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Characteristics Analysis of (6G) Wireless Networks: Review, Vision, Challenges

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Abstract

In the midst of the revolution in wireless communications, specialists expect that the current 5G cellular networks will not meet the rapid technical requirements of smart terminals broadly in the next few years. Between 2027 and 2030the expected, a new framework for wireless communication (6G) with the aid of artificial intelligence is expected to be launched. This paper presents a vision and analysis of the upcoming network architecture (6G), The most important technical challenges and possible solutions for (6G).

Keywords: wireless networks; beyond 5G; 6G; satellite networks; terahertz; cell less architecture.

1. Introduction

Cellular wireless communication systems have gone through multiple stages of development that is called generations: at the rate of almost every decade a new generation appears, starting from 1980. The end of the last decade witnessed the launch of the current generation (5G) with features that differ from previous generations in and quality of service QoS provided, including applications Online including online games, HD videos, multimedia, IoT, mobile shopping and payment, and smart homes/cities [1, 3].By the end of 2025, 65% of the world's population will have 5G coverage with ultra-fast internet with published data rate speed test speeds in the range from 193 to 430 Mbit/s [4]. Figure 2 shows a commercial G network diffusion map. South Korea is one of the first countries to launch 5G networks with 86,000 base stations in nearly 85 cities since mid-2019 [5].

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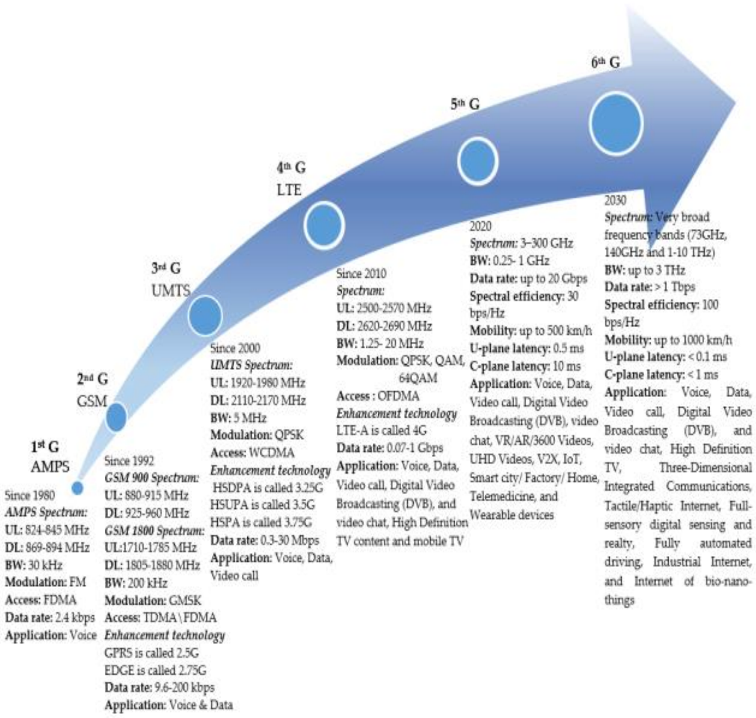


Figure 1: Major Features for different generations of wireless cellular communication (1-6G) [5].

