6G Lean RAN White Paper

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China Mobile Research Institute

Preface

This white paper aims to put forward the driving force analysis, architecture design, key technologies and challenges by China Mobile for 6G lean radio access network. We hope that it can provide reference and guidance for the design scheme of 6G access network architecture and protocol stack function in the industry.

contents

1 Background

With the rapid expansion of the network scale and the increase of the service requirements, the network architecture is becoming more and more complex. Cost and power consumption are potential problems that need to be solved. In order to solve these problems, the design of 6th Generation Mobile Networks (6G) will move towards a simple way and adopt a lightweight network architecture. We hope that the future network will be as concise as possible， support plug-and-play and dynamic switching, so as to save power consumption and cost. In this white paper, the driving force, architecture and key technologies of 6G lean access network are researched and analyzed.

On the one hand, the driving force of 6G lean radio access network comes from the potential problems of the existing network, on the other hand, it needs to solve the new requirements and new scenarios introduced with the development. The cost and energy consumption of radio network are the bottleneck problems of radio network construction. These problems have begun to appear in the 5th Generation Mobile Networks (5G), and they will become more and more prominent for 6G. In 6G, flexible and dynamic networks should be considered and plug-and-play enabling technologies should be explored. Signaling and data decoupling is studied as a potential technology. Wide area signaling coverage is carried out through low-frequency signaling cells to ensure the reliability of the control plane, such as reliable mobility management and fast service access; On the other hand, dynamic data cells loading are adopted to improve the data transmission capacity of the network and reduce the interference between cells. In terms of new network application scenarios, with ubiquitous network connections, integration of ground, air and space and the introduction of differentiated new application scenarios, using the existing protocol architecture will inevitably lead to increased complexity. Lean radio access network realizes the unified access of a variety of air interface technologies by adopting a unified wireless protocol architecture, functional design and process framework, so as to simplify the network [1]. The digitization and intellectualization of social development have derived a series of new service requirements, such as holographic communication, synaesthesia interconnection, smart medicine, smart factory, etc. The definition of service requirements has also expanded from three dimensions of delay, bandwidth and number of connections to multiple dimensions [2]. Traditional connection-oriented communication methods and design ideas based on data transmission and processing may not cover all the requirements of 6G. With the help of data technology, operation technology, information and communication technologies (DOICT) and other new means, the network can realize the simplification of protocol design, efficient data transmission, robust signaling control, on-demand network function deployment and accurate network services through the enhancement of functions, so as to achieve the effect of "strong ability and simple structure".

The plug-and-play network construction mode enables the number of cells to increase dynamically according to the development of the services. In hot spot areas, more data cells can be switched on to provide users with better services. In areas with low service requirements, some data cells can be switched off to save the network energy consumption, which can directly reduce network construction costs, network energy consumption and redundancy, thereby realizing cost and energy savings.

Figure 1 shows a schematic diagram of the lean network. Through the accurate control of access points in the cloud combined with link management, the functions such as self-discovery and self-adding of access points are realized to achieve the flexible expansion of network coverage and the plug and play of nodes [3].

