Innovative VR Streaming Service over 5G networks: Design and Implementation

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Abstract

In recent years, with the maturity of VR hardware devices, many VR software content such us 360 videos, games, and commercial applications have gradually enriched. But we still see the bottleneck of VR promotion. The image frame of VR is rendered by the GPU, and it still needs a certain level in the hardware configuration. This has increased the cost of upgrade the computer equipment and purchasing the VR device. In the near future, 5G will be able to provide high-bandwidth, low-latency wireless network services, and SDN technology will virtualize mobile network hardware functions, it will be able to create exclusive network transmission services according to different usage scenarios. So 5G and SDN are considered the basis for high-quality VR streaming applications. In this study, by providing VR content streaming service through 5G and SDN network, the rendering work is per-formed by the server, and the image frame is instantly transmitted back to the user through the network, thereby reducing the amount of rendering of the device, and also decreased the time of installation the VR application. Through the SDN dynamic control mechanism, VR streaming media traffic can be given higher priority. This research is divided into application service design and network optimization design. In the application service design, we designed the architecture of video stream and controller information backhaul. In the network optimization design, dynamic traffic and packet priority control are provided to optimize the transmission network, enabling the high-traffic image frame to be transmitted with low latency.

Keywords: *VR, 5G, Video streaming, Network Optimization, SDN.*

1. Introduction

VR technology is booming in modern society. The widely known VR devices used head-mounted displays and controllers to provide immersive experiences. With VR devices, users can realize their own imagination and feel a strong sense of presence. The maturity of VR technology make imagines can be exhibited in a new way. Innovation makes people curious, then willing to understand this technology, thus opening the territory of the entertainment industry. In the entertainment industry, VR is used in movies or game scenes. In recent years, VR has also touched the medical community. Through VR, it is possible to train clinical medical skills, improve the relationship between doctors and patients, or combine rehabilitation with artificial intelligence. It is a VR application that has attracted attention in modern times. VR is a valuable addition to the fields of digital entertainment, information and workspace. In this regard, VR needs a suitable processing platform. However, adding a platform will also increase many costs, especially in single-use scenarios. So, it needs to be considered for cost-effectiveness.

The current VR devices are still not perfect. To provide a high-quality VR experience, high-quality VR images must be provided with very low latency. This must rely on a computer with high image rendering capabilities and the computer must use a cable to directly connect to the VR device. The shape and portability of the device are severely limited, and not all computers have such computing power, which adds to the cost of hardware acquisition. The idea of handing over VR pictures to cloud computing soon was proposed. The cloud provides a highly computational server to reduce the computational burden on the local VR device and the computer. But in the meanwhile, there is a fatal bottleneck in VR streaming. In VR applications, users will instantly interact in virtual environments. The controller data needs to reach the server of VR streaming in time, and the server needs to render the high-quality screen quickly and pass it to the client instantly. So, low-latency and high bandwidth transmission are indispensable to ensure. If there have a small amount of time delay will cause the user to feel an uncomfortable “fragmentation” feeling under long-term use. This is caller “VR motion sickness”.

It exists two ways to solve the dilemma: using cloud and doing network optimization [1]. Cloud computing can significantly reduce hardware costs, and the key advantage of the cloud is that it can accommodate many of the computing and storage requests generated by the application. Since the essence of cloud VR is to put content and computing into the cloud, it has a certain dependence on network functions and rendering calculations, and is extremely sensitive to network delays. Thus, it brings out the necessity of network optimization.

To optimize the network, this study will provide VR streaming services over 5G networks and SDN. SDN can dynamically control the packet delivery status. And the use of 5G relatively large bandwidth, low latency and high transmission rate network characteristics, is very beneficial to promote VR streaming. There is a key technology called “network slicing”. The so-called network slicing is to use the software-defined network in the physical network to cut and virtualize the meshes and to do network function virtualization (NFV). In this way, each virtual network is logically independent, destroying individuals due to other network errors will not occur simultaneously, thereby affecting other services.

This study expects to complete network optimization so that VR streaming applications can have better results.

2. Related Work

In recent years, the VR industry has gradually been closely integrated with emerging technologies such as 5G and Internet of Things [3]. 360° video has been successfully developed and is currently the most widely known technology in VR. Because they preserve immersive experience, allowing people to better share their life and experience. This technology has also been adopted by many companies and has developed popular VR devices, among which Head Mounted Displays (HMDs) are the most popular products. [2] The specific implementation of these devices has set new milestones for the development of VR.

The 5G network is envisioned to offer a variety of different services, each with different characteristics in transmission, so there are different needs for the network. For example, there is a low-latency requirement for large-scale Internet of Things, and there is a high-frequency requirement for mobile broadband streaming services. For some vehicle networking, smart factory and other special mission scenarios have high reliability and ultra-low latency requirements. Traditional mobile networks need corresponding information communication equipment when facing various network services. In the face of 5G, the application scenarios are more than ever, and operators are bound to need to purchase more different devices for different service plans.

