Research on the status quo and future forecast of 6G

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Abstract. The commercial launch of 5G has already begun globally, in the meantime, academia and industry have carried out research on 6G as planned. 6G will bring a new perspective of communication technology, incredible technological innovation, fulfilling coverage technology application, and massive scale of in-depth technology integration. This paper describes technological vision on 6G based on the current situation of mobile communication technological development, and then considers the future directions of technological development from the perspective of 6G, this paper introduces new value offered in the 6G era to support the potential use cases put forward in Chapter 4. Requirements of 6G reveal the goals of mobile development—smarter, faster and greener, which provide reference for industry and society in the 2030s.

Keywords: Evolution of communications, 6G technological vision, Future directions, Potential use cases.

1. Introduction

Since the first cellular-based mobile communication service in the world was launched by Nippon Telegraph and Telephone Public Corporation (NTT) on December 3, 1979, mobile communication technology has evolved into a new generation every 10 years. 6G is anticipated to completely change the structure of human society, fueled by the incalculable advantages of 5G. This paper will describe the technological vision and future forecast on 6G. The following Chapter 2 will introduce the related research on 6G. With application cases, Chapter 3 explains the requirements for 6G wireless network technology, and then provides specific technologies to realize the requirements and use cases. Chapter 4 describes new values created and potential applications in 6G era.

2. Status quo of 6G

As the application demands increasing, there is also ongoing research into the development of 6G technology, which is expected to be the next generation of wireless mobile communication technology after 5G. Nowadays, various research institution has been launching their research and views on 6G Outlook, researchers and scholars at home and aboard are passionate in discussing telecommunications expected in 2030s in many platforms such as “Beyond 5G Promotion Consortium [1]”.The eighth Framework Programs for Research and Technological Development (FPS), known as Horizon 2020, was officially launched by the European Commission in October 2018 with the title “5G Long Term Evolution” request for proposals. There were 8 projects chosen from a total of 66 proposals and they had begun in early 2020. In the most accepted project—"Smart Connectivity Beyond 5G", European Commission expressly stated that their vision is to provide early research activities on 6G. Countries with developed communication technology, such as China, the United States, the European Union, Japan, and South Korea, etc. have launched research and development plans in 6G continuously. University of Oulu in Finland, with the assistance of local government, launched its 6G project 6Genesis and organized the first global 6G Wireless Summit in March, 2019. Since then, it released a series of technical white paper with major universities, research institutions and enterprises, which has significant influence universally. In June 2019, the Ministry of Industry and Information Technology (MIIT) established the 6G promotion group IM 12030; In November 2019, several departments of the Ministry of Science and Technology of the United Nations set up a 6G technology promotion working group and an overall expert group to begin the comprehensive 6G research. In addition, domestic and foreign enterprises, such as China Mobile, China Unicom, Datang Mobile and VIVO, have also released 6G white papers since 2019. The IMT-2030 Promotion Group also released its first white paper on the 6G vision and requirements in June 2021.

Based on the development process of 5G, the whole 6G research and development will be divided into two stages. The first stage (2018-2025): vision, demand definition and key technology research and verification; system concept design and prototype verification. The second stage (2026-2030): 3 GPP starts the research and formulation of relevant standards, end-to-end industrialization promotion, business and application cultivation and commercial deployment. At present, the global research on 6G is in the stage of defining the vision requirements and looking for key technologies.

The International Telecommunication Union's Radiocommunication Sector (ITU-R) Working Party 5D (WP 5D) [2] established a timeline for the standardization of 6G in June 2022. The "WP 5D timeline for IMT forwards 2030 and beyond" claims that [2] the ITU-R recommendations will be finished in or around mid-2023, the requirements will be finished in 2026, and the proposal deadline will fall in or around 2028. The technical specifications established and suggested by 3GPP will serve as the basis for the ITU-R recommendations, which will be described as 6G specifications. It is anticipated that the 3GPP will begin discussing full-scale standardization in 2024, taking this method into account.

3. 6G Requirements and directions

The 6G network will primarily be built using the 5G architecture, building on the technology used in prior mobile communication systems and benefiting from what 5G has accomplished. Fig.1 [3] shows the requirements that people aiming to achieve for 6G wireless networks after going through 5G Evolution [4]. The 6G requirements will expand and diversify, taking into account both improved 5G requirements as well as brand-new requirements that were not taken into account in 5G. From a 5G perspective, it is not required to meet every criterion at once, but certain novel use cases will call for a mix of requirements. The requirements for 6G wireless network technology are outlined below, along with use scenarios.

