New Multi-Access Network Transmission Technology to Enhance Edge Computing

Pang-Chen Liu, Huai-En Tseng, Shun-Kai Yang, Fei-Hua Kuo
Telecommunication Laboratories
Chunghwa Telecom
Taoyuan, Taiwan, R.O.C.
{bliu, w180112, conan, philip2}@cht.com.tw

Abstract—**The 5G era is officially coming. It bringing many new applications, such as self-driving cars, 3D VR, etc. Among them, edge computing technology is particularly critical which can reduce latency and increase throughput, thereby promoting the resources expansion and services diversity. This paper proposes to use high-speed network transmission technology RDMA and multi-access network transmission architecture to apply to multi-access edge computing including collaborative computing, data synchronization and data backup, etc. It is to provide low-latency and high-throughput network transmission so that edge computing users have better user experience.**

Keywords-Edge computing;RDMA;DPDK;SDN;Vertical peration;Horizontal operation

I. INTRODUCTION

The new generation of 5G technology provides many new service features. The ITU-R plans to provide use cases of the next-generation mobile communication system IMT-2020 [1], including Enhanced Mobile Broadband (eMBB), Ultra-reliable and Low Latency Communications (URLLC) and Massive Machine Type Communications (mMTC). In the early stage of 5G development, following the high-transmission audio-video demand of 4G, telecom operators will continue to focus on eMBB applications, and then gradually expand to URLLC and mMTC applications. Therefore, telecom operators will have to spend a lot of construction costs to upgrade the backbone and core network.

As shown in Figure 1, taking the edge computing equipment (MEC，Multi-access Edge Computing) deployed close to the base station, when the end user uses the mobile device to access services on the Internet, the base station receives the signal from user mobile device, the edge computing equipment can first determine whether the service packet can be served by the edge computing equipment, or whether it still needs to pass through the backbone and core network. Traffic offload through edge computing technology can not only provide users with faster service response time, but also reduce the large amount of bandwidth occupied by service packets that need to pass through the backbone network and core network, so it can reduce the cost of network construction.

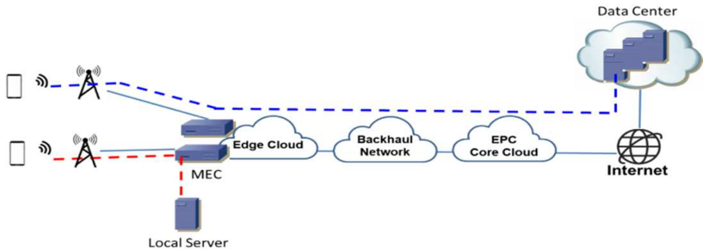

Figure 1. MEC deployment application architecture

However, the edge computing capabilities are decentralized from the network center to the edge, close to the location of the terminal. In the edge computing architecture, the applications of data synchronization, collaborative computing and data backup require high throughput between edge computing sites. The general x86 host network transmission technology can only reach 10Gbps. In a large and complete edge computing architecture, network throughput becomes a limitation, so we propose a high-performance RDMA (Remote Direct Memory Access) network transmission technology. The highest bandwidth is up to 400Gbps between the edge computing hosts to hosts.

The service packets on the home network to access the Internet must be accessed through the transport network, and access to cloud services through the Backhaul Network and Evolved Packet Core (EPC), as shown in Figure 2. However, under each node and network architecture, there are lots of bottlenecks with network latency and service bandwidth. The low latency and high reliability requirements of the network are extremely strict. In order to achieve this goal, the access network architecture will inevitably be changed. This paper focuses on the introduction of edge computing MEC technology to avoid all information being processed in the core cloud, and fast response at the near-end edge to reduce delay.

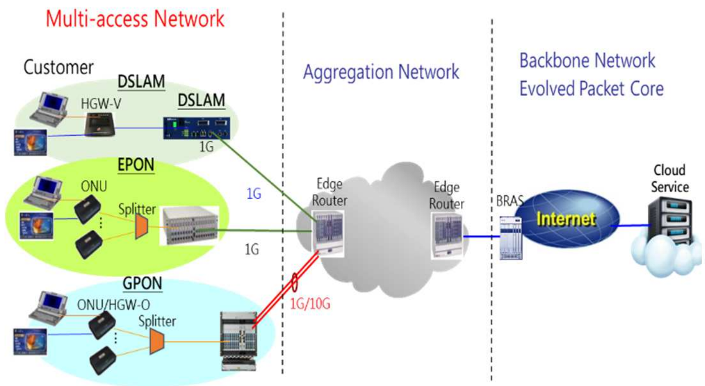

Figure 2、Access Network Architecture

II. HIGH THROUGHPUT NETWORK TRANSMISSION

The different crosstalk for the wire-pairs due to the twist structure inside the copper cable would result in the different loop performance. After self-far-end-crosstalk cancellation (Vectoring) technology was implemented, the self-FEXT would be dramatically decreased, and be close to equal for the wire-pairs. The impact of the crosstalk from the neighborhood wire-pairs would be reduced for the loop performance, and the interdependence of the loop quality and performance would be more obvious. After artificial intelligence (AI) module learned the interdependence, the evaluation result of the field loop quality through the AI module analysis and classification could be utilized for the reference of the real-site provision.

