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An MEC and NFV Integrated Network Architecture

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Abstract

The demand for 5G services and applications is driving the change of network architecture. The mobile edge computing (MEC) technology combines the mobile network technology with cloud computing and virtualization, and is one of the key technologies for 5G networks. Compared to network function virtualization (NFV), another critical enabler of 5G networks, MEC reduces latency and enhances the offered capacity. In this paper, we discuss the combination of the two technologies and propose a new architecture. Moreover, we list the application scenarios using the proposed architecture.

Keywords

MEC; 5G; NFV; cloud computing; network architecture evolution

1 Introduction

According to the IMT-2020 promotion group's description, the development of 5G networks is mainly motivated by two future visions: one is to increasingly enhance user experience of "people-oriented" mobile Internet, and the other is to support the Internet of Things (IoT) services that will create an "Internet of Everything". To meet the requirements of different scenarios, the 5G network should have the following capabilities: high-speed and high-bandwidth access capabilities for upgraded mobile applications such as voice calls, Internet access and ultra-high-definition video; ultra-dense device access and management capabilities for IoT device interconnections such as digital medical, open-air gatherings and concerts scenarios; and low-latency and highly-reliable end-to-end communication capabilities for the Internet of Vehicles (IoV), industrial automation, and other vertical industry applications [1]. However, the current mobile communication networks are far from these capacities.

With the mutual penetration and influence of the mobile network and Internet technologies, the software defined networking/network function virtualization (SDN/NFV) technology that uses such IT technologies as cloud computing, virtualization and software has become an important enabler for 5G networks, and has been applied in wide area networks (WANs) and metropolitan area networks (MANs). SDN/NFV enables resource management and interconnection across the data center at the WAN level, and achieves hardware resource virtualization and resource scheduling within the data center at the MAN level. However, the application of the NFV technology at the radio access network level is still under research in the industry [2]–[4].

Mobile edge computing (MEC), a new network architecture technology for the fusion of mobile access network and IT technology, has recently been proposed. MEC uses the wireless access network to provide services and cloud computing functions required by telecom users, and to construct a carrier-class service environment with high performance, low latency and high bandwidth to improve communication experience of mobile users. In 2014, the ETSI formally included MEC into the standards for discussion [5], signifying that MEC had become one of the key 5G technologies [6]–[7]. Network equipment manufacturers have worked together with telecom operators to develop the MEC platform and solutions, and made a public demonstration [8]–[11]. MEC has also been tested in the first experimental phase of 5G network in China. The expected performance has been achieved in the test [12].

This paper introduces the MEC technology and network architecture, compares MEC with NFV, integrates these two technologies, and enumerates the applications of MEC and NFV integrated architecture. Finally, this paper summarizes and forecasts the development of the MEC technology.

2 MEC Technology

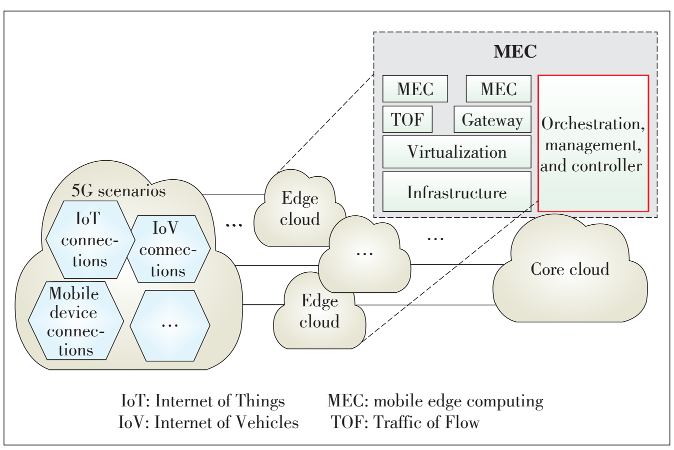
2.1 Basic Concepts

According to the ETSI definition, the MEC technology is to provide wireless access networks with IT and cloud computing capabilities by deploying Commercial Off-The-Shelf (COTS) on the wireless access side [13]. According to IMT-2020, MEC is to place the service platform on the edge of the network and provide nearby service computing and data caching for mobile users. **Fig. 1** gives out the location of MEC in the 5G network architecture.

