The Development of Mobile Communications in 5G and 6G

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Received: January 2021 Revised: February 2021 Accepted: April 2021

ABSTRACT:
Extensive use of communication and information technologies has led to the introduction of different generations of mobile communications. The first to fourth generations (1G-4G) of communication are fully recognized in the world, the fifth generation (5G) is gradually being implemented in different countries, and studies and research on the sixth generation (6G) are in the early stages. The development and deployment of the new generation of mobile communication will have a significant influence on the development and presentation of mobile communications. In this paper, a brief review of the development trend of mobile communication generations with a focus on 5G and especially 6G has been done with respect to the visions, technologies, challenges and issues related to these two generations.

KEYWORDS: wireless communications, wireless networks, 5G, 6G.

1. INTRODUCTION

In recent decades, much progress has been made in the field of mobile communications. By changing the nature of the system, rate, technology and frequency, a new generation (G) of communications is introduced. Each generation has new standards, capacities, techniques and features compared to the previous generation. The first generation (1G) was fully analog and offered only voice calls to users. With the introduction of the second generation (2G) which was a digital technology, it became possible to send text messages to users. Third generation (3G) supports multimedia messaging service (MMS) with higher data transfer speeds and increased capacity. The fourth generation (4G), by combining 3G mobile internet and fixed internet, was able to support wireless mobile internet, also increases QoS and bandwidth and reduces resource costs. The fifth generation (5G) offers Wireless World Wide Web (WWWW), while the sixth generation (6G) proposes to integrate 5G and satellite networks to provide full global coverage of mobile communications [1].

Currently, 5G wireless communication systems are being implemented in various countries. To be successful in this implementation, technical issues related to 5G must be continuously enhanced and improved, for example, cases related to the Internet of Things (IoT) and industrial usages must be examined. Producing and setting up 5G infrastructure requires a higher cost than 4G infrastructure, by reducing costs, operators can be encouraged to invest in 5G. With the advancement of technology, smarter devices will be introduced that can use 5G. 5G has less latency and more communication channels and rate than 4G.

Research on 6G has been under way for some time, but it is still in its infancy. First it is necessary to examine the shortcomings of 5G. In general, the goal of mobile communications is to achieve higher frequency spectrum and data rates. It is predicted that the data rate in 6G will increase to 1 terabyte per second, to achieve this data rate, signals must be sent at frequencies above 1 terahertz. While sending signals in 5G is in the GHz range. Comprehensive research is underway to use the terahertz frequency spectrum in various fields such as the characteristics of this frequency band, chip hardware design, computational and software architecture, and energy resources.

With the advent of the new generation of mobile communications, other technologies are evolving or changing the way they are used. With the advent of 5G, For example, smartphones play an important role in the development of the use of the IoT, smart homes and other remote control equipment. Also, with the advent of a new generation of mobile communications, the way of processing, mining and using of data will change. For instance, with the advent of 5G, the use of smart devices and applications has increased. It is worth noting that with the advent of 6G, other technologies and applications will be introduced that will replace smartphones.

Paper type: Research paper
DOI: https://doi.org/10.52547/mjtd.10.2.87
How to cite this paper: N. Khiadani, **"The Development of Mobile Communications in 5G and 6G"**, *Majlesi Journal of Electrical Engineering*, Vol. 10, No. 2, pp. 87-95, 2021.

Based on the experience of implementing and using the previous generation mobile communication system, we know for standardization and development of each generation of wireless networks, almost ten years is required. In general, when one generation entered the implementation phase, the attention of experts was drawn to the study of theoretical and technical cases of the next generation. For example, studies on 5G started ten years ago and we expect 5G to be used in all countries by 2035. Also, the study on 6G has been started for some time and we expect the studies to be completed by 2029 and then 6G will be implemented in some parts of the world, albeit in a limited way.