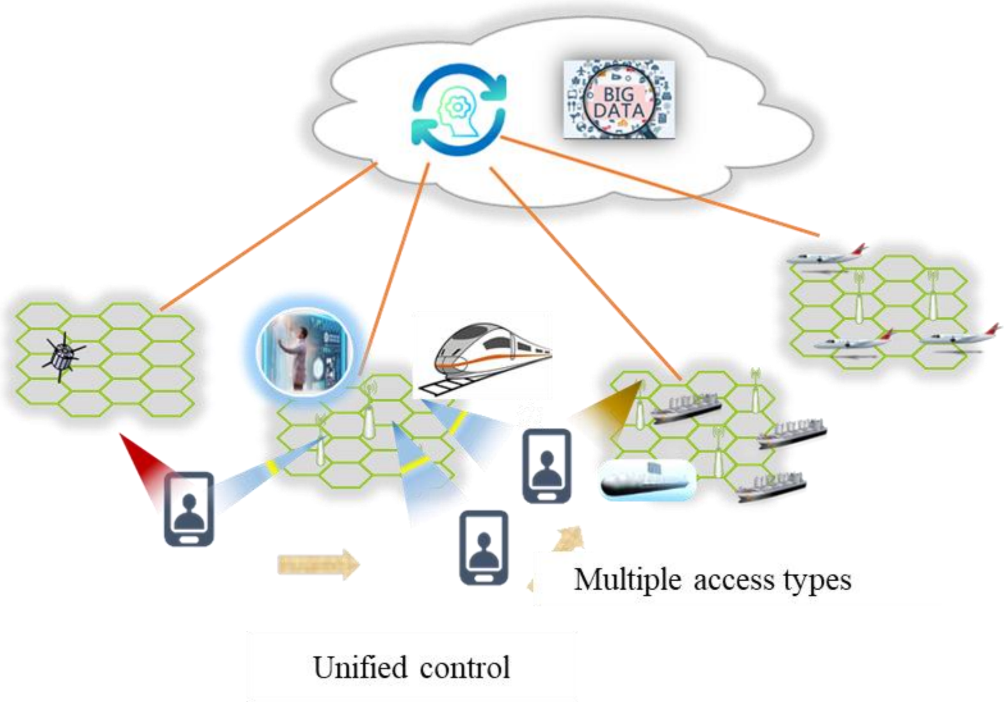

Fig. 1 Schematic diagram of the lean network

2 The driving force of 6G lean radio access network

2.1 From "build before use" to "deploy on demand"

A high-quality communication network is an important basic guarantee for the development and prosperity of new applications. According to past experience, advanced construction provides an important platform support for application innovation. The network construction adopts the principle of width coverage first and then depth coverage to continuously improve user experience. As of August 2021, China has built more than one million 5G base stations, accounting for more than 70% of the world's total 5G base stations. The 5G network has covered all prefecture-level cities across the country, as well as more than 95% of county-level urban areas and 35% of town areas. The number of 5G users have exceeded 539 million. With the rapid expansion of network scale and the increase of service requirements, continuing the current network architecture method will lead to higher and higher network costs. As the frequency band becomes higher, the construction of base stations will be more intensive under the same network performance and network quality requirements. Considering that the available frequency bands are getting higher and higher, if the 6G network continues to follow the current architecture, a large number of base stations need to be deployed densely to meet the requirements of coverage and throughput, which directly leads to further increase in the cost of 6G network. How to save network costs through technical method such as architecture design without the user experience deterioration is an issue that needs to be considered in the early stage of 6G network construction. lean network architecture and on-demand flexible network deployment are considered as potential approaches for 6G network deployment. Wide-area coverage is achieved through low frequency bands, and hot spot coverage is flexibly and dynamically added on demand. The plug-and-play method is adopted to ensure the flexible expansion of the network on demand, so as to realize the network performance according the requirements

2.2 From "high energy consumption" to "green network"

With the development of technology, the single-bit energy consumption of 5G is one-fifth of that of 4G. Because of the large bit rate and high throughput of 5G base stations, the power consumption of a single station is four times that of 4G. Nowadays, the energy consumption of 5G has received extensive attention in the industry. According to statistics, by 2023, the power consumption of 5G base stations is expected to account for 1.3% of the electricity consumption of the society. By 2026, the power consumption of 5G base stations will rise to 2.1% of the electricity consumption of the whole society. According to the existing network development trend, the complexity of 6G network will increase exponentially. The existing network has a single form, the base station has all functions, and the resources of the network are unbalanced, which may further increase the energy consumption. In order to realize a green network, reducing energy consumption is an important issue that must be considered and solved in the 6G era. Through the decoupling of signaling functions and data functions, signaling cells are deployed at low frequencies to achieve wide-area coverage, and dynamically enabled data cell functions can be customized on demand to reduce network energy consumption. In this way, the network utilization rate is improved, and energy saving is realized.

2.3 From "Three Scenarios" to "More Diversified Scenarios"

The driving force of network development is the continuous improvement of human well-being. The digitization and intelligence of social development have generated a series of new service requirements. By 2030, more applications will emerge to support the digitization of the entire world, such as holographic communication, communication and perception interconnect, smart medical treatment, and smart factories. Typical application scenarios will also change from "three major scenarios" to more fragmented application scenarios. As shown in Figure 2, the definition of 6G service requirements will also introduce new indicators, such as AI capabilities and perceptual computing capabilities. Service metrics will expand from single-point performance requirements to more diverse extreme performance requirements. 6G network should have enough flexibility and expansivity to support various unforeseen new demands emerging with the rapid development of society.

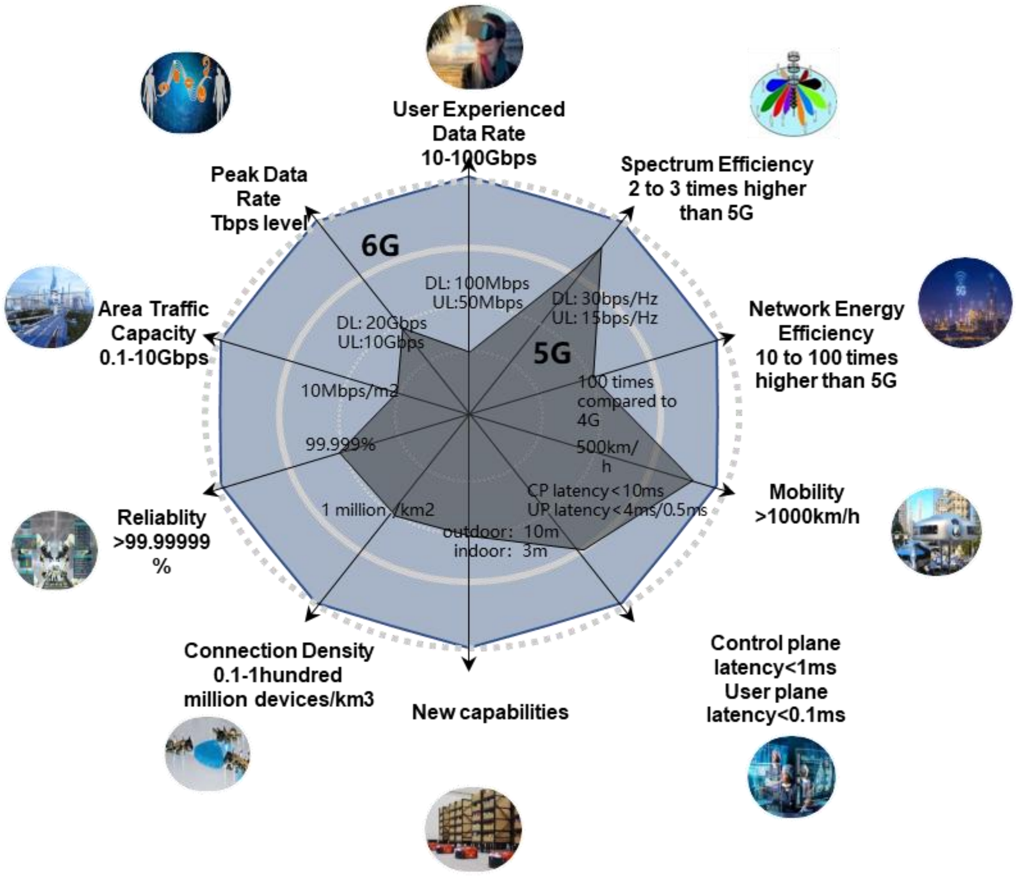

Figure 2 Key performance indicators of 6G scenario [4]

