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Recommendation

ITU-T F.746.14 (12/2022)

SERIES F: Non-telephone telecommunication services

Multimedia services

Requirements and reference framework for cloud virtual reality systems

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Recommendation ITU-T F.746.14

Requirements and reference framework for cloud virtual reality systems

Summary

Cloud virtual reality based on cloud capabilities, can effectively shield terminal differences, reduce the difficulty of application development, lower some specific industry entry barriers, and promote the industry business chain cooperation.

Recommendation ITU-T F.746.14 focuses on the overall requirements of cloud virtual reality systems and the related requirements of each layer including content requirements, network requirements, control requirements, resource requirements and terminal requirements, as well as the reference framework for related high-level functions.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
1.0	ITU-T F.746.14	2022-12-14	16	11.1002/1000/15188

Keywords

Cloud virtual reality, reference framework, requirements, virtual reality.

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The approval of ITU-T Recommendations is covered by the procedure laid down in WTSA Resolution 1.

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1 Scope

This Recommendation specifies the requirements and reference framework for cloud virtual reality systems.

The scope of this Recommendation includes:

1) overview of cloud virtual reality systems;
2) reference framework for cloud virtual reality systems;
3) requirements for cloud virtual reality systems.

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

[ITU-T J.1631] Recommendation ITU-T J.1631 (2021), *Functional requirements of E2E network platforms to enhance the delivery of cloud-VR services over integrated broadband cable networks.*

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following term defined elsewhere:

3.1.1 degree of freedom (DoF) [b-ITU-T G.1035]: Represents the ways an object can move within a space, which is a key element in helping create an immersive environment for a user.

3.2 Terms defined in this Recommendation

This Recommendation defines the following term:

3.2.1 operations latency: The time it takes for the entire process from the terminal issuing a control command to the application content responding to the operation request and completing output.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

2D Two Dimensions

3D Three Dimensions

3I Immersion, Interaction and Imagination

API Application Programming Interface

ARM Application Resource Manager

ATW	Asynchronous Time Warp
CDN	Content Delivery Network
Cloud VR	Cloud Virtual Reality
CPU	Central Processing Unit
3DoF	Three Degrees of Freedom
E2E	End-to-End
FOV	Field of View
FTTH	Fibre To The Home
GPU	Graphic Processing Unit
HMD	Head-mounted Display
OAM	Operation, Administration and Management
QoE	Quality of Experience
SDK	Software Development Kit
VR	Virtual Reality
WDM	Wavelength Division Multiplexing

5 Conventions

In this Recommendation:

– The keywords "**is required to**" indicate a requirement which must be strictly followed and from which no deviation is permitted if conformance to this document is to be claimed.

– The keywords "**is recommended**" indicate a requirement which is recommended but which is not absolutely required. Thus, this requirement need not be present to claim conformance.

6 Overview

Cloud virtual reality (cloud VR) is a new method for providing service of virtual reality based on cloud capabilities, which comprehensively uses cloud computing, rendering, audio and video processing and other multimedia technologies. Cloud VR continues and enhances VR related immersion, interaction and imagination (3I) attributes.

Cloud VR has a processing method based on cloud unified content storage and cloud logical computing, which is different from VR terminal mode that finishes logic computing, graphics rendering, and content storage by VR terminals. For the implementation of cloud VR, there are several ways used for graphics rendering, and audio and video processing, such as cloud and terminal collaboration, and terminal alone.

There are many kinds of cloud VR application scenarios, which have different classifications.

– From the industry dimension, cloud VR application scenarios are divided into personal consumption-level scenarios and enterprise-level scenarios. Personal consumption-level scenarios include video-on-demand, live broadcast, games, social networking, education and other analogous fields. Enterprise-level scenarios include military, medical, construction, industrial manufacturing and other analogous fields.

– From the interaction dimension, cloud VR application scenarios are divided into weak interaction scenarios and strong interaction scenarios. Weak interaction scenarios are mainly VR video services, including VR videos, and VR live broadcasts. Strong interactive

scenarios usually involve cloud real-time rendering, and interaction with virtual environments or objects, including VR games, VR education, VR fitness, VR social and VR industrial manufacturing.

Two level services and two types of interaction services need different service, network and terminal capabilities, and service logic processing in cloud VR.

Use cases of the cloud VR services are discussed in Appendix I.

7 Reference framework of cloud VR systems

Figure 7-1 shows the reference framework for cloud VR systems. The cloud VR systems implement cloud-based operations through various types of application contents and through various services at the resource layer supported by the control layer, and delivers cloud VR contents to different types of terminals through the network to complete the entire service process.