The continuation of this article is as follows: First, Section two provides a brief description of evolution from the 1G to the 6G. The third and fourth sections present the features, applications and challenges of the 5G and 6G, respectively. Conclusions are presented in the fifth section

2. THE EVOLUTION OF MOBILE COMMUNICATION GENERATIONS

Since the 1980s, every decade, a new generation of mobile communication systems is introduced. Increasing advances in information and communication technology have resulted in the development of communication systems.

The first generation of mobile communications (1G) was introduced in the early 1980s. The data rate in this generation is a maximum of 2.4 Kbps. The main subscribers that used this generation include Advanced Mobile System (AMPS), Total Access Communication System (TACS) and Nordic Mobile Telephone (NMT). This generation has many shortcomings including low capacity, low quality voice communications and insecurity [2].

In the late 1990s, the second generation of mobile communications (2G) using digital technology was introduced. The first 2G system, called Global Mobile Communication Systems (GSM), supported data communications and data rates of up to 64 kbps. Also in this generation, services such as text messaging and email were provided. GSM, Code Division Multiple Access (CDMA) and IS-95 [2], [3] were the most important technologies of this generation.

The new generation that was introduced after 1G and 2G was called 2.5G, which was created by combining 2G with General Packet Radio Service (GPRS) and a number of new features. The framework used by the 2.5G system is the same as the 2G system, but it also uses packet switching, while previous generations used only circuit switching. The data transfer rate in this generation increases to 144 kbps. GPRS and Enhanced Data Rate for GSM Evolution (EDGE) were the main technologies of this generation [2], [3].

The third generation of mobile communications (3G) was introduced in 2000. In 3G, the data rate reaches up to 2 Mbps, and this generation also integrates high speed mobile access with Internet Protocol (IP) services. Specifications of this generation include higher data rates than previous generations, improved service quality (QoS), global roaming and better voice quality [2], [3] .In addition to voice calling, 3G offers advanced services to users, including data services, TV / movie access, , email, web browsing, video conferencing, pagination, fax and navigation maps. This generation's bandwidth is 15-20 MHz, which is used for high-speed Internet, video chat, etc. An organization called the 3rd Generation Partnership Project (3GPP) introduced the 3G mobile communication system. This system is known in Europe as UMTS (Universal Mobile Telecommunications Systems). ITU-T calls this system IMT2000. In the United States, this system is called CDMA2000 [1].

With the advent of technologies such as Wideband CDMA (WCDMA), High Speed Uplink / Downlink Packet Access (HSUPA / HSDPA) and Evolution-Data Optimized (EVDO), a new intermediate generation of wireless communication called 3.5G was introduced, the data rate of 3.5G is 5 -30 Mbps [3].

The next intermediate generation was called 3.75G, which introduced Long-Term Evolution technology (LTE) and Worldwide Interoperability for Microwave Access (WIMAX). Using LTE and WIMAX increases the network capacity and lots of users can use some services including video on demand, web services and peer-to-peer (P2P) file sharing [2], [4], [5], [6].

In the late 2000s, the fourth generation of mobile communications (4G) was introduced, which was all IP-based. The main objective of 4G technology is to provide high data rates, high capacity, high quality, security and low-cost services through a common IP-based platform for voice and data services, multimedia and the Internet. The data transfer rate in this generation is from 100 Mbps to 1 Gbps [1]. 3GPP introduces the LTE Advanced standard as the 4G standard with WIMAX. 4G services include multimedia messaging service (MMS), high-definition TV content and mobile TV, digital video broadcasting (DVB) and video chat, [4], [5], [6], [7], [8].

The fifth generation of mobile communications (5G) is being implemented in different parts of the world since 2020. 5G has a high data transfer rate, very low latency, low power consumption and lots of connections. The three basic services are Enhanced Mobile Broadband (eMBB), Massive Machine Type Communication (mMTC), and Ultra Reliable Low Latency Communications (URLLC) [5], [9], [10].