2.4 From "Flat network" to "Cube network"

From the ubiquitous connection needs of human beings, it can be seen that the future mobile communication technology is also moving towards full coverage of the sea, space, air and ground, enabling a wider range of collaborative control connections in the network. From the perspective of social development trend, the network from 4G to 5G has become more and more extreme, and its coverage has become wider and wider. However, the coverage rate in some specific areas is still low. For example, in order to better meet the needs of environmental monitoring, field rescue, and ocean exploration, the communication network must have the ability to connect beyond the land and across the ocean, and is distributed in sparsely populated unmanned or semi-unmanned areas. It can be seen that the air-space-ground integrated wireless network is also a part of the lean radio access network. The air-space-ground integrated network integrates the terrestrial network and the non-terrestrial network by using a variety of technical means to provide users with better quality of service. The non-terrestrial network composed of near-earth satellites and various aircraft can provide three-dimensional network coverage for remote areas (such as oceans, mountains, etc.), which is conducive to helping the ground network to achieve ubiquitous coverage in the whole area. The ground mobile network provides basic big data storage and processing capabilities, and can provide higher transmission efficiency. The two complement each other and can realize the transformation from " Flat network " to "Cube network".

2.5 From "expert experience" to "high-level network autonomy"

As of the end of June 2021, China Mobile has operated 5.28 million base stations, ranking first in the world in total. The large scale of base stations, multi-mode coexistence, large amount of network parameters, and diverse scenarios all put forward high requirements for network operation and maintenance. Facing more dimensions scenarios, more service types, and more parameter configurations in 6G, the network operation and maintenance methods will move towards a high level of network autonomy. Virtualization and service based infrastructure provide the basis for flexible resource allocation at the resource layer, on-demand generation of network layer functions, and flexible network orchestration, which also aggravates the difficulty of network management. Orchestration and management are a crucial part of ensuring diverse service experience for users. Efficient orchestration management can match resources at the resource layer (including radio resources, computing resources, storage resources, deployment space resources, etc.) with network functions to maximize usage efficiency. As network functions become more flexible, the original manual operation and maintenance methods have higher requirements for operation and maintenance personnel. The management of the access network domain and the configuration of wireless parameters will become more and more complicated with the flexibility of network functions. Access network domain management through expert experience will become a bottleneck in network operation, maintenance and management. The 6G lean radio access network also needs to explore high-level network autonomous operation and maintenance methods based on artificial intelligence (AI) and digital twins for self-optimization, self-evolution, and self-growth to solve potential network efficiency, cost, and user experience issues.

3 Lean radio access network architecture

In order to realize cost and energy consumption reduction in the future network and raise the adaptation capability for new scenarios and demands, 6G radio access network needs to make breakthroughs in architecture design and explore new flexible architecture to adapt to future changing demands.

- **Control plane and user plane decouple**

The requirements of the control plane are different from that of the user plane. The requirements of the control plane include satisfying as many users as possible, improving user density and user mobility performance, reducing the handover frequency and improving reliability. The requirements of the user plane include higher peak rate, user experience rate, and traffic density. The traditional base station has fixed functions, and the use of ultra-dense network to improve the performance of user side usually brings about switching, load balancing and interference problems. The 6G lean radio access network realizes wide-area coverage through low-frequency signaling cell, and on-demand data transmission through medium-high frequency data cell. Combined with the perception of service demand, the data cell can be turned on or off on demand to realize the reduction of network power consumption.

- **Service based architecture**

In the service-based architecture, the functions of base stations can be flexibly matched. Considering the flexible expansion of the network, complete network functions can be provided by reconstructing service functions and the combination of multiple services to flexibly support different service scenarios and requirements. Emerging services have obvious personalized requirements, and the network needs to be able to flexibly adapt to service requirements. Network function design needs to explore a network function service definition with low cost, good real-time performance and adaptability to various business requirements. Through the service based architecture, network functions can be customized on demand, resources can be configured on demand, and functions can be dynamically generated, providing architectural support for the lean radio access network.

- A unified architecture supporting multiple air interface technologies

Considering differentiated application scenarios such as ground, sea and air, 6G radio access network will be carried out in accordance with the unified architecture design. Through the radio access network supporting the integration of different access systems, the unified access of multi-network including the ground, underwater, satellite is realized . Through the unified control of air interface, terminals can access the network indiscriminately,thus reducing the complexity of accessing networks.

- **Plug and play**

With the booming development of emerging services, the demand for network continues to increase. In some areas with unexpected services, plug and play provides on-demand network coverage, thereby reducing the cost of the network from the perspective of network architecture.

To support the above features, wireless network functions can be divided according the dependence of air interface technology:

Table 1 Network function and the dependence of air interface technology

Dependency	Network function
Closely related	PHY，Scheduling and resource allocation in MAC
Related	RRC

Relatively independent	PDU processing, i.e. encryption and decryption, integrity protection and reordering, and so on

According to the characteristics of different network functions, network functions can be divided into four parts: radio resource control, high-layer packet processing, air interface adaptation and physical layer processing. The lean radio access network architecture adopts the form of cloud-edge-end collaboration. It dynamically allocates radio, computing, and storage resources on demand and generates network functions through orchestration and management. High-layer packet processing and radio resource control can be deployed in the cloud, and the advantages of DOICT and intelligent can be fully utilized to analyze the network state and service model, and the capability of service packet type awareness can be realized to enable self-optimization of network control. The network selects an appropriate data transmission link based on the data packet type analysis results and service requirements. Through air interface adaptation, the network selects appropriate physical layer processing according to the requirements of high-layer packet processing, and realizes the integration and unification of network industry adaptation and multiple air interface access. Air interface adaptation also includes network management of edge devices. Through self-configuration of edge devices on the cloud, edge devices can be plugged and played. By detecting network resource usage, network status, users and services, and combining artificial intelligence and other technologies, network orchestration management predicts network status and possible performance deterioration, and updates network orchestration management policies in advance. The possible architecture of lean radio access network is given in Figure 3. On the basis of service based architecture, network functions are generated and deployed on demand, control plane and user plane are designed separately, and edge devices are self-managed to realize the integration and unification of various air interface access and plug and play.