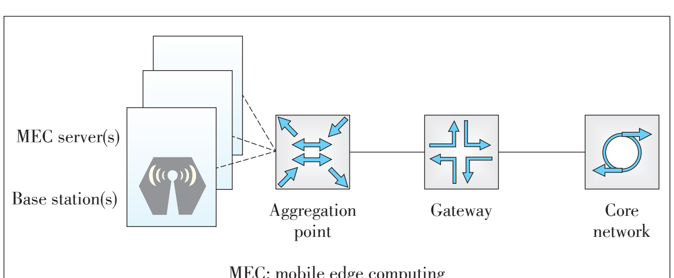
MEC can be flexibly deployed on the mobile wireless base station or the convergence point of a variety of access technologies. If deployed on the base station side, the operator can go deeper to analyze user scenarios such as mobile data traffic, wireless network environment, and the user´s specific location to provide a better user experience and enable a smart base station (**Fig. 2**). If deployed on a converged point, the operator can implement operation support for multiple services in the region to provide customized and differentiated services for different services, thus improving network utilization efficiency and adding values (**Fig. 3**).

2.2 MEC Architecture

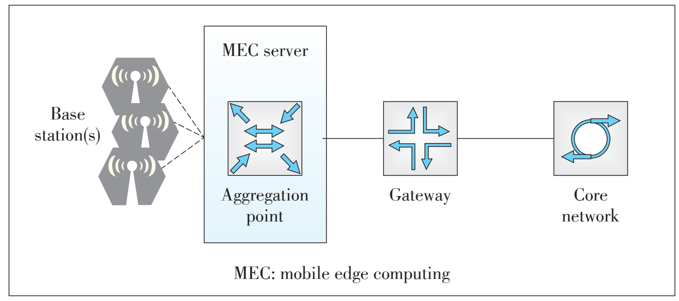
The MEC system architecture (**Fig. 4**) consists of a mobile edge host and associated management components. The mobile edge host includes the mobile edge platform and the virtualization infrastructure. The mobile edge platform has all necessary functions to support various types of mobile edge applications on the mobile edge host. It also provides a variety of mobile edge services to other mobile edge hosts and itself. The mobile edge platform is responsible for providing services including



▲**Figure 1. The location of MEC in 5G scenarios.**



▲**Figure 2. MEC network architecture solution 1: MEC deployed on the base station [13].**



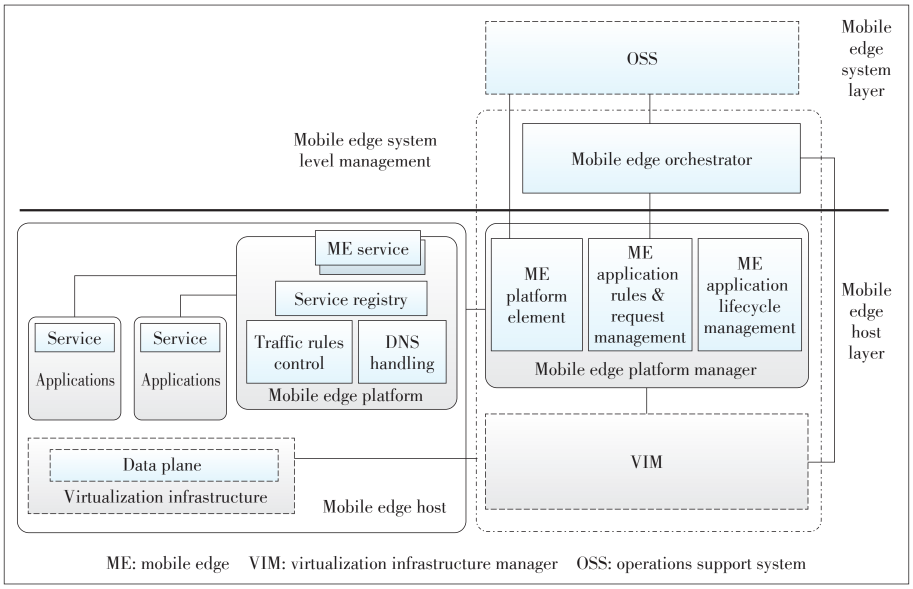
▲**Figure 3. MEC network architecture solution 2: MEC deployed on the aggregation point [13].**

service discovery, traffic forwarding control and domain name system (DNS) management. Service discovery ensures that mobile edge applications discover or utilize mobile edge services; the traffic forwarding control service is responsible for forwarding traffic data packets; and DNS management ensures that applications are discovered in the network [14]. Mobile edge applications run on a mobile edge host in the form of a virtual machine instance to utilize or provide mobile edge services.

