Analysis of the commercial prospect of 6G communication

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Abstract. As the global implementation of fifth generation (5G) wireless technology nears completion, there is an escalating demand for enhanced network capabilities, including higher speeds, increased bandwidth, and greater data volume. Concurrently, the development of sixth generation (6G) networks is gaining momentum. It is projected that 6G networks will offer speeds that are several orders of magnitude greater than those of 5G, thereby enabling real-time communication across various sectors. This paper aims to forecast the potential applications of 6G technology in several key domains, namely telemedicine, autonomous vehicles, and the metaverse, leveraging the existing foundations of 5G technology and the emerging capabilities of 6G technology. Additionally, this study will review the initial applications of 6G, offering insights that may influence the future architectural design and deployment of 6G networks. Furthermore, this research identifies several anticipated trends in 6G development, including ubiquitous connectivity, three-dimensional coverage, interdisciplinary integration, and advanced intelligent communication systems. These elements are expected to define the trajectory of 6G technology's evolution and its integration into diverse technological ecosystems.

Keywords: Construction, 6G network, future development, application areas

1 Introduction

In the information age, the upgrading of communication systems is an inevitable result. Meanwhile, with the introduction of new concepts such as AI, ChatGPT and the Metaverse, 5G will soon be unable to meet the needs of people's production and life [1]. Nowadays, most of the research and development of 6G systems in various countries are in their infancy, however, the commercialization and civilianization of 5G systems have been basically completed, so it is particularly important to analyze and summarize the development process and commercial prospects of 6G for the development of the communications industry.

At the beginning of this article, it mainly reviews the historical process of communication system iteration and briefly describe the basic principles and some key technologies of the 6G communication system, which explains how wireless communication has influenced and changed the world as we know it today since its

Y. Yue (ed.), *Proceedings of the 2024 International Conference on Mechanics, Electronics Engineering and Automation (ICMEEA 2024)*, Advances in Engineering Research 240,
https://doi.org/10.2991/978-94-6463-518-8_14

inception. In the second part we compare the competitive advantages of 6G compared to the previous generation of communication systems. What's more, the contribution of this article also includes: systematically analyzes three application scenarios, including telemedicine, autonomous driving, and the metaverse, that may flourish under 6G technology in the future. In addition, at the end of this paper, the research results of this paper summarize the application prospects of 6G, which will guide the development of the communication industry in the future.

2 Principles of 6G communication systems

2.1 The history of 6G

Since the 80s of the 20th centuries, mobile communication has revolutionized the world and has had a profound impact on people's lives. Prospects over the next ten years include an explosion of speed-hungry applications that will produce digital information shared by billions of connected devices, including people, AI agents, linked robots, cars, and drones [1]. In addition to influencing the specifications for upcoming 6G connect-compute-control systems, this data avalanche is also generating serious doubts about the viability of future 6G networks and about workable hardware and technological solutions that can successfully achieve the previously unheard-of performance requirements for 6G networks. It is true that there can be a discrepancy between the anticipated 6G capabilities, the available technology, and the surroundings [2]. And the 6G communication system will change the future market pattern. The development of communication systems is a process of continuous iteration:4G replaced 3G,5G replaced 4G and 6G will replace 5G.

6G technology has further expanded and enhanced its capabilities on the basis of the original 5G technology, enhanced mobile broadband, massive Internet of Things, low latency and high reliability are the three typical scenarios of 5G, and 6G will further build super wireless broadband, ultra-large-scale connection, and extremely reliable communication capabilities on the basis of these three typical scenarios, and expand new scenarios of perception and intelligent services, namely communication perception fusion and inclusive intelligence. In addition, the scope of 6G services will be further extended to the air, space, and ground to achieve global three-dimensional coverage. The history of wireless communications shown in figure 1.

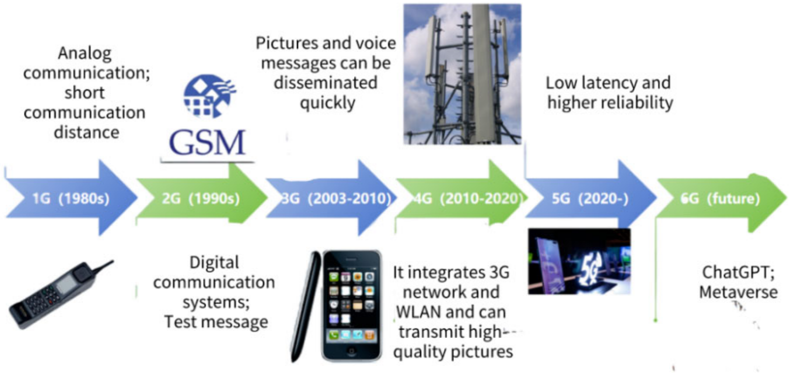

Fig.1. History of wireless communications (Photo/Picture credit: Original)