A. Traditional networks and DPDK

In traditional networks, it will take lots of time in packet processing. For instance, NIC (Network Interface Card) will trigger system interrupt after receiving packets, and then ISR (Interrupt Service Routine) will take over next step. By calling callback function in NIC device driver, packets will be sent to network stack and then user space. In these procedures, there may be massive memory copy, cache miss or hardware interrupt. Besides, BSD socket API provides easy used and powerful networking programming interfaces, but these interfaces are built with lots of system calls, it will cause lots of context switched and soft-interrupt in system.

To overcome the overhead in operating system, Intel publish DPDK (Data Plane Development Kit) in 2010. As shown in Figure 3, DPDK uses UIO (user space I/O) device driver to make packets can bypass kernel space and use polling mode user space driver to poll the packets to user space application [4]. The packet processing under DPDK at x86 platform can be increased from 1Mpps (Million Packets per Second) to 14Mpps and when the packet size is 1.5KB, this throughput is equal to 200Gbps.

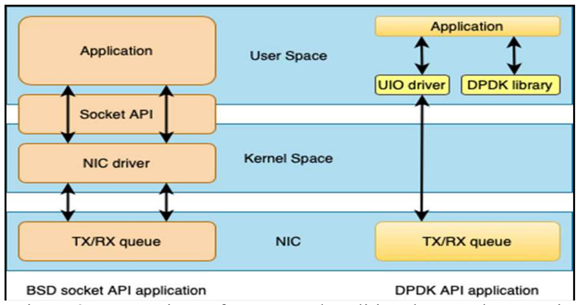

Figure 3. Comparison of DPDK and traditional network transmission

B. RDMA and DPDK

However, DPDK is not only way to improve transmission throughput. RDMA (Remote Direct Memory Access) is another method. Unlike DPDK elevating packet processing procedures to user space, RDMA offloads these procedures to NIC. At sender side, RDMA offloads the transmitted packets from application to NIC and use NIC to do the rest procedures such as encode IP frame [2]. At receive side, RDMA NIC will automatically move received packets to reserved memory location. At this time, there's no any CPU resource involved.

RDMA can be divided to 3 different protocol [3], Infiniband, iWARP, RoCE. Infiniband is the earliest RDMA implementation protocol. Unlike ethernet network, Infiniband is built under Infiniband network, and it provides 10 Gbit/s to 400Gbit/s networks in data center. iWARP is also one of the RDMA implementation protocol. The most important feature is capable with ethernet network and data can be transmitted with TCP connection. However, throughput under iWARP is very low. All of the iWARP NICs only support 10Gbp/s.

The other important RDMA protocol is RoCE (RDMA over Converged Ethernet). It supports not only Ethernet networks but also high throughput transmission. There are two types of RoCE, RoCEv1 and RoCEv2. RoCEv1 only contains Ethernet header, but uses Infiniband header in L3. Therefore, RoCEv1 cannot be routed. In RoCEv2, L3 Infiniband header is replaced to IP and UDP header, so packets with RoCEv2 can be routed in different network subnet. RoCEv2 also uses UDP rather than TCP, because UDP can provide lower latency and higher throughput than TCP. Figure 4 shows difference between each RDMA implementation.

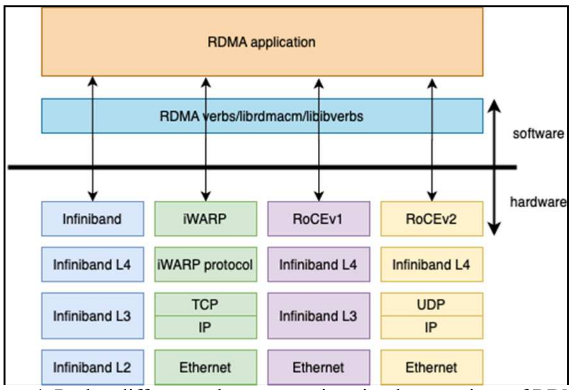

Figure 4. Packet differences between various implementations of RDMA

As above, we can know that unlike DPDK, RDMA needs to be in strict network environment, but RDMA provides high speed network performance. In this paper, we use RDMA between each edge computing node network transmission to make each edge node improve synchronization and concurrency performance.

