

Overview of 6G: Potential Trends and Applications

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Abstract—With the developing technology, the demand for the use of mobile communication is also increasing. It takes time to establish a standard for mobile communications. The increase in the number of devices using mobile communication and the technological diversity bring the need for faster communication in this regard. While 5G mobile communication network being tested in certain regions, studies on 6G have also accelerated. With 6G technology, people's interaction with artificial intelligence will greatly increase and new experiences will be gained in many subjects such as the internet of things, autonomous vehicles, and remote surgeries. The widespread use of artificial intelligence algorithms brings with it the necessity of very high processing power. It is also thought that 6G technology will enable faster processing in a shorter time by rapidly moving the processing power of the cloud to edge devices, phones, and all other smart objects. Terahertz waves, an option that can be a solution against network limitations, are another application that will become more common with 6G, as it transports very large amounts of data at ultra-high speeds with minimum time. In this study, we researched the potential trends and applications of the 6G mobile communication network. As a result of the study, it is understood that the basic channel modelling methods for 6G are like 5G and with the studies that accelerated in the last two years, the standards will be determined in the next 3 years and the designs will be seen in the next 10 years.

Keywords—6g technology, mobile network, wireless communication, wireless network, sixth-generation wireless

I. INTRODUCTION

In today's world, where we encounter technological innovations almost every day, it takes time to establish a standard in mobile communication. The increase in the number of devices using mobile communication and technological diversity bring the need for faster communication in this regard [1] [2]. It did not take a long time for mobile communication to come into our life, the emergence of the internet and our first-generation mobile communication to reach 5G [3]. Although we say that the 5G mobile communication network is only used for testing purposes in certain places today, we can state that it will become a standard in the next few years and will lead up to 6G.

Since the 1970s mobile devices that have been developing like personal digital assistants, handheld computers, smartphones, iPods and tablet computers, and laptop, MP3 players, flash disks, portable hard disks, and new ones are added day by day [4]. As a result of this technologic growth, mobile networks changing for meeting the needs. Cell phone internet technology today is mostly based on 4G, which was introduced in late 2009 [2]. 4G has radically increased the data flow rate in mobile phones. It also enabled online activities such as HD video streaming and video games [1] [2].

5G is a new generation wireless phone technology. While 5G technology, which has not been opened to all users around the world, is still being developed, studies have started on 6G technology to adapt fast technological needs.

Studies on 6G has accelerated in the past years, different countries have created specialized research groups. In 2018 Finland started to research terahertz (THz) spectrum, artificial intelligence (AI) and sensor studies on 6G. Following year, different studies, in different countries such as United States, South Korea, European Union (EU), China, started about THz spectrum with different frequency domains, reviews about 6G system requirements and edge intelligence technologies. In 2020 and 2021 studies focus on reviewing of 6G key features, use case scenarios, AI application models and communication techniques on 6G [5-8].

This study mainly focuses on potential trends, channel models and applications of 6G. In the following sections of this study, firstly brief information about progress of mobile networks will be given. Then 6G channel models will be briefly explained. After that, 6G application and technologies will be discussed.

II. PROGRESS OF MOBILE NETWORKS

The purpose of wireless communication is to provide high quality, reliable communication just like wired communication and every new generation service means a big step in this direction. The development of GSM technology over time is called 1G 2G 3G 4G. The letter "G" means generation [1]. Each generation brings extensive innovations and changes compared to the previous generation, each generation is faster than the previous generation and comes with new applications.