Sixth generation of mobile communications (6G) is the integration of 5G and artificial intelligence and the advent of new information technologies, such as edge

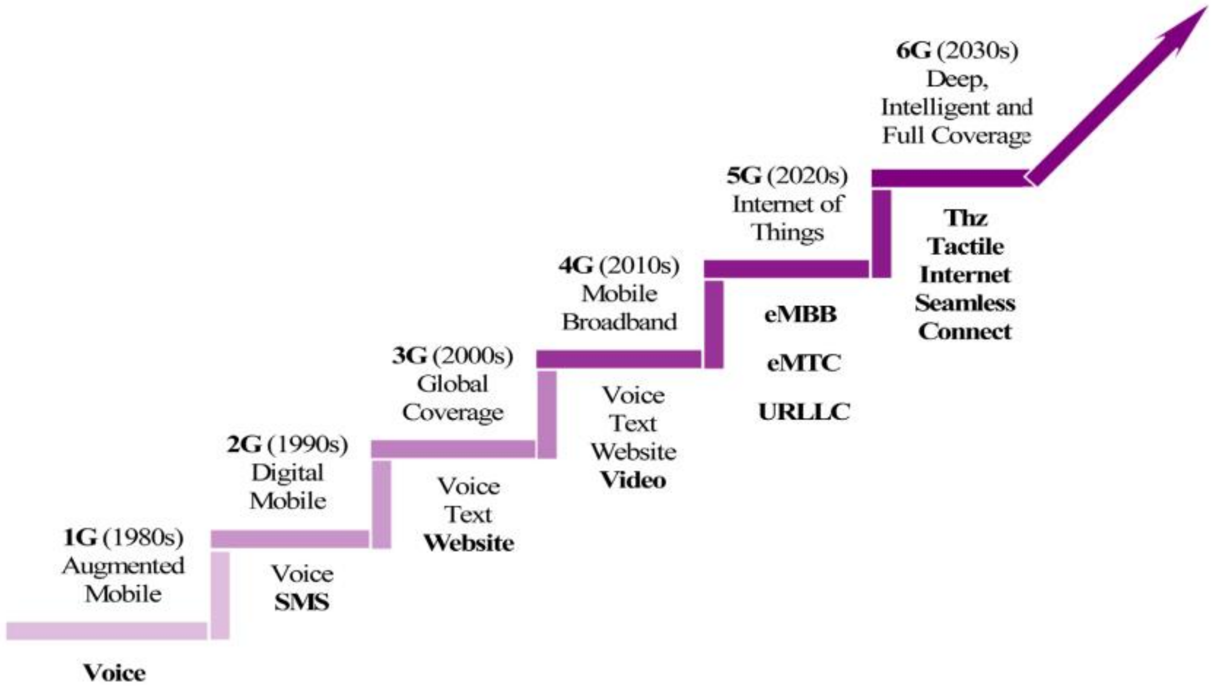

Fig. 1. Evolution trends and technologies of different generations of mobile communications [11].

computing and big data. 6G has many applications in industries, transportation, and healthcare and so on. The 6G network can integrate the IoT and various industries by connecting everything deeply, intelligently and seamlessly [10].

Figure 1 shows the evolution of mobile communication generations from 1G to 6G. As wireless technologies grow, data rate, mobility, coverage, and spectral efficiency increase and new services are provided.