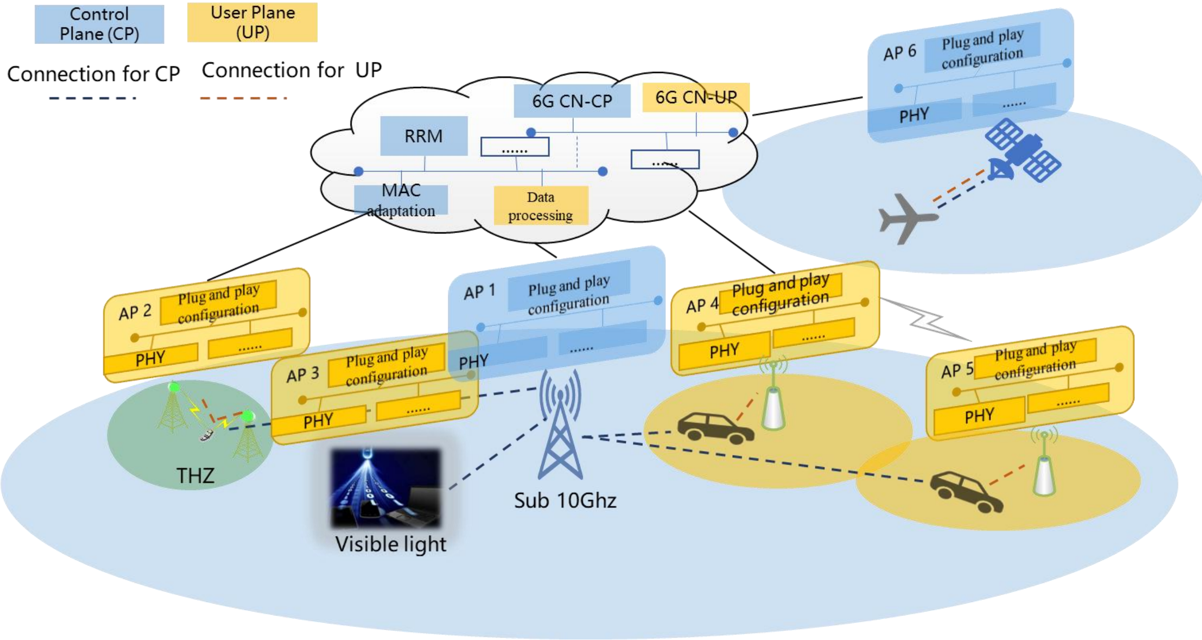

Figure 3 The lean network architecture

4 Key Technologies of 6G lean RAN

From the perspective of reducing cost and power consumption, and improving the adaptability of new services and new scenarios, the 6G lean radio access network proposes a flexible and scalable access network architecture. At the same time, the lean radio access network also needs a series of key technologies to cooperate with this architecture to achieve breakthroughs in the form of network construction, meet extreme service requirements flexibly and on demand, realize the three-dimensional full coverage of the air, ground and sea, reduce network costs and energy consumption, and achieve a high level of network autonomy. Signaling and data decoupling, lean network function design, and network management and orchestration are the three most important aspects. Under the traditional network deployment, signaling and data are delivered through the same base station, and the functions of the base station are unified and undifferentiated. For signaling and data decoupling, the base stations are divided into independent signaling base stations and data base stations according to their functions. The signaling base station realizes wide area coverage, and the data base station realizes on-demand deep coverage, providing technical support for reducing network cost and power consumption. In terms of lean network functions, the rapid development of intelligence has introduced new ideas for protocol stack design. We can learn from the experience of intelligence and explore the impact on standard and protocol function design in the aspects of service quality reliability, link adaptation, data packet feature mining, and wireless resource control. In terms of network management and orchestration, the plug-and-play link control technology can quickly identify newly added nodes, automatically establish connections, and dynamically provide service according to service requirements. Thus, the cost, energy consumption and scale redundancy of the network can be effectively reduced, and cost and power consumption can be saved.

4.1 Signaling and data decoupling

The traditional network topology is relatively static. As the frequency bands used increases, the network becomes denser and the cost increases. Facing the sharp increase of wireless network cost and energy consumption, the decoupling of signaling and data will change the way of network construction, and the network will transform from high energy consumption to green energy saving. Different from the traditional CU-DU architecture, which divides network functions horizontally, the architecture of signaling base stations and data base stations is divided vertically according to specific functions. The signaling base station is responsible for the signaling plane function, and the signaling cell performs wide-area signaling coverage through low-frequency to ensure the reliability of the control plane, such as reliable mobility management and fast service access. One signaling base station may correspond to multiple signaling cells. The signaling cell focuses on signaling plane processing and is the anchor point of the radio resource control (RRC) function. The data base station performs user plane operations and is responsible for data transmission. It can quickly upgrade the data processing capability of the network in a plug-and-play manner. A cell responsible for data transmission is called a data cell, and one data base station may correspond to multiple data cells. The data cell focuses on the processing of data. Through the decoupling of data and signaling carried by different frequency bands, wide-area coverage of signaling and deep coverage of data plane can be achieved, and the number of handovers can be reduced. On the other hand, the data cell function can be generated on demand and dynamically turned on and off. Flexible data base station loading can reduce the energy consumption of the network on the premise of ensuring the network data transmission capability. This provides a new idea for network deployment. The network capabilities can be dynamically adjusted according to network conditions to match the actual needs.