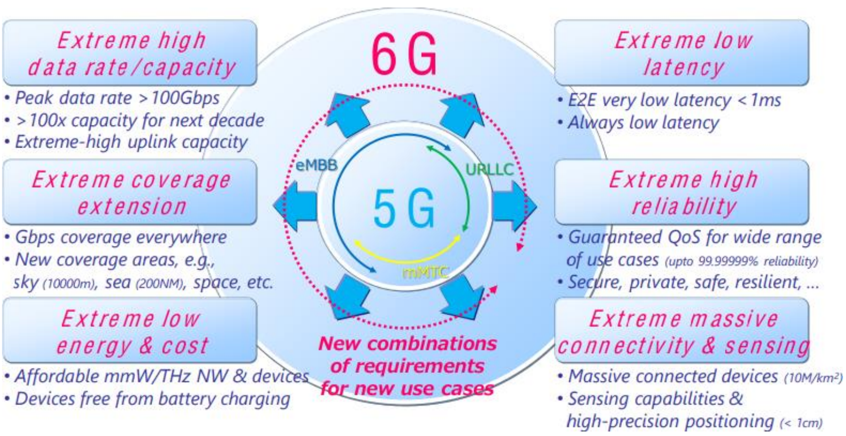

Figure 1. 6G requirements [4]

3.1. Extreme-high-speed and high-capacity

Every generation of mobile communication systems has to increase system capacity and data rate. Due to the achievement of extraordinarily fast communication speeds and massive communication capacities—more particularly, exceeding 100 Gbps communication speeds and more than 100 times the capacity—many users will benefit from 6G at the same time in this scenario. When communication speed approaches the level of information processing speed of the human brain, it will be possible to transmit not only images (visual and aural), but also sensory quality information of the five actual senses, therefore expanding multi-sensory communication. This ultra-high-speed, high-capacity communication service requires a user interface that is better than a smartphone. The creation of wearable terminals, like spectacle terminals, and the application of 3D holographic replication are two examples.

To achieve these needs and use cases, the wired portion must include optical full-mesh network technology [5] and ultra-high-capacity optical communication technology of IOWN APN [6]. This will allow for smooth, large-capacity, end-to-end wireless and cable connection at very high speeds.

3.2. Extreme coverage extension

Coverage presents another significant difficulty. The goal of 6G is to create a network that can reach every corner of the planet and even space. Both heavily populated places and the furthest points where the equipment is located should be covered by the service. It is important to make this technology accessible in a range of settings, including space, the sea, and land. It is anticipated that this would lead to the creation of new industries, increasing the activities of people and things. Logistical solutions such as drone-assisted home delivery and unmanned or very complex operations in primary industries including agriculture, forestry, and fisheries are promising application cases. The 2030s could also see the emergence of future use cases such as space exploration, underwater transport, and flying cars. One could envision a digitally integrated world as a result. This appears to be the only way that digital media is conceivable.

In order to fulfill these demands and scenarios, communications to any location via technologies like the collaborative infrastructure platform of IOWN are unavoidably needed. These technologies also include coverage expansion technologies like non-terrestrial networks and integration of diverse wireless technologies [7].

3.3. Sustainability, extreme-low power consumption and cost reduction

Today's nations are aiming for more sustainable technology development as a result of global and climate change. There are worries that when more antennas are installed or Internet of Things devices are used, 6G technology will further reduce the carbon footprint. But 6G can save a significant amount of energy, just like SG's intermittent signal technology. The activities that produce enormous amounts of carbon emissions in daily life will be stopped by the proper application of 6G technology in health, agriculture, entertainment, and other industries.

Additionally, reaching the global objective of a sustainable society has significant obstacles due to the extremely low power consumption, cost reduction, and terminal equipment of mobile communication systems networks. Researchers are aiming to considerably lower the power consumption and cost per unit of communication speed (bit) in the network, presuming that the number of communications will continue to rise in the future. For instance, to get great performance and financial gains when traffic grows 100 times, CAPEX / OPEX per bit must be decreased below 1 / 100.

To meet these requirements, photonics-electronics convergence technologies such as IOWN APN [8], disaggregated computing [9], etc. are needed. Additionally, in order to further reduce CAPEX/OPEX, flexible network function deployment and advanced OAM (Operation and Maintenance) techniques must be employed.

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3.4. Extreme-low latency

Wireless communication is the nervous system that transfers information if we compare the network physical fusion system to the human body. End-to-end low latency will become a requirement for more sophisticated real-time interactive AI systems. The target latency is 1 ms end-to-end or less, which is incredibly low. Thus, with low-latency feedback from cyberspace, it is possible to achieve no "sense of incongruity" services, where AI remotely controlled devices that can read near or exceed human flexible movements and subtle communications are also expected. For example, through remote control of the robot by artificial intelligence, we can instantly determine what the user wants from information such as voice, intonation and facial expressions, and may achieve response services that are like or more focused than humans. Especially in the world after COVID-19, this ultra-low-latency communication is highly expected to be used in various fields, such as remote office, remote control, telemedicine, distance education, and so on.