Therefore, network slicing has been proposed [4], for different application scenarios of 5G, combining different network functions to achieve highly flexible, multi-purpose customized network services. In fact, network slicing combines cloud computing, NFV and SDN software and hard technologies to achieve. First, virtualize the Core Network function by NFV, transfer the virtual cloud function to the virtual machine to achieve Core Cloud, and control the virtual switch, router, and SDN channel through SDN to connect the virtual server in each Core Cloud.

By implementing hardware functions in software and abstracting the system architecture, virtualization, and stylization, physical network resources can be cut into multiple parallels, independent virtual logical networks. Each virtual logical network can quickly provide a customized network according to different service requirements and use network resources more efficiently.

3. System Design

The goal of this research is to provide interactive VR streaming services through 5G networks combined with SDN and network slicing (Figure 1). The VR streaming frequency is protected by the network slice, and the low-latency, high-bandwidth wireless transmission is implemented by the 5G wireless network.

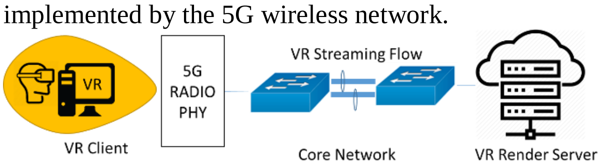

Figure 1 System Overview

In practice, it is mainly divided into three parts: VR Streaming Application, SDN architecture and 5G communication.

In our network architecture (Figure 2), the VR streaming server sends traffic to the virtual network, where traffic passes through several switches and hosts, and the traffic is monitored and controlled by the SDN controller. Finally, the traffic is sent to the ePC, which is then sent by the 5G eNB to the UE(VR client). In the meanwhile, the hosts in the virtual network use Iperf to perform background traffic on the link between VR streaming server and the VR client to test whether the VR streaming traffic will be interfered.

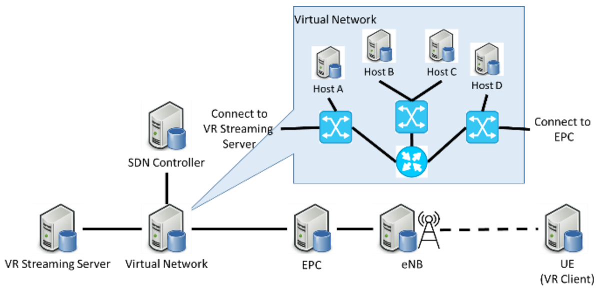

Figure 2 Network Architecture

3.1. VR Streaming Application

This part mainly provides server-side and client-side VR streaming application services. The server is responsible for the rendering of the screen, and the screen is transmitted to the client-side display to reduce the burden of client-end computing.

The architecture is shown in the Figure 3. Regarding video data transmission, in the server-side part, we perform Video Capture on the existing 3D application, and perform image compression encoding with H.264, using WebRTC transmission. In the client-side, we use WebRTC to receive the image and use WebGL to project the image onto the corresponding VR screen.

Regarding the controller data transmission, the WebVR is used to obtain the VR helmet position and controller data on the client-side, and the WebRTC message channel is used to transmit back to the server end, and the analog simulator is used for simulation.

Since WebRTC is based on P2P connection, the signaling server and the STUN server are used in the transmission process to handle the problem of cross-domain connection. Before establishing a connection, both parties must have a session with the signaling server, and the signaling server is responsible for letting both parties know the location of the other party. When connecting, if one of them is in the NAT, the STUN server will obtain the external network location of the user in the NAT and provide it to the other party so that the other party can connect with the user in the NAT.

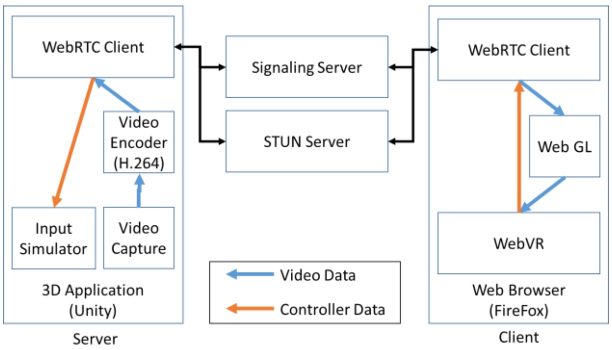

Figure 3 VR Streaming Architecture

3.2. SDN

In this research, mininet used to be a virtualized network platform, we were able to create a realistic virtual network. [8] Using Ryu as the controller, which is a component-based software-defined networking framework [9], and using FlowVisor as the hypervisor, which offers bandwidth isolation by utilizing a proxy between the virtual host and controller.