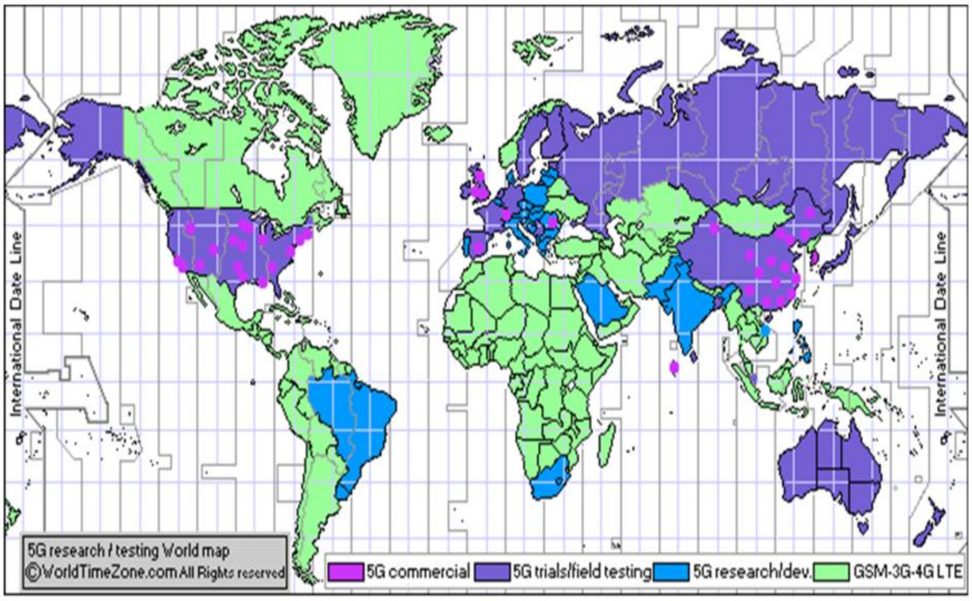


Figure 2: world coverage map to 5G commercial network (December 2019) [6].

Despite the broad services offered by 5G networks, which include ultra-reliable and low latency communications and (uRLC), enhanced mobile broadband (eMBB), massive machine type communications (mMTC), specialists nonetheless anticipate that there will be a significant jump in wireless data demand (data-hungry applications), and the number of connected peripherals will increase up to 100 times in a given cubic meter. In addition, some applications (such as transmit 3D videos) and mobile applications supported by artificial intelligence (AI) technology require more bandwidth that is not currently available in 5G. These challenges prompted academia and industry to develop a future vision for the next generation (6G) [7]. The next generation (6G) is expected to provide extremely high speed, increased capacity for streaming data that will support new applications such as vigorous medicine, computer disaster forecasting as well as virtual reality (VR). Figure 1 shows the stages of development of wireless cellular communication systems [8]. 6G communication systems are expected to provide a large coverage for subscribers due to unconventional technologies, allowing them to communicate with each other everywhere at high speed. Figure 3 shows the timeline for 6G connections.

