Research on user scale requirements based on 5G core network resource pool calculation

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ABSTRACT

With the widespread application of 5G technology, user demand is constantly increasing, and the user base is also growing. How to allocate core network resource pools reasonably based on user size and demand, and effectively utilize resource efficiency has become an urgent problem to be solved. This article first analyzes the development history of the core network and points out that the evolution of the core network has gone through stages of 2G, 2.5G, 3G, 4G, and 5G, gradually achieving an increase in network speed. It is also pointed out that the scale of 5G base stations and 5G users in the first half of 2024 will increase by varying degrees compared to the same period last year. Secondly, the factors affecting the 5G core network resource pool were analyzed, including technological development, business requirements, cost considerations, architectural flexibility, maturity, and reliability. According to the calculation formula, provide a method for calculating network bandwidth and configuring resources such as port firewalls. Finally, the network bandwidth and port configuration of three different provinces were calculated through examples.

Keywords: 5G, Core network, Network bandwidth

1. INTRODUCTION

The significance of the 5G core network lies in meeting the rapid development needs of various services that include extensive data and connectivity in the future, as well as meeting the ever-changing demands of the Internet of Things[1].

The 5G mobile broadband system, as a network that integrates multiple services and technologies, aims to meet three major business scenarios and corresponding performance requirements through the evolution and innovation of ICT technology, namely eMBB (Enhanced Mobile Broadband), uRLLC (Ultra Reliable Low Latency Communication), and mMTC (Massive IoT Communication). In order to achieve these goals, 3GPP has defined a new 5GC core network with 4S (SBA architecture, Network Slicing, CUPS, and Stateless) and two core network architectures (5GC or EPC) to adapt to different wireless deployment scenarios[2]. The progressiveness nature of this network architecture avoids repeated investment and frequent network transformation, helps to achieve a leading market position, and also facilitates centralized construction and intensive operation and maintenance, unifies network access, helps to introduce big data, artificial intelligence, improve network intelligence, expand vertical industry cooperation, and quickly launch new businesses.

In addition, the 5G core network also has the ability to quickly customize, operate based on slicing, and have highly automated intelligent operation and maintenance capabilities, which cannot be met by the 4G core network (EPC) networking architecture built based on traditional architecture[3]. Therefore, the 5G core network is not only a reflection of technological progress, but also a key infrastructure for addressing market challenges and meeting user needs. It is of great significance for promoting digital transformation, improving production efficiency, and optimizing user experience.

2. OVERVIEW OF CORE NETWORK

2.1 Development history of core network

The mobile communication network is divided into two parts, one is the access network and the other is the core network. The core network is the core of the network, and base stations or access networks are only responsible for connecting

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International Conference on Optics, Electronics, and Communication Engineering (OECE 2024), edited by Yang Yue, Proc. of SPIE Vol. 13395, 133953Q · © 2024 SPIE · 0277-786X · Published under a Creative Commons Attribution CC-BY 3.0 License · doi: 10.1117/12.3050173

terminals. Business is implemented and controlled by the core network[4]. That is to say, the core network is the part responsible for implementing and controlling services in mobile communication networks.

The core network mainly includes two functions: user management and business implementation. User management is the use of terminals to manage the access of users, including authenticating incoming users, verifying whether they are legitimate users, and checking their location and other information[5]. Business implementation includes helping users achieve telephone end-to-end transmission, internet access connection, as well as docking duration and traffic statistics.

At present, the evolution of the core network has gone through several stages including 2G, 2.5G, 3G, 4G, and 5G, as shown in Figure 1.