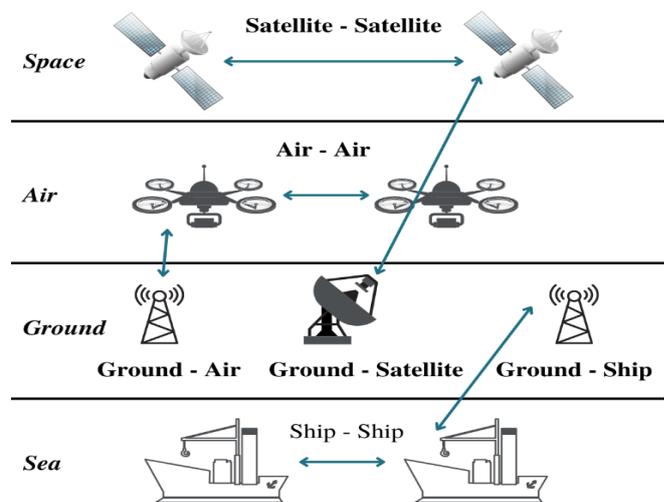


Fig. 1. 6G Integrated Networks

A. 1G,2G,3G,4G

1G is the first generation of mobile systems. It is an analogue system and carries sound only [1] [2]. As a result of this phone calls can be listened to by anyone. It is not resistant to interference and does not enable services like data communication. 2G is a digital communication-based system and considered as the basis of the real GSM system. SMS is an application which is comes with this technology [1]. Name of this technology re-named as 2.5G, 2.75G with the evolution of the GPRS, EDGE and MMS technologies [2]. With 3G technology, smart phones have started to transfer voice, image even video. Web browsers and internet-based game applications on smart phones started to use [1] [2]. 4G is an IP-based technology that users can receive and transmit data with high speed [2]. With 4G technology, it is possible to transfer HD video, video chat and run 3D applications and transfer files at very high speed [1] [2].

B. 5G and 6G

5G is a technology that powers IoT (Internet of Things) networks and facilitates new high-bandwidth applications [2]. It provides about 10 times faster data transmission speed of fourth generation technology. 6G is the technology that can integrate satellite communication networks and 5G [3]. The purpose of 6G is to be able to integrate such satellite networks to provide network location identifier, multimedia and internet connectivity, and weather information services to mobile users [2]. Li-Fi technology, visible light communication technology with high energy LEDs, is used instead of Wi-Fi in communication technology. This technology not only provides high data rate and data centre, but also offers a smart communication environment with full artificial intelligence support [9]. With this technology, in the future, three-dimensional vision, smell, touch and taste senses can be transmitted, real-time remote health services can be provided, smart infrastructures can be developed, autonomous vehicles and cyber-physical systems can be created [10].

III. 6G CHANNEL MODELS

Since wireless channels are the basis for infrastructure architecture, network optimization, and performance assessment in 6G networks [11], we researched the 6G wireless channels to understand 6G networks and supporting technologies. 6G wireless channels may operate in a variety of frequency bands and scenarios. Fig. 1 demonstrates an example of 6G integrated networks such as space, air, ground, and sea. Previous works mostly focus on 4 main parts as satellite channel, unmanned aerial vehicle (UAV) channel, maritime channel, and optical wireless channel.

A. Satellite Channel

Satellite networking has sparked a lot of interest in wireless communication networks, and it is seen as a potential way to have wide impact owing to its functional services and low cost [9]. Ku (12–18 GHz), K (18–26.5 GHz), Ka (26.5–40 GHz), and V (40–75 GHz) are the most used frequency bands [4][9]. Climate dynamics, such as thunder, cloud, fog, snow, and so on, have a significant impact on the satellite communication channel. Attenuation is primarily caused by rain, particularly in frequency bands above 10 GHz [12].

B. UAV Channel

3D launch, high agility, spatial and temporal nonstationary, and airframe shadowing are some of the special

characteristics of the UAV channel [13]. In general, there are two types of UAV channels: air-to-air and air-to-ground.

C. Maritime Channel

Maritime channel is also known as the UAV-to-ship channel [10]. The maritime connectivity channel mostly involves air-to-sea and near-sea-surface channels as part of the space-air-ground-sea interconnected networks [14]. To communicate with ships, the UAV works as the base station (BS) for air-to-sea networks.

D. Optical Wireless Channel

Optical wireless bands are electromagnetic spectra of infrared (780-106 nm), visible light (380-780 nm), and ultraviolet (10-380 nm) carrier frequencies [11]. They can be used for wireless networking in a variety of environments, including indoors, outdoors, underground, and underwater. There is no multipath fading, no Doppler effect, and no bandwidth regulation in optical wireless compared to standard frequency bands [15].

