CTNet2025

网络架构白皮书

内容摘要/Abstract

1、网络是运营商的最大核心资源，也是实现中国电信战略转型的主要抓手。网络架构作为网络的灵魂所在，决定了网络的竞争力和发展潜力，网络架构重构是中国电信根本性和战略性创新。

The network is the largest core resource for Carriers, and it is also the main factor in realizing China Telecom’s strategic transformation. As the soul of the network, a network’s architecture determines the competitiveness and development potential of the network. Thus, the fundamental and strategic innovation of China Telecom is reconstruction of network architecture.

2、中国电信以简洁、敏捷、开放、集约为特征，构建软件化、集约化、云化、开放的CTNet2025 目标网络架构，打造新一代的信息基础设施，主动、快速、灵活适应互联网应用。

China Telecom is building a software-intensive, cloud-based, and open CTNet2025 target network architecture with concise, agile, open, and intensive features, for a new generation of information infrastructure that proactively, quickly and flexibly adapts to Internet applications.

3、中国电信以SDN/NFV 为技术抓手，以网元云化部署、软件定义网络智能控制、部署新一代运营系统、网络 DC 化改造等为网络切入点，推进网络的纵向解耦、横向打通。

China Telecom takes SDN/NFV as its technological starting point, along with network element cloud deployment, software defined network intelligent control, next-gen operation system deployment, and network DC transformation as the network entry point, thus boosting the network’s vertical decoupling and horizontal connectivity.

4、中国电信以面向政企客户的随选网络，以及面向公众客户的超高清视频为业务切入点，提供网络可视、资源随选、用户自服务的用户体验。

China Telecom offers on demand network services for government and business customers and UHD video streaming for public customers, serving as a business entry point and providing network visualization, on-demand resource selection, and self-service user interfaces.

5、中国电信以CTNet2025 为目标，引入开源软件，提高运营能力，创新研发合作模式，引入更广泛的合作伙伴，共建更加开放和健壮的产业生态链。

Through CTNet2025, China Telecom aims to introduce open source software, optimize operational capacity, and innovate research and development cooperation to involve a wider range of partners and a more open and robust industrial ecosystem.

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1. 网络架构重构的驱动力
Driving forces for restructuring network architecture

1. 1 网络架构的价值与意义 / Value and significance of network architecture

2013 年，国务院就发布了“宽带中国”战略实施方案，宽带首次成为国家战略性公共基础设施，并提出了“优化架构、提升容量、智能调度、高效可靠”的建设思路。十八届五中全会出了“实施网络强国战略”，并纳入“十三五”规划的战略体系，“十三五”规划纲要提出“加快构建高速、移动、安全、泛在的新一代信息基础设施”，并明确要“布局未来网络架构、技术体系和安全保障体系”。2016 年4 月19 日，习近平总书记在网络安全和信息化工作座谈会上强调了“网信立国”，要求要进一步加快构建新一代信息基础设施。

In 2013, the State Council issued the "Broadband China" strategy implementation plan, and for the first time, broadband became national strategic public infrastructure. The State Council then proposed “architecture optimization, capacity increment, intelligent arrangement and management, efficiency and reliability” development concept. Of the concept to “Implement the strategy of cyber power” was proposed in the 18th Communist Party of China’s fifth plenary session, and was subsequently incorporated into the “Thirteenth Five-Year Plan” strategic system. The “Thirteenth Five-Year Plan” planning compendium proposed to “Accelerate the process to develop a new information infrastructure generation incorporating high-speed, mobility, security, and ubiquity”, and expressed the need for an “Overall restructuring of the future network architecture, technical system and security system.” On April 19th, 2016, President Xi Jinping emphasized “Network and information to be the country’s foundation” during the Network Security and Informatization Work Conference, and clarified the need to further accelerate the development of the next generation of information infrastructure.

中国电信作为信息基础设施的建设者和运营者，建设好新一代信息基础设施责无旁贷。“十三五”时期，中国电信明确了“做领先的综合智能信息服务运营商，筑力网络强国、服务社会民生”的企业战略；提出了打造智能连接、智慧家庭、互联网金融、新型ICT应用、物联网的“一横四纵”生态圈，以用户为中心，提供高速、泛在、灵活、智能的网络服务。网络作为企业的重中之重，是支撑业务发展、打造生态圈的关键，而网络架构则是网络的灵魂，决定了网络竞争力和发展潜力。

As the builder and operator of information infrastructure, China Telecom is duty bound to build a new generation of information infrastructure. During the 13th Five Year Plan period, China Telecom made clear its corporate strategy of “being a leading comprehensive intelligent information service operator, building a strong network and serving the people’s livelihood”; it proposed to build a “one horizontal and four vertical” ecosystem of intelligent connectivity, intelligent family, Internet finance, new ICT application and Internet of Things (IoT), which is user-centered and provides high-speed, ubiquitous, flexible and intelligent network Service. As the top priority of enterprises, network is the key to support business development by creating an ecosystem, with network architecture being the soul of the network, which determines the competitiveness and development potential of the network.

网络架构（Architecture）是一整套高层次的抽象设计准则和演进目标，是为设计、构建和管理一个通信网络所提供的技术方向和技术框架，包括但不限于网络的分层分域和演进、重要的接口类型和网络协议、命名和寻址、管理和安全边界的确定等。网络架构的设计属于网络的顶层设计，可用于指导网络的具体技术构思和工程设计，其角色是确保后 续技术设计的一致性和相关性，并能够满足网络架构相关的网络功能要求。为此，网络架构比特定的技术设计更普遍、更稳定，技术寿命更长，可以为几代不同的技术设计服务。

Network architecture is a set of high-level abstract design principles and evolutionary goals. Fundamentally, it is a technical direction and a framework for the design, development, and management of communications networks, including without limitation to the hierarchical domain segmentation and network evolution, key interface types and network protocols, naming and addressing, management and security boundary determination. Network architecture design is a network's top-level design, which can be used as a guide for the network's specific technical conception and engineering design. The role of network architecture design is to ensure the consistency and applicability of the subsequent technical design, and to meet the network's functional requirements in terms of network architecture. Therefore, network architecture is more universal and stable than specific technology design, and, as a technology, has a longer life cycle and can serve several generations of different technology design.

1.2 网络架构的沿革 / The evolution of network architecture

1.2.1 电信网络发展的四个阶段 / The four stages of telecommunications network development

从整个电信网络的历史沿革看，可以划分为四个大的阶段：模拟通信、数字通信、互联网通信、软件定义网络。

Network architecture evolution, from the perspective of the entire telecommunication network history can be divided into four major stages: analog communication, digital communication, internet communication, and software-defined networking.

从电信网诞生到 1970 年代，电信网基本都处于模拟通信时代，这一阶段的主要技术特征是基于模拟电路的专用通信系统，代表性技术有载波通信（包括明线载波、电缆载波、模拟微波通信等）和模拟蜂窝移动通信。

Ever since the early days of telecommunications networking in the 1970s, telecommunications networks were essentially analog communications. The main technical feature at this stage was the dedicated, analog circuit-based communication system. The representative technologies at the time included carrier communication systems (including open line carriers, cable carriers, and analog microwave communications) and analog cellular mobile communications.

1980年代全球开始进入数字通信时代，这一阶段的主要技术特征是语音和数据的数字化，基础是PCM、TDM和分组通信，代表性技术是PDH传输、SDH传输、X.25分组通信、ATM 通信、程控数字交换和数字蜂窝移动通信等。

The world began to enter the age of digital communication in the 1980s. The defining technical characteristic at this stage of telecommunications development was the digitization of voice and data based on PCM, TDM and packet communications. The representative technologies at the time were PDH transmission, SDH transmission, X.25 packet communication, ATM communication, programmed digital exchange, and digital cellular mobile communications.

1990 年代全球陆续进入互联网通信时代，这一阶段的主要技术特征是全 IP 化，最典型的表述是 IP over Everything 和 Everything over IP，IP 成为互联网通信的基础性技术成为业界共识，代表性技术是TCP/IP，代表性业务是万维网、电子邮件、搜索和即时消息等。

The world gradually entered the era of Internet communication in the 1990s. The main defining technical characteristic at this stage was full IP, and the most typical expression of such was IP over Everything and Everything over IP. IP became the base technology for internet communications and was the industry consensus, with the representative technology being TCP/IP and the representative businesses being the world wide web, E-mail, online search, and instant messaging.

目前全球通信产业已经开始进入第四个历史阶段，即软件定义网络阶段，这一阶段的主要技术特征是网络架构的变革，即从垂直封闭架构转向水平开放架构，体现在网络控制与转发分离、网元软硬件的解耦和虚拟化、网络的云化和IT化等多个方面 ， 代表性技术有 SDN、NFV和云计算。这一阶段的来临为电信网络的深化转型提供了强大的武器，不仅带来了历史性的发展机遇，而且也带来了前所未有的严峻挑战。

The global communications industry is currently entering the fourth stage, in which networks are defined by software. The main technical characteristic at this stage is the transformation of traditional network architecture, specifically from a vertical closed architecture to a horizontal open architecture, embodied in several aspects such as network control and forwarding, hardware and software decoupling, the virtualization of network elements, cloudification. The representative technologies right now are SDN, NFV and cloud computing. The advent of this stage provides a powerful tool for the deepening transformation of telecommunication networks, which not only brings about historic development opportunities, but also unprecedented challenges.

1.2.2 IT架构发展的经验 / IT architecture development experience

摩尔定律揭示了两个发展方向：高性能和低成本。电信业重视前者，代表性的门槛就是电信级的质量；而IT业重视后者，采用适度的性能要求和宽松的可靠性要求、以及通用工业标准的IT设备降低成本。两者带来的显著差异是，IT业20年来成本降低4个量级 （降低约58%），而以传输和移动为代表的电信设备的成本只降低了3个量级（降低约 30%），彼此间有 10 倍的差距。

Moore's law points to high performance and low cost. The telecoms industry values the former, with the representative threshold being carrier-grade quality, while the IT industry focuses on the latter, utilizing common industry standard IT equipment to reduce costs while maintaining performance and reliability. The main difference between the two industries is that the IT industry has reduced costs by nearly four orders of magnitude (decreased approximately 58% over the past 20 years), whereas the telecommunications industry has reduced costs for telecommunications equipment, represented by transmission and mobility, by only three orders of magnitude (decreased approximately 30%) - a 10-fold difference.

IT业在上世纪70年代仍是封闭的烟囱群，但从1980年代开始打破封闭的垂直架构（从小型机向 X86 转型），转向开放的水平架构，其基本思路是软硬件解耦（OS 操作系统从设备中分离），双方分工清晰、各自发展 ，从而促进了产业链的开放和技术业务创新。

The IT industry was treated as a resource and a source of information in the 1970s, however, it began breaking the closed vertical architecture (X86 transformation from minicomputer) to an open horizontal architecture in the 1980s. The basic idea behind this was decoupling software and hardware (separating OSs from devices), the two parts that clearly share workloads, and developing them separately, thus promoting the idea of industry value chain and technological business innovation.

而对性能的追求使得电信业的网络设备一直保持着专业化和高成本，设备仍然是软硬件一体化的垂直架构，整个生态系统较为封闭（厂商控制着从硬件、系统软件到业务软件 的生产），产业链发展缓慢（只有有限的电信设备厂商），电信设备不仅设计较为复杂、 成本高昂、升级改造难度很大，而且不同厂商的设备兼容性和互通性不好，这直接造成了电信业网络的建设维护成本高、开放性差以及灵活性不足，也限制了运营商在网络和业务上的创新。

Subsequently, telecommunications network equipment maintained its specialized nature and high cost as a result of the pursuit of performance, and the equipment still integrated hardware and software in vertical structures. The entire ecosystem was relatively closed (with vendors controlling hardware, system software, and business software development) and industry value chain development was slow (owing to a limited number of telecommunications equipment manufacturers). Telecoms equipment was not only complex, expensive, and difficult to upgrade, but also face challenges in terms of equipment compatibility and interoperability between different manufacturers, which directly led to the expensive development and maintenance, poor openness, and insufficient flexibility of telecommunications networks, along with limiting network and business operator innovation.

随着 SDN/NFV 的引入，电信网络设备的封闭性有望打破，硬件和软件将实现解耦，生态系统将走向开放，产业链将获得健康发展，这将不仅有利于降低运营商的 CAPEX 和 OPEX，而且有利于实现网络的开放，增强网络的弹性，促进新型网络和业务的创新。

With the introduction of SDN/NFV, the closed nature of telecommunications network equipment will hopefully be opened up. Hardware and software will be decoupled, ecosystems will be opened, and the industry value chain will be healthily developed. This would not only contribute to reduce carriers' CAPEX and OPEX of carriers, but would also be conducive to achieving network openness, optimizing network resilience, and improving innovation in new networks and services.

