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Investigation on Interworking Architecture of 4G/5G Network Based on Software Defined Network

Shaowen Jing, Hui Wang

School of Information Engineering, Henan University of Science and Technology, Luoyang, Henan, 471000, China

Abstract: The cost of deploying a large-scale 5G network in a short time is too high for operators. Moreover, a large number of network devices deployed in the LTE era are still in operation, and it is impossible to complete the replacement of devices in a short time. The interworking between the newly deployed 5G network and the existing 4G network is particularly important. The 5G network is the inheritance and development of the 4G network, and the improvement of network elements into network functions is more obvious in the 5GC and EPC of the 5G core network. With the development of software-defined network SDN technology and network function virtualization NVF technology, the formulation of 5G core network standards is more perfect, which separates the control plane from the data plane, makes the network framework flexible, and increases the network expansion ability. This paper continues to discuss the deep application of SDN paradigm in 5G core network, and continues to reduce the coupling between network functions. This research mechanism can also be applied to SDN paradigm and 4G core network EPC. According to the application of the above SDN paradigm, this paper discusses the possibility of interworking between 4G networks and 5G networks with different core networks, and discusses a network interworking architecture.

Keywords: 5G network core; Evolved Packet Core; Software-defined network;4G and 5G.

1. Introduction

All With the exponential growth of users of personal media and large-scale machine communication, 4G network is no longer suitable for the current complex network environment. In the past few years, the conception and planning of 5G network have been put on the agenda [1]. The future three application scenarios of 5G network proposed by 3rd generation partnership project, namely, Enhanced Mobile Broadband (eMBB), Massive Machine Communication (mMTC) and Ultra-reliable Low Delay Communication (URLLC), are all based on the service-based 5G core network [2]. The construction of 5G core network relies on network function virtualization (NVF)[3-4] and software-defined network (SDN) technology [5-6], in which network function virtualization technology aims to get rid of the limitation of hardware, run network functions on software, and support network operation by supporting one or more virtual network function functions in a virtual environment, while software-defined network technology is used to introduce abstraction between network control plane and data plane. The control plane and data plane of the network are separated, which reduces the coupling between the control plane and data plane. The data plane and control plane are independent of each other, but the interface is open for communication. It is precisely because of the application of software-defined network and network function virtualization technology that the scalability, flexibility and network dynamics of 5G network architecture are increased. The 5G core network inherits and develops the 4G evolved packet core network (EPC). for example, EPC has a large number of network elements such as mobile control entity [7] (MME), home subscriber server (HSS), service gateway (SGW), packet data network gateway (PGW), policy and charging rule function (PCRF), etc. the 5G core network is built on service-based architecture (SBA). Decoupling and reorganizing the network elements of EPC, that is, decoupling of software and hardware, separation of control plane and user plane, etc., MME network elements in EPC are divided into network functions such as access and mobility management function (AMF), authentication server function (AUSF) and session management function (SMF), which is only the division of a network element. Similarly, the functions of SGW-C and PGW-C are integrated into.

In this paper, the SDN paradigm is further applied to the 5G core network, and the user plane function UPF and the session management function SMF are further decoupled to enhance the scalability and flexibility of the network system. In the future, the 5G network will be deployed in a large area, but it will not be dismantled in a short time due to the deployment of a large number of LTE network equipment. The 4G network with EPC as the core network still occupies a relatively large market share, mainly because the cost of hardware upgrading is relatively high. If the network is separated from the wired side and the wireless side, it is the most important hardware equipment base station on the wireless side. Although there are many gNB networks composed of 5G base stations, the vast majority of base stations are mainly 4G base stations, and 4G base stations form non-standalone networks (NSA) with some 5G base stations after upgrading. Of course, the integration of 4G and 5G networks is not only reflected in the base station on the wireless side, but also in the core network side. This kind of integration forms are various. In the non-standalone networking (NSA), LTE and 5G NR access are combined with 4G enhanced packet core (EPC) and "standalone" (SA) solutions, based on 5G new radio (NR) access and 5G core (5GC). This paper will also focus on the interworking between 4G and 5G networks.

2. Background Study

In this chapter, we will introduce the 5G core network (5GC) and the 4G core network (EPC) in detail, and explain the inheritance and development of the 5G core network to the 4G core network, and also explain the software-defined network technology (SDN) in detail.

