

Overview of the Development of Wireless Communication Technology in Electronic Engineering

Jiali Guo^{1,a,*}

¹*Glasgow College, UESTC, Chengdu, Sichuan, 611700, China*
a. 2022190907022@std.uestc.edu.cn

**corresponding author*

Abstract: With the rapid development of the information society, wireless communication technology plays a crucial role in the field of electronic engineering. From the initial 2G to the current 5G, this technology has continuously evolved, driving the progress and development of human society. The rise of emerging technologies such as the Internet of Things (IoT) and artificial intelligence (AI) presents both challenges and opportunities for wireless communication. A thorough understanding of the evolution, application fields, and future trends of wireless communication technology is essential for grasping the pulse of technological advancement and driving innovation. However existing research on the development of wireless communication remains significantly limited. Therefore, this paper will provide a comprehensive summary of the characteristics of each generation of wireless communication technology. In addition, it will list several key application areas of this technology and, based on available materials and literature, identify the opportunities and challenges facing the wireless communication field, providing a reference for future research and development.

Keywords: Wireless communication technology, electronic engineering, 5G, Smart IoT.

1. Introduction

As the information society continues to advance, wireless communication technology has emerged as a foundational element in electronic engineering. From the introduction of 2G, the steady evolution of this technology has consistently propelled societal development.[1]. The mobile internet introduced by 3G, high-definition video and online applications led by 4G, and now the ultra-high-speed data transmission and low-latency connectivity enabled by 5G, each technological revolution has shaped new application scenarios and industry landscapes [2,3]. The rise of emerging technologies such as the Internet of Things (IoT) has further expanded the application scope of wireless communication, particularly in fields like smart IoT and autonomous driving. However, the growing demand for wireless communication also presents a variety of significant challenges.

The widespread application of wireless communication technology has fostered the rise of emerging industries, such as the Internet of Things (IoT), which has promoted employment growth, created numerous job opportunities, and improved people's quality of life and social well-being. The development of wireless communication technology has also driven the advancement of smart city construction, enhancing urban management efficiency and service quality, and promoting sustainable urban development. Overall, the development of wireless communication technology has not only

driven economic growth and innovation but also contributed to social progress and an improved standard of living, laying a solid foundation for building a digital, intelligent society.

This article aims to comprehensively review the development of wireless communication technology in the field of electronic engineering, focusing on the technical characteristics and application scenarios of each generation, and to explore its extensive applications in modern communication networks, smart IoT, and industrial automation. By reviewing and analyzing the evolution of wireless communication technology, we can better understand the trajectory and key milestones of technological advancement, providing valuable insights for future innovation. Additionally, analyzing the broad applications of wireless communication technology reveals its crucial role in driving social progress and economic development, thereby offering theoretical support and practical guidance for technological innovation and industrial upgrading in related fields.

2. The importance of wireless communication technology in electronic engineering

Wireless communication technology plays a vital role in electronic engineering. With the rapid development of the information society, the demand for communication has been increasing, with emergence and advancement of wireless communication technology providing more convenient and efficient means of information transmission [4]. In the field of electronic engineering, wireless communication technology is not merely a communication tool; it also serves as a bridge connecting people and things, facilitating the transmission and sharing of information, and driving social progress. Through wireless communication technology, people can engage in voice calls, video calls, and data transmission anytime and anywhere, greatly enhancing work efficiency and convenience in daily life. The application of wireless communication technology has also expanded the scope of electronic engineering, enabling innovations such as smartphones, smart homes, and wearable devices, thereby making life more intelligent and convenient [5]. The importance of wireless communication technology in electronic engineering is self-evident; it is not only a driver of technological innovation but also an enabler of social progress, creating a more convenient and intelligent way of life for humanity.

3. The development history of wireless communication technology

With the continuous development of mobile communication technology, the evolution from 2G to 5G has gone through multiple stages, each with its unique technical characteristics and application scenarios. Table 1 summarizes the main features of each generation of mobile communication technology. It is evident that from 2G to 5G, mobile communication technology has continuously evolved, progressing from simple voice calls to application scenarios supporting ultra-high-speed data transmission and low-latency communication [6]. As shown in Table 1 below, during the evolution from 2G to 5G, traditional services such as voice input and SMS have gradually been replaced by new Internet-based products. Communication latency has decreased, while information transmission speeds have improved. This has led to the transition of data transmission from simple forms to applications in large-scale industries and smart homes.

Table 1: Characteristics and Applications of Communication Technologies in Different Periods

Mobile Communication Technology	Technical Characteristics	Main Applications
2G	Digital Communication, SMS Service, Voice Call	Simple Data Transmission, Basic Communication Services

Table 1: (continued).

3G	Broadband Data Services, Video Calls , Mobile Internet	High-Speed Data Transmission, Multimedia Communication
4G	High-Speed Data Transmission, Internet Access, Mobile Video	High-Definition Video Streaming, Online Gaming, Mobile Office
5G	Ultra-High-Speed Data Transmission, Low-Latency Communication, Massive IoT	Vehicle-to-Everything (V2X),Smart Home, Industrial Automation

The advent of 5G technology will further promote the development of fields such as the Internet of Things (IoT), intelligent transportation, and the industrial internet, providing robust support for the construction of a digital society [2].