1.3 现有网络架构的不足 /Current network architecture shortfalls

总体上看，现有网络架构是由大量私有 / 内部接口互联的“传送承载”和“业务控制” 两个大的功能层级和多个子层构成的复杂封闭体系，同时有 IT 支撑系统作为其辅助系统， 保障网络的正常运行，如下图所示。

Generally speaking, the current network architecture is a complex, closed system made up of two large, functional layers, namely "conveyor loading" and "operational control", along with several sublayers interconnected by a large number of both private/internal interfaces, with the IT support system serving as the auxiliary system to ensure the network's normal operation as shown in the figure below.

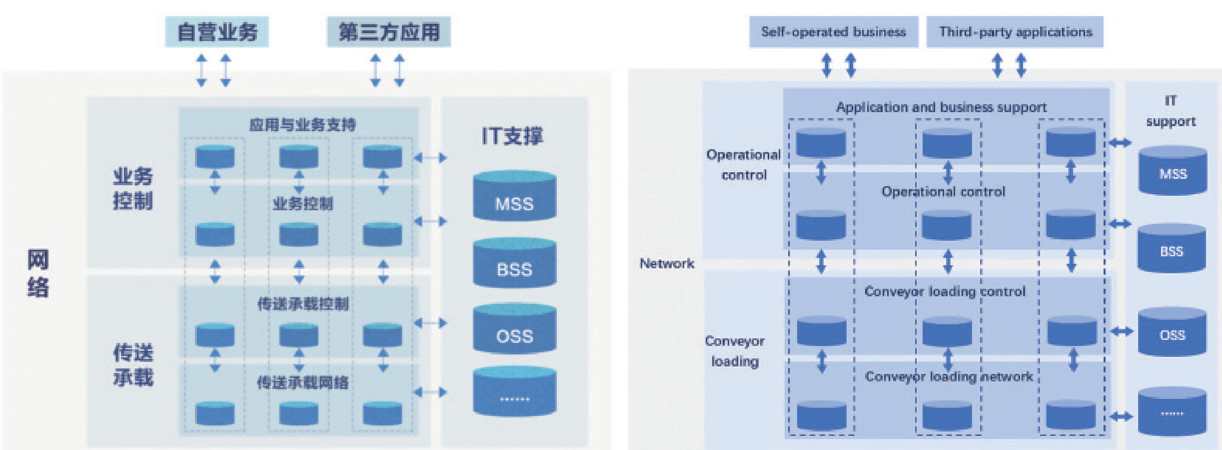

图 1：现有网络架构（功能图）/Figure 1: Existing network architecture (functional diagram)

这一架构主要有以下三大特点：
This framework consists of the following three main characteristics:

(1) 业务独立运营，业务控制层级以及与之配套的传送承载层级中，存在大量的垂直封闭系统，包括大量采用专用的网元设备、与硬件紧密绑定的网络功能及相应的控制单元。
(1)Independently operating businesses. There are many vertical closed systems in the business control layer and its corresponding conveyor loading layer, including many dedicated network element devices, as well as a range of network functions tightly bound to the hardware and corresponding control units.

(2) 网络自成体系，为单一功能需求构建专用的网络或者网络平台，各个单元彼此间资源不共享，存在大量私有的接口和协议。
(2)Self-contained networks. With dedicated networks or network platforms developed for a single functional requirement, self-contained networks are networks where resources are not divided among different units and involve many different private interfaces and protocols.

基于该架构，电信运营商在过去数十年中取得巨大成绩的同时，也面临着根本性的困境：
Although telecom carriers have progressed significantly over the past decades, they also face fundamental difficulties based on this architecture:

(1) 网络刚性：网络由大量单一功能的专用设备构成，使得网络构成复杂，网络缺 乏灵活性。
(1)Network rigidity: Networks are made up to a large number of dedicated, single-function devices, which makes them complex and rigid.

(2) 网元封闭：网元采用软硬件垂直一体化的封闭架构，设备功能扩展性差、价格昂贵且易于被生产厂商锁定。
(2)Network element closure: Network elements adopt a vertical hardware and software integration architecture. Devices have poor functional scalability, are expensive and are easily locked by manufacturers.

(3) 业务烟囱：新业务、新功能的提供需要开发新设备、新协议，造成设备种类和 网络数量大量繁衍，形成大批烟囱群，业务难以融合，新业务开发困难, 难以满足快速灵活的业务部署需要。
(3)Business isolation: Providing new services and functions requires the development of new equipment and protocols, which leads to an explosion in the quantity of equipment and network types, thus forming a cluster of isolations which makes it difficult for business integration, new business development, and to meet fast and flexible business deployment demands.

(4) 运营复杂：存在大量厂家、大量类型各异的专用设备 / 系统，规划、建设和运维复杂，运营成本居高不下
(4)Complex operation: The sheer amount of different manufacturers and different types of dedicated devices/systems makes it difficult to plan, develop, operate, and maintain telecommunications network, which, in turn, results in high operating costs.

1.4 网络架构重构的驱动力

“互联网 +”已上升为国家战略，进一步推动了移动互联网、云计算、大数据、物联网等与现代制造业和服务业的结合，这将对信息基础设施提出更高的能力要求。为了顺应“互联网 +”的发展需要，作为其基础的电信网的升级改造势在必行，特别是作为网络灵魂的网络架构需要进行重定义、重设计，构建新型的泛在、敏捷、按需的智能型网络，以进一步巩固网络发展基础，营造安全网络环境，提升公共服务水平。

The elevation of "Internet Plus" to national strategy level further promotes the combination of mobile Internet, cloud computing, big data, and the Internet of Things with modern manufacturing and service industries. Such a combination will result in higher capacity requirements on information infrastructures. It’s imperative to upgrade the telecommunication network as the foundation if we are to adapt to “Internet Plus” developments. Particularly, network architecture, regarded as the network’s soul, must be redefined and redesigned to build a new ubiquitous, agile, and on-demand intelligent network, further consolidating the foundation of network development, creating a more secure network environment and improving the overall level of public services.

同时，运营商在面临 OTT 严峻挑战的外部形势下，企业内部也开始面临着业务创新难、增长乏力、量收剪刀差持续扩大的被动局面，因此需要通过网络架构重构增强网络活力，降低运营成本，促进网络开放与业务创新，提升运营商的竞争力。

Meanwhile, while carriers are facing the severe external challenges of OTT, organization interiors also have to face the difficulties in business innovation, sluggish growth, and the passive condition of continuous price growth. Therefore, network architecture reconstruction is necessary to enhance network vitality, decrease operating costs, improve network openness and business innovation, and improve carriers’ competitiveness.

网络架构重构需要实现两个根本性转变。第一，实现从“互联网被动的适应网络向网络主动、快速、灵活适应互联网应用”的根本性转变；第二，网络资源的部署应打破行政管理体制和传统组网思路的制约，例如从传统以行政区域分层为导向的组网转向以 DC 为核心的组网新格局。

Network architecture reconstruction requires two fundamental changes. First, the fundamental transformation of "the adaptation of passive internet networks to active ones, and the quick and flexible adoption of Internet applications” must be realized. Second, network resource deployment must break the restriction of administrative systems and traditional network considerations, such as shifting from traditional networks guided by administrative devision stratification to the new network patterns focuses on DC.

2、网络演变趋势/Network evolution trend

2.1 运营从分散到集约/ Decentralized to intensive operation

由于历史原因，传统的电信运营商一般沿袭了自下而上的网络组织和运营方式，各省 / 地市均有相对独立建设和运营的基础网络，普遍存在着“网络分层规划”、“网络分段建设” 和“网络分段运营”的现象，很大程度上导致了网络资源使用效率低下、业务端到端体验 较差等结果。

Traditionally, telecom carriers generally adopted the bottom-up method to organize and operate their networks. The basic network construction and operation in each province or city is relatively independent and there is a general phenomenon of “Hierarchical network development", "Network segment construction," and "Network segmentation operation," which has led to a largely inefficient use of network resources, and a poor business end-to-end experience.

随着互联网的发展，特别是用户对互联网应用一致性体验需求，对于网络运营的模式提出了新的要求，未来网络必须具备“统一集约规划”、“统一集约建设”和“统一集约 管控”的三大集约化运营特征。

As the internet developed, especially in terms of users' demand for consistent internet application experiences, new network operation model requirements have been proposed. In the future, networks must have three intensive operation characteristics: "Unified and intensive planning", "Unified and intensive construction," and "Unified and intensive management and control".

2.2 管道从“硬”变“软”/ ″Hard” to “Soft” network pipeline

传统网络是刚性固化的，网络扩容成本很高，扩容周期很长，无法适应互联网、移动互联网、云计算、物联网的弹性需求，未来的网络应能做到按需动态伸缩。

Traditional network pipelines are rigid and solid, with high expansion costs and long expansion cycles. Therefore, they cannot adapt to the flexible demands of the, mobile Internet, cloud computing, and the Internet of Things. Future networks should be able to scale dynamically on demand.

传统的运营商网络，更多关注网络底层的传送能力，而对于承载网络能力向上层应用和业务的开放并无特别的考虑，因此缺乏标准化的能力开放接口，网络能力很难灵活的被业务所调用。这也在一定程度上导致了目前许多互联网业务/应用不依赖于承载网络的能力, 采用特定的应用层协议对其应用进行优化设计 ， 包括纠错、流量均衡和应用加速等。

Traditional network carriers pay closer attention to underlying network transmission capacities, though pay no particular attention to opening and carrying network capacity over to the upper applications and services. This has led to a lack of standardized capabilities and open interfaces, meaning that businesses find it difficult to flexibly invoke network capabilities. To some extent, this has also led to the fact that many Internet services/applications are independent of network hosting capabilities. They have been optimized and designed with specific application layer protocols in mind, including error correction, traffic balance, and application acceleration.

为此，从更好的适应互联网应用的角度出发，未来网络架构必须要求网络能力接口的开放和标准化，通过软件定义网络技术，能够实现面向业务提供网络资源和能力的调度和 定制化，同时为进一步加速网络能力的平台化，还需要提供网络可编程的能力，真正实现网络业务的深度开放。

Therefore, for a better adaption of the Internet application, future network architecture must require the network capability interface to be opened and standardized. By using software to define network technology, such software should be able to schedule and customize business-oriented network resources and capabilities. Moreover, it is necessary to provide network programmable capabilities to further accelerate network capability platformization and truly realize the deep opening of network services.

2.3 网络和云深度融合/ Web and cloud deep integration

在互联网发展的过程中，基于云计算来提供业务已经成为大势所趋，但是目前云与网之间缺乏灵活互动的机制，通常计算资源、存储资源和网络资源彼此间是独立静态配置的，特别是在跨广域网的场景下，相关的资源通常无法统一按需提供。同时，在现有运营商网 络中，网络的分层、分域部署一般是基于传统电信业务（如，语音）的特点依赖于行政区域和地理位置的划分来组织，互联网中数据和流量的核心起源地和终结点数据中心（IDC）在该架构中只是以网络边缘的一类接入节点的角色存在，无法适应网络流量流向的动态变化。

Throughout the internet's development, providing business based on cloud computing has become the modern-day trend. However, there is currently no flexible interactions between the cloud and the web. Computer resources, storage resources, and network resources are typically configured statically and independently of each other. Particularly across WAN, related resources are often not uniformly available on demand. Meanwhile, existing carrier networks, network stratification and multi-zone deployment are generally based on traditional telecom business characteristics (e.g., voice), and organized based on their administrative areas and geographic locations. The core origin and endpoint data center (IDC) of the internet data and traffic only exist as network edge access nodes in the architecture, unable to adapt to dynamic changes in network traffic flow direction.

未来网络中，业务、IT和网络都可以基于云化技术实现和部署，从而降低网络业务部署的成本，提升了效率；云化的网络资源池可以基于 DC 集中部署，在提供计算、存储等虚级化资源的同时，网络资源也可以随云资源池的需求而按需随动，支持计算、存储和网络资源的统一动态分配和调度，通过 SDN 和 NFV 的跨域协同，真正实现云与网的深度协同。此外，考虑到互联网业务的流量布局主要由数据中心所决定，今后数据中心应成为网络的核心，网络架构的设计和组网布局都应以数据中心为核心。

In the future, business, IT and network can be deployed based on cloud technology, thus reducing the cost of network business deployment and improving efficiency. Cloud network resource pools can be based on centralized DC deployment, while providing computing, storage and other levels of virtual resources. The network resources can also follow the cloud resource pool requirements as necessary, thus supporting the unity of the computation, storage and network resources dynamic allocation and scheduling. Furthermore, through cross-domain SDN and NFV collaboration truly put in-depth cloud and web collaboration into effect. In addition, considering that the traffic layout of Internet business is mainly determined by the data center, the data center should become the core of the network in the future. Moreover, the design and layout of the network architecture should also adapt the data center as the core.

