Abstract

The use of mobile devices has witnessed a remarkable growth over the years, driving the advancement of wireless communication technologies. The key characteristic of these devices, portability, has played a crucial role in the evolution of mobile communication technologies, enabling uninterrupted communication in diverse environments. Cellular networks, which have undergone significant developments, provide wireless communication services across vast geographical areas. These networks have embraced numerous generations of network technologies (1G, 2G, 3G, 4G, etc.) to accommodate the rising number of devices and the ever-increasing communication demands anticipated in the future. This article aims to explore the evolution of both older and newer cellular network technologies, analyzing the enhancements made in network conditions throughout the years. Furthermore, it delves into research pertaining to projected network capacities for next-generation cellular network technologies.

Introduction

Mobile communication, one of the major sources of information exchange in today's world, has experienced significant advancements in recent years due to its continuous growth. According to the Cisco Annual Internet Report, it is projected that the number of mobile devices in use will reach 13.1 billion by 2023. This ongoing increase in numbers necessitates the development of new network technologies and allocation of resources to meet the growing communication demands of these devices. The primary concerns in mobile communication technologies revolve around providing wide coverage, enabling communication from any location without movement restrictions, and facilitating high data exchange rates.

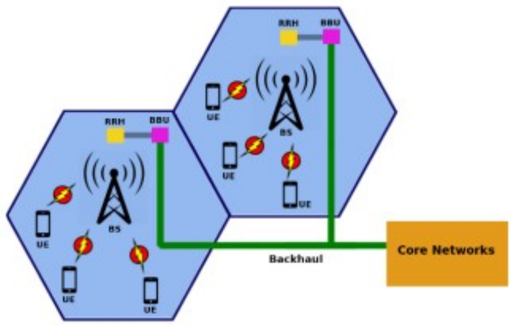

Fig. 1 Cellular Network model

Mobile wireless communication technologies have been evolving and continue to do so within the framework of periodically updated communication technologies. The aim is to create technologies that can address these demands with new generation networks. Figure 1 illustrates the cellular network model, which is a fundamental component of mobile communication technology. This network model establishes communication between end users (UEs) and core networks through base stations (BS), allowing seamless communication without location restrictions. As the number of users and the need for capacity and coverage areas vary, the emergence of numerous new generation network models has become inevitable. This work provides an overview of both old and new generation network technologies (1G, 2G, 3G, 4G, 5G, etc.). It explores the approaches and concepts used in these networks, as well as the emergence of new technologies and their key features. Chapter II delves into the overall coverage of these next-generation networks, placing them in context. Chapter III discusses the interrelationships between these networks, highlighting their advantages, disadvantages, and general evaluations through tables and comparative analyses.

2. Network Generations Overview

This section focuses on the examination of new developments and changes in response to user demands within the general structure of generation networks. It explores the utilization of new technologies and provides an overview of the network's general characteristics.

2.1. 1G (First Generation)

The first generation (1G) network model, initially introduced in the 1980s, employed analog signal technology and offered a transmission rate of approximately 2.4Kbps. It was primarily designed to support voice communication and did not facilitate data sharing. Within this model, various standards were utilized in different regions, such as the Advanced Mobile Phone System (AMPS), Nordic Mobile Telephone (NMT), and Total Access Communications System (TACS). It should be noted that due to the utilization of circuit switching technology, this model was unable to provide services to users while on the move.

2.2. 2G (Second Generation)

The 2G network model, introduced in the 1990s, utilized digital signal technology and offered transmission speeds of approximately 10Kbps. It represented the second generation of network technology and supported the Global Systems for Mobile Communications (GSM) standard. Additionally, it introduced features like Short Message Service (SMS) and email services, marking the first instance of these services in cellular networks. The 2G model employed multiplexing technologies such as Code Division Multiple Access (CDMA) and Time Division Multiple Access (TDMA), enabling data transmission alongside voice communication. Similar to the 1G model, circuit switching was used as the sharing method, and bandwidth was allocated between users.

Over time, the 2G network witnessed the introduction of certain sub-versions, such as 2.5G and 2.75G. The 2.5G network, also known as the intermediate network, incorporated General Packet Radio Services (GPRS) access technology, supporting transmission speeds of up to 50Kbps. It introduced features like Multimedia Messaging Service (MMS) for multimedia messaging. Another sub-version, 2.75G, implemented Enhanced Data rates for GSM Evolution (EDGE) technology, enabling speeds of up to 144Kbps. Unlike the 1G and 2G models, packet switching was utilized in these sub-versions, allowing more efficient data transmission

2.3. 3G (Third Generation)

The advent of the 3rd generation (3G) network model in the late 2000s brought significant advancements, providing support for transmission rates of approximately 384Kbps. This network model marked the introduction of video calling alongside voice and data transmission, setting the stage for enhanced communication capabilities. 3G networks utilized various access technologies, including CDMA2000, Wideband CDMA (WCDMA), and Universal Mobile Telecommunications Systems (UMTS), enabling faster and more efficient connectivity. Over time, subsequent versions of the 3G network, such as 3.5G and 3.75G, were developed, equipping the networks with advanced resources and technologies. The introduction of High-Speed Downlink Packet Access (HSDPA) access technology in these newer versions allowed for speeds of up to 2Mbps. Additionally, the implementation of High-Speed Uplink Packet Access (HSUPA) access technology enabled transmission rates of around 30Mbps. Some sources refer to HSPA as 3.5G, while HSPA+ is also referred to as 3.75G, signifying further improvements and enhancements in the 3G network.