The mobile edge management system consists of the mobile edge orchestrator (MEO), mobile edge platform manager (MEPM), and virtualization infrastructure manager (VIM). The MEO has a global view of the MEC system, including information on all deployed mobile edge hosts, information on available services and resources in each host, and information on instantiated mobile edge applications and network topologies. In addition, it is responsible for the ME application installation, application integrity check and authentication. The MEPM corresponds to a single mobile edge host. It is responsible for mobile edge platform element management, ME application lifecycle management and ME application rules and requirements management. The application rules and requirements refer to the rules and requirements associated with various types of mobile edge applications, including the required resources, maximum latency/delay, required or useful services, traffic rules, DNS rules, and mobility support. The MEPM obtains the latest information on the services available in the system from the MEO and interacts with the OSS to implement fault configuration and performance management functions.

The VIM manages the virtualized resources assigned to mobile edge applications. It can obtain information from the MEO for managing application images and virtualization resources and for monitoring resource availability. In addition, it interacts with the MEPM to manage the virtualization resources associated with the mobile edge application lifecycle.

In addition to the functional modules described above, the MEC architecture also includes modules for user portals, UE applications and user application lifecycle agents, as well as interfaces for communication between the modules. Wherein an UE application is an application run by the user terminal and has the capability of interacting with the mobile edge system through the user application lifecycle management agent. An



▲**Figure 4. MEC system architecture.**

user application lifecycle management agent allows initiation and instantiation of the terminal application request, termination of terminal application requests, and relocation or removal of user applications in the mobile edge system. It also informs an terminal application of the state of a user application. The specific functions of the interface in MEC can be found in [14].

2.3 Work Related with MEC Standardization

The MEC concept was originated in the 3G era. After the 3G smart phone became popular, the MEC idea was embodied in the mobile CDN specifically developed for the mobile network. Some operators and manufacturers proposed that, based on 4G base stations, the computing capability can be integrated in the 4G base stations. This is the "prototype" of the MEC technology [16]. In 2013, Huawei, IBM, Intel, Nokia, NTT Docomo and Vodafone formally put forward the MEC technology [13]. In October 2014, the ETSI ISG introduced the MEC into the standards, and conducted in-depth studies on service scenarios and technical requirements for the MEC technology. ETSI has published five MEC-related standards, including terminology, service scenarios, technical requirements, framework and reference architecture, and Proof of Concept framework, as shown in **Table 1**. The MEC application interface standardization and what services are to be provided with the MEC are still under discussion.

The MEC Proof of Concept (POC) is another key work of the ETSI, which solicits MEC prototypes and verification tests to promote the development of the MEC industry. The MEC POC has eight projects (**Table 2**), the project participants are from all the network service sectors, including network equipment manufacturers (Intel and Nokia), telecom operators (China Mobile and Deutsche Telekom), and Internet companies (iQIYI and SeeTec) [17]. In 2016, Nokia used the MEC networking solution to build a live broadcast platform in Shanghai International Circuit to provide live broadcast services to the audience. With this MEC solution, the live video had only a delay of as short as 0.5 second [11].

In the first test phase of the IMT-2020 (5G) promotion group, three Chinese operators completed the performance and functional test of mobile edge computing with Huawei, Nokia, Shanghai Bell, Datang and Intel. In the next phase of the test, Intel will explore the commercial value brought by the MEC technology for the mobile edge entrance; Nokia will use the AirScale cloud base station server to deliver the MEC access network architecture to meet the needs of a variety of 5G application scenarios; and China Telecom will set up pilot MEC sites in multiple Chinese provinces to verify main 5G service scenes [12], [18].