2.4 走向运营开发一体化 / Operation and development integration

在现行的网络运营模式下，厂商和运营商之间、运营商和客户 / 用户之间基本上都是采用的简单的“售卖”模式，一方向另一方出售从第三方采购的基础资源或能力，主要由“供给”决定“需求”。此外，现有网络主要依赖单向流程化的工程建设和网络维护来提供网络服务，紧耦合的网络软硬件及专用设备决定了网络能力的深度和广度。但是在互联网业务和应用快速发展的情况下，网络与业务之间必须要形成运营开发一体化的新关系，两者需要构成开发、销售、服务、反馈、维护等多节点闭环的互动机制，才能实现弹性灵动的网络服务。

Under the current network operation model, the simple "sales" model is basically adopted between manufacturers and carriers, as well as between carriers and customers/users. One party sells the basic resources or capabilities to the other party, themselves purchasing from a third party, in which the "supply" determines the "demand." Additionally, the existing network mainly relies on the one-way process of engineering construction and network maintenance to provide network services. The tightly coupled network software, hardware, and dedicated devices determine the depth and breadth of network capabilities. However, with the rapid development of Internet business and applications, a new relationship of operation integration and development must be established between network and business. It is necessary to form a multi-node, closed-loop interaction mechanism incorporating development, sales, service, feedback and maintenance to realize elastic and flexible network services.

为此，未来网络架构中需要支持客户 / 用户对网络服务的定制，网络能力具备可迭代开发的特点，运营商借助对网络设备的软硬件解耦、通用化 IT 设备引入等多种手段，与供应商之间的关系从单纯的售卖走向更多的集成创新，需要产业链各方更广泛的参与到网络软件化的合作研发中，从而真正深入到网络运营中。运营商也将探索更深入的合作创新模式，引入业界的合作伙伴，实现对用户和应用的快速响应。

Therefore, future network architecture must support the customer/user’s network services customization and the network must be capable of interative development. By decoupling network device hardware and software and introducing standardized IT equipment, supplier relationships will change from pure sales to a more integrated innovation, with each member in the industry value chain required to participate more in the cooperative research and development of network software to truly dive deep into network operation. Carriers will also need to explore deeper collaborative innovation models, bringing in industry partners to achieve a quicker response to users and applications.

3、目标网络架构/Target network architecture

3.1 目标网络特征/ Target network features

为了适应互联网新时代的大环境，更好的生存和发展，运营商必须对现有网络架构进行重构，从而在根本上改造网络的特征，改善网络的能力，改进网络的服务。

To adapt to the political and economic environment of Internet new era, and for improved survival and development, carriers must reconstruct existing network architectures to fundamentally transform the network characteristics, improve the network capabilities, and improve network services.

中国电信的目标网络应具备如下的新特征。

China Telecom's target network must have the following new characteristics:

（1）简洁：网络的层级、种类、类型、数量和接口应尽量减少，降低运营和维护的复杂性和成本。

（1）Simplicity: the network level, type, kind, size should be minimized to reduce the complexity and operation and maintenance costs.

（2）敏捷：网络提供软件编程能力，资源具备弹性的可伸缩的能力，便于网络和业务的快速部署和保障。

(2)Agility: networks must provide software programming capabilities, flexible and scalable resources, and facilitate the rapid network and business deployment and support.

（3）开放：网络能够形成丰富、便捷的开放能力，主动适应互联网应用所需。

(3) Openness: the networks may form rich and convenient openness and take the initiative to adapt to the needs of Internet applications.

（4）集约：网络资源应能够统一规划、部署和端到端运营，改变分散、分域情况下高成本、低效率的状况。

（4）Intensive: network resources should be able to plan, deploy and operate end-to-end in a unified way, thus changing the current high cost and low efficiency conditions under the decentralized and sub-domain circumstances.

伴随着上述特征的实现，中国电信将进一步为客户提供“可视”、“随选”、“自服务” 的网络能力，提升用户体验。

With the realization of the above features, China Telecom will further provide customers with "visual", "optional" and "self-service" network capabilities to improve user experiences.

（1）网络可视：面向客户，提供基于应用的网络资源视图

（1）Network visualization: Customer-oriented. Provides an application-based view of network resources.

（2）资源随选：面向业务，提供按需、自动化的网络资源部署

(2)Resources on demand: Business-oriented. Provides on-demand, automated deployment of network resources.

(3)用户自服务：面向服务，提供基于客户网络的自助管理
(3) User self-service: Service oriented. Provides self-service management based on customer networks.

3. 2 目标网络架构 / Architecture of target network

为实现上述目标，面向2025年的中国电信目标网络架构从功能层划分，将由“基础设施层”、“网络功能层”和“协同编排层”三个层面构成。
In order to achieve the above goals, China Telecom's 2025 target network architecture will be divided into three layers, namely the "infrastructure layer", "network function layer" and "collaborative arrangement layer".

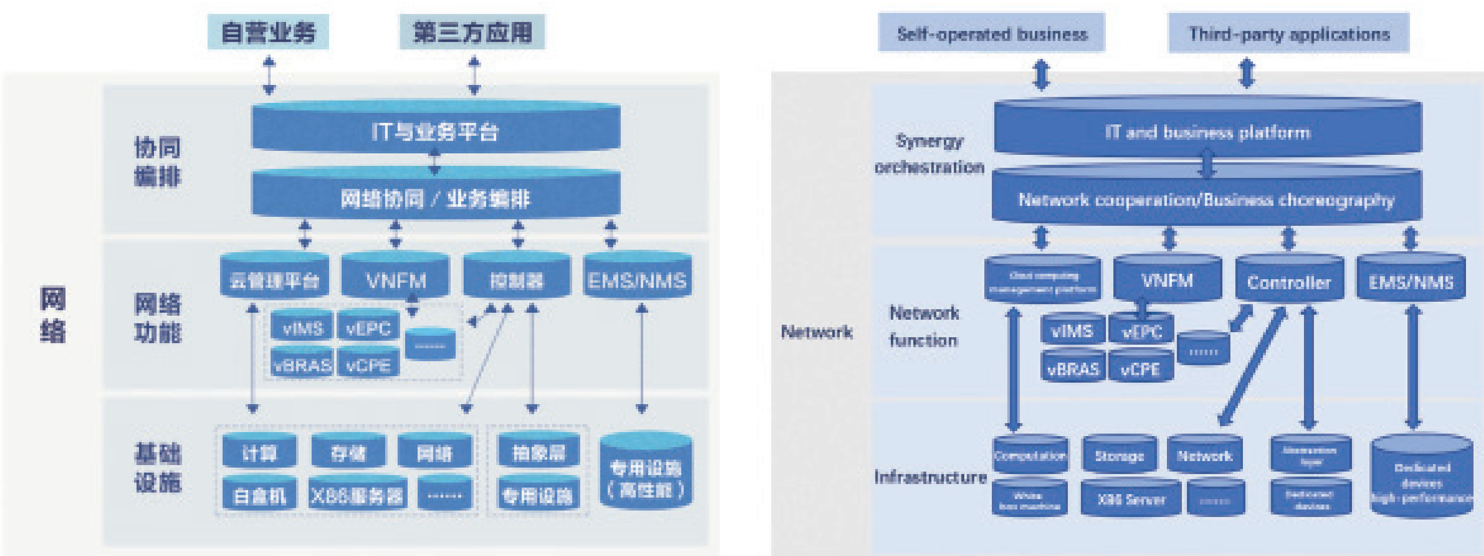

图 2：目标网络架构（功能图）/ Figure 2: Target network architecture (function diagram)

(1)基础设施层：由虚拟资源和硬件资源组成，包括统一云化的虚拟资源池、可象的物理资源和专用高性能硬件资源，以通用化和标准化为主要目标提供基础设施的承载平台。其中，虚拟资源池主要基于云计算和虚拟化技术实现，由网络功能层中的云管理平台、VNFM 及控制器等进行管理，而难以虚拟化的专用硬件资源则依然主要依赖于现有的 EMS 和 / 或 NMS 进行管理，某些物理资源还可以通过引入抽象层的方式被控制器或协同 器等进行管理。
(1) Infrastructure layer: Composed of virtual and hardware resources, including unified cloud-based virtual resource pools, materialized physical resources, and dedicated high-performance hardware resources, while providing an infrastructure hosting platform with the main goal of generalization and standardization. Thereinto, the virtual resource pool is primarily based on cloud computing and virtualization technology implementation, managed by the cloud management platform, VNFM and the network function layer controller. While dedicated hardware resources that are difficult to be virtualized still mainly rely on and are managed by the existing EMS and/or NMS, some physical resources can also be managed by the controller or collaborator through the introduction of the abstraction layer.

(2)网络功能层：面向软件化的网络功能，结合对虚拟资源、物理资源等的管理系统 / 平台，实现逻辑功能和网元实体的分离，便于资源的集约化管控和调度。其中，云管理平台主要负责对虚拟化基础设施的管理和协同，特别是对计算、存储和网络资源的统一管控； VNFM主要负责对基于NFV实现的虚拟网络功能的管理和调度，控制器主要负责基于 SDN 实现的基础设施的集中管控。为便于快速部署实施，简化接口和协议要求，规避不同 管控系统间信息模型不同造成的互通难度，这些系统与现有的 EMS/NMS 间不建议直接进行互通，可通过网络协同和业务编排器进行梳通和协调，完成端到端的网络和业务的管理。

(2) Network function layer: Software oriented network function is combined with the management system/platform of virtual resources, and physical resources, achieving the separation of logical functions and network element entities so as to facilitate the intensive control and scheduling of resources. Thereinto, the cloud management platform is mainly responsible for the management and collaboration of virtualized infrastructure, especially the unified management and control of computing, storage and network resources. VNFM is primarily responsible for the management and scheduling of virtual network functions based on NFV, and the controller is mainly responsible for the centralized control of infrastructure based on SDN. In order to facilitate the rapid deployment and implementation, simplify interface and protocol requirements, and to avoid communication difficulties caused by different information models, and to avoid different control systems, it is not recommended to develop direct communication between these systems and existing EMS/NMS, however, communication and coordination can be facilitated and coordinated through network collaboration and business synergy to achieve end-to-end network and business management.

(3)协同编排层：提供对网络功能的协同和面向业务的编排，结合 IT 系统和业务平台的能力化加快网络能力开放，快速响应上层业务和应用的变化。其中，网络协同和业务编排器主要负责向上对业务需求的网络语言翻译及能力的封装适配，向下对网络功能层中的不同管理系统和网元进行协同，从而保证网络层面的端到端打通；IT系统和业务平台的主要作用则是将网络资源进行能力化和开放化封装，便于业务和应用的标准化调用。

(3) Synergy orchestration layer: Provide collaborative network functions and business-oriented synergy. Combine IT system and business platform capabilities to speed up the opening of network capabilities. Quickly respond to the changes of business and application needs. Thereinto, network collaboration and business synergy are primarily responsible for the network language translation of business requirements, and the encapsulation and adaptation of business capabilities, coordinating different management systems and network elements in network function layers to ensure end-to-end functionality throughout the network level. The primary role of IT system and business platforms is to encapsulate network resources capability and openness, thus facilitating the standardization of invoking businesses and applications.

该网络架构带来的新变化主要有 ：

The new changes brought by network architecture mainly include:

(1)设施的标准化和归一化：目标网络架构中的基础设施，除少数必须采用专用硬件的设备或系统外，将大量采用标准化的、可云化部署的硬件设备，统一基础资源平台，并结合抽象层技术对于非云化部署的设备实现跨网、跨域、跨专业的端到端资源管控和统一管理。

(1)Device standardization and normalization: Infrastructures in target network architecture, except for a few devices or systems that require the use of dedicated hardware, the majority will adopt standardized and cloud deployed hardware devices to unify basic resource platforms. Furthermore, it will combine the technique of abstraction layer to realize the cross-network, cross-domain, and cross-industry end-to-end resource control and unified device management for without cloud deployment.

(2)功能的虚拟化和软件化：目标网络架构中的网络功能，将大量采取软件的形式与硬件解耦，便于实现网络能力和服务的按需加载和扩/缩容。同时,网络资源与服务将具备可编程能力,实现资源的灵活调配与业务的敏捷提供。

(2)Function virtualization and softwarization: Network functions in the target network architecture will be largely decoupled from hardware through software, so as to facilitate the implementation of on-demand loading and the expansion/contraction of network capabilities and services. Moreover, network resources and services will have the programmable ability to achieve the flexible deployment of resources and the agile provision of businesses.

(3)IT能力的业务化和平台化：目标网络架构中，对于IT系统不再仅定位于网络的支撑服务，更多考虑将IT打造成为能力平台，提供对外开放的服务；同时，IT技术不仅运用于传统的业务平台和软件系统，将更多地体现在网络功能层和基础设施层的各个方面。

(3)Business and platformization of IT capabilities: In the target network architecture, the IT system is no longer positioned as the only support service only in the network, but considered more as a capability platform providing open services. Meanwhile, IT technology is not only applied to the traditional business platform and software system, but also reflected more and more in the overall network function layer and infrastructure layer.

