can only do certain things, people go for products that allow them to fully manage a building and have the simplest precise control over smart devices. It takes almost a decade to develop each standard and each generation of wireless networks. So we expect the formation of the sixth generation to take approximately from 2020 to 2029. We predict that by 2035, 5G networks will be fully ubiquitous, after which 6G will be introduced in a limited way.

II. EVOLUTION IN MOBILE COMMUNICATIONS FROM 1G TO 6G

The first analog communication system was introduced in the 1980s. Since then, a new generation of communication systems has been introduced almost every ten years. Each generation has a better quality than the previous generation and with improved QoS level offers new services and new features. The goal of 5G and 6G is respectively to increase capabilities 10 to 100 times, compared to previous generations of wireless communications. Over the past ten years, mobile data traffic has increased dramatically due to the introduction of smart devices and machine-to-machine (M2M) communications. Figure 1 shows the predicted exponential growth of mobile communications. Traffic volume is expected to increase 670 times in 2030 compared to mobile traffic in 2010 [1]. The International Telecommunication Union (ITU) predicts by the end of 2030, total mobile data traffic will be

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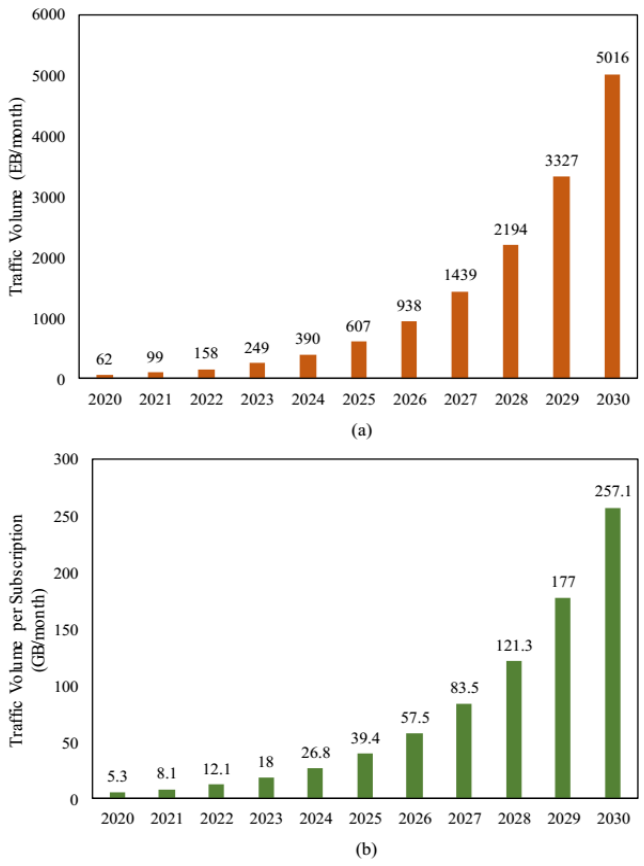

Fig. 1. The predicted growth of global mobile connectivity during 2020-2030 [1], [2]. (a) Total global traffic volume, (b) traffic volume per subscription.

more than 5 ZB per month. The number of mobile subscribers was 5.32 billion in 2010, and is expected to increase to 17.1 billion by 2030.

In addition, the use of M2M communications will increase exponentially. The amount of mobile traffic for each of the relevant devices also increases. In 2010, the volume of mobile traffic was 5.3 GB per month. This traffic will increase 50 times in 2030. Compared to 2010, the number of M2M subscriptions in 2020 and 2030 will increase 33 times and 455 times, respectively. Table 1 compares some of the uses of mobile communications in 2010, 2020 and 2030.

Recently, adaptive and intelligent data-driven methods have become popular with researchers. Intelligent networks based on the fifth generation of wireless communications can provide artificial intelligence operations [3]. It is estimated that by 2030, 5G capacity will reach its final limit [4]. Then, to provide advanced services, intelligent network management and adaptation realized only using 6G networks. Hence, the overgrowth of user needs compared to what the 5G offers leads to the sixth generation of wireless communications. Some key motivational trends behind the evolution of 6G systems are as follows: high bit rate, high reliability, low latency, high energy efficiency, high spectral efficiency, new spectrum, green communications, intelligent networks, network availability, communications convergence, localization computing, control and sensing. Therefore, 6G will be fully digital wireless communication and network [4].

Table I . Global Trends for Wireless Connectivity

Issue	2010	2020 (predicted)	2030 (predicted)	unit
Mobile Subscriptions	5.32	10.7	17.1	Billion
Smartphone Subscription	0.645	1.3	5.0	Billion
M2M Subscriptions	0.213	7.0	97	Billion
Traffic Volume	7.462	62	5016	EB/month
M2M Traffic Volume	0.256	5	622	EB/Month
Traffic per Subscriber	1.35	10.3	257.1	GB/month

III. Vision and Requirements of 6G

A number of research studies have provided vision into 6G and a series of advanced planned research activities have Started [4], [6], [7], [8], [9] and [10]. In [11], [12] and [13], practical implementation, multiple access, air interface and data center are presented for 6G communications. The author of [14] says that with the advent of the 6G in 2030, a fully digital, intelligent, data-driven information society enables almost instantaneous and almost by unlimited wireless connection. 6G will be the main actuator for achievement this scheme; It will connect everything, provides complete wireless coverage, and integrate all functions such as metering, communication, computing, storage, control, positioning, radar, navigation, and imaging, to support full-vertical applications [15]. 6G will be an intelligent systems with human-like intelligence and awareness. It will be both human-centric and machine-centric, and it will provide several ways to communicate and interact with smart terminals [15].