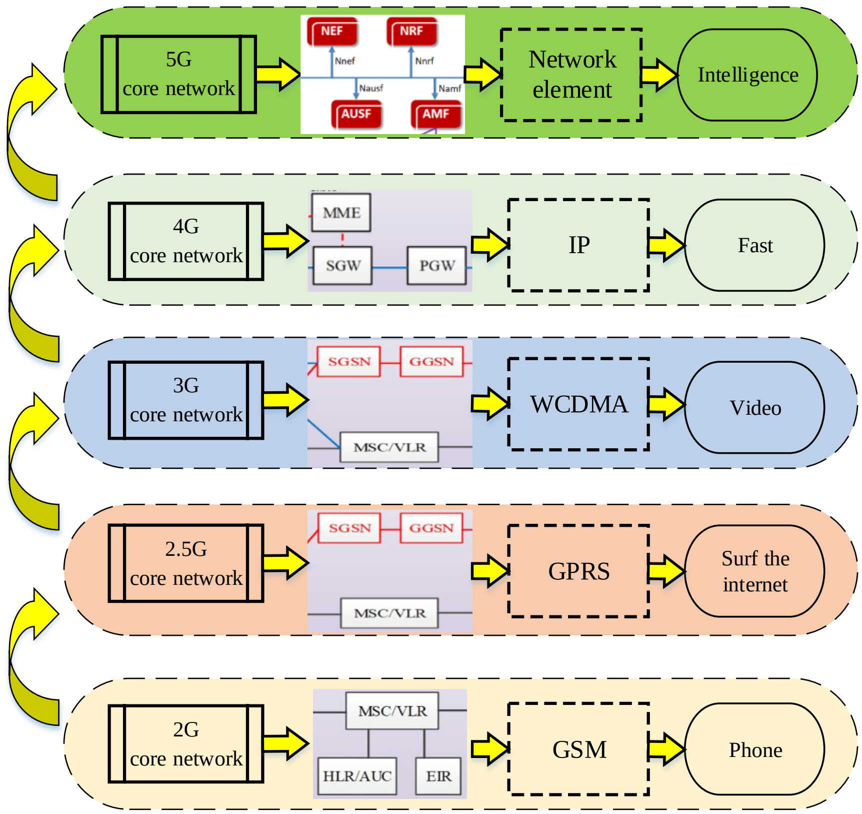


Figure 1. Development history of core network

2G core network. The core network emerged from the 2G era, followed by 2.5G, 3G, 4G, and evolved all the way to the current 5G era. In the 2G era, we could make phone calls, but the base stations and core network equipment in the 2G era were very bulky[6]. Due to technological limitations at that time, the base stations and core networks could only use dedicated equipment, which was very large in size and weight, making it very inconvenient to use or transport. In addition, the base stations in the 2G era not only had base station transceivers, but also base station controllers. The base stations in the 2G era also served as part of the core network functions.

2.5G core network. After the 2G era, due to incomplete technological evolution, the first era to arrive was not 3G, but the 2.5G era. 2G uses GSM technology, while 2.5G uses GPRS technology[7]. GPRS is the abbreviation for General Packet Radio Service technology, which is a mobile data service available to GSM mobile phone users and belongs to the data transmission technology in the second generation of mobile communication. GPRS is a continuation of GSM. Compared to 2G, 2.5G has an additional line, IP data network, because in the 2.5G era, we can already access the internet, but the network speed can only transmit some text data. Look at this IP data network line, there is an SGSNs, which are serving GPRS support nodes, and a GGSNs, which are gateway GPRS support nodes. The SGSNs and GGSNs work together to complete the mobile communication network packet service function[8]. So in the 2.5G era, the core network evolved into the circuit core network and the packet core network, responsible for voice and data services respectively, that is, making calls and accessing the internet.

3G core network. After the end of the 2.5G era, we entered the 3G era. The 3G era uses WCDMA technology, which stands for Wideband Code Division Multiple Access and is the third-generation wireless communication technology[9]. In the 3G era, base stations and core networks are still specialized equipment, but there is a trend towards transitioning to general-purpose devices. In the 3G era, online chatting is now possible, allowing users to send text and emojis, pictures, and watch videos, further enriching their leisure life.

4G core network. After the end of the 3G era, we entered the 4G era, which is now widely present in our lives. Most of our mobile phones are still 4G phones, and the base stations and core networks of the 4G era have shed their bulky labels and entered the era of universal use. Although small base stations appeared in the 3G era, they were further improved in the 4G era, truly opening the chapter of "putting towers into boxes"[10]. In the 4G era, from base stations to core networks, it's not just about changing names. All signaling interactions are based on IP. Specifically, different types of information streams that need to be transmitted through links are uniformly converted and summarized into TCP/IP data streams, which can be transmitted through a set of TCP/IP networks without the need to build different transmission media and management platforms for different services. It's about integrating all services into one, which greatly reduces transmission costs and further improves transmission speed.