需要特别指出的是，在该网络架构中，为克服现有网络中存在的大量私有和封闭接口 / 协议的难题，对于层间以及相关的功能系统之间应尽量采用开放 API 接口，并引入通用化的协议，优先使用开源的技术方案，实现网络的更大程度的开放。总体来说，应采取如下的思路：

In order to overcome the problem of a large number of private and closed interfaces/protocols in existing networks, particularly in this network architecture, open APIs must be used to the maximum extent between layers and related functional systems, and generalized protocols must be introduced, prioritizing the use of open source technology solutions, and thus realizing a greater degree of network openness. Generally speaking, the following ideas should be adopted:

(1)在网络功能层及网络协同和业务编排器的北向接口方面，可采用 Restful 协议 和 XML 方式等，采用描述性语言简化技术实现的难度，重点加快对相关网络业务模型 的标准化和模块化，实现对上层应用的 APP 化支持，并满足对下层功能的统一适配。

(1)In terms of the network function layer and the northbound interface of network collaboration and business synergy, Restful and XML can be used, introducing descriptive language to simplify the difficulty of technical implementation, thus focusing on accelerating the standardization and modularization of relevant network business models, realizing APP support for the upper application, and satisfying the unified adaption of the lower functions.

(2)在网络功能层及网络协同和业务编排器的南向接口方面，通过引入互通性、一致性较好的接口协议，如 Openflow、NetConf/YANG 等，屏蔽基础资源的差异性，简化对底层设备的管理配置要求。

(2)In terms of the network function layer and the southbound network collaboration and business synergy interface , through the introduction of interoperability and consistency of interface protocols, such as Openflow, and NetConf/YANG to mask the difference of basic resources and to simplify the management and configuration requirements of underlying devices.

(3)对于跨平台、跨系统的场景，通过网络协同和业务编排器来“疏通”新老系统，可采用定义协议总线的方式来兼容现有的南北向接口，减少东西向互通的复杂度；对于基础设施中虚拟化资源的管理和协同，应该尽量采用标准化、开源的方案，如采用 OpenStack 对云化资源进行管理，采用开源的 Hypervisor 对虚拟资源进行适配。

(3)For cross-platform and cross-system scenarios, the new and old system may be “facilitated” through network collaboration and business synergy. By defining the protocol bus, the existing northbound and southbound interfaces are compatible, and the complexity of eastbound and westbound communication can be reduced. For the management and coordination of virtual resources in infrastructure, standardized and open source solutions must be adopted to the greatest extent, such as by utilizing OpenStack for cloud resources management and open source Hypervisor for virtual resources adaptation.

在新型络架构实施过程中，将采取运营开发一体化的模式，运营商逐步深度介入系统开发，从而缩短新业务的开发、上线、运行、维护及迭代的周期。重点自主开发协同编排层、超级控制器，实现对网络跨厂商、跨域、跨专业的协同与编排，同时合作开发网络功能层，与产业界共同丰富网元功能与网络控制能力。

Business and platformization of IT capabilities: In the target network architecture, the IT system is no longer positioned as the only support service only in the network, but considered more as a capability platform providing open services. Meanwhile, IT technology is not only applied to the traditional business platform and software system, but also reflected more and more in the overall network function layer and infrastructure layer.

在新一代网络架构中，将把网络能力进行原子化封装，形成网络能力池向第三方提供丰富的网络开放能力，并通过与产业各方的通力合作，共同繁荣未来新一代网络的可持续发展生态体系。

In the new generation of network architecture, the network capacity will be atomized wrapped, forming a network capacity pool to provide rich open network capabilities to third parties through full cooperation with all parties in the industry, therefore promoting the sustainable development ecosystem of the new generation network in the future.

3.3 目标网络能力/Target network capability

为使中国电信的网络具备快速、有效支撑互联网应用和互联网 + 应用的能力，同时也为了能在网络性能和功能上具备差异化的竞争优势，中国电信面向 2025 年的目标网络能力将达到如下指标：

In order to enable China Telecom's network capability to quickly and effectively support Internet applications and Internet + applications, as well as to have differentiated competitive advantages in network performance and functions, China Telecom's target network capacity for 2025

(1)简洁：以传送网一二干融合为抓手促进网络层级的减少；全国 90% 地区提供不大于 30ms 的传送网时延；网络种类、网元数和网络节点数明显减少。

(1) Conciseness: To promote the reduction of the network layer with the integration of transmission network as the starting point; 90% of areas in the country provide no more than 30ms transmission network delay; The number of network types, network elements and network nodes come up with an obvious reduction.

(2)敏捷：全面规模提供“随选网络”业务，具备分钟级的配置开通和调整能力。

(2) Agility: To provide "on-demand network" services on an overall scale, with configuration opening and adjustment capabilities in minutes.

(3)开放：提供用户自定义的服务，具备4个维度（网络、业务、资源、服务）的能力开放

(3) Open: To provide user-defined services with open capabilities in four dimensions (network, business, resources, services).

(4)集约：80% 网络功能软件化，全部业务平台实现云化，业务可全网统一调度。

(4) Intensive: 80% of network functions are softwarized, meaning all business platforms are cloud-based, and services can be uniformly scheduled across the network.

4、演进路径/Evolution path

4.1 指导原则和演进路径/Guiding principles and evolutionary paths

为实现上述网络架构重构的目标，相关的演进工作将遵循如下主要原则：
In order to achieve the above goal of network architecture reconstruction, the applicable evolution process must follow the following main principles:

(1)在对SDN/NFV等新技术的引入过程中，新系统应优先基于SDN/NFV部署； 部分老系统可逐步引入 SDN/NFV。
(1) During the introduction of new technologies such as SDN/NFV, the new system should be primarily implemented based on SDN/NFV; Parts of the old systems can be gradually introduced into SDN/NFV.

(2)基于通用的硬件基础设施部署 NFV 时，要尽量避免形成不同厂家/地域/专业的新的“烟囱”群。
(2) When deploying NFV based on a common hardware infrastructure, it's necessary to try to avoid forming new "chimney" clusters among different manufacturers, geographies, or specialties.

(3)IT 系统和技术和网络资源需要深度融合，通过网络协同和业务编排器，实现网络端到端管控。
(3) To realize end-to-end network control through network collaboration and business synergy, IT systems, technologies and network resources must be deeply integrated.

对于演进路径，中国电信坚持“网络云化”和“新老协同 / 能力开放”两条腿并行的方式，分近期和中远期两阶段推进：
As for the evolution path, China Telecom adheres to the simultaneously"network cloudification" and "New and old openness with collaboration/capability" approach, propelling in the near, mid, and long terms:

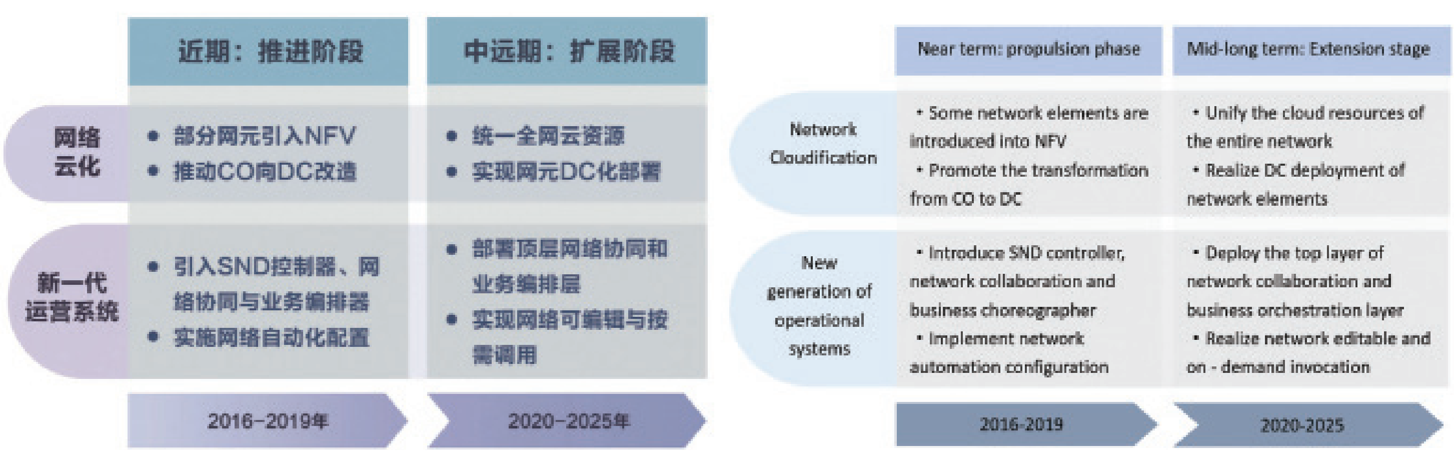

图 3：目标网络演进路径（两阶段）/ Figure 3: evolution path of the target network (two-stage)

(1)近期（2016-2019 年）/ Near term (2016-2019)

a)网络云化：选择部分代表性网元和系统（如 CPE、BRAS、EPC、IMS 等）， 结合相关系统升级换代工作，引入 NFV。结合虚拟化网元统一部署的要求，推动部分具备条件的机房（CO）向数据中心架构（DC）的方式改造。

a. Network cloudification: Select some of the representative network elements and systems (such as CPE, BRAS, EPC, IMS, etc.) and introduce NFV by combining related systems and updating and upgrading tasks. Combine the virtual network element unified deployment requirements , thus promoting, and transforming qualified COs into DCs.

b)新老协同/能力开放：在IP网和光网络中引入SDN控制器、网络协同和业务编排器。 网络协同和业务编排器管理“新”网络，优化现有OSS管理“老”网络。重点强化网络分析系统，实现网络可视化，实施统一的全网自动化配置。

b. New and old openness with collaboration/capability: Introduce SDN controller, network collaboration, and business synergy into IP and optical networks. Network cooperation and business synergy managing “new” networks and optimizing the existing OSS management of “old” networks. The emphasis is on strengthening the network analysis system, achieving network visualization, and implementing the unified automatic configuration of the whole network

(2)中远期（2020-2025 年）/ Mid-long term (2020-2025)

a)网络云化：基于DC承载各类网元，以DC为核心组织端到端网络；统一全网云资源，实现网元硬件资源的通用化

a. Network cloudification: Carry various network elements based on DC, organizing end-to-end network with DC as the core; Unifying all network cloud resources, and realizing universalization of the network element hardware resources.

b)新老协同/能力开放：部署统一的顶层网络协同和业务编排器，实现“新老”网络 与设备协同和业务端到端一点提供；重点实现网络可编程，网络资源可按需调用。

b. New and old openness with collaboration/capability: Deploy unified top-level network collaboration and business synergy to achieve “new and old” network and device collaboration and end-to-end business provision; Focus on realizing programmable networks and invoking network resources on-demand.

4.2 网络层面主要切入点/Main network layer entry point

网络层面的主要切入点如下图 4 所示。
The main network layer entry point is shown in figure 4 below.

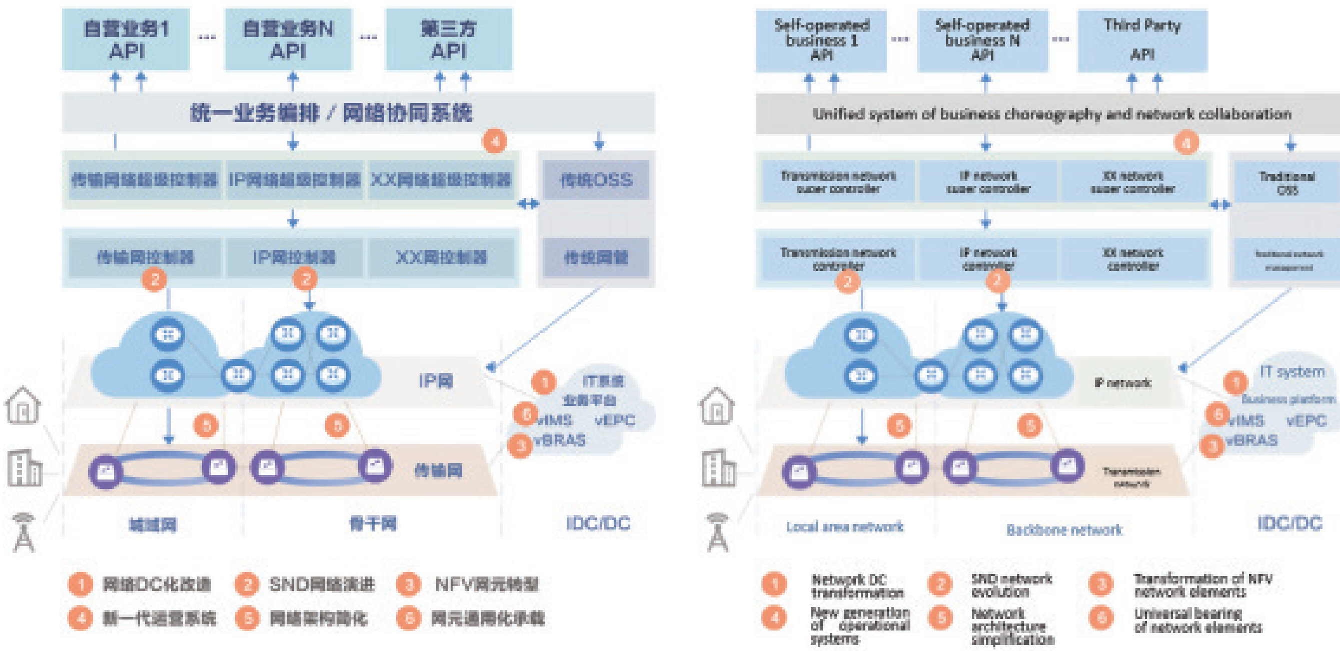

图 4：网络层面的切入点/ Figure 4: Entry points at the network level

4.2.1 推进 CO 的 DC 化改造，适应未来网络的云化发展
4.2.1Promote the DC transformation of CO to adapt to the cloud development of future networks

a）以适应业务发展和 DC 演进为导向，以 DC 为核心构建新一代网络，开展具备条件的电信机房的 DC 化改造，以 DC 流量为主优化调整 IP 与传送网络架构。

a) With the direction to adapt to business development and DC evolution, developing the next generation of networks centered around DC, carrying out the DC transformation of qualified telecommunications rooms, optimizing and adjusting IP and transmission network architecture focusing primarily on DC traffic.

b）结合企业客户业务需求和自有网络改造需求推进 DC 布局的分层化。

b) Promote the layering of the DC layout based on business requirements of enterprise customers and the transformation requirements of owned network.