2.1. 5G Network Architecture

The 5G core network architecture (5GC) and the 4G core network architecture (EPC) are shown in Figure 1 and Figure 2 respectively. They are both core network standards formulated by the 3GPP Organizing Committee, but they are quite different. Because of the introduction of software-defined network and network function virtualization technology, the control plane and data plane of the 5G core network are separated, and the network element in the EPC era is improved to be network function (NF), which can make the whole network more flexible. The new network functions developed in the later stage need not be limited by hardware, and they can communicate with the existing network functions in the form of developing interfaces, and different network functions are highly independent. The main network functions of the 5G core network are [8]:

Authentication service function AUSF, a network function, integrates the network functions of MME and HSS in the 4G core network EPC, and its main function is to provide authentication function to verify the authority of the client.

Access and Mobility Management Function (AMF), which performs the same network functions as the MME network elements in EPC, performs registration, connection, reachability and mobility management, provides a message tunnel for the session transmission between UE and SMF, and can provide authentication and authentication functions for users when accessing, and the terminal and wireless core network control plane access points.

Session management function (SMF), which is mainly responsible for the creation and termination of sessions, automatically assigns IP addresses to the user terminal UE, and communicates with the user plane function UPF through N4 interface for implementing the flow control strategy.

The network slice selection function (NSSF) is mainly responsible for determining the network slice range that the UE is allowed to access.

Network Open Function (NEF) is an essential network function for edge computing in the 5G era.

Policy Control Function (PCF), a unified control core framework provided by 3GPP standard for 5GC, makes the control strategy at the network end efficient and simple.

Unified Data Management Function (UDM), which differentiates some functions of HSS network element in EPC, is mainly responsible for 3GPP AKA, user identification and other functions.

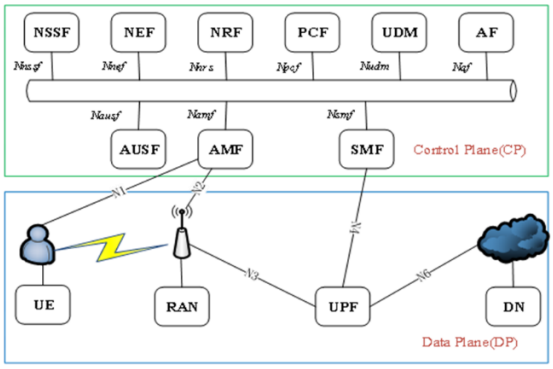


Fig. 1 5G network architecture

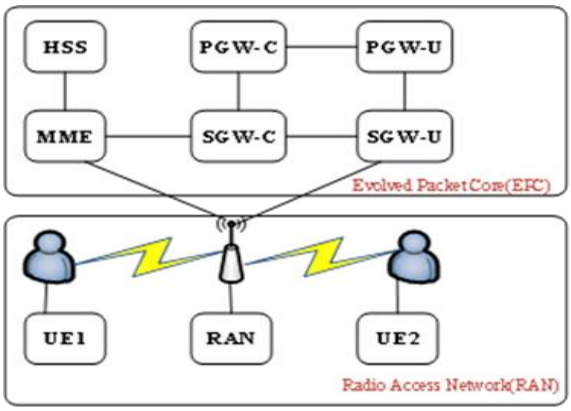


Fig. 2 EPC network architecture

2.2. Interworking Between 5GC and EPC

As shown in fig. 3, EPC is connected to a group of entities communicating with each other through MME and next generation radio access networks RAN and AMF, while 5GC, the 5G core network, is connected through EUTRAN. EPC moves users to 2G or 3G networks through the specified interfaces. The interconnection scheme proposed by 3rd generation partnership project supports communication between MME and AMF, and the signaling interaction between them can be transmitted through N26 interface. For other details, please refer to the 3GPP standard [8].

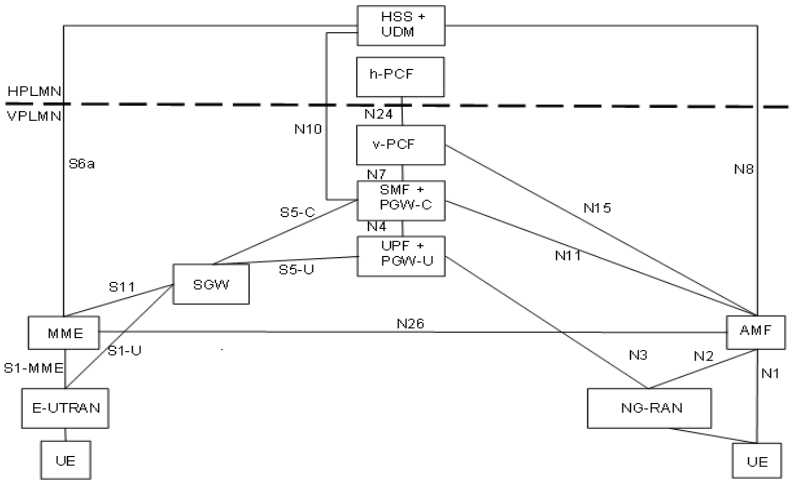


Fig.3 Schematic diagram of 4G/5G interworking formulated by 3GPP [8]