3 NFV Technology

The NFV technology uses cloud computing and virtualiza-

▼**Table 1. MEC standards released by ESTI Industry Specifications Group (ISG) [15]**

Number	Title
GS MEC 002	MEC, technical requirements
GS MEC 003	MEC, framework and reference architecture
GS MEC 001	MEC, terminology
GS MEC-IEG 004	MEC, service scenarios
GS MEC-IEG 005	MEC, proof of concept framework

MEC: mobile edge computing

▼**Table 2. MEC POC projects completed by ETSI [17]**

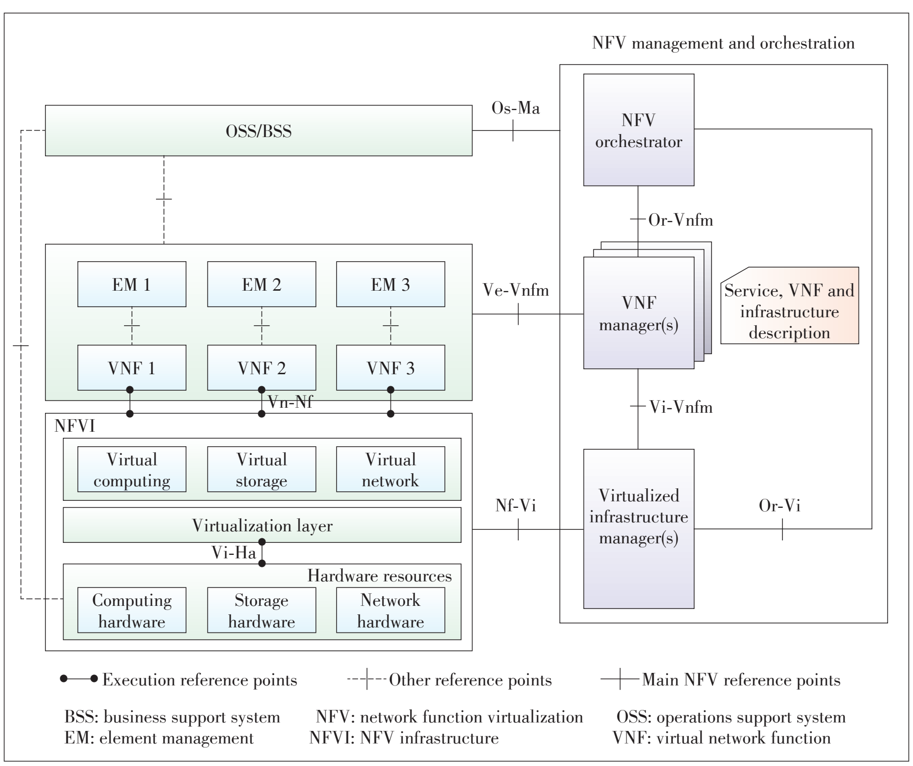
Application case	Participants
Video user experience optimization	Intel, China Mobile, iQIYI
Edge video orchestration and video clip playback	Nokia, EE (a British telecom operator), Smart Mobile Labs
Radio aware video optimization in a fully virtualized network	Telecom Italia, Intel UK, Eurecom, Politecnico di Torino
Video analytics	Nokia, Vodafone Hutchison Australia, SeeTec
FLIPS-IP-based flexible service	InterDigital Communications, UK "Bristol Is Open", Intracom (Greece), CVTC, Essex University (UK)
Enterprise services	Saguna, Adva Optical Network (Germany), Bezeq International (Israel)
Healthcare—dynamic hospital user, IoT and alert status management	Quortus Ltd.(UK), Argela (Turkey), Turk Telekom
Multiservice MEC platform for advanced service delivery	Brocade, Gigaspaces, Advantech, Saguna, Vasona, Vodafone

tion technology to strip out the network functions from dedicated hardware devices so that network functions can be delivered with software in an independent way. In the NFV technology, the independent network element function is applied to the cloud computing platform built on the standard server to realize the rapid expansion/contraction of the network, enhancing the resilience and flexibility of the network.

3.1 NFV Architecture

According to the NFV reference architecture developed by the ESTI (**Fig. 5**), the NFV has two horizontal layers: the network service (NS) domain and management and orchestration (MANO) domain. The NS domain consists of three vertical layers: the NFV infrastructure (NFVI), virtual network function (VNF), and operational support layer. The MANO domain consists of three entities: the virtualized infrastructure manager (VIM), VNF manager (VNFM), and NFV orchestrator (NFVO), which are responsible for the whole lifecycle and scheduling strategy management of NFVI, VNF and network services [20].

