OAI-based End-to-End Network Slicing

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***Abstract*—Network slicing is a key technology of 5G network to realize flexible customization for various services based on Network Function Virtualization and Software Defined Network. In this paper, we discuss end-to-end network slicing in terms of non-standalone 5G standard, where eMBB and uRLLC scenarios are supported using 4G core network. Firstly, we present eMBB and uRLLC slices at the user plane respectively. To reduce end-to-end delay in the uRLLC slice, Mobile Edge Computing is introduced. Secondly, both eMBB and uRLLC slices share the same control plane at core network. Finally, we establish a testbed based on the open source software of OAI. Experimental results demonstrate that our proposed scheme can increase the downlink rate for eMBB slice and reduce the delay for uRLLC slice.**

***Index Terms*—Network slicing, eMBB, uRLLC, OAI;**

I. Introduction

Network slicing, a key technology of 5G network, can flexibly provide various customized services for users with different requirements e.g., three main 5G application scenarios i.e., enhance Mobile Broadband (eMBB), ultra-Reliable and Low Latency Communication (uRLLC), and massive Machine Type Communication (mMTC)[1].

The technology of end-to-end(E2E) network slicing provides a logical network. Based on the core technology of Software Defined Network (SDN) and Network Function Virtualization (NFV), the system architecture of E2E network slicing contains three layers: Infrastructure layer, Network slicing layer and Management layer.

Many literatures have talked about architecture of network slicing. [2] focuses on the basic principles of each layer accommodating 5G ecosystem, and underlines the coexistence of dedicated and shared slices within the common 3-layer architecture. A novel network management and orchestration framework is proposed in [3], and the deployment, configuration, activation, and life cycle management of network slices can be performed automatically. [4] elaborates network slicing from an E2E perspective, including Core Network (CN), Radio Access Network (RAN), and transport network (TN).

SDN/NFV, as the fundamental technologies of network slicing, can provide flexible deployment of Virtual Network Function (VNF) and customized resource allocation[5]. NFV can implement multiple VNFs on a common physical infrastructure to replace dedicated network elements, and the cooperation of multiple VNFs can form various network slices. Meanwhile, SDN can provide centralized control and simplify data distribution of network slices[6]. A novel network slicing scheme is proposed by incorporating the capabilities of SDN into the NFV architecture[7]. [8] proposes a network slicing architecture based on SDN/NFV to meet various services. On account of SDN/NFV, a management system for 5G network slicing is established[9], which can provide network slices' isolation and resource allocation on demand for different services.

Mobile Edge Computing (MEC), as a key technology of the uRLLC slice, reduces E2E delay and releases congestion by pushing the computing capability near the data sources[10]. A novel MEC approach[11] is proposed for Internet of Things (IoT), including the SDN-based core network, and Virtual Machine (VM)-based IoT devices. [12] envisions a real-time, context-aware collaboration framework, comprising MEC servers and mobile devices.

On the other hand, various open source software brings great convenience to the implementation of network slicing, such as OpenAirInterface (OAI), srsLTE, Amarisoft, etc. However, OAI basically implements almost all the network functions of LTE, from evolved Node Base station (eNB) to Evolved Packet Core (EPC)[13].

Obviously, there are many literatures on theoretical analysis of network slicing. However, to the best of our knowledge, few works about the implementation of E2E network slicing is based on open source software. In addition, OAI owns the current mature technology and supports for modifying and compiling codes to complete debugging the network. Thus the OAI-based E2E network slicing is studied in this paper, and the main contributions are shown as follows:

- We present two isolated network slices for eMBB and uRLLC respectively at the user plane. And MEC is introduced into the uRLLC slice to reduce E2E delay.
- We propose a shared control plane for both eMBB and uRLLC slices at CN so that they could be managed centrally.
- We establish an OAI-based testbed to prove the feasibility of our proposed network slicing scheme.

The rest of the paper is arranged as follows. We begin with an introduction of OAI-based E2E network slicing in section II, and then an experiment is done to verify the feasibility of the proposed scheme in section III. Finally, the conclusion is given in section IV.