3. VISION AND REQUREMENTS OF 5G

With the growing demand of users, a new generation of wireless communication called 5G was introduced. 5G uses two advanced multiple access technologies called Beam Division Multiple Access (BDMA) and Non- and quasi- orthogonal or Filter Bank Multi Carrier (FBMC) multiple access [12]. 5G has very useful IEEE standards 802.11ac, 802.11ad and 802.11af [13], [14], [15], [16], [17]. 5G supports many devices and applications such as smartwatches, autonomous vehicles, IoT and tactile internet. The ITU has considered three basic services in 5G, which include eMBB, eMTC and URLLC. 5G wireless communication systems ought to face six challenges, which consist of higher capacity, higher information rates, decrease end-to-end latency, plenty of device connectivity, cost reduction, and reliable Quality of Experience provisioning [18], [19]. The following are 5G challenges [20]:

3.1. High Data Rates

The most important evaluation parameter in different generations of mobile communications was data rate. The appearance of mobile internet and services such as high definition (HD) video streaming, virtual reality on smartphones, in addition to increasing the number of tablets, laptops and other wireless devices, have increased the data rate of the communication network. Has been mobile. 5G networks have a maximum data rate of about 10 Gbps, which is 100 times better than current 4G networks [21]. In addition to increasing the maximum data rate, within the most noticeably worst case, at the edge of the cell, the information rate ought to increment to 100 Mbps, which is hundred times way better than 4G systems data rate at the edge of the cell. Capacity is, in fact, the optimal estimate of the maximum data rate that the user can experience. However, the impact of adjacent and co-channel interference and path loss make the maximum information rate tough to attain. Hence, the data rate at the edge of the cell is more technically important, since this data rate must back 95% of clients associated to the network. Another parameter that is determined based on the data rate is the area capacity. This parameter determines the full sum of network data for each unit of the region. By definition, the capacity of a region unit is usually bits per second per unit of range. This standard has expanded 100 times in 5G compared to 4G network. This request for data rates can be attained by methods like massive MIMO systems, millimeter-wave communications and Wireless Software Defined Networks (WSDN), and so on [20].

3.2. Low Latency

5G supports some applications like tactile internet, virtual reality and multiplayer games, the acceptable latency for these applications is about 1 millisecond [22]. Tactile Internet is a relatively new application that uses wireless networking for real-time control applications. The acceptable delay in these programs is about 1 millisecond [23]. 5G supported applications communicate with the user in real time, and since any system latency is undesirable for the user, latency is an important parameter in 5G. 5G networks support machine type communications (MTC). MTC communication means automatic communication of devices with each other [24]. MTC-based applications should have very little latency. To achieve this level of latency reduction, SDNs must be used to plan an adaptable design within the upper layers of the network, as well as innovative technologies in waveform design [20].

3.3. Reducing Energy Consumption

5G wireless systems lead to the further development and application of IoT [25]. IoT devices are actually a group of sensors that, according to the purpose of use, collect information in surroundings and send it to a base station as central server. These sensors usually consume very little power, not be expensive and have a long life. These sensors are not continuously associated with the base station and they were turn on sometimes, they must be synchronized with the base station each time they are turned on. Because the synchronization phase consumes more energy than the data transfer, the battery of these sensors is not capable of performing synchronization every time. The 5G solution for this is to support loose syncing or no need for syncing. 5G also places restrictions on the power required for decoding computational operation, header length, and data transmission, and more. As the number of associated intelligent gadgets increments, so does the number of base stations required to back these gadgets. Since the cells are tiny, the number of required base stations will increment. Base stations must save energy because even a small amount of energy savings can lead to large energy savings on a large scale [20].

3.4. High Scalability

As the number of gadgets associated with the network is continually expanding, scalability is an imperative parameter within wireless communication network planning. With the coming of 5G, the IoT and vehicle-to-vehicle (v2v) communication innovations are growing significantly. Therefore, to effectively support a significant increase in the number of smart devices and services, the network must be highly scalable. In fact, all sections and layers of the network must be scalable. At the physical layer, we must be able to transfer large volumes of data, so there must be sufficient resources in the frequency spectrum. Also, the transmitted power must be controlled to minimize interference. At the MAC layer, protocols must be designed so that a large number of devices can access the channel. In network and transmission layers, intelligent routing algorithms must be designed for a large number of users [26]. Utilizing WSDNs, and virtualizing network performance, scalability in networks can be attained by changing all layers of radio access to core networks [20].