IV. 6G APPLICATIONS AND TECHNOLOGIES

6G is expected to offer far more advanced services in terms of coverage and data rate, allowing users to experience new communications with virtual participation anywhere [12]. Therefore, we researched the application areas and technologies of 6G. In this section, information about the potential application areas and technologies of 6G is given.

A. 6G Applications

Studies demonstrates that millimeter-waves (MmWave) communication systems have a high potential for 5G [15]. On the other hand, data transmission over millimeter-waves, and even transmission of this data with shorter waves in outdoor environments become extremely difficult [16]. The shorter wavelengths, have more sensitive connections and greater risk of tripping over walls and other obstructions. Therefore, THz communication steps ahead for 6G applications. A THz access point can support bandwidth-intensive applications such as *virtual (VR) /augmented (AR) extended reality (XR)*, as the THz band can easily meet ultra-high data rate requirements [17].

Adapting wireless systems to human users to support services directly with *Brain-Computer-Interface (BCI)* is also a possible application area for 6G. People using wireless BCI technologies can interact with devices or other people around them [18]. Wireless BCI services need high speeds, ultra-low latency, and high reliability which THz band can be meet this requirement [17]. It can be possible collect data remotely from the human body [16].

With the help of the THz band, 6G technology can reach ultra-high data rates for wireless communications [21] [22]. Robots, autonomous vehicles, unmanned aerial vehicles (UAVs) can be designed to communicate with each other without outsider impact [21]. Connected Robotics and Autonomous Systems (*CRAS*) can be one of the primary use cases, needs strict requirements across the speed-reliability-latency spectrum balance [18].

Ensuring the security of information exchange is an important feature of a good communication. Advances in *quantum computing* have opened the possibility of breaking existing encryption algorithms in real time [23][24]. Research continues 6G and quantum communications and security. As

6G technology becomes operational, the capabilities of smart machines will provide many potential benefits such as better access, faster data processing. Working together with machine learning, the best place where computing will take place will be independently determined, including decisions about data storage, data processing and data sharing [24].

With GPS technology, accurate outside positioning has now become an essential feature in most applications. It is considered certain that such an important and effective application will be implemented for *indoor positioning* with the 6G with more advanced communication technologies [16].

B. 6G Technologies

To enable the services mentioned in the previous section and improve their performance, several new technologies should be integrated into 6G.

- *Higher Data Rate*: As the spectrum of the existing frequency band becomes increasingly full, it will be necessary to develop new frequency bands higher than the extreme high frequency band, such as submmWave, terahertz [25]. To make mobile mmWave a reality in early 6G systems, further development of mmWave technologies will meet the needs to some extent, but as 6G advances it will become necessary to leverage frequencies in the terahertz (THz) band [18].
- *Edge Artificial Intelligence (AI)*: There has been a great deal of interest in the use of artificial intelligence [23] for the optimization and design of wireless networks in recent years, due to the availability of machine learning. Edge AI with 6G will benefit network operations, wireless propagation environments and communication services [16].
- *Quantum Communications*: Quantum optical technologies are considered a promising use in machine learning applications and access networks of telecommunication infrastructures [26]. With the combination of machine learning algorithms (e.g., reinforcement learning and unsupervised learning) it is possible to operate the network in an autonomous [27]. With the help of the quantum computing security and long-distance networking problems can be improved.
- *Integrated Networks*: The connectivity of the system can be increased by improving the connection range and density [25]. To meet this need, drones can be used to supplement terrestrial networks for connection to hotspots and regions where infrastructure is weak [18].

V. CONCLUSIONS

In this paper, we have reviewed progress of mobile networks 1G to 6G, 6G channel models, potential 6G applications and enabling technologies.

As a result of this study, it has been seen that research are at the channel modelling level yet and it is expected that the use of channel modelling in satellite, UAV, maritime, optical wireless types, also research studies will be carried out and become widespread in the 6GHz-300GHz frequency range and industrialization applications will be made in the 6Ghz-16Ghz frequency range.

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