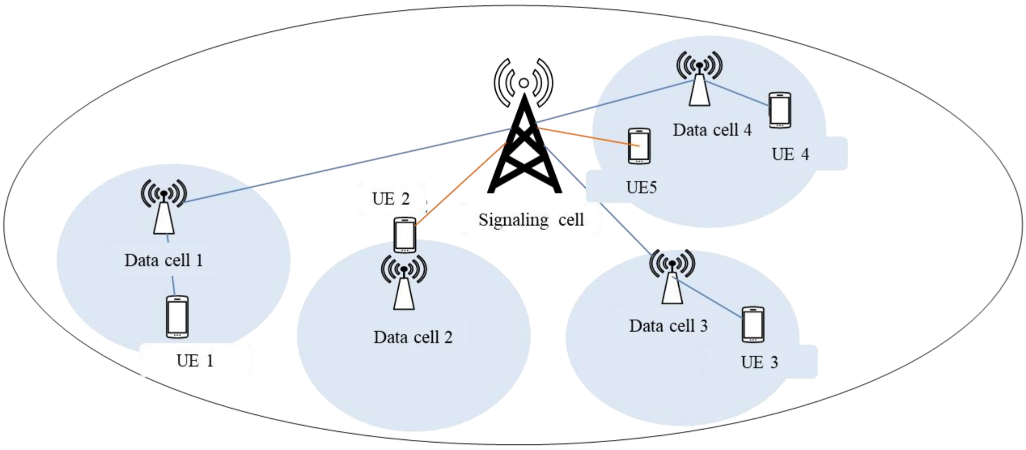

Figure 4 Schematic diagram of signaling cell and data cell

4.1.1 On demand deployment

The tidal effect generally exists in office buildings, schools, residential areas, etc. In different areas and time periods, the degree of busyness and leisure of the cell is different. The distribution of network data services is also unbalanced, and a large number of data services occur in a small number of areas. In order to adapt to the growth of services, data cells can be dynamically activated on demand to ensure the coverage of hots pot areas. Through real-time perception of service requirements and network status, more data cells are turned on in hots pot areas to provide better services to users, and some data cells are closed in areas with lower service requirements to save energy. In the case of decoupling of signaling and services, enabling data cells on demand not only ensures the availability of connections, but also reduces unnecessary power consumption, realizing flexible matching of networks and services. Starting from the needs of the service, combined with the topological connection of the data cells, a policy of turning on the data cells on demand is generated, so as to further reduce the energy consumption on the basis of meeting the needs of users. In addition, the data cell function can also be customized according to the scenario, and the data cell function can be flexibly configured according to the needs of different types of services, such as flexible configuration of physical layer bandwidth, data packet processing method, etc., so as to better match the current service types and characteristics. Through the unified arrangement and management of network computing power, radio resources, hardware resources and other shared resources and network functions, the network cost and energy consumption can be further reduced.

4.1.2 Data cell assisted access

As the anchor of the signaling plane function, the signaling cell is responsible for the processing of signaling plane functions such as user access, RRC connection state management and handover. Users usually access the network through signaling cells, but the access user capacity of signaling cells is limited by physical resources such as access resources. In order to further improve the access capacity of the access network, user access assisted by data cell resources is explored. Through the random access resources configured by the data cell, more users can use the resources in the data cell to perform random access. The data cell forwards the signaling related to random access to the signaling cell, and the signaling cell performs RRC connection control. Correspondingly, the transmission mechanism of the system information can also be further lean, for example, the method of acquiring the system information of the data cell on demand.

4.1.3 Data link establishment and handover

After the data cell is loaded, it needs to establish a handshake with the signaling cell, and sends the configuration of the data cell to the signaling cell at the same time. The signaling cell should save the configuration of the data cells within its coverage. The selection of the serving data cell is an important step that the terminal needs to perform before data transmission. The network needs to formulate a unified data cell selection strategy. For example, as the user moves within the coverage of the signaling cell, the user's signaling plane anchor point does not change, but the data cell that serves the user may change, and the data link needs to support adaptive handover to ensure a consistent user experience.

4.2 Lean network functions

The development of society has derived users' higher requirements for latency, reliability, and mobility. Traditional connection oriented communication methods and design ideas based on data transmission and processing may not cover the multi-dimensional requirements derived from the development of society. Therefore, it is necessary to explore the enhanced design of lean network protocol functions. Driven by DOICT and other new technologies, the design idea of 6G protocol system will move towards the combination of simplicity and intelligence. It adopts a lightweight network architecture and intelligently adjusts the network capability according to the network state to match the network capability with the actual demand. The function design of lean network includes three parts: closed-loop quality of service (QoS) management, intelligent resource control and flexible link adaptation. Closed-loop QoS management is oriented to the new requirements of the network. It flexibly adapts to the service requirements through the closed-loop QoS status reporting, and flexibly adjusts the network resource scheduling through the QoS status perceived by RAN to meet the service requirements. Intelligent resource control introduces artificial intelligence to optimize network control methods on the basis of traditional expert experience, and reduces the complexity of network control, and realizes network self-optimization and self-control. Flexible link adaptation simplifies the design of radio link, and realizes the flexible on-demand matching between service requirements and radio links through intelligently analyzing data packet characteristics.

4.2.1 Closed-loop QoS management

6G era will be a highly data-driven and intelligent era. New services such as holographic image, extended reality (XR) service, virtual space perception and interaction have put forward more extreme requirements for the service quality assurance of 6G networks. The bottleneck of QoS guarantee lies in the air interface capability. How to combine the air interface capability with service requirements is the core issue of wireless side QoS guarantee. With different service characteristics, users have different experiences on whether QoS can be satisfied. For example, for automatic driving services, once QoS cannot be guaranteed, the user experience will deteriorate rapidly; for video services, if QoS cannot be guaranteed temporarily, the user experience will not deteriorate rapidly.