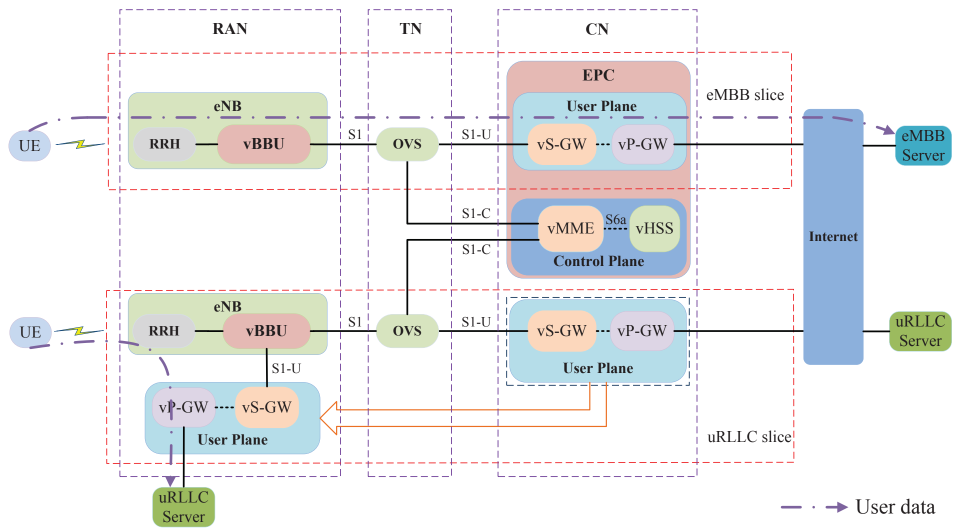

Fig. 1. OAI-based E2E network slicing for eMBB and uRLLC

II. OAI-based End-to-End Network Slicing

The system model of OAI-based E2E network slicing is presented in Fig.1. Based on OAI, all the network elements get softwarized by deploying on the common x86 servers. Hence, the EPC in Fig.1 is a bundle of software components that provides the functions of Mobility Management Entity (MME) and Home Subscriber Server (HSS) at the control plane of CN, and Serving Gateway (S-GW) and Public Data Network Gateway (P-GW) at the user plane of CN. The eNB is a bundle of software components that provides the functions of Baseband Unit (BBU) and standard interfaces, including radio interface (i.e. LTE-U) and core network interfaces (i.e. S1-C and S1-U). Besides, the Remote Radio Head (RRH) of the eNB is provided by dedicated hardware. Specially, BBU processes base band signal, while the RRH sends and receives radio signal. HSS and MME provide the functions of users' authentication, mobility management and session managemen-t, while vS-GW and vP-GW accomplish the functions of user IP allocation and data forwarding.

A. eMBB Slice

The eMBB application scene calls for large data rate, high network density, and full network coverage to promote users' quality of service. Thus we devise an integral slice including the CN, TN and RAN, while allocate more computing, storage and spectrum resources for the eMBB slice.

In order to get all the network elements virtualized, BBU and EPC are deployed on VMs, and then they are turned into virtual BBU (vBBU) and virtual network functions of EPC, i.e. virtual HSS (vHSS) and virtual MME (vMME) at the control plane, and virtual S-GW (vS-GW) and virtual P-GW (vP-GW) at the user plane. Furthermore, VMs provide an isolated operating environment for network functions. In this way, all these network functions of the eMBB slice are isolated from the other slices, e.g., the uRLLC slice.

To get all the interfaces isolated, the General Packet Radio Service Tunnelling Protocol (GTP) is introduced into the eMBB slice. Specially, GTP-Control plane (GTP-C) is used over S1-C for signaling transmission, while GTP-User plane (GTP-U) is used over S1-U for data forwarding, so we can obtain a virtual transmission pipe between BBU and EPC. Meanwhile, an virtual switch, e.g., Open vSwitch (OVS), is deployed on physical switches, which can provide different slices with isolated virtual data queues. Hence, the integration of GTP and OVS can guarantee logical isolation among different slices at TN.