III. New Technology and Architecture of Network Transmission for Edge Computing

A. Analysis of edge computing network transmission requirements

In edge computing, AI computing applications are very diverse. In addition to better resources in the computing pool, low latency and high throughput also need to be greatly improved. The synchronization and decentralized architecture in edge computing can get better network throughput to make end devices respond speed up [5]. Edge AI provides end devices to feedback user data, and uses edge computing to return to cloud computing for verification and training, and then performs machine learning predictions through edge computing, and realize the deployment of the original analysis functions of the cloud to the end devices in different scenarios. Table 1 shows the types of computing.

Table 1. Comparison of computing types

Attributes	Cloud Computing	Edge Computing	Edge AI
Computing architecture	Cloud Architecture	Edge Architecture	Flexible Architecture
Network Latency	Minutes	Milli to Sub-Second	Millisecond
Bandwidth Requirements	GB-TB	KB-GB	GB-TB
Security Requirements	High	High、Mixing	High

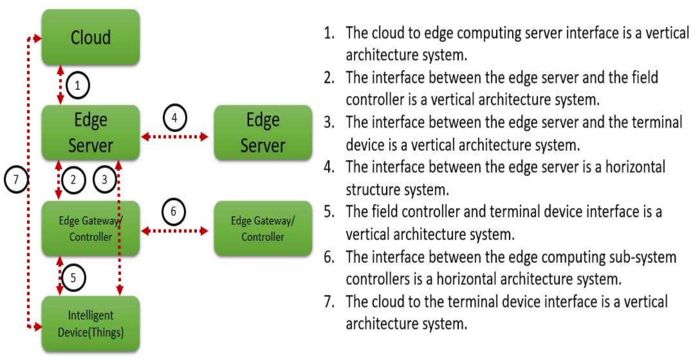

Figure 5. 7 major interfaces of edge computing

B. Edge computing network transmission scenario

Regardless of Edge AI and edge computing, the cloud moves to the edge, the communication between computing nodes must have fast transmission capabilities. In the horizontal transmission and vertical transmission architecture system [6], different computing architectures are formed on the interfaces of "gateway", "server", and "cloud", and presenting seven main interfaces, as shown in Figure 5. The most important thing is that under different network architectures, the network throughput of a single host interface is not improved, and the collaborative processing and data synchronization cannot show the effect of edge computing. So high-performance network and structural changes are the key.

C. RDMA network transmission is applied to vertical and horizontal architecture

In edge computing, although computing nodes are decentralized from the center to edge, and closer to end device, so we need to improve the transmission capabilities between edge computing nodes. We propose to use RDMA network transmission technology for each nodes, so that the computing nodes have the transmission capacity of telecommunication network element equipment (such as BRAS, large router).

Edge computing is an indispensable application for data synchronization and backup. Edge computing nodes synchronize the data after computing to avoid repetitive computing and consumes resources, so computing work is handed over to the full-time computing node, and the backup work needs to be handed over to the full-time nodes, which requires high-performance network transmission to back up and synchronize a large of data. Based on architectural analysis, both horizontal and vertical network require high-speed network transmission, horizontal network transmission is between edge computing nodes, and vertical network transmission is between routers, cloud nodes, or edge computing nodes. As shown in Figure 6.