3.5. Connectivity and Reliability

Improving coverage and handoff efficiency is another requirement of wireless networks, especially when using millimeter wavelengths. With the increment within the number of base stations and the number of associated gadgets, as well as the presentation of tiny cells, femtocell and picocell, the number of handoffs to and from the base station will at slightest twofold. Therefore, we need new methods to provide better service at the edge of the cell. Another issue is authentication and privacy related to the handoff [27]. Each communication with the authentication server takes hundreds of milliseconds while the acceptable delay in 5G is one millisecond. Because millimeter waves have a higher frequency band, the signal transmission range is enormously decreased. Consequently, keeping up network could be a huge challenge for 5G networks. For important and essential services, high reliability and connectivity must always be maintained.

3.6. Security

Following the popularity of mobile payment applications and digital wallets since 2015, the security of wireless networks has received much attention [28]. The general objective of security is, to secure the base association and maintain client privacy. Because the 5G system faces a significant increase in data traffic across the network, 5G security, in addition to providing a reliable connection to users, takes into account the security of the entire network, including authentication, authorization and accounting, development of new encryption protocols and security of cloud computing and administration exercises. 4G networks could not provide a single standard for user privacy, 5G networks have fully addressed this issue. Given the proliferation of IoT in 5G networks, security issues need to be considered more carefully, and different parts of the network, such as operators, manufacturers, services, and protocols, need to work together on a variety of security issues. On the other hand, the Internet has ended up one of the essential frameworks of society, so new national laws regarding the security obligations of wireless networks must be considered.

4. VISION AND REQUIREMENTS OF 6G

Experts estimate that 5G will reach its final capacity by 2030 [29]. Therefore, we need to introduce the new generation of mobile communications, 6G, to benefit from advanced services, intelligent network management and compatibility. A number of research papers on 6G have been submitted and a number of advanced research activities have been initiated [29], [30], [31], [32], [33], [34]. Practical implementation, multiple access, air interface and data center for 6G communications are presented in some articles [35], [36], [37]. The 6G system uses new technologies consist of Wireless Tactile Internet (WTI), High Performance Computing (HPC) and Visible Light Communication (VLC) [30], [38], [39], [40]. 6G compared to previous generations has a higher peak data rate, a higher user experience data rate, , higher traffic density, lower end-to-end latency, higher spectrum efficiency, stronger spectrum support capability, higher connection density, stronger mobility stronger situating capability, higher network energy efficiency , higher reliability, , and so on [41], [42], [43].

Some of the features of 6G are as follows [11]:

- The maximum data rate in 6G is 1 Tbps, while for 5G it is 20 Gbps.
- 6G user experience rate is of the order of Gbps, while this case in 5G can reach a maximum of 1 Gbps
- The maximum latency of 6G is 0.1 ms, which is almost the same as on-line processing, while in 5G the latency is one milisecond.
- 6G traffic density can be varied from 100 to 10,000 $Tbps/m^2$, while 5G can support a maximum traffic density of 10 $Tbps/m^2$.
- 6G provides services to mobile users at speeds above 1000 km/h such as airplanes and high-speed trains, while 5G is capable of service at speeds of up to 500 km/h.
- The 6G spectral efficiency is varied from 200 to 300 bps/Hz, whereas in 5G we can only send 100 bps per Hz.
- Reliability (coding error rate) in 6G is 10^{-6} or less, which is 10 times better than 5G.
- 6G positioning accuracy is 1 meter for outdoor and 10 cm for indoor, while in 5G the values are 10 times higher.

4.1. Applications of 6G

In fact, 6G is a continuation of the 5G system and improves its performance. Applications intended for 6G include healthcare, Internet access over the air, holographic communications, smart city, emergency rescue systems, autonomous systems, intelligent industries and wireless tactile Internet, and more.