After achieving all the network functions virtualized, including vBBU at RAN, OVS at TN, vHSS and vMME at the control plane of CN, and vS-GW and vP-GW at the user plane of CN, and interfaces isolated, including GTP-C over S1-C, GTP-U over S1-U, we could obtain an E2E network slice, i.e., the eMBB slice. Obviously, this slice is logically integral.

B. uRLLC Slice

The User Equipments (UEs) of uRLLC scene mainly calls for low latency services. Normally, UE exchange data with uRLLC servers via S-GW and P-GW at EPC, but they are too far away from UEs. Furthermore the heavy loads of S-GW and P-GW may cause network congestion. Therefore, the E2E delay is too large to meet the requirement for the uRLLC slice.

Based on MEC, we push part functions of vS-GW and vP-GW next to vBBU, as shown in Fig.1. Of course, there are several other solutions for MEC. However, our solution is simple, and we could use the standardized network functions (i.e. S-GW and P-GW) and interfaces (i.e. S1-U and SGi). Furthermore, we could deploy third-party applications on the local uRLLC server next to vBBU, which can provide real-time services for UEs directly. Hence, the E2E delay can be reduced greatly and the backhaul congestion can be released largely.

C. Centralized Control Plane

The shared control plane of CN can manage multiple network slicing instances centrally. Different from the traditional network slicing schemes, which each instance is allocated to a independent CN slice as well as RAN slice, centralized control plane avoids unnecessary resource consumption. In addition, the functions of control plane are quite the same in the eMBB and uRLLC slices, including mobility management, session management, etc. Thus, in this paper, we provide centralized control for the eMBB and uRLLC slices by sharing the control plane at CN.

Firstly, we separate the network functions of the control plane from EPC, i.e. MME and HSS, and deploy them in independent VMs to form vHSS and vMME in Fig.1. Secondly, the vHSS manages all the UEs' subscription information and vBBUs' information of both the eMBB and uRLLC slices, e.g., ID, MNC and MCC. Finally, the shared control plane is responsible for management of two slices, e.g., UEs' authentication in two slices, resource allocation in two slices and EPC in the uRLLC slice.

III. Experiment

We establish an OAI-based testbed to evaluate the proposed network slicing scheme. The experimental scene is shown in Fig.2 and Fig.3, including two x86 servers, a switch, two Universal Software Radio Peripheral (USRP) and two LTE mobile phones.

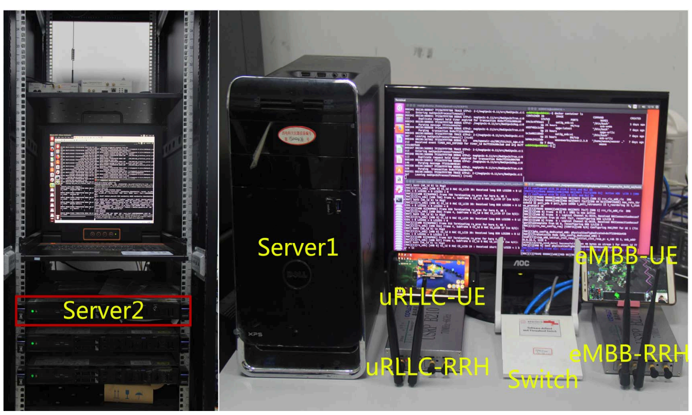

Fig. 2. Testbed of OAI-based E2E network slicing

There are two VMs in the x86 server2 based on VMware workstation, running the user plane of the eMBB slice and the shared control plane respectively. And there are one VM and two containers based on Docker, a lightweight virtualization technology in the x86 server1. The user plane of the uRLLC is deployed on the VM, and vBBUs of two slices on the containers.

The resources of two slices include virtual computing, storage and radio resources, as shown in Table I. Specially, vCPU is a computing resource unit after virtualization for two servers. In order to support the eMBB service with higher data rate, more vCPU, memory, spectrum and higher transmitting power are allocated to the eMBB slice.