2.2 The theory of 6G communication system

In this article, this paper mainly discusses the hardware technical implementation of 6G. The need for high computing power: It is suggested that greater spectrum bands be used in 6G networks in order to reach the desired bandwidth. Reducing the spacing between elements enables the integration of higher frequency bands and facilitates the implementation of Massive Multiple Input Multiple Output (MIMO) and beamforming systems that utilize a significant number of antenna elements, up to 1024, while maintaining a system size that is manageable [3]. When using conventional methods, the systems' processing power and power density would expand rapidly because of the significant increase in data-rate that the physical layer's compute-intensive signal processing algorithms must handle. Complex digital pre-distortion (DPD) is required when using wideband power amplifiers at higher frequencies in order to improve the power amplifiers' linearity [4].

Higher rate and reduced latency are unavoidable for 6G communications due to the introduction of several new services. To assess 6G performance in this context, three metrics are suggested. These are latency, user-experienced data rate, and peak data rate [5]. Obviously, they are the challenges that causes retardation of 6G commercialized progress. The hardware foundation of 6G shown in figure 2.

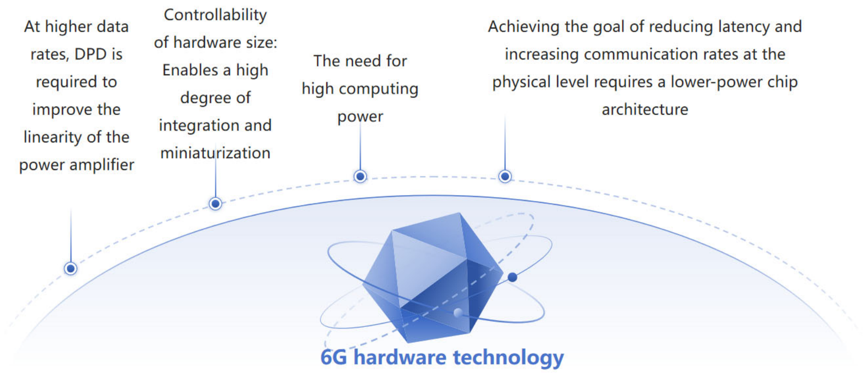

Fig.2. 6G Hardware technology (Photo/Picture credit: Original)

2.3 The advantage of 6G communication system

The swift advancement of wireless cellular communications from 1G to 5G has resulted in an increase in the number of linked devices, including industrial machinery, vehicles, sensors, household appliances, and more. When everything is intelligently connected whenever and wherever it is, this tendency will continue into 2030 and beyond. If smart gadgets can detect their environment and communicate with other smart devices, then connectivity will become more intelligent. Reducing the size of co-located radar and communication systems and shortening the time it takes for information to move between them are predicted outcomes of effective Integrated Sensing and Communication (ISAC) systems, which include fully integrated and loosely connected systems. With every advancement in wireless cellular technology, bandwidth and spectrum are increased. In 2030 and beyond, the terahertz frequency band (0.1~10 THz) will fully utilize its advantages of ultra-large bandwidth and ultra-high communication rate, supporting massive device connections and ultra-high user data rates at the Tbit/s level. This is one of the core technologies that is expected to meet the requirements of 6G. Since terahertz communication can achieve Tbit/s communication rate, it is considered a significant alternative air interface technology. Terahertz communication is expected to be widely used in various applications such as holographic communication, small-scale communication, ultra-large capacity data backhaul, and ultra-high-speed transmission over short distances, among other scenarios. Furthermore, ultra-high bandwidth is needed for high-precision location and high-resolution perception imaging of network and/or terminal devices, which also creates new opportunities for terahertz communication applications [6]. The channel properties of terahertz are substantially different from those of millimeter and microwave in the low frequency bands and visible light in the high frequency regions. Terahertz waves have higher transmission losses, more noticeable scattering effects, and more frequency selectivity than millimeter waves.

Terahertz waves are less likely to be blocked, have stronger fluctuations and reflected energy, and have less route loss than light waves.

3 Commercial prospect analysis

3.1 Opportunities and challenges in the communications industry

Presently, almost 50% of the global population resides in rural and remote areas lacking fundamental internet services. Non-terrestrial networks offer a cost-effective and reliable solution for providing connectivity and broadband services to regions where constructing terrestrial networks is prohibitively expensive. Operators can flexibly deploy non-terrestrial networks through non-terrestrial network nodes such as satellites, drones, and high-altitude platforms, and realize interconnection through various devices such as smartphones, tele-medicine, automatic drive, laptops, fixed lines, and TVs.

