

Overview of Wireless Communication Technology Development

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Abstract: Wireless mobile communication technology has gone through multiple generations of technical iteration, profoundly changing human communication modes and promoting social-economic development. Starting from digital 2G network, this paper sorts out the technical characteristics, core technologies and typical application scenarios of 2G, 3G, 4G and 5G mobile communication systems. It analyzes the evolution logic of mobile communication from voice-oriented service to mobile broadband and Internet-of-Everything. On this basis, the paper discusses the future developing trends of wireless communication technology, including 6G research, integrated sensing and communication, space-air-ground integrated network and artificial intelligence empowered network. Existing technical challenges are also summarized, which can provide reference for vocational teaching and related engineering research.

Keywords: wireless communication; 2G; 3G; 4G; 5G; technology evolution; future trend

1. INTRODUCTION

Wireless mobile communication is one of the most important information infrastructure in modern society. Every ten years, a new generation of cellular communication technology emerges, bringing revolutionary changes in transmission rate, time delay, connection scale and service form. After the analog-based 1G era, digital communication represented by 2G opened the modern mobile communication development process. With the rapid growth of user demand for mobile internet, multimedia services and industrial interconnection, 3G, 4G and 5G have been successively commercialized, and communication services have expanded from person-to-person voice interaction to large-scale human-machine-thing interconnection.

Studying the evolution path from 2G to 5G helps to grasp the core law of wireless communication technology upgrading. This paper firstly reviews the technical development course of 2G-5G, then forecasts the future development direction of wireless communication, and points out practical challenges for subsequent technology research and engineering promotion.

2. EVOLUTION OF WIRELESS COMMUNICATION FROM 2G TO 5G

2.1 Second-Generation Mobile Communication

2G entered large-scale commercial application in the early 1990s, realizing the transformation from analog communication to digital communication. The mainstream standards include GSM based on TDMA multiple access technology and IS-95 based on CDMA technology. Compared with 1G analog system, digital coding greatly improves voice quality and communication security. The most representative new service is SMS short message service, which becomes a widely popular text interaction mode.

The peak data rate of original 2G is only 14.4 kbps-64 kbps, which is mainly oriented to voice and short-message business. Later evolved 2.5G(GPRS) and 2.75G(EDGE) increase data transmission rate, and preliminarily support simple mobile internet access. Limited by low transmission capacity, 2G cannot bear large-volume multimedia data transmission task.

Its core value lies in popularizing digital mobile telephone and laying foundation for subsequent mobile data service.

2.2 Third-Generation Mobile Communication

3G is the first generation system specially designed for mobile data services, and formally commercialized in early 2000s. Typical standards include WCDMA, CDMA2000 and TD-SCDMA. It adopts CDMA as core multiple-access technology, theoretical peak rate reaches 384 kbps for mobile scenario and 2 Mbps for static environment.

3G realizes the integration of voice service and broadband data service. Users can browse web pages, send and receive emails, use multimedia message and realize preliminary video call. The subsequent HSPA and HSPA+ evolution versions further lift network rate, promoting the emergence of early smart-phone applications. However, 3G system still has obvious defects: network capacity is insufficient under high-density user scenario, anti-interference ability is limited, and it cannot support high-definition video and large-flow internet business on large scale.

2.3 Fourth-Generation Mobile Communication

4G(LTE/LTE-A) was commercially launched around 2010, taking OFDM and MIMO as core physical-layer technologies, adopting full-IP flat network architecture. The peak download rate of basic LTE reaches 100 Mbps, and LTE-A enhanced version can reach 300 Mbps or higher.

4G opens the era of high-speed mobile internet. It supports high-definition video streaming, mobile online game, mobile payment and various mobile internet applications, and greatly promotes the prosperity of smart-phone industry and mobile internet economy. Compared with 3G, spectrum utilization and system capacity are significantly improved, and end-to-end time delay is reduced. Nevertheless, when facing massive IoT access, ultra-low-delay industrial control and high-precision immersive business, traditional 4G still has prominent performance bottlenecks.