4.2.2 推进网络的SDN演进，实现网络敏捷的业务提供、灵活的资源调整及高效的业务保障
4.2.2 Promote the network SDN evolution. Achieve agile business provision, flexible resource adjustment and efficient network service guarantees.

a）利用SDN集中控制，加速多种智能专线业务（IP、传输等）的业务开通与灵活调度。

a) Centralized SDN control is used to accelerate the opening and the flexible scheduling of various intelligent dedicated line services (IP and transmission).

b)承载网（IP网、传送网等）与DC/云资源池统一协同编排，实现网络、计算、存储资源的统一指配。

b) Promote the layering of the DC layout based on business requirements of enterprise customers and the transformation requirements of owned network.

c)在骨干网和 DCI 引入 SDN 控制器、网络协同和业务编排器，实现跨域协同和网络流量优化。

c) Introduce the SDN controller, network collaboration and business synergy to backbone network and DCIs, while realizing cross-domain collaboration and network traffic optimization.

4.2.3 多专业多领域协同推进 NFV 转型，减少专用网元和系统。

4.2.3 The NFV transformation will be promoted in a multi-professional and multi-field coordinated way to reduce the number of private network elements and systems.

a)在城域网边缘逐步实现网元NFV化，基于业务链部署增值业务，实现城域网业务的灵活提供。

a) Gradually realize network elements transformation into NFV in the edge of the metropolitan area network. Based on the value-added services of service chain deployment, therefore achieving the flexible provision of metropolitan area network businesses.

b)在 EPC 和 IMS 引入虚拟化技术，适时部署 5G，实现对移动核心网的集约化管理与资源分配。

b) Introduce virtualization technology to EPC and IMS while deploying 5G timely to realize the intensive management and resource allocation of mobile core networks.

c)推进 CDN 控制平面以及业务边缘节点设备的虚拟化和池化，提升应对视频用户并发量激增的能力，并提供未来新业务的快速交付能力。

c)Promote the virtualization and pooling of CDN control surfaces and equipment of business edges and nodes. Improve the ability to cope with the concurrency burst of video users and provide fast new business deliverability in the future.

4.2.4 新增顶层网络协同和业务编排器，部署新一代 OSS 体系。

4.2.4 New top-layer network collaboration and business choreographer to deploy the next generation of OSS.

a)在单域／单场景基础上引入顶层网络协同和业务编排器，实现跨域协同以及实体网络与虚拟网络的端到端业务提供。

a) Introduce top-layer network collaboration and business synergy based on single domain/single scene, realizing cross-domain collaboration and end-to-end physical and virtual network service provision.

b)基于新一代 OSS 系统对实体网络与虚拟网络实施统一运营管理，推进多专业的网络协同和业务编排器， 实现物理资源、虚拟资源、CDN 与承载网络的有效协同，以及对 SDN/NFV 的业务配置与资源调度等功能。

b) Implement the unified operation and management of physical and virtual networks based on the new generation of OSS systems. Propel multi-professional network collaboration and business synergy. Achieve effective collaboration between physical resources, virtual resources, CDN and carrier networks, as well as business configuration, resource scheduling and other functions of SDN/NFV.

4.2.5 以 DC 为核心，简化网络架构；规模支撑高清视频，提升网络能力。

4.2.5 With DC as the core, simplify network architectures; Scalise support for HD video and improve network capabilities.

a)以 DC 为核心形成“骨干 + 城域”两层扁平化光网络架构，在城域光网络方面可突破传统行政区域限制，继续推进实施一二级干线的融合。

a) Forming the two-layer flat optical network architecture of “backbone + city area” with DC as the core, Break through the limitation of traditional administrative areas in terms of urban optical network and continue to promote the integration of primary and secondary trunk lines.

b)通过端到端的网络提速和 CDN 节点下沉，服务大规模、大流量的高清和超高清视频业务，实现全光覆盖与千兆到户；并打造全网边缘加速体系，提供固定移动融合视频 CDN 服务能力

b) Serving the large-scale and high-traffic HD and ultra-HD video service and realizing comprehensive optical fiber coverage and GigE to home through and-to-end network speed acceleration and the deployment of CDN nodes. Building the whole network edge acceleration system to provide capable CDN services to Fixed Mobile Convergence video.

4.2.6 基于通用硬件全面部署统一的云资源，实现网元的通用化承载。

4.2.6 Achieve the generalization bearing of network elements based on the general hardware deployment of uniform cloud resources.

a)全面部署通用化、标准化、定制化、统一的云基础设施，规模应用定制化服务器、容器技术，统一承载网络、IT 系统、业务平台、大数据系统、云产品，实现计算、存储和网络资源的统一管理、动态调度和弹性伸缩。

a) Comprehensive deployment of generalized, standardized, customized and unified cloud infrastructure. Utilize large-scale customized server and container technology. Uniformly hold hosting network, IT system, business platform, big data system, cloud products to achieve the unified management, dynamic scheduling and elastic scaling of computing, storage and network resources.

b)实现业务平台全部云承载，推进业务平台集约化部署，满足互联网 +、物联网、大数据等应用发展需求。

b) Entire business platform is cloud-based. Promote the intensive deployment of business platforms. Meet the development needs of “Internet plus”, Internet of things, big data and other applications.

4.3 业务层面主要切入点/Business level main point of entry

在近期，为加速网络重构工作的实施，中国电信将启动下述工作作为业务层面主要切入点。

Recently, in order to accelerate the implementation of network reconstruction, China Telecom will commence following work as the main business level cutting point.

4.3.1 政企客户
4.3.1 Government and business customers

以“随选网络”为切入点，结合云网协同需求，为政企客户提供快速开通、可定制、自动化、差异化、多层面专线及延伸业务。

Take “on-demand network” as the starting point and combine thus with collaborative cloud network demands. Provide government and enterprise customers with quick loading, customizable, automated, differentiated, multi-layer special lines and extended services.

目前 ，“随选网络”的典型业务形态包括：

Currently, the typical “on-demand network” business forms include:

a)智能型以太网：为客户提供端到端以太网连接服务，通过以太网接口替代现有传输专线，支持 GE/10GE/100GE 等多种带宽，提供可视（网络状态）、可配（自助开通）、 可调（带宽、QoS）的服务。通过 SDN 集中控制实现集约化配置，借助网络协同和业务 编排器，实现跨域端到端网络协同和业务编排 。

a) Intelligent Ethernet: Provide end-to-end Ethernet connection services for customers. Replace the existing dedicated transmission line through the Ethernet interface. Support GE/10GE/100GE and other bandwidths. Provide visible (network state), configurable (self-service opening), adjustable (bandwidth, QoS) services. Intensive configuration is achieved through centralized SDN control . Cross-domain, end-to-end network coordination and business synergy is realized with the help of network collaboration and business synergy.

b)云宽带/云专线：提供云和网络一站式服务，对云资源的变化(计算、存储等)，网络资源（如站点、VPN、QoS 等）可自动适配，客户可在同一界面实现对云与网资源 一站开通。承载网（IP网、传送网等）与DC/云资源池等统一进行网络协同和业务编排，提供安全、高 QoS 的云接入与云互联服务 。

b) Cloud broadband/cloud DC: Provide cloud and network one-stop services. Change of cloud resources (including computing and storage) and network resources (such as site, VPN, and QoS) that can be automatically adapted. Customers can realize the opening of cloud and network resources on the same interface. The carrier networks (IP network, and transmission network) and DC/ cloud resource pool carry out unified network collaboration and business choreography to provide secure and high-QoS cloud access and cloud interconnection services.

c)虚拟化企业网：基于虚拟化为企业客户提供网络切片服务，在企业/家庭网关基础上， 将增值功能（如防火墙、负载均衡、业务配置等）在局端侧实现，客户可自助配置，网络 资源按需扩缩容，降低 CAPEX 和 OPEX。

c) Virtual business networks: Provide network slice services for business customers based on virtualization, and realize value-added functions (such as firewalls, load balancing, and business configurations) on the local side based on enterprise/home gateways. Customers can configure independently, and network resources can be expanded and shrunk as necessary to reduce CAPEX and OPEX.

4.3.2 公众客户
4.3.2 Public customers

将视频作为未来基础性业务，将其打造成为继语音和数据之后的又一种基础网络能力。伴随 4K 终端的普及及内容的丰富，4K 业务已经逐步成为提升运营商竞争力的关键 手段之一。同时，伴随着 4K 终端价格的持续下滑，一个家庭多 4K 终端、以及围绕 4K 的智慧家庭业务普及发展将会是一个必然趋势，这意味着100M甚至1000M带宽需求将成为新时期家庭宽带用户的基本需求。4K 视频让超宽带的价值得到释放，未来随着更高清晰度的 4K、8K 业务以及 VR/AR 业务发展，将对网络的端到端高带宽保障和服务质量提出更高的要求。

Take video as a future basic service and build it into another basic network power following voice and data. With the popularity of 4K devices and massive content, 4K business has gradually become one of the key ways for carriers to enhance their competitiveness. Meanwhile, with the continuous decline of 4K device price, it will be an inevitable trend for more 4K devices in one family and the trend and development of smart home business around 4K, which means that 100M or even 1000M bandwidth demands will become the basic demands of household broadband users in the new era. 4K video releases the value of the ultra-wide band. In the future, with the development of more HD 4K, 8K and VR/AR services, higher requirements will be proposed for the end-to-end high bandwidth guarantee and network service quality.

4.4 网络架构重构面临的挑战/Network architecture reconstruction challenges

网络重构对于运营商而言，将是一个长期的、复杂的演进过程，具体来说，至少包括了以下几个方面的挑战：

Network reconstruction will be a long-term and complex evolutionary process for carriers. Specifically, it includes at least the following challenges:

(1)组织架构方面：未来的网络架构将采取水平分层、纵向解耦的技术路线，基于 SDN/NFV的网络架构变化打破了专业界限，集约化的管控和调度也将突破传统行政区 域的限制，同时网络的DC化改造使得传统按行政区组网转向以DC为核心的组网新格局，这些都将会对当前以专业、行政区管理的组织架构带来变化。

(1) Organizational structure: Network architecture in the future will follow the technical route of horizontal stratification and longitudinal decoupling. The transformation of network architectures based on SDN/NFV broke the professional boundaries, intensive control and scheduling will break the limitation of traditional administrative domains, meanwhile, the DC modification of conventional networking makes a new pattern of network with DC centered. All of these will make a difference to the current organizational structure in terms of professional and administrative district management.

(2)采购模式方面：由于 SDN/NFV 分层、分域的产品形态，使得专业间关联更为紧密，传统的独立采购方式需要向跨专业、跨领域协同采购的方式转变。同时软硬件分离后，产品价值向软件转移，而且存在开源软件、商用软件、自研软件混用的应用场景，需要建立新的价格模式和采购方式。

(2) Procurement model: Due to the SDN/NFV hierarchical and domain-specific product form, the correlation between specialties has become much closer. The traditional independent procurement model needs to be changed to the collaborative cross-specialty and cross-domain procurement model. Meanwhile, after the separation of software and hardware, the product value will be transferred to software, and there are mixed use application scenarios of open source software, commercial software and self-developed software, which require the establishment of new price models and procurement methods.

(3)运营能力方面：现有网络运营多基于软硬件一体的标准化网元，系统复杂而封闭。未来的网络架构能够更灵活的适配互联网应用对网络、资源的弹性伸缩需求，网络即服务的运营需求对运营商的开发运营一体化以及市场、网络和 IT 的协同能力提出了更高的挑战，需要构建快响应、高效率、灵活服务的运营能力。

(3) Operational capability: Existing network operations are mostly based on standardized network elements integrated with hardware and software, which is complex and closed. Future network architecture will have a more flexible adaptation of Internet application towards the flexible network and resource demands. The network-as-a-service operational requirements pose a greater challenge to the carriers' integration of market development and operation as well as synergy, network and IT, the need to develop responsive, highly efficient, and flexible service operation capability.