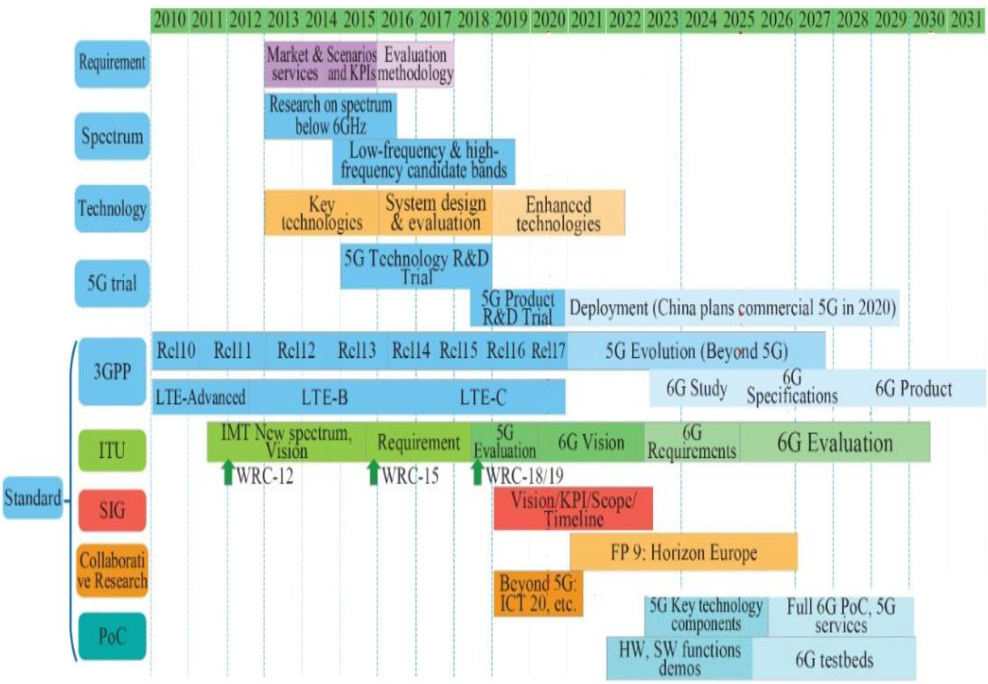


Figure 3: 6G wireless networks Timeline [8].

In this study, a comprehensive and broad conception was presented for most of the controversial topics about 6G communications in the context of services and difficulties in the main effective areas of future mobile phone networks: including, a vision regarding the challenges and solutions available, the main features, and the research activities at recent years for 6G communications.

2. 6G Networks Features for Future

There are some visions explained according to the future needs and requirements of 6G wireless technology.

2.1 The space resource use, frequency, time for 6G

Figure 4 shows, 6G requires to use a wide spectrum compared to previous generations to ensure high data speed. Some studies have suggested the multiplicity of frequency bands used in 6G, for example, millimeter wave band, terahertz band and visible light band to achieve transmission of hundreds of gigabytes per second. On the other hand, mobile phone networks will be combined with satellite systems and the Internet to build integrated networks. In the spatial dimension, a huge number of antennas will be used in transmitters regularly in the so-called ultra-huge MIMO(UM-MIMO) in the terahertz range. In the time dimension, there will be a clear improvement in response time, and there will be flexibility in the versatility of the systems as well, thus facilitating their compatibility with 2G to 5G [9]

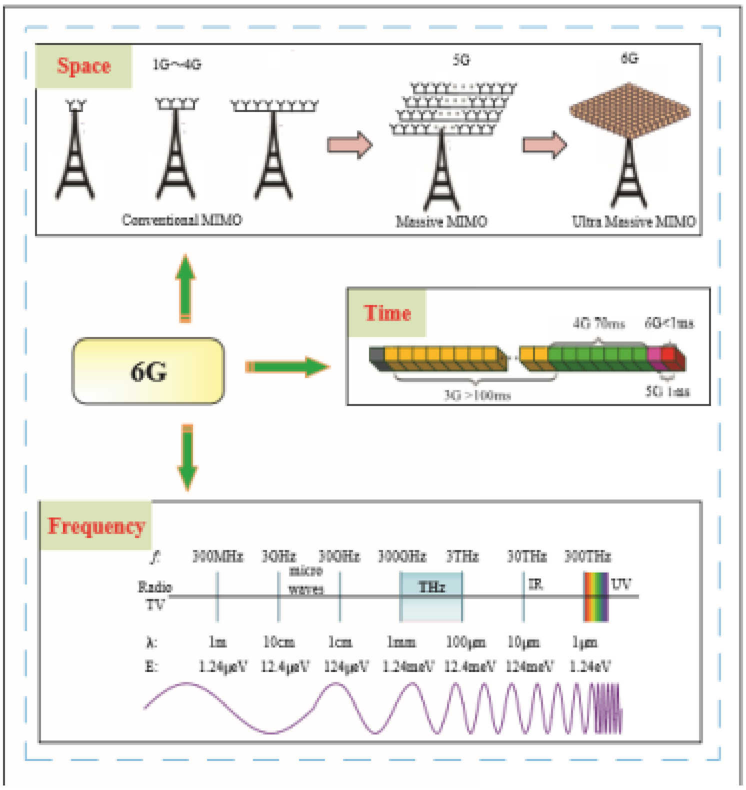


Figure 4: A framework of 6G founded on the space resource use, frequency, time [10].