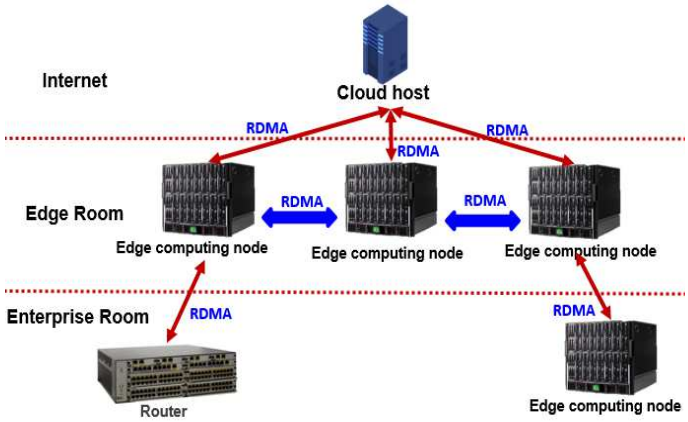

Figure 6. Vertical and horizontal architecture of edge computing

D. Collaborative computing applications of machine learning

AI needs to rely on computing power from training to prediction. Although traditional single architecture has GPU computing resources on each computing node, it is not enough to handle a large number of computing. The general decentralized architecture has reached the concept of collaborative computing, but the throughput between computing nodes is not ideal, and computing resources are not really utilized. Therefore, in the decentralized machine learning computing architecture, high-performance network transmission is required. In the distributed architecture, the addition of RDMA transmission technology and SDN (Software Defined Network) greatly improves the collaborative computing capabilities of machines, and under the flexible architecture, developers have better computing resource pools and highly flexible architecture adjustments. Figure 7 shows the collaborative operation of machine learning, which is applied to RDMA transmission technology and SDN architecture. Table 2 shows the comparison of machine learning distributed architecture types.

Table 2. Types of machine learning distributed architecture

Attributes	**Traditional single architecture**	**General distributed architecture**	**SDN distributed architecture**
Deploy	Easy	Complexity	SDN, easy to deploy
Scalability	Poor scalability	Difficulty	Easy
Architecture	Simple	Complex	Flexible
Performance	Single computing resource	Slow response time	Fast response time
Sync speed	No	Low throughput, slow synchronization	High throughput, fast synchronization

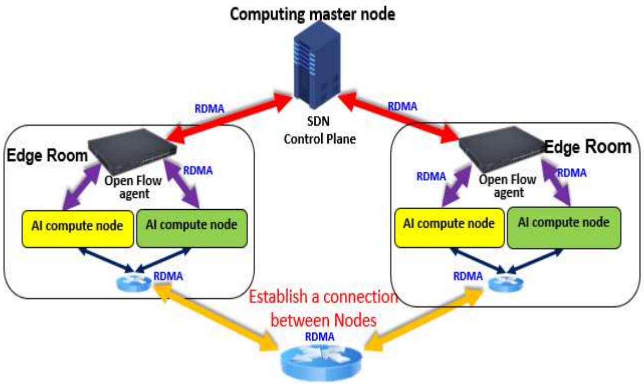

Figure 7. Machine learning collaborative computing applied to edge computing architecture

E. Application of access network to edge computing architecture

The access network is transmitted on the ODN (Optical Distribution Network) optical fiber network through OLT (Optical Line Terminal) and ONU (Optical Network Unit) equipment. The biggest advantage is that the construction cost will be lower than the ethernet network, and through the optical fiber network, create a high-bandwidth, low-latency network environment, and build a wider range. While edge computing nodes are placed on the access network, it will provide services similar to MEC.

Designed on the two layer architecture of the access network, it can flexibly adjust the service requirements, as shown in Figure 8. From the first layer, it is used in the internal network. The edge computing nodes can be set up on the OLT side, and the RDMA transmission technology can be applied between edge computing nodes for data synchronization, collaborative computing and data backup applications. The second layer provides Internet services for telecom operators, so the two layer architecture design allows end users to have edge computing services as well as Internet services. It is suitable for a wide range of applications, such as smart factories and smart buildings.

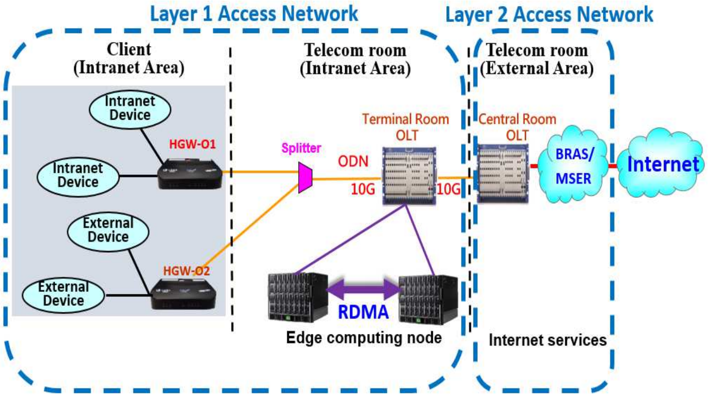

Figure 8 Two-layer access network architecture diagram

IV. CONCLUSIONS

Edge computing provides low latency network services. Although the computing center is placed at the edge and close to end devices, if the architecture and network transmission capacity are not improved, users will not feel so strongly about the low-latency of the network. This paper proposes to use high-speed network transmission technology RDMA to provide low-latency and high throughput network, which can be applied to edge computing to allow multiple applications of edge computing, such as collaborative computing, data synchronization, and data backup. In the edge computing network architecture, horizontal network transmission is between edge computing nodes, and vertical network transmission is between upper and lower routers, cloud hosts, or edge computing nodes. In order to improve the computing energy of edge computing, efficient network transmission is needed.

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