4.1.1. Healthcare

With the advent of 6G and the use of interdisciplinary sciences like biosciences, biomaterials, bioelectronics and bioelectric, many advances in health and medicine can be achieved. 6G can combine medical imaging results such as MRI, CT and test results such as blood and urine to give a more precise evaluation of a person's wellbeing. Also, artificial intelligence can have many applications in surgical and diagnostic work [44], [45].

4.1.2. Internet Access over the air

The air network offers two types of services: ground base stations and satellite communications. Each of these two types of services faces challenges. For example, the ground station must solve the problems caused by the high speed of the aircraft. The satellite station must provide high quality internet. Solving these challenges requires a very high cost. Due to the capabilities and technologies used in the 6G network, attaining the Internet anywhere and anytime with high quality and high data rate and low cost will be possible. [46].

4.1.3. Holographic Communication

5G supports holographic communications such as Augmented Reality (AR) and Virtual Reality (VR). The most important factor influencing the widespread use of AR and VR is that users have no restrictions on location and movement. With the rapid advancement of technology, holographic communications are gradually being upgraded from AR and VR to Extended Reality (XR). By presenting innovations and advances in this field, holographic wireless communication can be achieved. Holographic communications and holographic displays can be used anytime, anywhere. XR can simulate all five human senses and emotion [33],[47]).

4.1.4. Smart City

With the advancement of technology, communication systems have gotten to be an essential open foundation for smart cities. 6G supports data-driven activity processing applications by providing high-speed wireless communication. 6G offers a more efficient and comprehensive network by combining integrated network architecture and new protocols. By integrating artificial intelligence and 6G system at different levels, a new definition of smart city can be provided [48], [49], [50], [51].

4.1.5. Emergency Rescue Systems

6G can provide integrated network coverage in all areas. In fact, ubiquitous connectivity is one of the most important features of 6G systems. 6G can cover the blind spots of the existing network, like profound oceans and seas, valleys, mountains and deserts. In addition to extensive coverage, the 6G communication network has adaptably, ultralow power consumption and high accuracy. 6G offers many programs to save lives in emergencies and unpredictable events [52], [53].

4.1.6. Intelligent Industries

6G has very wide bandwidth, high reliability and ultralow latency, so it performs very well for realtime work information collection of machines, peripherals and workshops. Artificial intelligence and edge computing increase the accuracy and speed of work [54], [55]. With blockchain, data can be exchanged directly between all terminals of an intelligent industrial center, resulting in decentralized operations and increased industrial productivity. The 6G system flexibly connects any smart device / terminal within the industrial center and can integrate smart devices at the request of the product line.

4.1.7. Autonomous Systems

6G system can simplify the use of autonomous systems like Unmanned Aerial Vehicles (UAV).and self-driving vehicles. 6G makes it possible to use self-driving vehicles on a large scale. UAVs can be used in various fields, from military to agricultural and commercial applications, and many more. Also, in cases where the base station is down or non-existent at all, UAV can be used as High-Altitude Pseudo-Satellites (HAPS) to establish network coverage in that area [56], [57]

4.1.8. Wireless Tactile Internet

"Tactile Internet" means a communication network that can send control, touch and sensing / driving information in real time. The Internet is currently utilized to exchange data. Tactile Internet In addition to doing current Internet work remotely, it can remotely transmit and control subjects perceived through the sense of touch. 6G can provide Tactile Internet using artificial intelligence and IoT [58].

4.2. 6G Challenges

Each generation of mobile communications development faces challenges that include technical and non-technical challenges. 6G is no exception from this issue.

4.2.1. Technical challenges

6G technical challenges include terahertz waves, energy efficiency, everywhere and anytime connection, self- Communications and Networks Aggregation and Intelligence and Automation [11].