In the traditional QoS architecture, the Internet Protocol (IP) packet flow is first mapped to the QoS flow, and it is sent to the opposite end through the wireless bearer of the air interface [5]. The access network completes the mapping of QoS flow to data radio bearer (DRB), as shown in Figure 5 [6]. Due to the changes of air interface environment and network state, the satisfaction of QoS is a dynamic process. Usually, the base station maps the data packets with similar QoS requirements to the same radio bearer, and meets the users' QoS requirements by scheduling of the data bearer.

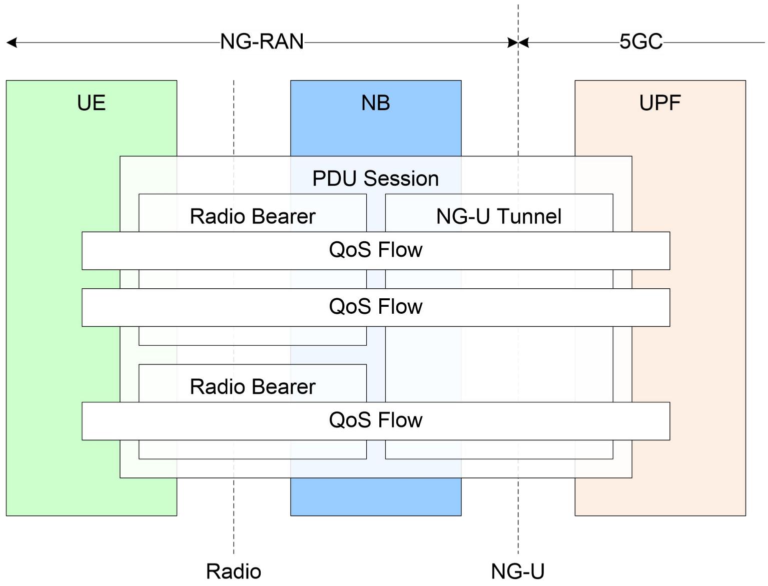

Figure 5 Qos architecture

For 6G new services, a new QoS mechanism should be designed to guarantee the flexible and extreme service requirements. Based on end-to-end QoS constraints, closed-loop QoS control realizes on-demand air interface services and efficient network capabilities with relatively limited air interface resources according to the service experience fed back by the terminal and the real-time air interface transmission characteristics. As shown in Figure 6, the network realizes QoS detection, modeling and adaptive adjustment of bearer services through flexible QoS detection mechanism combined with artificial intelligence/big data technology. Based on the service experience fed back by the UE, the access network intelligently judges the change trend of the subsequent service experience, and provides QoS guarantee intervention in advance.

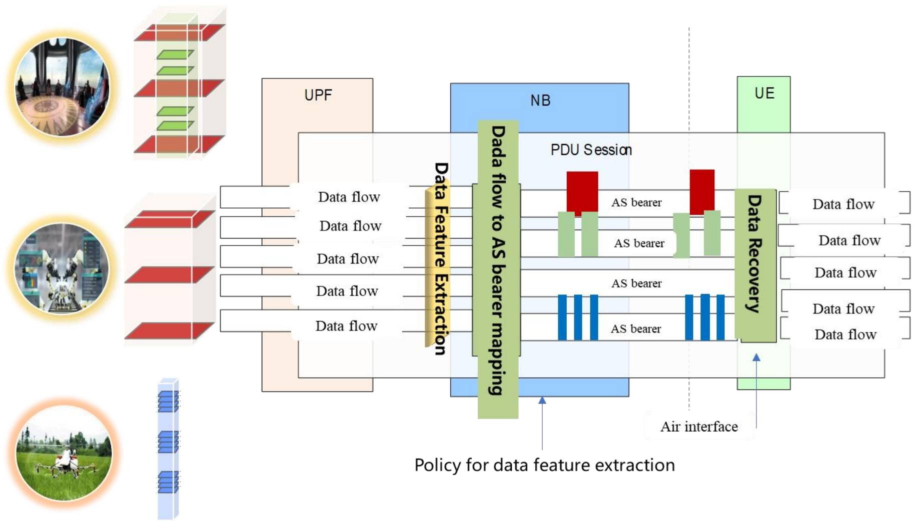

Figure 6 Closed loop architecture combining data characteristics and QoS feedback

4.2.2 Intelligent resource control

In order to meet the multi-dimensional needs of users in new 6G scenarios such as holographic communication, communication and perception interconnection, 6G networks require more efficient resource control to ensure the ultimate user experience. Resource control performs physical resource, data bearer, RRC state, handover and other related control through RRC configuration. The configuration of network parameters directly determines the performance of the network. The traditional resource control method is based on expert experience. However, with the increase of service types and the expansion of network scale, the traditional resource control based on expert experience presents the problems of inaccuracy, time-consuming and high cost. In order to solve this problem, the introduction of AI technology provides effective technical means. Intelligent resource control generates intelligent decision-making by collecting physical environment, user status and business-related information, combined with AI and expert experience. Intelligent resource control utilizes the closed-loop mechanism of data collection, training, reasoning, and verification, combined with the performance evaluation system, to further extend the previous expert experience control system into a self-optimizing and autonomous intelligent control system. Combined with fault analysis and root cause location, network intelligent control can discover potential problems in the control process in a timely manner and achieve closed-loop management and control. Intelligent network control can be used in various scenarios, such as handover, access control, link control, and energy saving, to endow the network with new capabilities through intelligent decision-making. Taking handover as an example, intelligent network control can perform intelligent analysis according to user environment, movement trajectory, and service characteristics, and generate suitable handover strategies. The network comprehensively determines the handover strategy with reference to the air interface environment and the handover delay and reliability requirements of different services. By monitoring the handover performance, the network continuously optimizes the intelligent handover strategy to realize the self-optimization of the intelligent control strategy.