2.2 Satellite communication channel

Although satellite communication has been used in the fields of navigation, communication and broadcasting for many years, it is still a research hotspot of modern wireless communication, and is used to provide global coverage due to its reliable service quality and low cost [6]. Generally, satellite communication orbits can be divided into geostationary orbits and non-stationary orbits. Geostationary orbit satellites use geostationary satellites 35,786 km above the equator to communicate; according to the distance from the satellite to the earth, non-stationary orbits can be further divided into low orbits, medium orbits, and high orbits. The frequency bands commonly used in satellite communications include Ku (12-18 GHz), K (18-26.5 GHz), Ka (26.5–40 GHz) and V (40-75 GHz) frequency bands. Satellite communication channels are greatly affected by dynamic weather conditions (such as rain, clouds, snow, fog, etc.). Rain is the main cause of satellite signal attenuation. Important factors, especially for electromagnetic waves in the frequency band above 10 GHz. In addition, the satellite communication channel exhibits the characteristics of great Doppler shift and Doppler spread, frequency correlation, large coverage area, and long communication distance. Due to the extremely long communication distance, the satellite communication channel can be regarded as line-of-sight (LOS)transmission, and the multipath effect can be ignored. At the same time, it is necessary to use large transmitting power and high-gain antennas to counter the large path loss caused by long distances and high frequency bands. Figure 5 shows the satellite network with 6G.

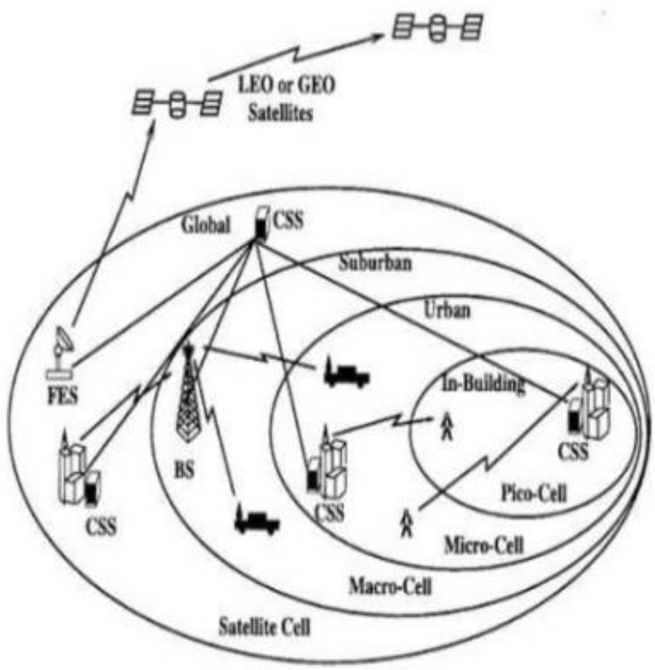


Figure 5: 6G with Satellite Network [11].

2.3 Connectivity vision to 6G

Artificial Intelligence(AI) technology will be an inevitable choice as the basis for building a 6G network, and "intelligence" is a feature of 6G. For Figure 6, the 6G vision can be summarized, where we note three features of smart communication "Deep Connection", "Holographic Connection" and "Universe Connection". Smart connectivity will overcome many of the challenges that will face 6G networks, namely, more complex and massive networks, meeting the needs of many terminals and smart devices, many and complex applications, as well as the complex and huge network itself needs smart management[12]. Ten years later (~2030), by connecting "anytime, anywhere" we will reach a more and more wide world. For the future vision of 6G, the nerve center of 6G will be "smart connectivity"; "ubiquitous connectivity", "deep connectivity" and "holographic connectivity" will be the core of the 6G network.