5G core network. Also known as 5GC, it still connects mobile phones to the core network through base stations. Currently, there are two different types of base stations: gNB is a 5G base station, and ng eNB is a 4G base station that has been upgraded to connect to the 5G core network. The reason why there are currently two types of base stations in operators' networks is that the 5G era has just begun, and many 4G base stations have not yet been able to be replaced with 5G base stations, so they can only temporarily support 5G networks through upgrades. The 5G core network has split the original multi-functional single network element into multiple network elements with single functions, which means that originally one person was doing ten things, but now ten people are doing one thing. Therefore, compared to before, 5G has greatly improved its speed.

2.2 User development

The construction of 5G networks is steadily advancing, as shown in Figure 2.

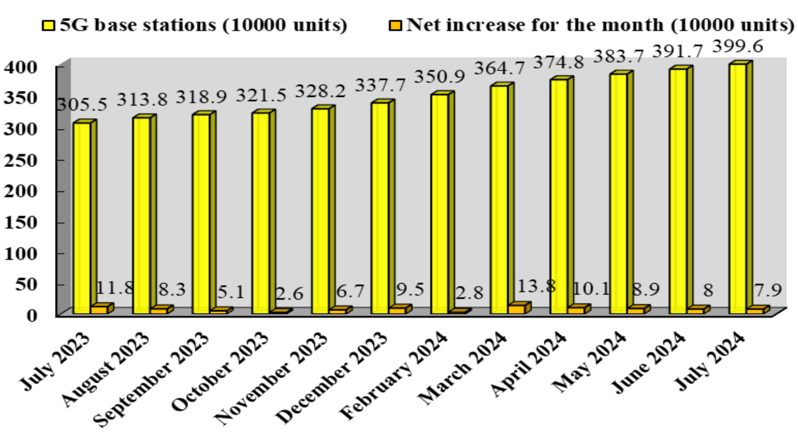
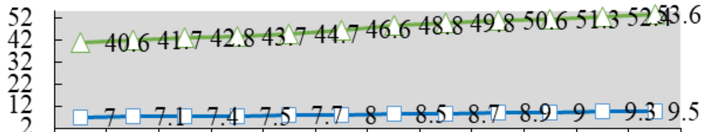


Figure 2. Development history of core network

According to data released on the economic operation of the communication industry, as of the end of July 2024, the total number of 5G base stations reached 3.996 million, a net increase of 619000 from the end of the previous year, accounting for 33.5% of the total number of mobile base stations and an increase of 0.5 percentage points compared to the first half of the year. Various regions are actively promoting the construction and application of 5G. As of the end of July, the number of 5G base stations in the eastern, central, western, and northeastern regions reached 1.767 million, 905000, 1.069 million, and 255000 respectively, accounting for 34.5%, 35.1%, 31.1%, and 32.6% of the total number of mobile phone base stations in the region; The number of 5G mobile phone users reached 417 million, 223 million, 246 million, and 63 million respectively, accounting for 54.2%, 53.8%, 53.1%, and 51.4% of the total number of mobile phone users in the region. As of the end of July, the number of 5G base stations in the Beijing Tianjin Hebei and Yangtze River Delta regions reached 370000 and 775000 respectively, accounting for 35.7% and 34.9% of the total number of mobile phone base stations in the region; The number of 5G mobile phone users reached 84.52 million and 171.2 million respectively, accounting for 56.1% and 53% of the total number of mobile phone users in this region.

The scale of mobile phone users is steadily increasing, while 5G users are rapidly developing, as shown in Figure 3.