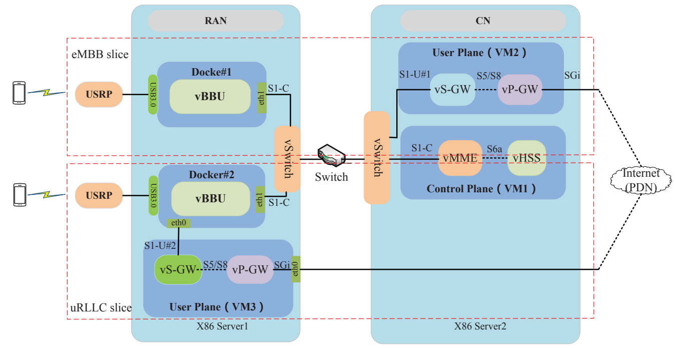

Fig. 3. Network topology of OAI-based E2E network slicing

TABLE I
RESOURCE CONFIGURATION

	eMBB slice	uRLLC slice
vS-GW and vP-GW	2 vCPUs, 2GByte	1 vCPU, 1GByte
vBBU	2 vCPUs, 4GByte	1 vCPU, 2GByte
Bandwidth	20MHz	10MHz
Transmitting power	125 dBm	90 dBm
Duplex mode	FDD	FDD
Central frequency	2.12GHz	2.66GHz

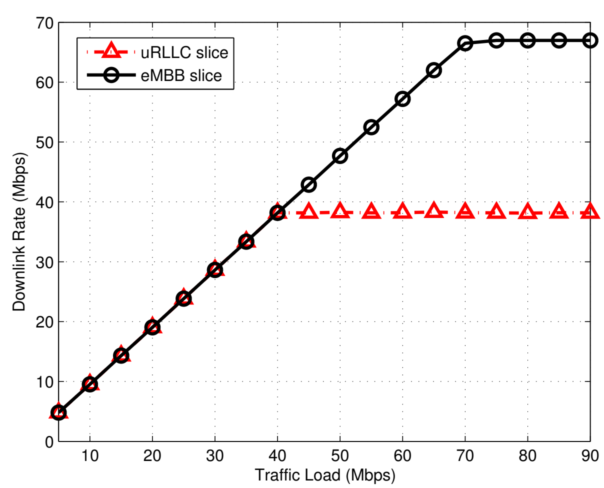

Fig. 4. Downlink rate of eMBB slices and uRLLC slice

Fig.4 shows the downlink rate of the eMBB slice and the uRLLC slice with the variation of traffic load. At the beginning, the downlink rate increases linearly with the increasing of traffic load. And when getting saturation, the downlink rate keeps constant, even though the traffic load keeps increasing. Specially, the peak rate in downlink of the eMBB slice is 66.96 Mbps, while that of the uRLLC slice is 38.16 Mbps. It proves that the proposed scheme can satisfy the requirement of higher rate for the eMBB slice.

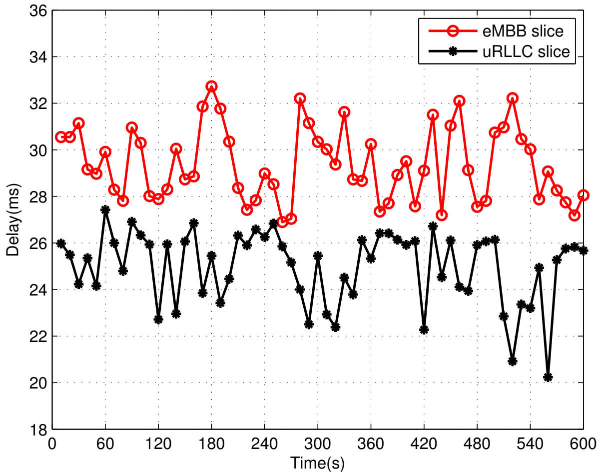

Fig. 5. E2E delay of eMBB and uRLLC slice

Fig.5 compares the E2E delay between the eMBB slice and the uRLLC slice. Specifically, the average E2E delay of the eMBB slice is 29.4 ms, and that of the uRLLC slice is 25 ms, lower than the eMBB slice. It can prove that the proposed scheme can reduce the E2E delay for the uRLLC slice by 10-20%.