It will be important to apply transmission / switching control technologies to lower overhead and jitter in communication and information processing in order to implement these needs and use cases.

3.5. Extreme-reliable communication

Reliability is a key need for wireless communication in industrial and critical applications. Particularly in industrial use cases, where factory automation and remote control of industrial equipment are concerned, the effectiveness and accessibility of communications can have a significant impact on safety and productivity. Therefore, the deployment of ultra-high reliability communication and the required performance are key needs for security, and 6G is anticipated to achieve higher dependability than 5G. In 5G, the realization to 99.9999% is investigated as a reliability, and in 6G, the improvement of one digit (99.99999%) is taken as a target value in ultra-high reliability low delay communication (URLLC). Moreover, when robots and drones become more commonplace and radio coverage is extended to include air, sea, and space, a larger range of highly dependable communication will be required. A more thorough end-to-end perspective is also required, one that includes data on application reliability.

Security has become a key issue in all areas. New technologies and usage habits have evolved in recent years as a result of the growth of technology, creating a variety of risks. The security gap could become extraordinarily large when loT devices are used more frequently with other technologies like MEC. As a result, faith in new breakthroughs always begins at a very low level. Trust problems can occur with less well-known technology like 6G. This might be described as a substantial obstacle that needs to be overcome. To implement these requirements and use cases, it will be necessary to enhance the reliability of wireless and wired networks through novel wireless network topology and optical access network designs based on the IOWN APN3-81 cascade loop topology.

3.6. Extreme-massive connectivity & sensing

Assuming network-physical convergence upgrades, the large number of devices related to human-object communication will be spread, and that the ultimate multi-connectivity of 10 times more than 5G demand (10 million devices per square kilometer) will become a 6G requirement. For people, consider the use case for cyberspace to support human thoughts and actions in real time through wearable devices and microdevices installed on the human body. In addition, it is expected to realize that all the transportation equipment, construction equipment, machine tools, surveillance cameras, and various sensors, including automobiles, are connected with the cyberspace, the solution of industrial, transportation and social problems, and the world of human safety and security and rich life.

To achieve these requirements and use cases, it will require co-coordinated transmission and receiving technologies across terminals, next generation data hub and data proxy technology [wireless sensing in 3-9l cellular networks, fiber environment monitoring technology [10], and space sensing in IOWN [11].

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4. New values offered and Applications in 6G era

4.1. New values – From Smart to Wellbeing

"Wellbeing" was mentioned in the Organic Act of the World Health Organization (WHO), which was established in 1946. The World Health Organization describes it as "a concept that every individual rights and self-realization are guaranteed and everyone is in good physical, mental and social condition [12]". Happiness, then, is essentially a state of total bodily, mental, and social health—that is, more than simply the absence of illness or frailty. For something to be considered "lasting" and complex, it must be multifaceted. Up until now, the concept of happiness has been used as a gauge of happiness in a wide range of situations. The concept of "lasting happiness" will be vital to society in 2030 and beyond, as its importance continues to grow in all countries. Looking back at the past society, from the period of high economic growth, people highly actively contributed to the society and were satisfied with their economic wealth. After the financial crisis, the society experienced a transition, people pursue personal happiness by protecting the things which make them feel satisfied. The "VUCA era," which runs from 2020 to 2030, is an unparalleled time in which the globe has undergone significant upheaval and the future is difficult to predict. This generation grows up with digital gadgets all around them, making it simple to satisfy their interests because they may use the wealth of information to pick a neighborhood. This expands the scope of the context in which they feel happiness, and in addition to their own happiness, they are also interested in the happiness of the people around them. We are witnessing the change in values, people cannot be satisfied with their own happiness, unless the people around us are also happy [12].

Given the above new values, we need a new culture of communication that enables natural communication between us in a virtually unconscious way. First, then "transmission", then "communication", and finally, we will achieve "mutual understanding". The development of "smart" features and convenience have been the main goals of communication services. A new priority of their value providing is anticipated to be achieving well-being going forward.

4.2. Potential applications

4.2.1. Satellite enabled secure smart city. Many social intervention areas have contributed to the growth of smart cities. People believe that the new use case in the 6G enabled market can definitely be leveraged by satellite connecting to the current smart city ecosystems. Blockchain can be combined with data fusion technology in smart city applications to increase the system's robustness and security. In use cases involving smart cities, such a combination can reduce the long-term requirement for safe automobile transportation. In order to develop current smart city initiatives into smart, secure, and robust applications, 6G can play a significant role.