(4)人才队伍方面：现有企业的网络工程师多基于传统设备，未来软件定义的网络将屏蔽底层硬件差异，需要增强运营商的软件开发团队与人才，提升软件快速迭代开发能力、网络和业务创新能力、以及对开源代码的掌控能力。

(4) Talent team: Existing enterprises' network engineers are mostly based on traditional equipment. In the future, software-defined network will shield the underlying hardware differences. Therefore, it is necessary for carriers to strengthen their software development team and talents, improve the ability of rapid iterative software development, network and business innovation, and improve their control over the open source code.

对中国电信而言，必须顺应技术发展趋势，做好网络重构与运营管理、设备采购、产品研发、人才队伍建设等一系列的协同工作。

For China Telecom, it is necessary to follow the trend of technology development and carry out a series of collaborative work including network reconstruction and operational management, equipment procurement, product research and development, and talent team development.

5、关键技术要素/Key technical elements

5.1 SDN 软件定义网络/SDN software-defined network

SDN（软件定义网络）是将网络的控制平面与数据转发平面进行分离，采用集中控制替代原有分布式控制，并通过开放和可编程接口实现“软件定义”的网络架构。

SDN (Software-defined Network) separates the network control plane from the data forwarding plane and replaces the original distributed control with centralized control. Furthermore, by the open and programmable interfaces, SDN can implement a “Software-defined” network architecture.

SDN在中国电信的网络架构重构工作中将首先应用于数据中心网络和IP网、传送网中，初期主要用于流量优化调度、快速开通配置等场景。

The application of SDN in the reconfiguration of China Telecom’s network architecture will be primarily implemented on the data center network, IP network, and transporting network.

(1)数据中心网络：目前中国电信云数据中心资源池运营中，遇到的主要问题是云资源池内部网络设备众多，网络特征复杂、运维难度较高的问题。SDN 引入可以实现对网络策略的统一配置以及对网络资源的灵活调度。一方面通过 SDN 控制器感知数据中心 链路带宽利用率，收集、分析数据中心全网流量分布情况，调配可用链路，并生成转发路 径下发给数据中心转发设备，实现链路带宽资源的有效利用。另一方面当虚拟机迁移时， SDN 控制器可感知到虚拟机迁移前后的源、目的位置，并将源交换机上的相关策略转移到目的交换机上，从而实现网络策略的同步迁移。

(1) Data Center Network. Until recently, the lack of cloud resource pool unified network devices, the complexity of cloud resource pools, and the high costs of operation and maintenance are the main problems in the practical operation of China Telecom’s cloud data center resource pool. Thus, the introduction of SDN enables the unified configuration of network policies and the flexible scheduling of network resources. On the one hand, the SDN controller makes it possible to sense the bandwidth utilization of the data center link, collect and analyze data center traffic distribution and allocate the available links. Based on that, the forwarding path is generated and sent to the data center forwarding device, which enables the implementation of the effective usage of the link bandwidth resources. On the other hand, The SDN controller could perceive the source and destination point of a specified VM before migrating and will move all the related configurations on the source switch to the designated switch, ensuring the synchronous migration of network policies and the VM.

(2)IP 网：目前 IP 骨干网的一个突出短板是流量调度缺乏足够的灵活性，限制了组网架构的扩展性和对应用需求的快速响应。借助 SDN，一方面可实现骨干网设备的功 能抽象，控制与转发更加灵活，可降低骨干路由器设备的复杂度；另一方面，引入智能化流量调度技术，实现多维度的客户和流量集中调度。而且，利用网络协同和业务编排器， 还可以更好的适配网络能力与应用需求

(2) IP Network: Currently, the insufficient flexibility in traffic scheduling, which limits the scalability of the networking architecture and the rapid response to application requirements, is a prominent shortfall of the IP backbone network. With SDN, for one thing, it can realize the function abstraction of the device in the backbone network, and makes the controlling and forwarding more flexible, which can reduce the complexity of the backbone router device. For another thing, introducing intelligent traffic scheduling technology enables centralized multidimensional customer and traffic scheduling. Moreover, by utilizing the network collaboration and service orchestrator, network capability and application requirements can be better adapted.

(3)传送网：目前的传送网主要采用静态网管配置方式，并且与所承载的应用和客户层网络是分离的，因此无法有效地应对动态的业务需求。通过引入传送网 SDN，实现传送网从“人工静态网管配置”向“实时动态智能控制”的演进，可提高业务开通速度、简化网络配置和运维。具体而言，可以利用SDN的开放性和集中控制的特点，实现对多厂商、多域组网环境的统一控制和管理；通过北向 API 接口的标准化和开放，传送网 SDN 可以提供多项新型业务，例如虚拟传送网业务（VTNS）、带宽按需点播（BoD）、 客户自定义的路径选择等；利用 SDN 集中控制的思路，分别在 IP 网和传送网中引入网络控制器，同时在两者之上引入一个综合的 SDN 控制器，

(3) Transport network: The current transport network mainly adopts the static network management configuration mode, which is separated from the carried application and customer layer network. Therefore, it cannot respond effectively to dynamic service requirements. By introducing the transport network SDN, the transport network realizes the transformation from “manual static network management configuration” to “real-time dynamic intelligent control”, which improves the service opening speed, and simplifies network configuration, operation, and maintenance. Specifically, by focusing on the SDN openness and centralized control, multi-vendor and multi-domain networking environment unified control and management can be achieved. Through the standardization and opening of the northbound API interface, the SDN transport network can provide multiple new services, such as virtual transport network service (VTNS), bandwidth on-demand (BoD), and customer-defined path selection. By using the centralized control of SDN, network controllers can also be introduced to the IP network and the transport network respectively, as well as applying a comprehensive SDN controller based on both.

(4)跨专业协同：目前各专业网的配置、管理通常是分块进行的，各自专业的业务管理、网络管理都分域分专业单独进行，相互之间的资源、管理、控制难以协同，响应时间长、资源利用率不高。利用SDN协同控制的思路，IP网和传送网可以协同组网，实现对IP和光层网络的统一控制和优化，快速响应突发业务需求，协调IP和光层的保护机制，提高资源利用率。同时，IP网和云资源也可以协同调度，实现IP网的连接资源（如 带宽、路径等）随云资源需求灵活而动、有机结合，从而更好地服务云业务应用。

(4) Inter-disciplinary collaboration: The present configuration and management of each professional network is typically carried out in the isolated blocks. Based on these isolated blocks, each responsible for separated operation in different sub-disciplines, the lack of coordination between different resources, management and controls led to the long response time and ineffective utilization of resources. Within the operation of SDN coordinated control, the IP network and the transport network can work together, which enables the unified control and optimization of IP and optical layer networks, and can also respond quickly to sudden service demands while coordinating the IP and optical layer protection mechanisms, and improving resource utilization. Meanwhile, the IP network and the cloud resources can also be co-scheduled so that the connecting resources (such as bandwidth and path) of the IP network can be flexibly and dynamically according to the cloud resource requirements, thereby better serving the cloud service application.

5.2 NFV 网络虚拟化/NFV network function virtualization

NFV（网络功能虚拟化）是指利用虚拟化技术，采用标准化的通用IT设备（x86服务器、 存储和交换设备等）来实现各种网络功能，目标是替代通信网中私有、专用和封闭的网元，实现统一的硬件平台 + 业务逻辑软件的开放架构。

NFV (Network Function Virtualization) refers to the application of virtualization technology to implement the various network functions, by using standardized universal IT equipment (x86 servers, storage and switching equipment, etc.). Based on the goal of replacing the private, dedicated and closed networks in the communication network element, an open architecture unifying the hardware platform + business logic software can be constructed.

采用 NFV 后，一方面网络设备功能不再依赖于昂贵的专用硬件，基于 x86 标准的 IT 设备成本低廉，可望能为运营商节省设备投资成本；另一方面，通过软硬件解耦及功能抽象，资源可以充分灵活共享，实现新业务的快速开发和部署，并根据实际需求进行自动部署、 弹性伸缩、故障隔离和自愈等，为网络服务的设计、部署和管理带来了更大的灵活性和弹性。

By applying the NFV, the network device functions no longer need to depend on expensive dedicated hardware. Instead, it can be expected that the lower cost of IT equipment based on the x86 standard can save operators investment expense. Alternatively, through the separation of the hardware and software, and the functional abstraction, resources can be shared fully and flexibly, enabling the rapid development and deployment of new services, accompanied by automatic deployment, flexible scaling, fault isolation, and self-healing based on actual needs, which make the design, deployment, and management of network services more flexible.

具体来说，NFV 在中国电信的网络架构重构工作中可以首先应用于固定和移动网络中的数据面的分组处理和控制功能中，如 vBRAS、vCPE、vEPC 和 vIMS 等。

Specifically, NFV can be applied in the reconfiguration of China Telecom’s network architecture, especially to the packet processing and control functions of data planes in fixed and mobile networks, such as vBRAS, vCPE, vEPC, and vIMS.

(1)vBRAS：BRAS是城域网中用户接入的终结点和基础服务的提供点，传统的 BRAS 基于软硬件一体化的设备实现，给新业务部署带来很多不便，例如，不同时期部署 的BRAS设备，无法通过软件升级方式实现同一功能，而且很多增值服务（如NAT、DPI等） 都需要专用硬件板卡，增加了大量成本。vBRAS 可以以功能集为单元对设备控制平面进 行重构，形成独立模块（包括用户管理、组播、QoS 和路由等），每个模块可按需在虚 拟机上部署。vBRAS 还可以提供可编程能力，将控制面通过 API 接口向上提供灵活的功 能调用，实现用户对网络业务的按需定制。

(1) vBRAS: BRAS is the endpoint for user access, and simultaneously the provision of basic services in the metropolitan area network. Traditional BRAS is based on hardware and software integration, which brings many inconveniences to the new service deployment. For instance, BRAS device deployment in different periods cannot provide the unified function through software upgrades. Besides that, many value-added services (such as NAT and DPI) require dedicated hardware boards, which leads to high costs. By a functional set as the basic unit, the vBRAS can reconfigure the device control plane to form a separate module (including user management, multicast, QoS, and routing), and each module can be deployed on a virtual machine as required. vBRAS also provides programmable capabilities to provide control planes with flexible functional calls up the API interface, which enable users to customize their network services on demand.

(2)vCPE：CPE处于网络边缘，数量多、版本多、更新快、成本高、三层配置 复杂且故障率较高。同时，CPE 直接面向用户，提供业务，是产生收入的关键点。因而 CPE 的虚拟化效益最明显，还可望在提供基本管道基础上，快速提供便宜、丰富、个性化的增值网络业务。另一方面，CPE功能复杂，处理能力要求高，但网络能力要求并不高， 适合虚拟化。

(2) vCPE: CPE is at the edge of the network, with multiple versions, fast updates, high operational costs, complex Layer 3 configuration, and high failure rate. At the same time, CPE, which directly provides users with services, is the key to generate revenue. Therefore, the virtualization benefits of CPE are clear, and it is expected to quickly provide a cheap, rich, and personalized value-added network service based on basic pipeline provision. Otherwise, the CPE has complex functions and high processing power requirements, yet the network capability requirements are low, which is ideal for virtualization.

所谓 vCPE 就是将传统 CPE 上的部分复杂功能上移到网络侧，客户侧设备最多仅保留二层转发、隧道封装和配置、基于二层的防火墙等功能，把大量三层功能挪到网络侧实现。 可以极大简化客户侧设备的配置难度，降低故障率，同时避免对客户侧网关频繁升级带来 的成本增加。

The so-called vCPE moves some of the complex functions of the traditional CPE to the network side. Retaining only the functions of L2 forwarding, tunnel encapsulation and configuration, and firewall based on L2 on the client-side device and moving a large number of Layer 3 functions to the network side. By doing so, it significantly simplifies the configuration of the client-side devices, reduces failure rates, and avoids the cost increase caused by frequent client-side gateway upgrades.

(3)vEPC: 现有 EPC 设备多基于 ATCA 架构，通用性差，增加了研发、测试和运维的成本，特别是移动互联网流量激增情况下，扩容升级的代价极高。vEPC 使得移动核心网元可以运行在通用硬件之上，实现EPC网元（MME、HSS、PCRF、SGW、PGW等）的高效部署。

(3) vEPC: Based on the ATCA architecture, the existing EPC equipment has poor versatility and increases the R&D, testing, and operation costs. The cost of expansion and upgrading is extremely high, particularly in the case of a mobile internet traffic surges. vEPC means that the mobile core elements can run on the general hardware to implement efficient deployment of EPC network elements (MME, HSS, PCRF, SGW, PGW, etc.).