IV. Conclusion

In this paper, two customized network slices for the eMBB and uRLLC are presented, providing users with high-throughput and low-latency services. Specially, MEC is adopted in the uRLLC slice to reduce E2E delay. Then we propose a shared control plane for the eMBB slice and the uRLLC slice to provide centralized control at CN. Finally, the experimental results verify the feasibility of the proposed network slices.

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References

[1] A Nakao, P Du, Y Kiriha, et al.,*End-to-end Network Slicing for 5G Mobile Networks*, Journal of Information Processing, 2017, 25(1):1C10, Jan.

[2] P. Rost et al., *Network Slicing to Enable Scalability and Flexibility in 5G Mobile Networks*, in IEEE Communications Magazine, vol. 55, no. 5, pp. 72-79, May 2017.

[3] A. Devlic, A. Hamidian, D. Liang, M. Eriksson, A. Consoli and J. Lundstedt, *NESMO: Network slicing management and orchestration framework*, 2017 IEEE International Conference on Communications Workshops (ICC Workshops), Paris, 2017, pp. 1202-1208.

[4] I. Afolabi, T. Taleb, K. Samdanis, et al., *Network Slicing & Softwarization: A Survey on Principles, Enabling Technologies & Solutions*, IEEE Communications Surveys & Tutorials, 2018, PP(99):1-1.

[5] I. Afolabi, M. Bagaa, T. Taleb, et al.,*End-to-end network slicing enabled through network function virtualization*, IEEE Conference on Standards for Communications and NETWORKING. IEEE, 2017:30-35.

[6] J. C. Bernardos, A. O. L. De, P. Serrano, et al., *An architecture for software defined wireless networking*, Wireless Communications IEEE, 2014, 21(3):52-61.

[7] J. Ordonez-Lucena, P. Ameigeiras, D. Lopez, J. J. Ramos-Munoz, J. Lorca and J. Folgueira, *Network Slicing for 5G with SDN/NFV: Concepts, Architectures, and Challenges*, in IEEE Communications Magazine, vol. 55, no. 5, pp. 80-87, May 2017.

[8] X. Foukas, G. Patounas, A. Elmokashfi and M. K. Marina, *Network Slicing in 5G: Survey and Challenges*, in IEEE Communications Magazine, vol. 55, no. 5, pp. 94-100, May 2017.

[9] H. ZHANG, N. LIU, X. CHU , et al., *Network Slicing Based 5G and Future Mobile Networks: Mobility, Resource Management, and Challenges*, IEEE Communications Magazine, 2017, 55(8):138-145.

[10] Y. Mao, C. You, J. Zhang, K. Huang and K. B. Letaief, *A Survey on Mobile Edge Computing: The Communication Perspective*, in IEEE Communications Surveys & Tutorials, vol. 19, no. 4, pp. 2322-2358, Fourthquarter 2017.

[11] X. Sun, N. Ansari, *EdgeIoT: Mobile Edge Computing for the Internet of Things*, in IEEE Communications Magazine, vol. 54, no. 12, pp. 22-29, December 2016.

[12] T. X. Tran, A. Hajisami, P. Pandey and D. Pompili, *Collaborative Mobile Edge Computing in 5G Networks: New Paradigms, Scenarios, and Challenges*, in IEEE Communications Magazine, vol. 55, no. 4, pp. 54-61, April 2017.

[13] J. C. Guey, P. K. Liao, Y. S. Chen, A. Hsu, C. H. Hwang, and G. Lin, *On 5G radio access architecture and technology [industry perspectives]*, IEEE Wireless Communications, vol. 22, no. 5, pp. 2C5, Oct. 2015.