3.2 6G and tele-medicine industry

With the support of 6G networks, the medical industry is expected to realize remote medical diagnosis and emergency rescue networks [7]. The medical device market is changing as a result of the integration of 5G with mobile products, remote picture transmission, and remote real-time control. Currently, there are two primary categories into which 5G medical device applications can be separated: scenes both inside and outside of hospitals. When 6G is used in the aforementioned circumstances, the Internet of Everything's high-speed information flow can help medical professionals diagnose patients more quickly.

The 6G communication network can do much more than 5G, and 6G telemedicine can achieve near-real-time telemedicine diagnosis and even remote surgery regardless of the impact of distance. The two primary components of teletherapy are remote surgical control and guidance. Remote surgical guiding still relies heavily on guidance, much like remote consultation. In order to enable remote real-time surgical treatment of patients who are far away, remote surgical control aims to implement the real-time transfer of image data, video and audio, robotic arm status, and the operation between patients and doctors. The surgical result is predominantly contingent upon the 6G network's latency, capacity, and dependability.

3.3 6G and autonomous driving industry

In the field of autonomous vehicles, how to identify road conditions and calculate the correct driving trajectory in real time has always been the most important issue. As a result, there are numerous restrictions. The camera's ability to discern lane markers depends heavily on the lighting conditions; in many situations, such as while driving into a low sun, which happens frequently, it will not function. Because the car's steering and throttle controllers are quite easy to manage these difficult control circumstances—indeed, they are common—the lane keeping assistant also malfunctions in scenarios where the lane curve is sharp or the speed is low [8]. However, the Internet of Everything in the 6G communication network can make up for these shortcomings.

By improving the existing autonomous driving information recorder, parameters such as time, mode, drive input, vehicle status, mode change information, and object information are recorded, and algorithms are designed to complete the real-time analysis of these information[9].These functions can be basically realized in the existing 5G network environment, but due to the limitation of bandwidth and the information rate is not high enough, 5G autonomous driving cannot solve all the security risks.

In South Korea, Kyungbok Sung and his team conducted tests on autonomous vehicles by connecting the dashcam to the onboard LAN through a Controller Area Network (CAN) [10]. They discovered that logging driving information is critical for developing autonomous vehicles. This type of data collection is valuable for various purposes, including analyzing issues within autonomous driving systems and assessing accident risks.

In contrast, agents in cooperative and connected vehicles share situational awareness through ad hoc vehicular networks (VANETs) by utilizing vehicle-to-vehicle (V2V) communication technologies like Cellular Vehicle-to-everything (C-V2X) and Dedicated Short-range Communication (DSRC) [11, 12].

We also need to introduce the concept of decision datasets. Perception module data is collected by decision-making datasets. These dataset's data structures allow for the division of the data into three primary categories. The first one is vehicle information for the ego, which includes controller area network (CAN) bus data, location data, and other information. Information about the surrounding area, including traffic signals and other users of the road, is the second. The information on the driver, which includes gestures, eye movements, and other things, is the third one [13]. 6G can cover all our design goals under 5G networks, and it's faster and more efficient than the latter.

3.4 6G and the Metaverse

Since Zuckerberg announced in October 2021 that Facebook would be a metaverse company, many internet giants have joined this emerging project.

We now live in an era and marked by the Internet, from the emergence of computers in the 40s of the 20th centuries to the Internet of Everything, but the concept of the metaverse may usher in a new era - not only the interconnection between people and things, but the entire social

architecture will be reshaped under the ultra-high-speed communication network virtual reality (VR), augmented reality (AR), artificial intelligence (AI), blockchain technologies and so on [14].

6G will advance cloud services by shifting numerous computing and storage tasks from smartphones to the cloud, among other cellular industry advancements. As a result, presentations can be rendered using the majority of the smartphone's processing power, increasing the visual appeal and affordability of virtual reality (VR), augmented reality (AR), and extended reality (XR). Furthermore, 6G will transform a transmission network into a computing network. The seamless integration and harmonious operation of computing, big data analytics, AI, machine learning, and transmission may be one of 6G's distinguishing features. According to this theory, 6G will be able to automatically determine users' transmission intent and provide personalized services based on their preferences and intents [15]. Through the combination of 6G networks, the Internet of Things and the metaverse, virtual reality technology may not be far away. As described in the game Cyberpunk 2077, the entire society will be connected to a huge network, and human production activities are inseparable from the Internet.

4 Challenges and prospects

4.1 Challenges

Compared with previous generations of communication systems, the advantages and application scenarios of 6G communication have been fully discussed above. However, with 5G communications already occupying most of the existing market, it is clear that there are more challenges in competing or opening up new tracks.