2.3. Software Defined Network

As shown in Figure 4, SDN architecture is mainly divided into three parts, namely application layer, control layer and data layer. The top application layer reflects the user's intended application program, which can be developed inside

the controller or communicated in the form of external interface. The lower layer of the top layer is logically centralized, that is, the control layer. The traditional IP network also has such a three-layer structure, but the difference from the SDN structure is that the control right is not centralized. The traditional IP network adopts distributed control, while the SDN architecture uses centralized control. The control layer can be composed of one or more controllers, which is responsible for opening the north/south interface to map the network operation from the application layer to the data layer. This layer is also the control center of the system. The network changes are mainly controlled by various controllers contained in this layer, and it is also responsible for providing abstract information about network elements, including statistical information and events, to business applications. The main task of the data layer is to forward the user data. The repeater and connector form the basic forwarding network, and the forwarding rules followed by the repeater are formulated by the upper controller. This layer only has the function of data forwarding and has no control right. SDN architecture mainly includes three mainstream interfaces, namely, northbound interface, southbound interface and east-west interface. Restful interface provides northbound interface services between various business applications and controllers in the application layer. Open API interfaces and privatized device interfaces can pass through such interfaces as long as the Internet software architecture conforms to rest architecture, in which rest architecture is a standardized Internet resource access protocol. OpenFlow interface, border gateway protocol (BGP) interface, PCE interface is a typical southbound interface, OpenFlow interface is a bottom-level interface protocol between the control layer and the data layer, which follows the traditional TCP/IP protocol family to realize the control of the data layer by the control layer; BGP interface adds some routing attributes to the traditional BGP protocol, which is used for the routing characteristics between controllers. Similarly, BGP interface is the most important interface on the east-west interface. PCE interface is used to solve the problem of interworking with traditional networks.

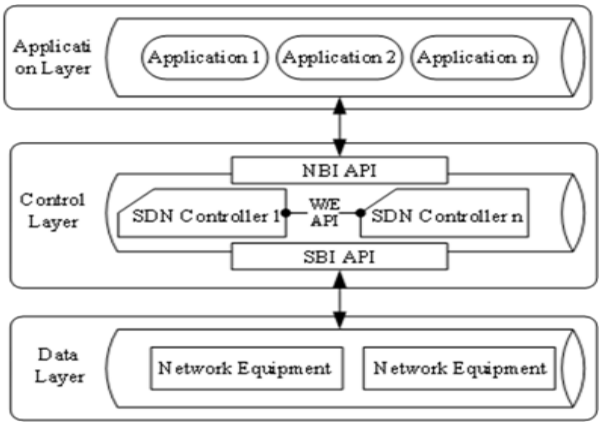


Fig.4 SDN three-tier architecture

3. 5G Core Network Based on SDN

Between the user plane function UPF and the session management function SMF, the SDN paradigm is further introduced, the N4 interface is abandoned, and the control plane and the data plane are further decoupled. The early 4G core network EPC or 5GC used a similar method [9].