Moreover, the impact of emerging technologies such as the Internet of Things (IoT) and artificial intelligence (AI) on wireless communication is becoming increasingly significant. The rapid development of IoT has enabled numerous devices to interconnect, requiring more efficient wireless communication technology to support this connectivity, thereby increasing the demand for large-scale device connections and driving wireless communication technology towards greater efficiency and stability [7]. The application of AI has also promoted the intelligence and optimization of wireless communication technology. Through intelligent optimization algorithms, AI enhances the performance and coverage of wireless communication networks, enabling smarter resource allocation and management. Together, these technologies drive continuous innovation and progress in communication technology, laying a solid foundation for building intelligent and highly efficient communication networks.

4. Applications of wireless communication technology in various fields

4.1. Communication networks and the internet

5G networks, with their advantages of high speed, low latency, and massive connectivity, have brought innovation to various fields, including mobile communications, smart homes, and the industrial internet. In the field of cloud computing, elastic resource scaling and efficient sharing have become key driving forces, with applications spanning data storage, deep learning, artificial intelligence inference, and other complex tasks. Moreover, internet technology refers to the set of technologies and protocols used to connect computer networks globally, enabling computers worldwide to communicate, exchange information, and share resources [4]. The integration of communication networks and internet technology allows mobile devices to facilitate information exchange and screen sharing anytime and anywhere. The high transmission speed and low latency of 5G technology provide strong support and assurance for internet communication [4].

4.2. Smart IoT and smart cities

Smart IoT technology enables highly intelligent management of physical devices connected to the internet, providing strong support for applications such as smart homes and smart health monitoring. These technological development trends include device miniaturization, low power consumption, and higher levels of automation. Meanwhile, as the core of modern urban management, smart cities leverage the integration of wireless communication and big data technologies to further improve efficiency in areas such as transportation, security, and environmental protection [7]. Particularly in intelligent transportation, real-time data sharing and intelligent decision-making systems optimize

traffic flow, reducing congestion and accidents. The widespread adoption of high-speed broadband networks, the development of low-power wide-area network (LPWAN) technology, and advancements in multiple-input multiple-output (MIMO) technology all provide better support for urban construction and development while promoting broader IoT application [4,8].

4.3. Autonomous driving and industrial automation

In the field of autonomous driving, wireless communication technology provides reliable real-time information exchange support for self-driving vehicles, enabling intelligent transportation systems to dynamically manage complex road conditions and achieve precise navigation [7]. With the widespread deployment of 5G networks, industrial automation has experienced a significant upgrade in large-scale remote monitoring and smart manufacturing. The application of the Industrial Internet of Things (IIoT) and Vehicle-to-Everything (V2X) technologies has enabled smart factories to achieve highly flexible production management capabilities, supporting remote control, real-time data monitoring, and equipment maintenance. In this process, the low latency and high-speed connectivity of wireless communication provide critical support for the efficient operation of industrial robots and automation equipment, significantly enhancing the level of intelligence and automation in production processes.

5. Technical challenges and future prospects

With the rapid development and widespread application of wireless communication technology, challenges such as spectrum scarcity, spectrum efficiency improvement, security and privacy protection, as well as environmental and energy consumption issues have become pressing concerns. First, with the increase in mobile communication users and the emergence of new applications, existing spectrum resources are struggling to meet the growing demand, making effective management and improvement of spectrum utilization efficiency a key issue [6]. Second, security and privacy protection are becoming increasingly important in communication networks, especially in the 5G era, where the extensive application of IoT and massive data transmission have exacerbated security risks, making security a prerequisite for technological applications [2, 6]. Lastly, environmental and energy consumption issues are becoming more prominent with the large-scale deployment of wireless communication equipment. The high density of 5G base stations and devices has further increased energy consumption and carbon emissions. In response, green communication technologies, intelligent energy-saving techniques, along with the adoption of new materials and renewable energy are providing solutions to reduce energy consumption [1]. By optimizing network architecture and enhancing energy management efficiency, communication systems can achieve sustainability and environmental friendliness, thereby promoting the long-term sustainable development of society.

However, the future of wireless communication technology is also filled with revolutionary developments and transformative opportunities. The widespread adoption of 5G, 6G and more advanced wireless communication technologies have become the focus of global attention. 6G is expected to achieve qualitative leaps in data transmission rates, network capacity, and latency. Compared to 5G, 6G will offer higher transmission speeds, lower latency, broader coverage, and more diversified application scenarios [4]. The advancements in this technology will extend beyond the field of communication and will deeply integrate with frontier technologies such as artificial intelligence, big data, and the Internet of Things (IoT), fostering innovation and development across multiple industries [9]. At the same time, cutting-edge technologies like quantum communication and terahertz communication are also gaining attention. Quantum communication, due to its absolute security, is expected to address the vulnerabilities and risks of traditional encryption methods, while

terahertz communication provides possibilities for ultra-high-speed data transmission. These technologies will propel wireless communication towards greater efficiency, security, intelligence, and environmental sustainability, injecting new vitality into societal progress.