	July 2023	August 2023	September 2023	October 2023	November 2023	December 2023	February 2024	March 2024	April 2024	May 2024	June 2024	July 2024
Number of 5G mobile phone users (in billions)	7	7.1	7.4	7.5	7.7	8	8.5	8.7	8.9	9	9.3	9.5
Proportion of 5G mobile phone users (in billions)	40.6	41.7	42.8	43.7	44.7	46.6	48.8	49.8	50.6	51.3	52.4	53.6

Figure 3. Development history of core network

As of the end of July 2024, the total number of mobile phone users of the three basic telecommunications companies and China Radio and Television reached 1.772 billion, a net increase of 28.12 million from the end of the previous year. Among them, the number of 5G mobile phone users reached 950 million, a net increase of 128 million from the end of last year, accounting for 53.6% of mobile phone users, an increase of 7 percentage points from the end of last year.

3. 5G CORE NETWORK RESOURCE POOL COMPUTING

3.1 Influence factor

The influencing factors of core network resource pool mainly include technological development, business requirements, cost considerations, architectural flexibility, maturity, and reliability.

Technological development. With the development of Network Function Virtualization (NFV) and Software Defined Networking (SDN) technologies, operators are able to build more flexible and scalable network architectures, enabling resource sharing and elastic scaling of network elements, thereby supporting rapid innovation and deployment of services.

Business requirements. With the rapid change of mobile Internet services, operators need to break the closed characteristics of traditional telecommunications networks to meet the growing business needs. NFV technology enhances system flexibility and improves maintenance and management efficiency by implementing traditional telecommunications equipment functions through software and running them on general hardware devices.

Cost considerations. The cost transparency of NFV equipment leads to a rapid decrease in procurement costs, which helps to reduce the total cost of ownership (TCO). The centralized deployment of NFV equipment in the region facilitates intensive operation and maintenance management, significantly reduces operation and maintenance costs, and improves resource utilization.

Architecture flexibility. The user interface devices of NFV are very suitable for flexible deployment requirements, and in the 5G slicing deployment scenario, NFV devices can better meet user needs. This flexibility helps meet different differentiated needs, supporting on-demand, elastic, and long-term evolution requirements.

Maturity level. Virtualization devices have been deployed on a large scale in the IT field, accumulating rich experience. In the field of CT, there are already several hundred vEPC commercial networks operating stably worldwide, indicating that the application of virtualization technology in the telecommunications industry has become relatively mature.

Reliability. The NFV telecom cloud resource pool needs to meet the deployment requirements of telecom grade high performance and high reliability, with the ability to unify orchestration and intelligent scheduling to ensure service continuity and stability.

In summary, the construction and development of core network resource pools are influenced by multiple factors such as technological progress, market demand, cost control, architectural flexibility, maturity, and reliability.

3.2 Formula

As mentioned earlier, due to the compatibility of both 4G and 5G networks, some 4G base stations temporarily support 5G networks through upgrades. Therefore, the calculation of users and traffic within the core network needs to take into account both 4G and 5G, as shown in formulas （1）to（6）. It is necessary to separately calculate the active users of 4G and 5G, calculate the traffic of 4G and 5G based on this, and finally calculate the total traffic to obtain the network bandwidth.

4G active users=total scale x proportion of users x proportion of active users x proportion of 4G (1)

5G active users=total scale x proportion of users x proportion of active users x proportion of 5G (2)

4G data=4G active users x 4G speed/1000/1000 (3)

5G traffic=5G active users x 5G speed/1000/1000 (4)

Total flow=4G flow+5G flow (5)

Network bandwidth=total traffic/traffic utilization rate (6)

Finally, select the appropriate router and firewall based on the calculated network bandwidth. When configuring a router, the first choice is to select ports based on network bandwidth, and then configure the number of ports and the direction of entry and exit. Finally, calculate the total number of ports in a single room and remote disaster recovery. The firewall configuration is the same.

4. EXAMPLE

By 2025, the total scale will be 10 million households, with provinces A, B, and C accounting for 30%, 30%, and 40% respectively, and active users accounting for 30% each. The proportion of 4G and 5G is 40% and 60% respectively, with speeds of 150Kbps and 250Kbps, and a data utilization rate of 80%. The above parameters are shown in Table 1.