2.4 Fifth-Generation Mobile Communication

5G starts large-scale commercial deployment after 2019, following IMT-2020 performance requirements defined by ITU. Three major application scenarios are defined: enhanced mobile broadband(eMBB), massive machine-type communication(mMTC), ultra-reliable and low-latency communication(uRLLC) . 5G New Radio(NR) supports multi-band operation including Sub-6GHz and millimeter wave. Key technologies contain massive MIMO, beam-forming, ultra-dense networking and network slicing.

5G achieves peak rate of 20 Gbps, millisecond-level end-to-end latency, and supports one-million-level device connections per square kilometer. It not only optimizes consumer-oriented internet experience, but also expands wireless communication to industrial production, intelligent transportation, telemedicine and other vertical industries, realizing the transition from “consumer mobile internet” to “Internet of Everything”. At the same time, 5G still faces practical difficulties such as high construction cost of millimeter-wave base station, weak signal penetration and complex optimization of vertical-industry adaptation

Table 1. Main technical features of 2G-5G

Generation	Core Technology	Typical Peak Rate	Representative Services
2G	TDMA / CDMA	14.4-64 kbps	Voice call, SMS
3G	CDMA	384 kbps-2 Mbps	Web browsing, video call
4G	OFDM-MIMO	100-300 Mbps	HD video, mobile payment
5G	Massive MIMO, Network Slicing	10-20 Gbps	IoT, industrial control, VR/AR

3. FUTURE DEVELOPMENT TRENDS OF WIRELESS COMMUNICATION

3.1 Research and standardization of 6G communication technology

After 5G, the industry turns to 6G research. It is expected to complete technical research phase in 2025-2027 and realize commercial application after 2030 . 6G will adopt terahertz communication, intelligent metasurface and semantic communication. It will obtain higher transmission rate, lower time delay and higher positioning accuracy, and support holographic communication, tactile internet and full-domain emergency communication.

3.2 Integration of communication and sensing

The integration of sensing and communication is an important development direction. Future wireless base stations can realize wireless communication and target perception simultaneously by using same hardware resources. It can complete environment monitoring, target tracking and high-precision positioning without additional sensing equipment, which is of great value for smart city and automatic driving scenarios.

3.3 Space-air-ground-sea integrated network

Traditional ground cellular network cannot cover desert, ocean, mountain and other remote areas. Future wireless communication will integrate satellite communication, UAV aerial base station and ground cellular network to build space-air-ground-sea integrated network, so as to realize seamless global signal coverage, support remote medical treatment and disaster emergency communication business.

3.4 Space-air-ground-sea integrated network

AI will deeply participate in the whole process of wireless network: including intelligent channel estimation, intelligent resource scheduling, automatic network optimization and intelligent fault diagnosis. Artificial intelligence helps reduce network operation cost, improve spectrum efficiency and adapt to complex and changeable service requirements.

3.4 Main existing challenges

Future wireless communication also faces multiple challenges: high-frequency signal propagation loss, huge energy consumption of dense base-station deployment, data security and user privacy protection, as well as high cost of equipment and chip. The balance among performance, energy consumption and cost is an important problem to be solved in the next-generation wireless system.

4. CONCLUSION

From 2G digital voice, 3G mobile data, 4G broadband internet to 5G Internet of Everything, each generation of wireless communication technology brings leap-forward promotion of transmission performance and service capacity. Technical evolution is driven jointly by user service demand, breakthrough of physical-layer technology and industrial-ecology promotion. Looking forward to the future, wireless communication will develop toward 6G, integrated sensing-communication, space-air-ground integration and AI-driven intelligent network. While pursuing performance improvement, the industry also needs to properly solve the problems of energy consumption, cost and information security. For higher vocational colleges, mastering the evolution law of wireless communication can lay solid theoretical foundation for cultivating communication technical-skilled talents.

5. REFERENCES

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