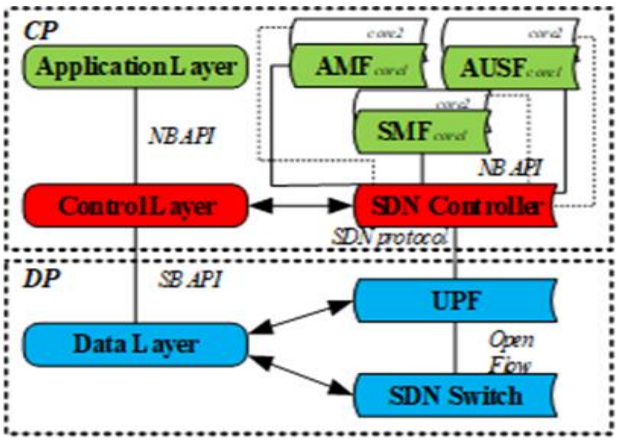


Fig. 5 SDN 5GC architecture

The newly built 5G core network architecture is a typical three-layer SDN network. The control plane component is realized by the application program, and the application layer is mainly composed of network functions such as AMF, SMF, AUSF, NSSF, UDM and PCF (only three main control functions are drawn in the figure), so as to get rid of the shackles of hardware and realize various network functions by software. The control layer consists of one or more SDN controllers, and the controllers can communicate with each other. The data layer is composed of SDN switch and hardware or software of user plane function UPF. The application layer, control layer and data layer correspond to Figure 4 respectively. SDN controller can be used as the relay of network function communication of control plane components. For example, AMF and SMF can communicate with each other through SDN controller, and SDN controller can also be used as a communication bridge between mirror slices of different control plane components. In the case of ultra-dense network deployment, seamless interconnection among multiple network slices can be realized through this network architecture. For example, multiple control mirror slices can access multiple data slices, and SMFs with different sub-slices 1 and 2 can control the flow of specific data plane slices through the same SDN controller.

4. Realization of Interworking Function Between 5GC and EPC Architecture

The interworking architecture between 5GC and EPC based on software-defined network constructed in this section fully complies with the design principles of OpenEPC[10] and Open5GC[11]. The main network elements of 4G core network EPC are composed of hardware, such as MME, S-GW and other network elements, and their hardware supports OpenFlow protocol, which means that seamless communication between network elements and between network elements and SDN controller can be achieved by using OpenFlow protocol. The key network function (NF) in 5GC, a 5G core network, exists in the form of virtual software. Similarly, the network functions can communicate with each other using OpenFlow protocol, as well as between NF and SDN controller. As shown in Figure 5, the communication between SDN controller and network elements in EPC is the same as that in 5GC. This section assumes that all network elements and network functions are integrated with software-defined network technology, which is the premise of this section framework.

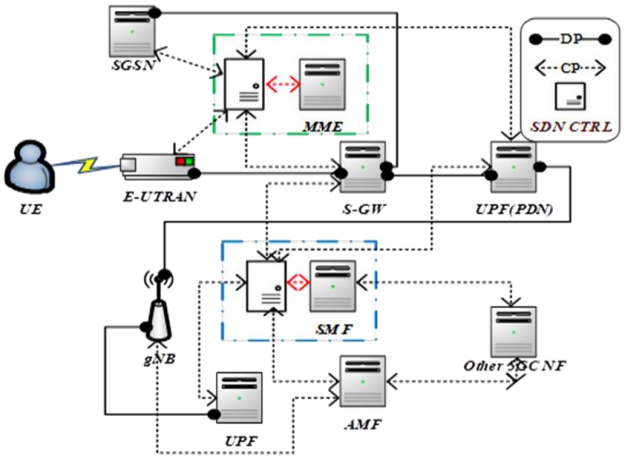


Fig. 6 Interworking Architecture of 5GC and EPC Core Network (Part) [12]

As shown in fig. 6, two different SDN controllers communicate with the mobility management entity or virtual network function under their respective control [12]. The communication between the mobility management entity or virtual network function and different SDN controllers uses OpenFlow protocol, and the signaling exchange between the mobility management entities or virtual network functions uses the protocol formulated by 3GPP, while the interaction between the mobility management entity and virtual network function can use SDN protocol. In EPC, the SDN controller is deeply bound to the MME entity. Similarly, the SMF network function in 5GC is deeply integrated with another SDN controller. In many studies, the AMF function in 5GC is consistent with the MME in EPC, but it is feasible to bind SMF in 5GC with SDN control instead of AMF in this paper. Firstly, the three control network functions AUSF, AMF and SMF in 5GC are consistent with those performed by the MME in EPC. After the MME is decoupled by SDN and NVF technologies, its network capabilities are subdivided into three 5G core network functions. Secondly, in the mobility management of UE, AMF only exchanges signaling with gNB, but rarely interacts with other network functions. On the contrary, SMF communicates frequently with other network functions, and SMF.

5. Summary

In this paper, the difference and correlation between the 4G core network EPC and the 5GC of the 5G core network are explained firstly, then the software-defined network technology is introduced in detail, and finally the software-defined network technology is deeply integrated with the 5G core network. Based on this, the interoperability between the 4G core network EPC and the 5GC architecture of the 5G core network is discussed.

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