(4)vIMS：现有物理 IMS 网络主要面临资源利用率不均衡、资源隔离困难和扩缩容慢等问题。vIMS 可以为自营业务和政企客户快速组织独立的专网，在隔离的同时提高资源利用率，支持业务的定制。此外，vIMS 可以快速搭建业务测试环境，对预上线的业务进行仿真测试，缩短业务上线时间。

(4) vIMS: The unbalanced resource utilization, difficulty in resource isolation, and slow expansion and contraction are the main issues faced by the existing physical IMS network. vIMS can quickly organize independent private networks for private owned businesses and government and enterprise customers, improve resource utilization and support business customization while isolating. Furthermore, vIMS can quickly set up business test environments to simulate and test pre-launched services and shorten business online time.

在NFV引入过程中，重点需进行跨层之间的标准化工作，尤其要规避“软烟囱”的引入，即避免在网络软件化后，虽然网络功能由专用硬件实现改变为软件化实现，但依然无法实现软硬件分层解耦、单厂家设备研发锁定的问题。

Through the introduction of NFV, it is important to carry out standardization work among the different layers, particularly to avoid the introduction of “soft chimneys”, meaning the avoidance of the fact that network software being implemented by softwares instead of dedicated hardwares. The layered decoupling of the software and hardware, and the locking of R&D of the single-factory equipment cannot yet be realized.

5.3 云计算技术/Cloud computing technology

云计算是在虚拟化技术、分布式技术以及互联网技术发展到一定阶段出现的一种新型的IT服务提供模式和解决方案，是对传统IT的“软件定义”，带来IT的部署、运维和提供方式的变革，其主要的技术特征包括：

Cloud computing is a new type of IT service delivery model and solution following the certain development of virtualization technology, distributed technology and Internet technology. It is a “software definition” for traditional IT, which brings about the deployment, operation and maintenance of IT systems. Its main technical features include:

(1)自动化：IT 的部署和提供实现自动化，人工参与和手工操作的程度大大降低，从而大大提升了 IT 的部署和提供效率。

(1) Automation: The deployment and provision of IT achieved automation, which reduced artificial participation and manual operations, and immensely enhanced the deployment and delivery efficiency of IT .

(2)多租户：使得 IT 资源可以实现非常灵活的多用户 / 客户共享，获得很高的利用率。

(2) Multi-tenancy: with the IT resources, you can achieve very flexible multi-user/customer sharing, and achieve high utilization.

(3)开放：基于互联网服务的API接口实现对IT控制与管理能力的开放，真正可以做到在应用软件中定义和驱动云计算，也有利于实现云计算的自助化服务。

(3) Openness: the Internet-service based APIs enable the openness of IT control and management capabilities. It facilitates the defining and driving of cloud computing in application software and is also beneficial to cloud computing self-service.

(4)弹性伸缩：传统硬件很难实现灵活的伸缩，云计算使得 IT 资源可以按需、快捷的扩展和回收，满足各种突发性和快速扩展性的业务需求。

(4) Flexible Scalability: It is difficult for traditional hardware to achieve flexible scaling. The IT resources required for cloud computing can be expanded and recycled on demand, which could meet various burst and fast-scaling business needs.

具体来说，云计算的关键技术包括：
The specific key technologies for cloud computing include:

(1)虚拟化技术/Virtualization technology

服务器虚拟化技术是云计算服务的基石之一。服务器虚拟化技术（主要是指 X86 服 务器虚拟化，X86服务器已经成为云计算基础设施的标准配置）包括CPU、内存、IO 虚拟化技术，是处于硬件和Guest OS（指的是运行在虚拟化后虚机上的操作系统）之间的一层新型系统级软件技术，可以为各种 Guest OS（Windows Server、Ubuntu、 CentOS 等）提供与实际硬件无异的“硬件环境”（模拟各种硬件能力），并且实现多个 Guest OS 同时运行在同一个硬件平台之上，使得多个业务系统可以同时运行同一个服务 器之上并且互相在性能和数据上实现隔离，安全性得到保证，资源管理效率和资源利用率都获得了极大的提升。

Server virtualization technology is a layer of new system-level software technology between operating systems on a virtual machine, and is located in the hardware and Guest OS (refers to running after virtualization). It (mainly refers to the X86 server virtualization, as the X86 server has become the standard cloud computing infrastructure configuration) including CPU, memory, IO virtualization technology. This technology provides the actual hardware (simulating various hardware capabilities) for a variety of Guest OSs (including Windows Server, Ubuntu, and CentOS), and is no different to the actual “hardware environment”. It also enables multiple guest OSs running on the same hardware platform at the same time. By increasing the number of business systems running on the same server at the same time, it achieves isolation with the mutual interactivity between the performance and the data. This means that this technology can guarantee the security and resource management efficiency while greatly improving resource utilization.

(2)软件定义存储与网络技术/Software-defined storage and network technology

如果把服务器虚拟化技术视为“软件定义服务器”，那么为了实现云计算的自动化，存储和网络同样也需要“软件定义”化，以保证存储和网络资源的部署可以同样实现敏捷。软件定义存储相比传统主流的 SAN 存储，基于 X86 服务器并通过软件实现方式提供数 据块存储接口，可以在实现更高的扩展性和 IO，满足云计算大规模部署的需要，同时在存储的配置和管理上实现自动化。软件定义网络主要是利用 SDN、NFV 和 Overlay 网络虚拟化技术（例如 VXLAN）实现在云计算资源池中实现网络多租户和网络自动化。

If server virtualization technology is regarded as the “software-defined server”, then the storage and networking also need to be “software-defined”, to be able to guarantee their agile deployment to automate cloud computing. Compared with the SAN storage of the traditional mainstream servers, software-defined storage provides the storage interface of data block based on X86 server and implements software. It enables higher scalability and IO, realizing the large -scale cloud computing deployment needs, as well management and storage automation. The software-defined network mainly uses SDN, NFV and Overlay network virtualization technologies (such as VXLAN) to realize network multi-tenancy, and network automation in the resource pool of the cloud computing.

(3)分布式技术/Distributed technology

分布式技术由来已久，但在互联网不断发展的过程中，分布式技术有了新的发展，以MapReduce、DFS（分布式文件系统）、NoSQL、对象存储为代表的分布式技术为云计算带来了新的计算、存储、数据库能力，能够满足海量数据的处理、存储和管理。分布式技术构建的海量数据处理能力、文件和对象存储能力、数据库存储和管理能力成为新型的云计算服务类别，极大的丰富了云计算的服务能力，也使得云计算在满足互联网、移动互联网、物联网以及大数据方面得心应手。绝大部分分布式技术都有开源的版本，例如Hadoop/Spark技术体系、Swift对象存储、Ceph存储（同时支持块、对象和文件）等。

Distributed technology has a long history but enjoys new development based on the continuous development of the Internet. Represented by MapReduce, DFS (Distributed File System), NoSQL, and object storage, the distributed technology provides new computing, storage, and database capabilities to handle the processing, storage, and management of massive amounts of data. The massive data processing, file and object storage, database storage and management capabilities developed by distributed technology have become a new type of cloud computing service, greatly enriching the overall service capabilities of cloud computing, and also enabling cloud computing to meet the requirements of the Internet, mobile Internet, the Internet of Things, and big data. Most distributed technologies have open source versions, such as the Hadoop/Spark technology system, Swift object storage, and Ceph storage (which supports blocks, objects, and files).

(4)Docker 容器技术/Docker Linux Container

Docker 容器是一个开源的应用容器引擎，让开发者可以打包他们的应用以及依赖包到一个可移植的容器中，然后发布到任何流行的 Linux 机器上，也可以实现虚拟化， 是目前业界中最具代表性的容器技术。Docker 容器的关键是在容器中直接运行应用，省却了虚拟机 hypervisor 方案所需要的多个专用操作系统和 hypervisor 层，其架构简单，性能优良（规避了虚拟机层引入的损伤，接近裸机），扩展性好，部署快（启动时间为秒级），效率高，管理简单，运行成本低。Docker 容器对 SDN/NFV 既有协同发展和增强的一面，又在很多应用场景下可以替代 NFV 的作用，是一种轻量级的价廉物美的虚拟化技术。

The Docker container is an open source application container engine which allows developers to package their applications and dependencies into a portable container, and then publish them to any popular Linux machine and become virtualized. Until recently, the Docker container was the representative container technology. The key to the Docker container is to run the application directly in the container, eliminating the need for multiple dedicated operating systems and hypervisor layers for a virtual machine hypervisor solution. Based on its simple architecture and excellent performance (avoiding the damage introduced by virtual machine layers, close to bare metal), the Docker container has many advantages, such as the good scalability, fast deployment (second starting time), high efficiency, simple management, and low operating costs. The Docker container is a lightweight and inexpensive virtualization technology, and has a synergistic development and enhancement side for SDN/NFV. In many application scenarios it can also replace the role of the NFV.

5.4 开源软件技术/Open source software technology

开源软件（Open Source Software）是一种源代码可以被随意获取的计算机软件，这种软件的版权持有人可以在软件许可协议的规定之下保留部分权利并允许软件用户学习、修改、提高相应软件的质量。

Open Source Software is computer Software whose Source code is freely available and whose copyright holders retain some rights under the Software license which allows users to learn, modify, and improve the quality of the Software.

基于开源软件，可以降低运营商软件使用和研发的门槛和成本，加速新业务、新技术引入的步伐，主要价值体现在：

Based on open source software, it can reduce the threshold and cost of usage and research and development of carrier software and can accelerate the pace of new business and the introduction of technology. The main values are as follows:

(1)根据自身需求灵活快速的进行量身定制
(1) Develop customized products flexibly and quickly based on their requirements

(2)降低了软件开发门槛和风险
(2) Reduce the software development threshold and risk

(3)提升软件可靠性安全性
(3) Improve software reliability and security

(4)借力开源社区完善软件质量
(4) Improve software quality with the help of the open source community

在软件定义网络时代，运营商已经不可能再像传统做法那样购买商业软件或软硬件 一体化网络设备。引入开源软件，并基于开源软件实现自主研发对于运营商而言是“站 在巨人肩膀上”发展，是必然的选择。

In the era of software-defined networks, it is no longer possible for carriers to purchase commercial software or software-hardware-integrated network devices as they traditionally did. Introducing open source software and realizing the independent research and development based on open source software is an inevitable choice for carriers to “stand on the shoulders of giants.”

中国电信网络重构工作中，应引入开源软件，积极参与开源社区，增强基于开源软件的自主研发能力和运营开发一体化能力，将有助于提升对网络软件化的自主掌控程度。

Open source software should be introduced in China Telecom’s network reconstruction procedure. It will be helpful to promote the autonomous control degree to the network software by actively participating in the open source community and enhancing the ability of independent research and Integration of operation and development.

具体在开源软件和开源社区的选择方面，可以重点考虑：

Specifically, the selection of open source software and the open source community can be mainly defined as follows:

(1)基础平台开源技术：包括 Linux(操作系统)、MySQL/PostgreSQL/ MongoDB(数据库)、Apache/Nginx(WEB 服务) 等开源实现和相应的开源社区。

(1) Base platform open source technology: including Linux (operating system), MySQL/PostgreSQL/ MongoDB (database), Apache/Nginx (WEB services) and other open source implementations, along with their corresponding open source communities.

(2)软件定义网络开源技术：包括 OpenDayLight/ONOS(SDN 网络控制器)、Open Switch+OPNFV(NFV 开源实现) 等开源实现和相应的开源社区。

(2) Software defined network open source technology: including OpenDayLight/ONOS (SDN network controller), Open Switch+OPNFV (NFV open source implementation) and other open source implementations, along with their corresponding open source communities.

(3)云计算开源技术：包括 KVM/XEN（虚拟化技术）、Ceph/Swift（分布式存 储技术）、CloudStack/OpenStack（云资源管理）、Hadoop2.0、Spark/Storm（大 数据处理技术） 等开源实现和相应的开源社区。

(3) Cloud computing open source technology: including KVM/XEN (virtualization technology), Ceph/ Swift (distributed storage technology), CloudStack/OpenStack (cloud resource management), Hadoop2.0, Spark/Storm (big data processing technology) and other open source implementations, along with their corresponding open source communities.

5.5 新一代运营支撑系统/Next generation operational support system

新一代 OSS（运营支撑系统）是指在现有 OSS 系统中引入 SDN/NFV 的控制器、 业务编排和网络协同器，打破现有 OSS 系统的封闭性与烟囱式，形成对实体网络和虚 拟网络的跨专业、跨网络的端到端统一运营管理，是新型网络架构的关键元素之一。其中 ,LSO 是实现业务编排和网络协同器的关键技术，有助于 SDN/NFV 在现有环境中实 现平滑演进和端到端的业务提供。

The next generation of OSS (operation support system) refers to the introduction of SDN/NFV controllers, business synergy and network collaboration to the existing OSS system, thereby breaking the encapsulation and isolation of existing OSS system and forming an end-to-end unified operation management towards the cross-professional, cross-network real and virtual networks and is one of the key elements of the new network architecture. Thereinto, LSO is a key technology necessary to realize business synergy and network collaboration, and contributes to the realization of smooth evolution and end-to-end service provision in the existing environment.
actively participating in the open source community and enhancing the ability of independent research and Integration of operation and development.