Let's take Apple as an example, Apple's huge user base and user loyalty are undoubtedly important reasons for its long-term leadership in the Internet industry, but whenever a product is iterated, users of the old product will also become one of the obstacles to update, and the iteration of the entire network system is bound to consume more resources.

4.2 Solution

Based on the above research, although there are still some problems in the commercial application of 6G, they can be solved. The upgrading of communication systems is the trend of the times, but from the perspective of the era we are in today, the development of 6G is predictable and rapid. Building on 5G technology, 6G aims to broaden its scope from connecting people and objects to facilitating the efficient interconnection of intelligent twins. This evolution will advance the transition from the Internet of Everything to the Intelligent Connection of All Things, ultimately aiding in the realization of a society where everything is interconnected, fulfilling the vision of an "Internet of Everything."

5 Conclusion

Generally, 6G communication technology represents more than just an advancement in network capacity and speed; it also aims to reduce the digital divide and achieve the "ultimate goal" of the Internet of Everything. This encapsulates the essence of 6G. It will move towards shorter network latency, greater bandwidth, wider coverage, and higher resource utilization. In places we can see, such as in the telemedicine industry, where real-time communication brought about by high rates could save many lives, in the autonomous driving industry, higher computing power will make self-driving cars safer, and eventually, based on the concept of the metaverse, 6G will facilitate the expansion from the real-world system to the virtual world system. The new communication system will bring about a new industrial structure and industrial ecosystem, which will undoubtedly promote the shift of 6G to commercial and civilian applications

References

1. Lv Z. Generative artificial intelligence in the metaverse era. Cognitive Robot-ics, 2023.
2. Strinati E C, Peeters M, Neve C R, et al. The Hardware Foundation of 6G: The NEW-6G Approach. 2022 Joint European Conference on Networks and Commu-nications & 6G Summit (EuCNC/6G Summit). IEEE, 2022: 423-428.
3. Siriwardhana Y, Porambage P, Liyanage M, et al. AI and 6G security: Opportu-nities and challenges. 2021 Joint European Conference on Networks and Commu-nications & 6G Summit (EuCNC/6G Summit). IEEE, 2021: 616-621.
4. Strinati E C, Peeters M, Neve C R, et al. The Hardware Foundation of 6G: The NEW-6G Approach. 2022 Joint European Conference on Networks and Commu-nications & 6G Summit (EuCNC/6G Summit). IEEE, 2022: 423-428.
5. Guan N, Wu N, Wang H. Digital predistortion of wideband power amplifier with single undersampling ADC. IEEE Microwave and Wireless Components Let-ters, 2017, 27(11): 1016-1018.
6. Wang C X, You X, Gao X, et al. On the road to 6G: Visions, requirements, key technologies and testbeds. IEEE Communications Surveys & Tutorials, 2023.
7. Huawei Technologies Co., LTD.6G: The new journey of wireless communication. The overall vision and ability. 2024. https://www.huawei.com/cn/huaweitech/future technologies / 6 g - white - paper.
8. Cao Y, Zhang C, Ren H, et al. Application and Supervision of 5G in Medical Devices. 2023 7th International Conference on Biomedical Engineering and Appli-cations (ICBEA). IEEE, 2023: 81-85.
9. Zhiwei S, Weiwei H, Ning W, et al. Map free lane following based on low-cost laser scanner for near future autonomous service vehicle. 2015 IEEE Intelligent Vehicles Symposium (IV). IEEE, 2015: 706-711.
10. Sung K, Min K, Choi J. Driving information logger with in-vehicle communi-cation for autonomous vehicle research. 2018 20th international conference on advanced communication technology (ICACT). IEEE, 2018: 300-302.
11. Toghi B, Valiente R, Sadigh D, et al. Social coordination and altruism in au-tonomous driving. IEEE Transactions on Intelligent Transportation Systems, 2022, 23(12): 24791-24804.

12. Thal S, Henze R, Hasegawa R, et al. Generic detection and search-based test case generation of urban scenarios based on real driving data. 2022 IEEE Intelli-gent Vehicles Symposium (IV). IEEE, 2022: 694-701.
13. Lv P, Han J, Nie J, et al. Cooperative decision-making of connected and au-tonomous vehicles in an emergency. IEEE Transactions on Vehicular Technology, 2022, 72(2): 1464-1477.
14. Wang Y, Han Z, Xing Y, et al. A survey on datasets for the decision making of autonomous vehicles. IEEE Intelligent Transportation Systems Magazine, 2024
15. Maier M. 6G, Next G, and the Metaverse: Toward the Peak-Experience Ma-chine. 2022 13th International Symposium on Communication Systems, Networks and Digital Signal Processing (CSNDSP). IEEE, 2022: 637-641.