4.2.2. Healthcare. In order to keep people healthy, health care in the future will need a lot of intelligent services. Pervasive biomedical informatics (PBI) is predicted to replace current healthcare situations. A novel platform employing smart medical services will be created by combining artificial intelligence, biomedical engineering, and universal computing. It is possible to solve the targeted drug delivery issue by using molecular communication systems. This innovative platform may make tactile training easier for patients who are in distress. To promote the sharing of skills in the operating room, the tactile Internet protocol may be created and combined with 6G. By placing a smart bracelet on one's breast, the Edge-AI can assist individuals in understanding their health. A probable disease will be predicted by analyzing and interpreting complex CT scans, X-rays, and other radiological pictures. With the help of 6G's intuitive and intelligent network architecture, people's health will be greatly enhanced by ultra-low latency and increased capacity network services.

4.2.3. Recognition of objects, presence and texture. People may occasionally want to touch an object or animal they see on a network screen in order to feel the texture of its surface, which could be uniform,

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uneven, rough, or smooth. We will be able to communicate our feelings more fluidly if we can use our hands to feel the texture of the things we have imagined in our imaginations. Experiments show that the touch you feel when you touch something is generated by electrical signals from the skin. Tactile communication between individuals and even objects is feasible if we can use the stimulation produced by this electrical signal to feel things that are on the screen or in our imagination. When compared to MR’s visual representation of objects in space, touch allows for the sharing of more genuine emotions.

5. Conclusion

In this article, we visualized current development of 6G, related researches in 6G and standardization schedule for 6G. Following that, we discussed the requirements and opportunities of 6G technology, including use cases and technologies to turn the 6G technology into reality. We also focused on the new value changes in the viewpoint of interaction among human, society and technology. In addition, we discussed several possible applications after the realization of 6G. We believe that in order to actualize 6G from 5G evolution, “high data rate / high capacity,” “low latency,” and “massive connectivity” are need to become strengthened based on the development and forecast in the 6G vision. In parallel, we will investigate new technical frontiers in mobile communications, such as “realizing extremely low power consumption and cost communications” for the establishment of a sustainable society and “extending communication areas to the sky, sea, and space,” where it has proven difficult to provide sufficient coverage. Prospects for prospective uses also offer guidelines for the advancement of human society in the future.

References

[1] Beyond 5G Promotion Consortium “Beyond 5G White Paper ~Message to the 2030s~” https://b5g.jp/en/output.html
[2] ITU-R WP5D, “Attachment 2.12 to Chapter 2 of Document 5D/1361 (Meeting report WP 5D #41, June 2022)”
[3] White Paper ‘5G Evolution and 6G’ NTT DOCOMO, INC. January 2023 (Version 5.0)
[4] Kishiyama, Nakamura, “Real and Future for 5G Evolution and 6G,” MWE 2018 Workshop FR2A -1, November 2018.
[5] H.Kawahara, T.Seki, S.Suda, M.Nakagawa, H.Maeda, Y.Mochida, Y.Tsukishima, D.Shirai, T.Yamagushi, M.Ishizuka, Y.Kaneko, K.Koshiji, K.Honda, T.Kanai, K.Hara, S.Kaneko, “Optical Full-mesh Network Technologies Supporting the All-Photonics Network” NTT Technical Review, Vol. 18 No. 5 May 2020
[6] K.Nakajima, Y.Miyamoto, H.Nosaka, M.Ishikawa, “Ultra-high-capacity Optical Communication Technology” NTT Technical Review, Vol. 18 No. 5 May 2020
[7] T.Kuwahara, R.Ishibashi, K.Kawakami, H.Masutani, H.Yamamoto, S.Yasukawa, “Cooperative Infrastructure Platform for Delivering Mission-critical Services” NTT Technical Review, Vol. 19 No. 10 Oct. 2021
[8] T.Sogawa, M.Tomizawa, A.Okada, H.Gotoh, “All-Photonics Network and Photonicselectronics Convergence Technologies as a Vision of the Future” NTT Technical Review, Vol. 18 No. 10 Oct. 2020
[9] A.Okada, S.Kihara, Y.Okazaki, “Disaggregated Computing, the Basis of IOWN” NTT Technical Review, Vol. 19 No. 7 July 2021
[10] World Health Organization, “WHO remains firmly committed to the principles set out in the preamble to the Constitution,” Available at: https://www.who.int/about/governance/constitution (Accessed: 8 October 2021)
[11] IOWN GLOBAL FORUM,”Data-Centric Infrastructure Functional Architecture” 2022.
[12] “To the Future of People and Information Technology” Toward building a better relationship between technology and human society. https://www.jst.go.jp/ristex/hite/en/topics/382.html