The integration of emerging technologies such as artificial intelligence (AI) and quantum communication will also become a key development direction in the wireless communication field. The application of AI in wireless communication can not only achieve intelligent scheduling and management of network resources through deep learning and adaptive optimization but also enhance capabilities in wireless signal processing and beamforming, thereby improving the interference resistance, coverage, and overall performance of communication systems [10]. In the future, users will enjoy a more stable and faster communication experience. Quantum communication, with its absolute security based on the principles of quantum mechanics, is becoming a key technology to address the growing threat to network security. Technologies such as quantum key distribution (QKD) and quantum teleportation can provide more secure and reliable protection for wireless communication systems, effectively safeguarding users' and enterprises' communication data against hacking and data breaches.

Overall, with the development of 6G and more advanced technologies, combined with breakthroughs in frontier technologies such as artificial intelligence and quantum communication, wireless communication systems will advance towards greater intelligence, security, and sustainability. The integration and innovation of these technologies will empower wireless communication in the global digital transformation and information infrastructure, providing strong support for sustainable societal development and progress [11].

6. Conclusion

The development of wireless communication technology plays an indispensable role in electronic engineering. Each iteration, from 2G to 5G, has significantly advanced societal progress, promoting the global transformation towards informatization and digitalization. The advent of 5G technology has not only achieved ultra-high-speed data transmission and low-latency connectivity but has also expanded its applications in emerging fields such as IoT, autonomous driving, and industrial automation. However, alongside these advancements, challenges such as spectrum scarcity, security and privacy protection, as well as environmental and energy consumption issues have become increasingly apparent.

Looking ahead, 6G and more advanced wireless communication technologies will bring revolutionary progress, meeting the future demands of society for higher information communication requirements by improving data transmission rates, expanding coverage, and reducing latency. Meanwhile, the integration of cutting-edge technologies such as quantum communication, terahertz communication, and artificial intelligence will provide strong support for the security, intelligence, and sustainability of wireless communication systems. These technological breakthroughs will lay a solid foundation for building more intelligent, green, and efficient communication networks, driving the global economy and society towards greater intelligence and informatization.

In summary, the future of wireless communication technology is characterized by both challenges and opportunities. Through continuous innovation and technological integration, wireless communication will continue to lead the development of global information technology, making an irreplaceable contribution to the progress of human society, economic prosperity, and the improvement of people's quality of life.

References

- [1] Fu Guanghua & Rong Youlue.(2023). *Research on intelligent Development of Wireless communication technology. Network security and Informatization* (12),7-9.

- [2] Zhang Xiao-Dong.(2022). *Analysis and research of key technologies for 5G wireless communication system*. *China New Communications* (17),1-3.
- [3] Pei Chunsheng.(2024). *Analysis on the combined development of mobile communication technology and Internet technology in the new era*. *Digital Communication World* (06),223-225.
- [4] Loung, V. Y. K., Ngah, R., Owusu, J., Han, C. T., Tweneboah-Koduah, S., & Din, J. (2021, October). *Key technologies and future trends of 5G wireless network applications*. In *2021 IEEE 6th International Conference on Signal and Image Processing (ICSIP)* (pp. 908-914). IEEE.
- [5] Wu Guang-lightspeed.(2023). *Application research of wireless communication technology in digitization*. *Industrial Innovation Research* (14),90-92.
- [6] Zhang Wei & Shi Yaoguang.(2023). *Advantages and Development Problems of 5G Wireless Communication System*.(eds.) *Proceedings of the 37th China (Tianjin) 2023 'IT, Network, Information Technology, Electronics, Instrumentation Innovation Conference* (pp.58-61). Tianjin Optoelectronic Communication Technology Co., LTD.; Doi: 10.26914 / Arthur c. nkihy. 2023.022848.4.DOI:10.26914/c.cnkihy.2023.022848.
- [7] Zhao Ruohan, Zhang Dan & Wang Tiantian.(2023). *Development and application of information communication technology in the era of Internet of Things*. *Information recording materials* (09), 121-123. The doi: 10.16009 / j.carol carroll nki cn13-1295 / tq. 2023.09.036.
- [8] Li Minyi, Hu Rongxian, Liu Tao & Liang Weikun.(2023). *Explore the status quo and development trend of wireless communication technology intelligence*. *Information recording materials* (09), 30 to 33. Doi: 10.16009 / j.carol carroll nki cn13-1295 / tq. 2023.09.007.
- [9] Li, J., Zhang, S., Wang, J., & Xiao, H. (2023, December). *Application and Development of 5G Technology in Smart Logistics Industry*. In *2023 9th International Conference on Computer and Communications (ICCC)* (pp. 1329-1333). IEEE.
- [10] Dong Runlin & Wang Yangyang.(2023). *Integration of artificial intelligence and wireless communication technology*. *Communications and Information Technology (SI)*,90-94.
- [11] Tandel, T., & Trapasiya, S. (2023). *Reconfigurable Antenna for Wireless Communication: Recent Developments, Challenges and Future*. *Wireless Personal Communications*, 133(2), 725-768.