Table 1. Network bandwidth calculation parameters by 2025

Overall scope	10 million households	**Business model**	4G	5G
Province	Proportion	**Proportion**	40%	60%
Province A	30%	**Rate**	150Kbps	250Kbps
Province B	30%	**Network traffic utilization rate**	80%	80%
Province C	40%	**Proportion of active users**	30%	30%

According to formulas (1) to (6), the 4G active users, 5G active users, 4G traffic, 5G traffic, total traffic, and network bandwidth of provinces A, B, and C can be obtained respectively. The calculation results are shown in Table 2.

Table 2. Network bandwidth calculation results

Province	**4G active users**	**4G data（Gbps）**	**5G active users**	**5G traffic（Gbps）**	**Total traffic（Gbps）**	**Network bandwidth**
Province A	36	54	54	135	189	236.25
Province B	36	54	54	135	189	236.25
Province C	48	72	72	180	252	315

According to this calculation, the number of ports in each province is single room, and remote disaster recovery is considered. Based on the bandwidth calculation results, a 100G port was selected, and the calculation results are shown in Table 3.

Table 3. Calculation results of port quantity

Province	**Number of 100G**	**Entering and**	**Single room**	**Remote**

	ports	exiting the bureau	main port	disaster recovery
Province A	3	6	12	24
Province B	3	6	12	24
Province C	4	8	16	32

According to the above calculation results, the network bandwidth of provinces A, B, and C needs to meet 236.25 Gbps, 236.35 Gbps, and 315 Gbps, respectively. The number of 100G ports that need to be purchased is 24, 24, and 32, respectively.

5. CONCLUSION

(1) The application of 5G core network is of great significance. The 5G core network is a mobile network core layer device based on the 5G network architecture and is a core component of the 5G network. It is responsible for handling core functions in the network, including user connections, traffic management, service quality assurance, and security.

(2) The size of users and the proportion of traffic determine the network bandwidth. The calculation of users and traffic within the core network requires the simultaneous calculation of 4G and 5G users and traffic, and then the calculation of active users separately. Based on this, the traffic and total traffic are calculated, and finally the network bandwidth is obtained.

(3) In the future, the evolution of 5G core network is the optimal path for the construction of 6G core network. The 5G core network is standardized in a future oriented manner and allows for the utilization of 5G core network functions such as open capability, time sensitive and reliable communication, network slicing, intergenerational network interoperability, and roaming from the launch of 6G.

REFERENCES

[1] Liang, X., M., Fang, X., N., Zhu, Z. H., "Analysis of New Concepts of 5G Core Network in R18 Version," Telecommunication Engineering Technology and Standardization, 37 (08): 1-6 (2024).

[2] Luo, F., Y., "Comparison of Typical Cases and Standardization Mode Analysis of 5G Customized Private Network," Communication and Information Technology, (04): 54-58 (2024).

[3] Zheng, Z., Y., "5G Virtual Network Implementation Plan and Technical Research," Modern Information Technology, 8 (13): 1-4 (2024).

[4] Jiang, P., P., Meng F. Q., Cao J., et al., "Research and Application of 5G Voice End to End Connection Delay Optimization Strategy," China New Communications, 26 (07): 10-12 (2024).

[5] Li, P., P., Wu, H., Liu, J., J, et al., "Overview of 5G Security Technologies and Strategies for Intelligent Railways, Computer Science," 51 (05): 1-11 (2024).

[6] Guo, X., J., Qiu, W., "Research on Key Technologies and Deployment Plans of 5G NR Multicast Broadcasting," Broadcast and Television Technology, 51 (03): 62-68 (2024).

[7] Liang, J., Luo, X., F., Zhang, Y, T., "Application of Radio and Television 5G Network E2E Flow Control and Fault Scanning System in Asian Games Support," Radio and Television Information, 31 (03): 73-76 (2024).

[8] Zhang, J., H., "A Brief Discussion on Empowering Smart Factory Applications with 5G+Artificial Intelligence Technology," Guangxi Communication Technology, (04): 7-10 (2023).

[9] Xie, G., "Research on 4G/5G Interoperability Optimization Strategy in 5G Dual Domain Private Network," Wireless Internet Technology, 20 (22): 4-6+20 (2023).

[10] He T., "Research on the Design Model of Enterprise 5G Private Network Core Network," Telecom Express, (11): 27-32 (2023).