In our SDN architecture (Figure 4), FlowVisor connects to the Ryu controller by Northbound API and connects to the mininet by Southbound API. When flows have been created by mininet, it would be caught by FlowVisor and send to the Ryu controller according to the slice rules, and then the flows would be handled by the Ryu controller.

For the propose of simulating the network slicing, we pre-configured several queues templates to match the proper slices when the bandwidth is changed. We use Iperf to simulate the real network flows, and flows are detected by OpenFlow protocol, and then these flows will be allocated to the matching slice by the controller. In this way, we could combine the Ryu and FlowVisor to simulate the network slicing.

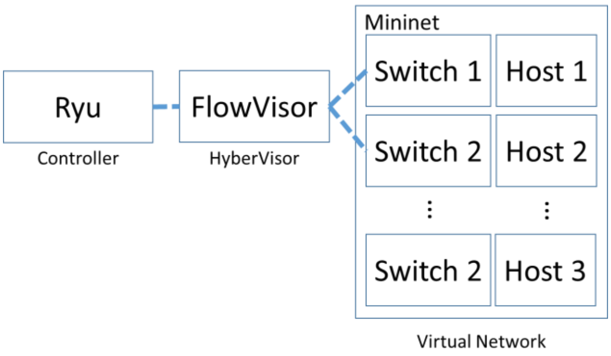

Figure 4 SDN Architecture

3.3. 5G

The increasing demand for mobile broadband services with the high data rate, speed, and quality of service has been the motivation for the 3GPP to develop 5G technology [5]. The main architecture of 5G is divided into E-UTRAN (Evolved Universal Terrestrial Radio Access Network) and EPC (Evolved Packet Core). The E-UTRAN is composed of base station eNB (eNodeB) and UE (User Equipment). The EPC is composed of four network elements: the Serving Gateway (Serving GW), the PDN Gateway (PDN GW), the MME and the HSS. The EPC is connected to the external networks, which can include the IP Multimedia Core Network Subsystem (IMS).

The radio protocol architecture for 5G can be separated into control plane architecture and user plane architecture. Control-plane transmission path is UE$\longleftrightarrow$

eNB⟵⟶MME. The user-plane transmission path is UE ←→ eNB ←→ Serving Gateway ←→ Packet Data Network Gateway. This way separated network control packet and data packet that can manage the system effectively and individual design each path.

In this study, we use USRP B210 as a radio base station and use OpenAirInerface(OAI) to control it. The OpenAirInterface (OAI) emulation platform is such a software platform, developed based on the real 5G protocols. Through different configurations, OAI platform achieves a variety of scenarios and providing a better approach to testing, evaluation and validating of the real 5G system [6]. We choose OAI for emulation because only OAI program is a full open-source implementation of the entire 5G protocol stack from the physical (PHY) layer to the network layer, and comprises all the components of the 5G system, such as the user equipment (UE), evolved Node B (eNB), and enhanced packet core (EPC) [7].

In this work in Figure 5, we used three PC to represent EPC, eNB, and UE. eNB connects USRP B210. UE used HUAWEI dongle to capture radio signals. In table II show that we set the parameter of this work.

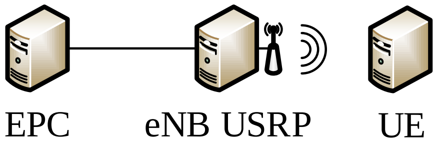

Figure 5 Connection of 5G System

TABLE I: Parameter of OAI

Frequency band	Band 7
Transmission mode	1
Duplex	FDD
Modulation	64QAM/16QAM(DL/UL)
Bandwidth	5MHz

4. Implementation and Demonstration.

In the VR Streaming application, we created the server and client application. The Server sends 2560*720 pictures at 60fps with an average delay of about 32ms and an average traffic of 4.2Mbps. In the 5G part, the average uplink and downlink transmission bandwidth is 7Mbps/16Mbps.

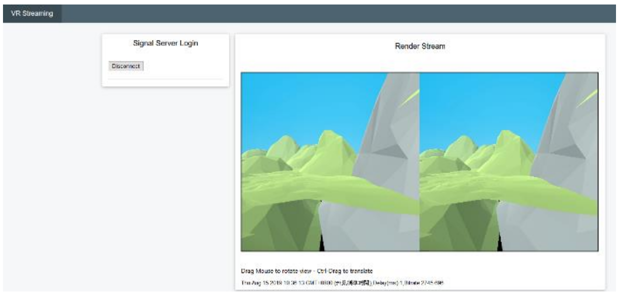

Figure 6 VR Streaming Client Application

Figure 7 VR Streaming Server Application

5. Conclusion

This study completed the VR streaming service on the 5G network. VR streaming server-client is implemented to achieve the purpose of reducing the computing load on the client-side. And through 5G Network Slicing and SDN, it provides VR Streaming low-latency, high-bandwidth network services.

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