The NFVI is similar to a cloud data center for hosting and connecting virtual functions. It is responsible for virtualizing the underlying physical resources and realizing the physical bearing of all the elements required by the VNF. The VNF is to virtualize all existing physical network infrastructure in the communication network on the basis of the NFVI, such as the residential gateway in a home network, DHCP server, and firewall. A single VNF may have multiple internal components, so it can be deployed in multiple virtual machines, each carrying one component of the VNF. One or more VNFs can serve the customer as a whole. The operational support layer does virtualization adjustments based on the current OSS/BSS. The MANO delivers orchestration and management for the NFVI, VNF, and NS through interactions of the VIM, VNFM, and NFVO, to achieve management and orchestration of entire network services [21].



▲**Figure 5. NFV architecture [19].**

3.2 NFV-Related Studies

In 2012, seven operators, including AT&T, Deutsche Telekom, Orange and Telefonica, co-established the NFV ISG at ETSI to develop the requirements and architecture specifications supporting the NFV hardware and software infrastructure, and the virtual network function guide as well. They also worked with other standard organizations to integrate existing virtualization technologies and related standards when necessary [4].

While the conventional standardization works were being carried out, the open source organizations were actively promoting the NFV technology. In 2014, telecom operators including AT&T and China Mobile and telecom vendors including Dell and Hewlett-Packard cooperated with the Linux Foundation on establishing an open source project, the Open Platform for NFV (OPNFV), aiming to build a complete NFV implementation standard. The OPNFV integrates existing open source components with new components and tests to ensure consistency, performance and interoperability across multiple open source components, thereby speeding up the development and deployment of the NFV technology. In June 2015, the organization officially released the first version of NFV open source framework [3].

4 MEC/NFV Network

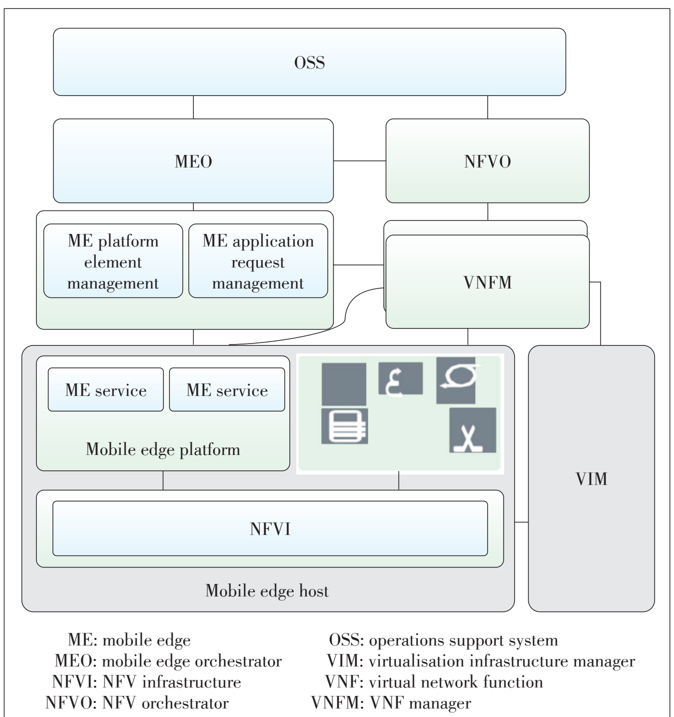
The MEC utilizes virtualization and cloud computing technologies to run and manage applications and services at the edge of the mobile network using virtualized platforms, providing a low-latency, high-bandwidth service experience. The NFV uses general-purpose open hardware and virtualization technology instead of traditional dedicated network equipment, to provide hardware and software decoupling for network functions and flexible management of network services and functions. The MEC and NFV have similar architectures and both require a network infrastructure virtualization platform. In addition, the management function of the two have components that can be combined and re-divided. Therefore, an MEC/NFV architecture is proposed in this paper, in a bid for achieving the goals of the MEC technology.

4.1 MEC/NFV Network Architecture

Fig. 6 shows the proposed MEC/NFV architecture. This MEC/NFV architecture has NFV system as the main body. It divides the MEC management modules in a new way and puts forward a new system architecture that features two vertical domains and three horizontal layers. The two vertical domains are the MEC domain supporting the upper layer application and the NFV domain supporting the underlying network resources. The three horizontal layers are the orchestration layer, the management layer and the basic resource layer from top down. The orchestration layer and the management layer span the MEC and the NFV domains, and the basic resource layer is provided by the NFV domain.