2.4. 4G (Fourth Generation)

Since 2010, the 4G network model has been widely adopted in mobile cellular network technologies, with various improved versions implemented and actively used worldwide to this day. This generation of mobile cellular networks supports high transmission speeds, reaching up to 100Mbps. Technologies such as Long Term Evolution (LTE) and Mobile Worldwide Interoperability for Microwave Access (M-WIMAX) are utilized in these networks. Advanced versions of LTE, such as LTE Advanced and LTE Advanced Pro (also known as 4.5G), further enhance the user experience. These advanced networks employ Orthogonal/Single Carrier frequency-division multiplexing (OFDM/SC-OFDM) multiplexing technology. In terms of data transmission, packet switching is used as the preferred model.

2.5. 5G (Fifth Generation)

Since its announcement in 2015, the new generation of 5G networks has been gradually deployed in various countries, although not simultaneously worldwide. These cellular networks represent the latest iteration, incorporating technologies such as WWWW (World Wide Wireless Web) and IPv6 to establish a robust cellular infrastructure. With data transmission rates exceeding 1Gbps, 5G networks offer high-speed connectivity. They provide users with an exceptional experience by delivering services in high-capacity coverage areas, regardless of frequency or mobility. The infrastructure of 5G networks is designed to ensure secure communication, employing a combination of circuit switching and packet switching (Packet switching) technologies. Multiplexing techniques like CDMA and Beam Division Multiple Access (BDMA) are utilized within these networks.

5G networks facilitate the development of smart cities, support low-latency and fault-tolerant healthcare applications, and seamlessly connect Internet of Things (IoT) devices. This technology enables high data rates and bandwidth for communication. By integrating the Mobile Edge Computing (MEC) system, 5G networks offer certain applications, such as Augmented Reality and low-latency streaming, with reduced delays. The MEC system brings cloud resources (execution, storage, etc.) closer to the user, resulting in lower latency compared to central cloud systems that are fixed in location. The combination of 5G infrastructure, cloud resources, and proximity to the user in access points has become a prevalent scenario in recent years. The MEC system contributes to providing low-latency services, ensuring trouble-free user experiences. Moreover, 5G networks optimize energy consumption in mobile devices, significantly reducing battery usage. This enables devices to operate with minimal resource consumption. The powerful network resources of 5G networks play a key role in ensuring the smooth operation of these systems and delivering reliable services..

3.The Future of Cellular Networks

The continuous development of cellular networks and the increasing demand for resources due to the growing number of devices and users necessitate the introduction of new generation networks. Organizations like Cisco, along with similar institutions, estimate the future number of users and devices, driving the development of network models that can cater to these demands. Consequently, it is anticipated that advanced network technologies such as 6G, 7G, or 7.5G will emerge, either in conjunction with or as replacements for the current 5G wireless network technology.

Researchers and experts in the field have conducted studies on the architecture and expected resources of the next generation cellular network technologies. For instance, some authors have proposed ideas regarding the general structure of networks like 6G and 7G, as well as the technologies that are expected to be present in these networks. In the case of the new generation models, one of the key differences from the latest 5G networks is the significant changes in coverage. It is emphasized that, in contrast to previous network generations, the integration of satellite systems will play a crucial role in achieving global coverage beyond the service areas accessible to users.

6G vs. 7G expectations

	6G	7G
Theoretical data rate	11 Gbps in early test	46 Gbps
Bandwidth channels	Three 160 MHz	Three 320 MHz
Spatial streams	Up to 8	Up to 16

Table 3

However, the integration of satellite networks, such as GPS, COMPASS, Galileo, and GLONASS, presents certain challenges and costs in terms of providing seamless service hand-offs and roaming between these networks. Moreover, it is predicted that the data transmission rates in these networks will reach 11Gbps and beyond, as illustrated in Table 3.

4. Conclusion

This study explores the overall framework of wireless cellular network technologies. The objective is to offer insights into the evolution of cellular networks, the technologies employed, and potential network models that may arise in the future. As user preferences increasingly gravitate towards mobile devices and their extensive utilization, the importance of cellular networks as fundamental communication infrastructure within wireless technology becomes apparent, particularly considering the mobility aspect of these devices. The ever-expanding pool of devices and users reinforces the expectation for continuous advancements in cellular network development.

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