6G usages include mobile Internet and the Internet of Things, because the 6G supports holographic, high-precision communications for tactile applications [16], [17]. This requires real time processing of large amount of data, very high throughput and low latency. In addition, 6G wireless networks support ultra-high quality videos such as SHD and EHD. 6G will have very low latency for the industrial Internet [16]. 6G can be used in very low power Nano-devices for example Internet of Nano Things and health care applications. 6G will expand range of human activity in everywhere such as see and space. 6G can be used in transportation systems including high speed trains and airplanes. 5G applications such as autonomous vehicles and IoT can be enhanced by using 6G. 6G has other uses including further enhanced mobile broadband, ultra-massive machine type communications, enhanced ultra-reliable and low-latency communications, long-distance and high mobility communications and ultra-low power communications [15].

In 6G wireless networks evaluation, several parameters are considered such as spectrum and energy efficiency, peak data rate, user-experienced data rate, area traffic capacity, connectivity density, latency, and mobility [18]. A minimum peak data rate is 1 Tb/s, which is expected to reach up to 10 Tb/s. These are 100 to 1000 times more than that of 5G, respectively [19]. A user-experienced data rate of 100 Mb/s in 5G, this value is improved 10 times in 6G and it is expected to

reach 10 Gb/s for some cases. 6G has low latency (10-100 μs) for high mobility systems such as high speed trains and airplanes. The connectivity density will reach up to 10^7 devices/km^2 and area traffic capacity will reach up to 1 Gb/s/m^2 in 6G, which are several times those of 5G. In 6G, a spectrum efficiency of 5–10 times and an energy efficiency of 10–100 times those of 5G. 6G will provide higher network capabilities for satisfying scenarios and applications for intelligent information society [15].

IV. Challenges of 6G Advancement

There are several technical issues that need to be addressed for the successful 6G deployment, including THz wave challenges, energy production and consumption, intelligence and automation, communications and networks aggregation.

The THz waves provide high data rates. However, data transmission over long distances has some problems because of high path loss. A new transceiver architecture design is needed for the THz communication systems. The transceiver must be able to operate at high frequencies, and we must ensure that very widely bandwidth is fully utilized. An effective range of different THz band antennas and minimum gain is another challenge in THz communications [1]. One of the problems that needs to be solved and is not expected to be a comprehensive solution in the near future is the relationship between the terahertz frequency spectrum and optical lines. The use of fiber optic lines over long distances has its difficulties, and according to the nature of the frequency spectrum, when the wavelength becomes shorter, objects, weather conditions and even foggy weather have a negative effect on the transmission signals. In addition, considering human health and safety, which could be affected by the propagation of THz waves is necessary [20]. Many studies must be done on the physical nature of terahertz signals.

Energy production and energy consumption are both problems in terms of cost and how to use the problems of today's devices. When we look at smartphones, we find that most of them need to be recharged daily and a charger should always be available. This is a limitation and with the advent of 6G there will be more problems. What is the best way to provide energy for data exchange at a low cost? Wireless transmission technology is gradually becoming ubiquitous and there have been some successes, but learning and cost reduction are the biggest obstacles to this technology.

One of the goals of 5G and 6G is the full realization of the Internet of Things and the connection of devices to communication networks. When this is done, we see a dramatic increase in the rate of information exchange, and inevitably we are forced to turn to artificial intelligence so that we can perform information extraction, pattern creation, image processing, and finally automation of tasks in the best possible way. Achieving such a level of intelligence and automation is a great task, but it is not easy to implement. In 6G networks, the balance between privacy and intelligence must be considered. Privacy is to the detriment of this level of intelligence [20]. Higher intelligence results in network complexity and cost.

5G supports different types of networks. 6G aggregates them dynamically. In the process of gradually realizing Internet of Everything (IoE), we encounter the problem of integrating other different complex industrial standards and technologies. In order to better support the IoE and industrial applications, 6G must be able to dynamically integrate multiple technology systems and also be able to intelligently and dynamically aggregate different types of networks and technologies. 6G must be able to aggregate different types of networks and technologies in a smarter and more flexible way to be able to provide complex and diverse scenarios and business needs in a dynamic and adaptive manner [21], [22].

V. Conclusion

Each generation of communication system comes with new features that provide better services to users. The launch of the 5G communication system will begin in 2020 in some parts of the world. Despite its attractive features, 5G will not be able to fully support the growing demand for wireless communication in 2030. Therefore, the sixth generation needs to be launched. Research on 6G has just begun and is still in its infancy. This paper briefly presents the vision and requirements of 6G communications. The main features of the 6G systems are high system capacity, high data rates, low latency, high security and high quality of service (QoS) compared to previous generations. At the end of this paper, some of the existing and possible challenges and obstacles in the way of achieving the launch of the 6G were explained.

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