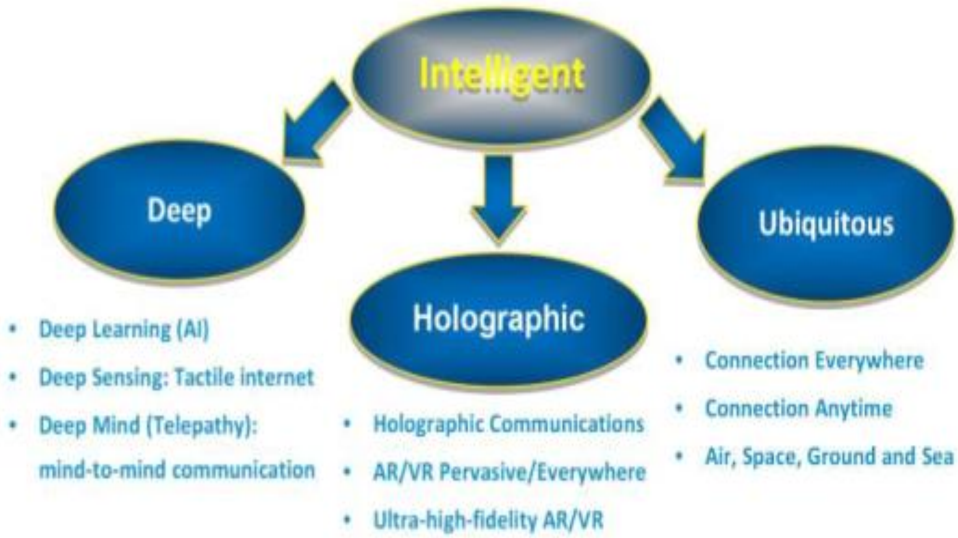


Figure 6: 6G vision [9].

2.4 6G Network Architectures

It is proposed that the 6G network be with a "cell-free" communication architecture, also called cell-free, to address the poor performance resulting from the handover of cellular stations [12]. In such an architecture, the subscriber can access the cooperative base station (or access points (APs)) by means of multipoint transceivers. Cell-free communication can lead to enhanced communication and reduced latency caused by the delivery process, which will be enhanced by the rapid deployment of heterogeneous communication systems and the use of multiple frequency bands [13]. The user machine in such an architecture will automatically select the best link from the available heterogeneous links. In a word, cell-free networks will enable easy transition of service subscribers, easing the traditional delivery process that causes data loss and delivery delays/failures. Figure 7 shows the Cell-Less 6G Network Architecture.

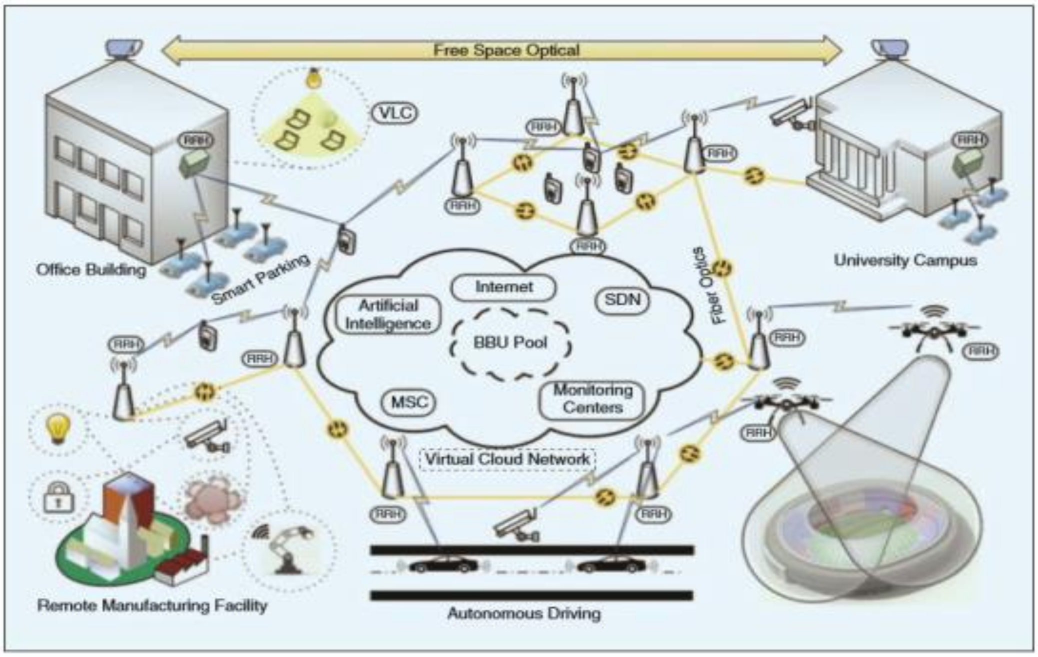
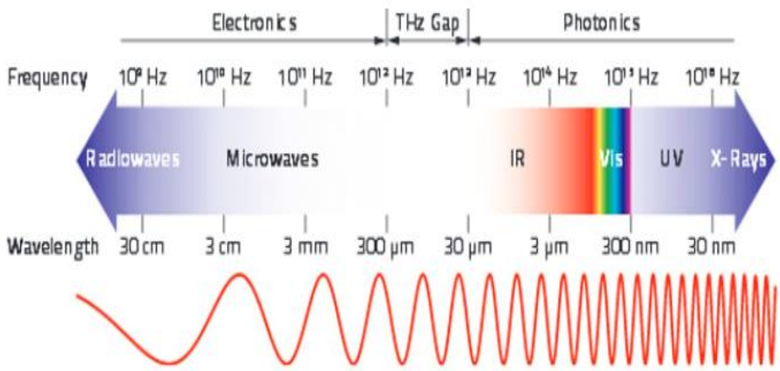