A. Terahertz Waves

There are many benefits to using high frequency waves, but there are also many challenges. The most important ones include free space loss and shadow fading and rapid changes in channel characteristics. The free space loss increases with increasing frequency. As the frequency increases, the effect of shadowing and signal attenuation increases due to absorption by obstacles. Also, increasing the frequency reduces the channel coherence time, ie the rate of channel changes increases over time and the channel conditions do not remain constant during the signal transmission. Therefore, the transceiver architecture must be designed with these in mind. The transmitter and receiver must be to have a good performance at high frequencies. Also, this very wide bandwidth should be able to be fully utilized. On the other hand, there are issues that terahertz waves are harmful to human health and safety.

B. Energy Production and Consumption (Energy Efficiency)

The 6G communication system has ultra-large wireless nodes, ultra-wide bandwidth, and extremely high throughput, and, so it requires a lot of energy. Even if energy consumption can be slightly reduced for each node, large-scale savings will be made. In addition, data processing consumes a lot of energy, as a result, intelligent connection of network components poses a significant energy consumption challenge. Therefore, saving energy is very important for 6G.

C. Everywhere and Anytime Connection

One of the goals for 6G is extensive coverage everywhere and at all times. To achieve this, there must be an ubiquitous IoT, a global recognition system, and a global network based on big data and deep learning. The goal of 6G is for anyone to be able to communicate with any object, anytime and anywhere [59].

D. Communications and Networks Aggregation

5G supports different types of networks. 6G aims to integrate a variety of networks, dynamically. To achieve this goal, several technical standards must be integrated and also integrated with complex technologies. The new concept that is being introduced is the Internet of Everything (IoE). 6G supports IoE and industrial applications by dynamically integrating multiple technology systems and aggregating different types of networks and technologies intelligently and dynamically. As a result, 6G can meet the complex and diverse needs of business and industry in a dynamic and adaptable way. [47]

E. Intelligence and Automation

6G dramatically increases the rate of data exchange to extract information, create patterns, process images, and ultimately automate tasks, so we need more AI than ever before. There is always a tradeoff between privacy and intelligence. Enhancing privacy prevents us from using high-level artificial intelligence [60]. On the other hand, using higher levels of intelligence will increase the cost and complexity of the network

4.2.2. Non-Technical Challenges

Non-technical challenges of 6G consist of industrial barriers, spectrum allocation and usage rules, and policies and regulations. 6G has many applications and can be used in many parts of society. That is, mobile communications will be integrated with other industries and fields. However, some industries or fields are reluctant to cooperate and create barriers to 6G deployment [61]. The use and allocation of terahertz frequency spectrum requires cooperation and coordination from different regions and countries. A single frequency range should be agreed upon and allocated as far as possible. Necessary coordination should also be established with users in other parts of the spectrum. [60]. Also, regulations and policies place many limitations on the widespread use of mobile communications. First, the differences in technical regulations between countries must be addressed, and second, global roaming issues must be considered. How to coordinate between different communications systems will be a complex issue [33], [62].

5. CONCLUSION

According to the generations of mobile communications, on average, every 10 years, a new generation of communication system is introduced. Each generation has newer features and provides better services to users than the previous generation. This paper provides a brief overview of the generations presented with a focus on 5G and in particular 6G. This article focuses on 5G and 6G perspectives, technology, applications and challenges. From 2020, the 5G system is gradually being implemented in different countries. With the advancement of technology, increasing demand for wireless communications, increasing data volume and the like, the 5G system can no longer fully support the services of interest to users. Therefore, the new generation of mobile communications, 6G, must be introduced. Preliminary research on 6G is in its infancy. 5G and 6G communication generations have higher system capacity, higher data transfer rate, less latency, higher security and higher quality of service compared to 1G to 4G generations. It is worth noting that in most cases the features of 6G are at least 10 times better than 5G. Although these two generations have many applications, but the development of each of these two generations, especially 6G, faces many technical and non-technical challenges. Using artificial intelligence and other innovations, 6G will meet the multiple needs of users, industry and society.

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