新一代 OSS 系统对于中国电信网络重构工作的价值主要体现在：

The value of the new generation of OSS system for China Telecom's network redevelopment is mainly reflected in:

(1)跨越物理和虚拟两网，支持真正端到端的业务管理，有助于现有烟囱式网络和网管系统向未来水平网络架构和管理架构的平滑演进。

(1) Step over physical and virtual networks, supporting true end-to-end business management. This helps the existing isolated network and network management system to evolve smoothly into the future horizontal network and management architectures.

(2)实现网络架构的自动化管理，节省运营成本，减少业务开通时间。

(2) Realize automatic network architecture management. Reduce operating costs and service loading times.

(3)利用对产品、服务、资源的抽象化屏蔽了下层网络复杂性，支持灵活的信息模型、快速数据源整合、业务虚拟化、业务保障和分析、业务流程管理等。

(3) The abstraction of products, services and resources shield the complexity of the underlying network, and support a flexible information model, the rapid integration of data sources, business virtualization, business assurance and analysis, and business process management.

为满足中国电信网络架构重构的需求，新一代OSS系统应包括以下几大功能要素：

To meet the requirements of China Telecom network architecture reconstruction, the new generation of OSS system must include the following major functional elements:

(1)能力开放：新一代 OSS 支持面向第三方的网络能力开放，能够提供多样化的开放性接口，支持运营商自营业务及第三方业务的便捷集成，丰富网络应用与业务生 态。

(1) Openness of capabilities: The new generation of OSS supports third party open network capabilities, provides diversified open interfaces, supports convenient carriers' proprietary business and third party business integration, and enhances network applications and business ecology.

(2)用户自服务：新一代OSS应提供面向用户的自助服务能力，为用户业务的“一站式”灵活提供、快速开通与自助管理提供平台，从而大大提升业务部署的速度，提升 用户的业务体验。

(2) User-self-service: the new generation of OSS shall provide user-oriented self-service capabilities. It will provide a platform for "one-stop" flexible provision, the quick loading and self-service user business management. Thus, greatly improving the speed of business deployment and overall business user experiences.

(3)资源随选：新一代 OSS 提供面向业务、按需、自动化的网络资源提供能力，能够结合 SDN/NFV 中增强的网络控制、分析、采集能力，形成对于动态跨域资源的实时自治闭环系统，从而实现网络的智能分析、编排。

(3) Optional resources: The new generation of OSS provides business-oriented, on-demand, and automated network resource supply capabilities, which can be combined with the enhanced network control, analysis, and collection capabilities in SDN/NFV to form a real-time autonomous closed-loop system for dynamic cross-domain resources, therefore realizing intelligent network analysis and synergy.

(4) 策略管理：新一代 OSS 具备端到端的策略管理能力，能够结合用户的业务需求、网络状态和资源现状，做出智能的决策与策略下发。

(4) Policy management: The new generation of OSS has the end-to-end policy management capabilities, which can make intelligent decisions and issue policies based on users' business needs, network status and current resource statuses.

(5) 面向业务与网络可视：新一代OSS应以业务与客户为导向，提供面向业务、面向客户的网络视图，并提供对网络资源、网络数据的分析能力

(5) Business-oriented and network-oriented: the new generation of OSS should be business-oriented and customer-oriented, providing a business-oriented and customer-oriented network view, as well as the ability to analyze network resources and network data.

在向 SDN/NFV 的网络架构演进过程中，新一代 OSS 系统应采用采用开源、开放的架构，通过纵向区隔、横向协同的方式引入，对于 SDN/NFV 的新设备由协同编排 器器实现对其业务配置与资源调度功能，重点针对实时、动态资源的调控；对于传统设 备则仍然由综合网管和专业网管完成业务配置功能，重点保障传统网络的稳定运行。两者之间可通过跨域的顶层编排器来实现统一运营、端到端的业务管理、以及网络架构的自动化管理（如图五所示）。

In the process of evolving to the SDN/NFV network architecture, the next generation of OSS system should adopt the open source and open architecture and introduce it through vertical separation and horizontal collaboration. For new SDN/NFV devices, the collaborative synergist realizes the functions of business configuration and resource scheduling, with a focus on the regulation of real-time and dynamic resources. For traditional devices, the integrated network management and professional network management still complete the service configuration function and focus on ensuring the stable operation of the traditional network. Together, the two can achieve unified operation, end-to-end business management, and automated network architecture management through a cross-domain top-level synergist (see figure 5).

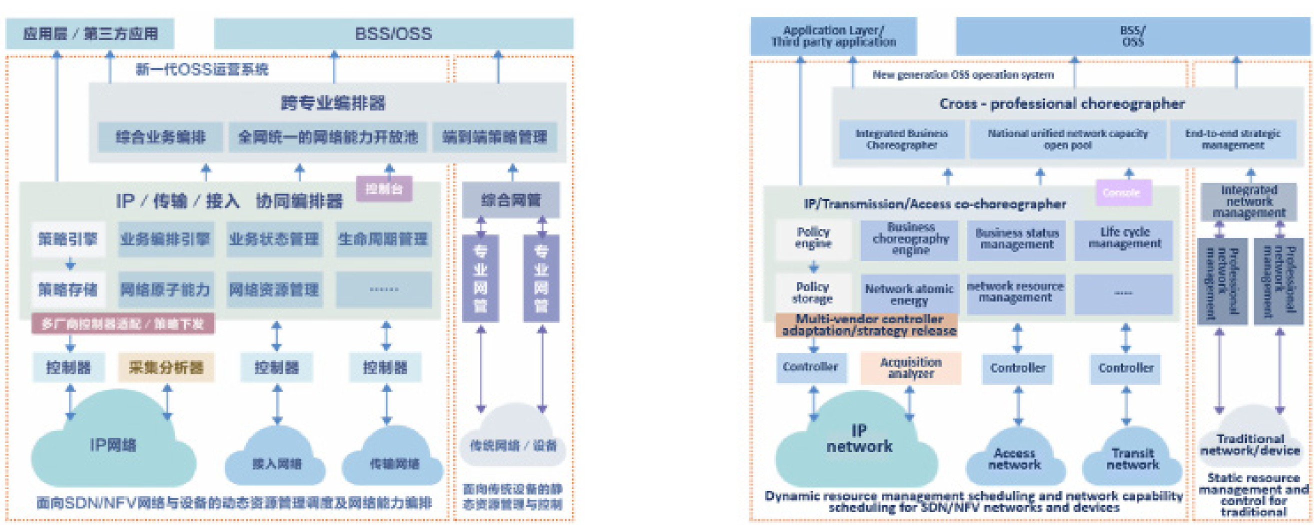

图 5：新一代运营支撑系统/ Figure 5: new generation operation support system

(1)跨专业顶层编排器：实现跨专业端到端业务的编排、全网能力开放、端到端策略管理；

(1) Cross-professional top-level synergist: Realize cross-professional end-to-end business synergy, open network capability and end-to-end strategy management;

(2)协同编排器：实现对单专业内多厂家控制器、跨域的协同以及网络服务能力的抽象提供，重点面向动态网络资源的管理与业务状态、网络原子能力封装与业务编排。

(2) Collaborative synergist: Realize the abstract provision of multi-manufacturer controllers, cross-domain coordination and network service capabilities within a single profession, focusing on dynamic network resource management, business state & network atomic capability encapsulation, and business synergy.

(3)控制器：用以本域内执行配置、实时策略，控制分布式模块和服务的状态

(3) Controller: Execute configurations and real-time policies within the domain and control the status of distributed modules and services.

随着云计算、大数据、SDN/NFV 等技术应用的不断发展，以及新一代运营支撑系统的实施部署，中国电信的 IT 系统与网络将从架构协同走向深度融合。基于通用硬件的云资源将逐步成为 IT 系统与网络的公共载体；基于新一代 OSS 系统能够有效实现端到端的网络控制、资源提供和业务配置，并实现自助、按需、自动化、一站式的资源提供、业务开 通和自助服务。

With the continuous development of cloud computing, big data, SDN/NFV and other technology applications, as well as the implementation and deployment of the next generation of operation support system, China Telecom's IT system and network will move from architecture coordination to deep integration. Cloud resources based on general hardware will gradually become IT system and network public carriers. Based on the next generation of OSS system, this can effectively realize end-to-end network control, resource supply and business configuration, and elf-service, on-demand, automation, one-stop resource supply, business loading, and self-service.

6、结束语/Conclusion

网络架构重构工作将对传统的通信产业链带来很大的影响。在互联网业务和应用快速发展的情况下，网络与业务之间必须要形成开发运营一体化的新关系，两者需要构成开发、销售、服务、反馈、维护等多节点闭环的互动机制，才能实现弹性灵动的网络服务。运营商和设备商之间、运营商和客户之间也将从目前简单的“售卖”模式转向未来的“集成创新” 和“联合开发”模式。未来网络架构将更好的支持客户对网络服务的定制，实现对客户和应用的快速响应。

The reconstruction of the network architecture will have a significant impact on the traditional communication industry value chain. With the rapid development of Internet business and applications, a new relationship of integration of development and operation must be formed between networks and businesses, and the two need to form a multi-node, closed-loop interaction development, sales, service, feedback, and maintenance mechanism to realize flexible and scalable network services. Carriers and device providers, along with carriers and customers, will also move from the current simple “sales” model to the futuristic “integrated innovation” and “joint development” models. In the future, the network architecture will better support customers’ network services customization and achieve faster customer and application response.

网络架构重构是中国电信的根本性和战略性创新。CTNet2025是中国电信未来网络架构重构的愿景 ， 是推动企业深化转型的重要抓手。中国电信将围绕 CTNet2025 为主线进行技术攻关、系统研发、试验验证、产业推广与业务突破，深度介入开发、测试、集成、运维等网络运营的全过程，重点突破SDN、NFV、云计算等核心技术，研发关键技术与相关系统，加强与 SDN、NFV 等标准组织及开源社区的合作，推进更广泛的产业链上下 游加入到网络业务的生态开发体系中。

Network architecture reconstruction is China Telecom’s fundamental and strategic innovation. CTNet2025 is the China Telecom’s future network architecture reconstruction vision and an important starting point to promote the deepening transformation of businesses. China Telecom will revolve around CTNet2025 as its main line to process technical research, system development, testing, industrial promotion and business breakthroughs. Deeply engage in the entire network operation process in development, testing, integration, and operations, breakthrough at key points on SDN, NFV, cloud computing, as well as other core technologies. Research and develop key technologies and applicable systems. Strengthen collaboration with standard structures like SDN, NFV and open source communities. Promote a wider range of upstream and downstream industry value chains to join in on the network business system ecological development.

中国电信愿以合作、开放、繁荣、共赢为宗旨，与产业链各方共创 CTNet2025 的美好明天。

China Telecom is willing to take cooperation, openness, prosperity and mutual benefit as its goal, and work with all industry parties for a better CTNet2025 future.

7、缩略语/Abbreviation

缩略语/Abbr.	英文全称/Phase	中文/Chinese
ATCA	Advanced Telecom Computer Architecture	高级通讯计算机架构
ATM	Asynchronous Transfer Mode	异步传输模式
BoD	Bandwidth on Demand	带宽随选
BRAS	Broadband Remote Access Server	宽带远程接入服务器
CAPEX	Capital Expenditure	资本性支出
CDN	Content Delivery Network	内容分发网络
CO	Central Office	机房
CPE	Customer Premise Equipment	客户终端设备
CPU	Central Processing Unit	中央处理器
DC	Data Center	数据中心
DFS	Depth-First-Search	深度优先搜索算法
DPI	Deep Packet Inspection	深度包检测
EPC	Evolved Packet Core Internet	演进分组核心网
GBR	Guaranteed Bit Rate	保障比特速率
HSS	Home Subscriber Server	归属签约用户服务器
IMS	IP Multimedia Subsystem	IP 多媒体子系统
IGP	Interior Gateway Protocol	内部网关协议
NFV	Network Function Virtualization	网络功能虚拟化
NAT	Network Address Translation	网络地址转换
MME	Mobility Management Entity	移动性管理单元
PCM	Pulse Code Modulation	脉码编码调制
PCRF	Policy and Charging Rules Function	策略与计费规则功能单元
PDH	Plesiochronous Digital Hierarchy	准同步数字系列
PGW	PDN GateWay	PDN 网关
QoS	Quality of Service	服务质量
OPEX	Operating Expense	运营成本
OSS	Operation Support System	运营支撑系统
SAN	Storage Area Network	存储域网络
SDH	Synchronous Digital Hierarchy	同步数字体系
SDN	Software Defined Network	软件定义网络
SGW	Serving GateWay	服务网关
TDM	Time-Division Multiplexing	时分多路复用
VTNS	Virtual Telephone Network Service	虚拟电话网络业务

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