4.2.3 Flexible link adaptation, ensuring ultimate user experience

The diversified services of 6G require more flexibility of radio links in network. Taking 5G downlink data as an example, as shown in Figure 7, through QoS flow, data packets are mapped to radio bearers, radio link control (RLC) channels, logical channels and finally to transmission channels [6]. Carrier aggregation and dual connection respectively implement one-to-many mapping from logical channels to transmission channels and radio bearers to RLC channels. The network dynamically adjusts the configuration of radio bearer, RLC channel and logical channel by RRC or MAC based on terminal service and air interface status. In this data processing, IP packets for each service are processed by each protocol layer to generate data packets that can be understood by the peer layer, then the peer protocol layer receives the data packets from the peer layer and sends them to the upper layer for processing. The result of this processing method is that the multi-layer processing leads to a large latency, and the functional redundancy between layers also reduces the processing efficiency.

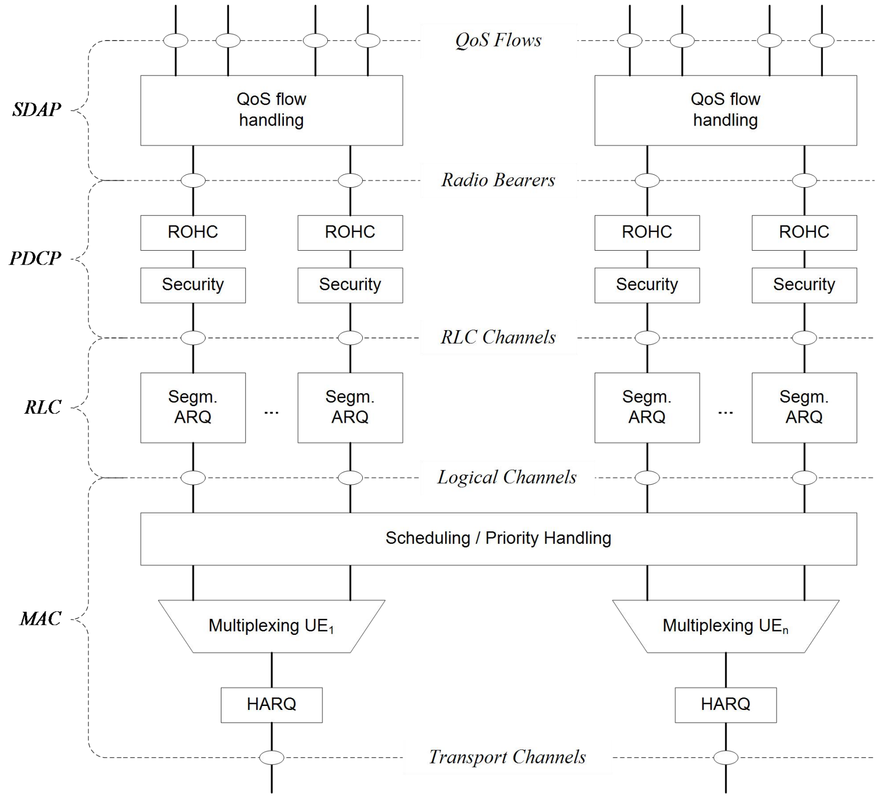

Figure 7. Downlink data mapping diagram

Facing 6G, in order to better adapt to service type changes, improve network flexibility, and avoid frequent link configuration updates, data links can be divided into upper-layer data links and lower-layer data links. Upper-layer data links are close to services, and lower-layer data links are more related to air interface. Each lower-layer data link can transmit and receive data from multiple upper-layer data links, and each upper-layer data link can be mapped to multiple lower-layer data links, thus flexible mapping between upper-layer links and lower-layer links can be achieved. The network configures a set of lower-layer links for each user that meet all possible service QoS requirements. With the help of intelligence, the network selects appropriate lower-layer links from the set based on service QoS characteristic values. The network allows flexible mapping between upper-layer links and lower-layer links to dynamically load and delete links. In Figure 8, according to QoS requirements of service flows, service characteristics, which including packet size, service cycle, transmission rate and latency, as well as the air interface status of the lower-layer links, such as link congestion and air interface quality, the network determines the upper-layer links and one or more lower-layer links from the lower-layer links set. Lower-layer links can carry packets from different users and services with similar QoS requirements and service characteristics. The network can dynamically update the mapping between upper-layer links and lower-layer links to realize link adaptation and link selection based on the air interface environment and service requirements.