First of all, the basic resource layer comprises virtual infrastructure and the VNF, which are implemented by the modules in the NFV domain. The NFVI implements a virtualized infrastructure for MEC to use and share with other network functions or applications. The VNF implements the ME application and service components in the MEC domain, and the network element functions of the NFV domain.

The VIM manages virtualized infrastructure. The VNFM controls the creation and release, expansion and shrinkage of ME applications and service instances, and interacts with the VIM to apply for VM resources based on the resource usage of MEC applications and services, monitor resource usage and warn for faults. The NFVO in the NFV domain is responsible



▲**Figure 6. MEC/NFV architecture.**

for the orchestration of the NFV-related services. It determines the number of VNFs, the VNF type, and the VNF topology to be deployed, creates the VNFM instance, and interacts with the VNFM and MEO.

The key to the MEC technology is to achieve an open framework, to support the development of user applications, and to simplify the deployment of related services. Therefore, outside the NFV domain, the MEC domain is responsible for the application service-related computing services, service content storage, content delivery and download acceleration, and the definition and management modules for the application service open interface. In the converged architecture, the MEC domain consists of three modules from bottom to the top: mobile edge platform, MEPM, and MEO. The mobile edge platform provides services such as application-level traffic forwarding, processing and calculation of application service content data, and real-time access network state awareness, which can be implemented by the VNF. The MEPM provides application service communication interface management, application-level traffic forwarding rule management, and DNS configuration and IP address conflict management. The MEO implements application and service orchestration based on the requirements of the operational system and service applications.

The interface between the MEC domain and the NFV modules in the converged architecture is responsible for the interaction between the service application information and the network service information in the MEC domain and the NFV domain to ensure the modules' awareness of application and the network system status. In this way, the modules in different domains at the orchestration and management layers can jointly meet the requirements for application services. For example, the MEO informs the NFVO of the update of the UE application instance and the mobile edge system status through the interface between the MEO and the NFVO, and the NFVO performs system orchestration according to the update information. The MEPM informs the VNFM of conflicts and location change state caused by network resources between different applications through the interface between the MEPM and the VNFM, and VNFM manages the network element instance lifecycle according to the message.

In the MEC/NFV architecture, NFVO, VNFM, VNF, NFVI and VIM function modules in the NFV domain corporately provide applications with network services and infrastructure services from top to bottom. The MEO, MEPM and mobile edge platform in the MEC domain collaborates and responsible for the application demand information and application instance management service. The orchestration layer and the management layer ensure the communication and status consistency of modules in the NFV domain and the MEC domain via the interfaces and jointly meet the performance requirements of applications for low delay and high bandwidth. In addition, the MEC/NFV architecture demonstrates the MEC benefits and makes as much use as possible of the NFV module to effectively enhance the resource utilization and reduce operating costs.

4.2 Application Scenarios of the MEC/NFV Network

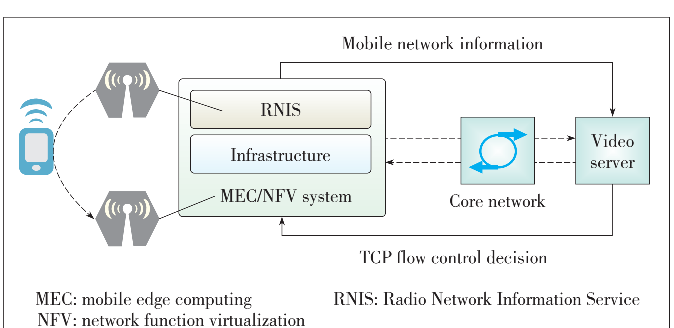
4.2.1 Optimized High-Speed and High-Definition Video Experience

Fig. 7 illustrates the use scenarios of high-speed mobile high-definition video experience optimized by the MEC/NFV system. The Radio Network Information Service (RNIS) provided by the MEC/NFV system provides applications with information such as the load capacity of the real-time mobile network of the wireless downlink interface. In the cellular network, the rapid movement of the user terminal causes changes to the underlying wireless channel environment. In a traditional network architecture, the information of the mobile network is hard to be perceived by the TCP network. The TCP protocol needs several handshakes to adapt to the change of the wireless network, and the delay is big (the dotted line in Fig. 7).