Figure 7: The Cell-Less 6G Network Architecture [14].

2.5 THz Communicat

The wireless data, expected to jump several times in 6G, with the number of terminals equipment expected to increase hundreds of times/ m^3. In addition, new bandwidths not available in the currently used (mm) bands are thought of as a necessity for some data-hungry applications (eg 3D video transmission). The terahertz wave is the electromagnetic wave whose frequency range is between microwaves and light waves (its spectrum lies between (0.1 and 10) terahertz and the wavelength is between (30 to 3000) microns) [15]. Compared with microwave and wireless optical communication, terahertz communication has many advantages for its unique characteristics, which determine that it has broad application prospects in secure broadband wireless access, high-speed short-range broadband wireless communication, satellite communication and so on. Terahertz wave has narrower beam, better guiding due to its narrower beam which gives it anti-jamming capability which can achieve secure communication within 2-5 km. On the other hand, terahertz wave is easily absorbed by moisture when it propagates in the air, which is suitable for high-speed wireless communication over short distances. Terahertz wave, it can achieve long-range lossless and extremely low-energy communication in outer space because it has near 350, 450, 620, 735 and 870 micron relatively transparent atmospheric windows. Terahertz wave, compared to optical wireless communication, has a wider frequency range, lower quantum noise, and the receiver is easy to align so it can be used in space communications. The electromagnetic spectrum, terahertz wavelength, and millimeter waves are shown in Figure 7 [16].



Frequency (THz)	Wavelength (µm)	Propagation mechanism	Attenuation effects	Supported link distances (m)	Approximate Bandwidth (THz)
0.3-3	1000-100	LOS, Reflection	Free Space Loss	< 10	Up to 0.3
3-30	100-10		Molecular Absorption High H_2O Peaks	< 1	> 1

Figure 7: Electromagnetic spectrum and wavelength of terahertz and millimeter waves [16].

3. Requirements and Challenges

There are many challenges and technical requirements for the 6G network. Researchers and specialists are working on upgrading and improving the performance of the fifth generation network to suit the current demand, including increased throughput, low delay, high reliability and the largest number of connections. In this section, we will present, discuss and analyze some of the technical requirements and challenges associated with the 6G network.