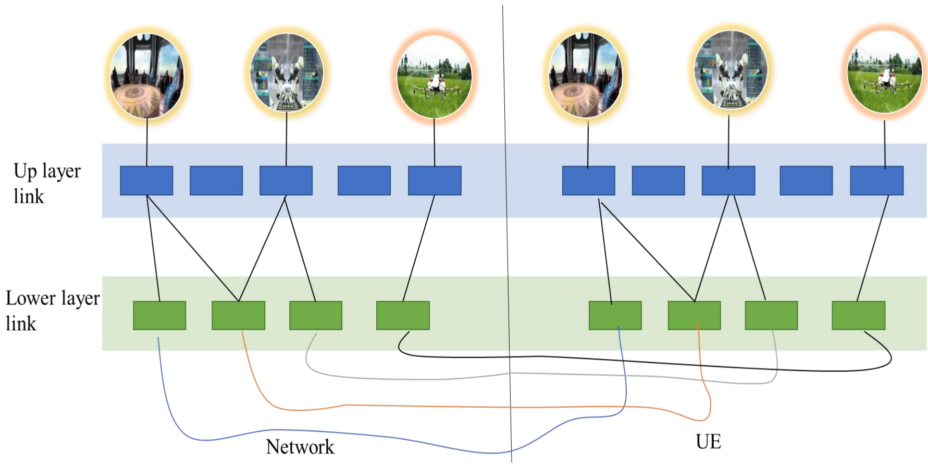

Figure 8. Flexible link adaptation

4.3 Management and Orchestration

In order to support the three-dimensional full scenario coverage, 6G radio access network needs to have abilities of plug and play, self-optimization and self-growth. 6G lean radio access network requires capabilities of efficient management and orchestration. Network orchestration, which can allocate appropriate computing power, storage, wireless and other resources for the network, combined with on demand generation of network function, based on artificial intelligence and digital twin, the self-optimization, self-evolution, self-growth of the high-level network autonomy operation and maintenance method can be realized for solving potential problems of network efficiency, cost and user experience. When new network nodes access the network, they can quickly shake hands and plug and play to achieve coverage expansion and on-demand network function deployment, which can effectively reduce network power consumption and function redundancy and save network costs. Network management of PNP nodes is mainly embodied in three aspects: access point awareness, access point self-configuration and self-optimization, and cloud-edge collaborative control. Access point awareness refers to the ability to sense access requests of different types of nodes and start appropriate handshake and control signaling processes. For different types of access points, it is necessary to accurately identify and quickly complete access to achieve flexible expansion of coverage. The self-optimization and self-configuration of access points can automatically complete the configuration and realize self-generation when an access point is added to the network. During running period of the access point, parameters can be adjusted and automatically optimized according to real-time scenarios, and services can be improved as needed, so that user requirements can be satisfied better. Cloud-edge collaborative control refers to the collaborative control between cloud and edge access points. Cloud provides flexible control of edge including access control, automatic allocation of bandwidth resources, and inter-link coordination. Edge access point controls resources within the range based on cloud configuration. In this case, high-speed and efficient transmission channels and wide and high real-time transmission bandwidth are required between cloud and edge to ensure real-time information exchange through plug and play interfaces.

3 Future Outlook

Looking back on the past year, the industry-university-research ecosystem for 6G network has shown a thriving situation. China Mobile proposed lean network as one of the characteristics of 6G networks in 2020. This white paper starts from the driving force of the 6G lean radio access network, and introduces the architecture and the involved key technologies of the lean radio access network. Looking forward to the future, the lean radio access network also needs to consider the following points aspects:

- **Standards and product ecosystem**

The development of technology is inseparable from complete and healthy standards and product ecosystem. Lean network proposes signaling base stations and data base stations with customized network functions, intelligence-driven protocol function design concepts, and high-level network autonomy technology. While enhancing protocol stack design with new technologies such as AI, high-quality data sets, selecting suitable models, and sharing models between different manufacturers are the keys to enhancing protocol stack design with the help of AI and other new technologies, which are inseparable from a healthy open source ecosystem. How to create a new industrial ecosystem that combines standards and open source is a question that needs to be answered in the future.

- **Network deployment**

The throughput and latency requirements of 6G networks are higher. High-rate and high-efficiency transmission channels and transmission networks with large bandwidth, low latency, and flexible topology are required for cloud-side collaboration in 6G lean radio networks to ensure the real-time information interaction between plug-and-play interfaces. Network deployment requires an integrated design of cloud, transmission network and network access points. The decoupling of signaling and data requires coordinating the available 6G frequency bands to give full play to the advantages of wide coverage and flexible service loading. In addition, we need to consider how to build sensitive and accurate perception capabilities to ensure dynamic and rapid wake-up of network nodes and functions.

- **computing and processing capacity**

lean radio network meets the extreme service requirements of 6G through lean architecture and intelligent means. The design of lean network puts forward new requirements for the computing power and storage of the network and terminal, and further puts forward new requirements for the chip. Unlimited increase of computing power demand, especially the terminal computing power demand, will increase the cost and power consumption of the network. How to find a balance between computing power demand and intelligence is a problem to be faced in the subsequent technical scheme design.

5G has begun large-scale commercial deployment in the world, and the global industry is incubating and nurturing services and applications around 2B and 2C. The experience and lessons of 5G will become a very important source of innovation for 6G research. 6G will further inherit and develop the technologies and concepts that have been verified and feasible in 5G. At the same time, 6G also needs to look ahead. In terms of requirements, the application scenarios in 6G will be more complex, and more flexible adaptability needs to be considered at the beginning of network design. The future 6G network needs to be as concise as possible, support plug and play, and support dynamic switching of functions, resources, and capabilities, thereby saving power consumption and costs. The 6G lean network supports distributed ground-air-space integration. Through a distributed and unified core network, and a unified access mechanism and protocol process, terminals can access different systems, including terrestrial, underwater, and satellite systems to achieve seamless connection and handover of user experience, and ensure 6G coverage anytime and anywhere. The lean network also needs to simplify the protocol as much as possible, and support the network deployment of decoupling of data and signaling links, such as using low frequency bands for signaling coverage, simplifying mobility management, ensuring real-time access of users, and switching on high-frequency bands on demand to support the bearing of high-rate services. Cloud-based hardware can be shared between multiple frequency bands and multiple base stations, or shared between communication functions, AI, and perception, thereby reducing the overall power consumption and cost of the network. Therefore, we should not only be down-to-earth, but also look up at the stars. Let’s promote the development of 6G lean radio access networks through the collaboration of industry, university, research and application, and explore 6G efficient network solutions together.

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LIST OF ABBREVIATIONS

abbreviation	
4G	4th Generation Mobile Networks
5G	5th Generation Mobile Networks
6G	6th Generation Mobile Networks
AI	Artificial Intelligence
DOICT	Data，Operation，Information and Communication Technologies
IP	Internet Protocol
MAC	Medium Access Control
QoS	Quality of Service
RLC	Radio Link Control
RRC	Radio Resource Control