When a mobile terminal of a mobile high-definition video application is moving fast, the RNIS service provided by the MEC/NFV system assists the video server in making a more reasonable TCP congestion control decision and ensures that the application layer code can match the estimated capacity of the wireless downlink (the solid arrow in Fig. 7). Among them, the TCP will no longer need to proactively detect the available wireless network resources, or reduce the data transmission rate according to relevant detection results. The MEC/NFV system in Fig. 7 is deployed on the base station. The infrastructure is provided by the cloud platform and is distributed inside base stations at different geographical locations and communicates through standard interfaces.

4.2.2 Optimized Mobile Game Experience

For applications requiring high data processing latency, such as gaming and augmented reality/virtual reality (VR/AR), the MEC offers lower latency and an optimized user experience. After the deployment of the MEC technology, the calculation of computing-intensive applications can be shunted to the wireless access network side. The MEC server with high computing performance can issue decisive orders in a short time to improve overall performance.



▲Figure 7. Mobile high-definition video experience optimization.

The mobile edge management system may consider relocating the mobile edge application (or its partial memory state) to better meet the latency requirement when the position of a game player moves into the area serviced by multiple mobile edge hosts. But if the relocation execution can take place in the key stages of the game, service degradation will still lead to a bad user experience. The MEPM allows the ME to pass the relevant parameters to the MEO. Thus, the ME application may suggest that the MEO perform relocation after the player reaches the checkpoint or when the game loads the next level, preventing a drastic downgrade of the service.

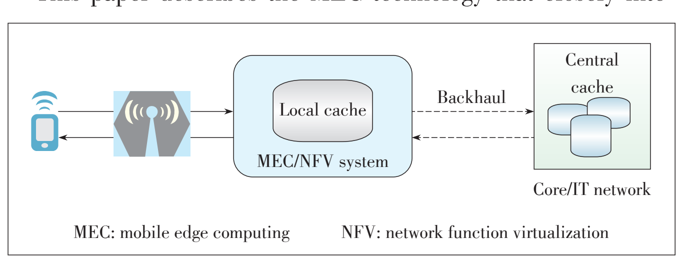
4.2.3 Local Content Caching of AR

The mobile edge application stores content that is frequently used by the user locally and provides content from the local cache when the user requests access to the content without the need to always transmit content over the core network, which reduces backhaul capacity and downloads. The network architecture of the local information cache is shown in **Fig. 8**, where the content can be sent to the device (see the solid line in Fig. 8) when the content is hit by the local cache of the MEC server, instead of being obtained through the backhaul network from the central cache of the core network/IT network, which greatly reduces the traffic pressure of the backhaul network.

The local content caching of the MEC technology brings great advantage to the AR service. Because the application services need to record the user location and camera perspective and such information is highly localized and needs to be updated in real time, so the information should better be stored locally rather than in the cloud. Otherwise, when AR services are used in a user-intensive scenario, frequent and large content access requests will cause greater bandwidth pressure on the backhaul network. Once the network congestion occurs, AR application latency will increase, and the user experience will be very bad. In Fig. 8, the MEC/NFV system is deployed on the base station, the local cache service is provided to the user by the MEC/NFV system in the form of services, and the infrastructure is provided by the cloud platform and located inside base stations at different geographical locations, and they communicate through standard interfaces.

5 Conclusions

This paper describes the MEC technology that closely inte-



▲Figure 8. Local content cache network architecture.

grates mobile access networks with IT technologies. To explore the benefits of MEC at the radio access network and extends the NFV framework, we propose a new MEC and NFV integrated network architecture with two vertical and three horizontal domains. Finally, the application scenarios of the proposed MEC/NFV architecture are also illustrated.

The MEC has the characteristics of localization, proximity, low latency, location awareness, and access to network context information. With MEC technology, network operators is capable of making use of existing network infrastructure to achieve low latency and real-time processing at network edge, thus effectively reducing operating costs while improving service levels. The MEC can create a new value chain and ecosystem. Mobile network operators should work with upstream and downstream vendors to jointly promote MEC technology research and development and commercialization to accelerate the development and deployment of 5G.

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