3.1 Peak Rate- THz Signal Generators

Increasing the peak rate of wireless mobile communication systems is a basic requirement, and it is one of the main technical indicators that the first generation of wireless mobile communication systems have sought to follow since its inception. Peak demand is expected to increase at the end of the current decade (~2030) outpacing what the current 1-5G mobile communication systems provide [17-24]. In a 6G view, the peak rate is assumed to be terabits (Tb/s). The exponential distribution of peak rate growth for the 1-5G mobile system is measured according to the starting time of each generation. The realistic vision of 6G, at least two applications can be seen that need a high peak rate: smart applications, 3D communications, and AR/VR augmented reality. Smart (big-data) applications require massive data transmission and this is a demand pushing for 6G, while 3D communications and AR / VR will be high-resolution and require a much higher data rate than other wireless applications we know today. To achieve high-definition immersive AR / VR, less interaction delay is also required, we also want to meet the high-speed demand anytime, anywhere, ultra-fast coverage performance.

3.2 Higher Energy Efficiency

It is expected that the next generation 6G networks will enjoy high throughput, high bandwidth, and the deployment of very large number of wireless nodes everywhere, which will face a huge challenge in energy consumption, resulting in huge carbon emissions and very high operating costs. Increasing bandwidth and spectrum efficiency will allow for a significant increase in throughput, while remaining a more serious energy efficiency problem. The huge number of dense and ubiquitous sensors, the massive data processing power consumption for “smart connectivity”, and the extremely large antenna processing power consumption are challenges that will lead to higher total power consumption while aiming to reduce power consumption per bit (J). /bit) as far as possible for the future 6G network [25].

3.3 Connection Everywhere and Anytime

Day after day the world is witnessing the progress of science and technology, in turn, human activities are expanding more, and it is expected to reach more, and the active areas will reach outer space, high altitudes, and the depths of the seas and oceans. The nodes of communication and nodes of the Internet of Things will spread over a wider area of people. The future communication networks can be described: covering space, air, land and sea, the Internet of everything, all purposes, possessing the characteristics of everything that exists everywhere, that is, anyone can interact and communicate with anyone [26].

3.4 New Theories and Technologies

Adding more spectrum resources available is one of the advantages of the next generation. On the other hand, it is necessary to strengthen some basic technologies, and make some breakthroughs in basic areas, for example, the new channel coding and modulation mechanism, the new signal sampling mechanism, the theory and technology of communication based on artificial intelligence and terahertz communication technology.

3.5 Self-Aggregating Communications Fabric

In addition to any of the technical and technical challenges and problems mentioned above, there are some non-technical challenges and problems that the 6G network must overcome to ensure its smooth launch in the future, such as consumer habits, trade barriers, policies and regulations. Mobile communications are no longer confined to their own field only, but will become more comprehensive, that is, they will penetrate into the social aspect and life in a large way and will be integrated with other vertical industries. On the other hand, the inherent behavior or relationship of interests pursued by other and traditional industries will create industrial barriers to the entry of mobile communications. Anticipating the use of the new frequency spectrum (terahertz) in the 6G system will face another non-technical limitation, as it requires coordinated allocation around the world to be as unified as possible, and coordinated with users of the same spectrum in other fields, for example meteorology and radar. After anticipating the entry of satellite communications, it will face severe restrictions in policies and regulations. Satellite communications will face more challenges in delivering global roaming.

5. Conclusion

In this paper, the most prominent technologies that will characterize the sixth-generation networks are discussed. On the other hand, the most prominent challenges and problems expected in 6G communication systems, which are considered an obstacle to future development, were identified. Next generation networks will support new frequency bands, most notably terahertz and visible light spectra, in addition to using the frequency bands used in 5G. From the structural side, 6G networks will support cell-free and aerial architectures to provide a hyper-connected society by 2030. At the end of this study, potential future conditions and requirements for important wireless multimedia data services are identified based on their set of KPIs. Ultimately, planning an advanced communications network that supports both AI and QML is essential to the success of a quality experience for advanced video and image applications.

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