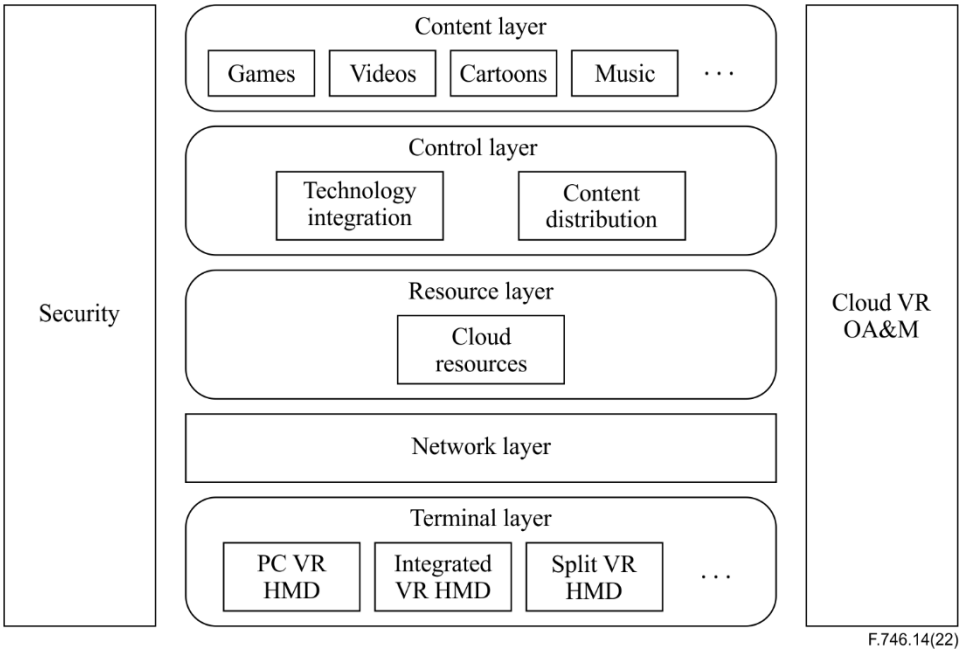

Figure 7-1 – Reference framework for cloud VR systems

The content layer provides various types of application content, including cloud VR games, cloud VR videos, cloud VR cartoons and cloud VR music. According to the industry application perspective, the content of the cloud VR system can divide into cloud VR education, cloud VR fitness, cloud VR social, cloud VR industrial manufacturing, etc.

The control layer provides cloud VR-related capabilities, including technology integration and content distribution:

– The cloud VR technology integration provides audio and video encoding, transcoding, graphics rendering, streaming issuance, control response, and other specified service capabilities for weak and strong interaction services using general cloud resource pool capabilities.

– The cloud VR content distribution provides distribution of processed cloud VR content from a cloud resource to a corresponding cloud VR user/terminal.

The resource layer provides general hardware computing resources such as central processing units (CPUs) and graphic processing units (GPUs) for cloud VR, and basic software capabilities such as virtual machines, containers or application virtualization.

The network layer provides the communication capabilities for other layers, operation, administration and management (OAM), the users and providers.

The terminal layer receive/send cloud VR related data from/to the cloud, performs partial local processing/computing, and displays the cloud VR content based on the support of software and hardware. There are mainly three types of terminals for cloud VR systems, including PC VR head-mounted display (HMD), integrated VR HMD and split VR HMD:

– PC VR HMD provides basic VR related device capabilities that include display, manipulation, sensing and other capabilities, but has no computing capability for complex media and service logic processing which is provided by PCs or proprietary game consoles.
– Integrated VR HMD provides all VR related device capabilities that include basic capabilities and computing capability.
– Split VR device provides basic VR related device capabilities, but has no computing capability which is provided by mobile terminals, such as mobile phones.

The cloud VR OAM provides centralized operating, management and maintenance functions in terms of content, technology integration, and terminals, including user authentication, content introduction, cloud VR technical capability access, and cloud VR terminal management.

Cloud VR provides multi-dimensional security mechanisms, such as the securities of cloud operation, service, data and user experience.

8 Requirements of cloud virtual reality systems

8.1 General requirements

8.1.1 Audio-visual

The overall audio-visual quality of the cloud VR systems is closely related to the content image/sound quality, computing/coding capabilities, network transmission quality, and terminal secondary processing/display capabilities. It is based on the final presentation of the user's image, sound and interaction requirements.

AV-01: It is recommended to have three-dimensional properties, and its presentation method is not limited to true three dimensions (3D) display or two dimensions (2D) picture synthesis 3D, etc.

AV-02: The image quality is required to reference standard [ITU-T J.1631] FEP related requirements.

AV-03: It is recommended to meet the same refresh rate of the cloud VR terminal's display.

8.1.2 Interaction

IA-01: It is required to have smooth human-computer interaction.

IA-02: It is required to have acceptable operations latency. In general, the terminal side collects control instructions and uploads them to the cloud through the network, and then the cloud completes the processing and sends the relevant results to the terminal through the network, and finally the terminal side completes the process of corresponding content and output results.

IA-03: It is required to meet three degrees of freedom (3DoF) capability, and support at least one common control method, such as handle, joystick, gesture and voice.

8.1.3 Compatibility

CB-01: It is required to be compatible with general cloud computing resource pools.

CB-02: It is required to be compatible with various cloud VR technology solutions.

CB-03: It is required to support various VR contents, such as cloud VR content released on the Steam online game platform.

CB-04: It is required to be compatible with network access methods that meet the transmission conditions.

CB-05: It is required to be compatible with various types and different brands of VR terminals that meet the capability requirements.

8.2 Content layer

The quality of cloud VR content is directly related to cloud VR 3I properties. The requirements for cloud VR content are as follows:

CT-01: The content is required to transplant to the cloud and run based on the cloud.

CT-02: It is recommended to have a flexible output method, which can be switched between panoramic and field of view (FOV) modes.

8.3 Control layer

8.3.1 The common requirements of the control layer

CP-01: The deployment server is required to support general cloud resource pool forms such as physical machines and virtual machines.

CP-02: It is required to support system recovery after software and hardware failures, including data backup/recovery and service node switching. The main types of server failures include plugging and unplugging hard disks, network disconnection, shutdown and restarting.

– With the cooperation of hardware and software, it is required to provide the ability to manage system failures.
– The design life is required to be greater than 10 years.
– The fault is required to be isolated in the module (e.g., the service node, etc.).
– The overall service capability is required to have 7*24 hours stable operation performance and 99.9% availability.
– The downtime for failures is required to not exceed 2 hours within three months.
– Short-term failures of related servers and other equipment are required to not cause alarms and service data.

CP-03: It is required to have flexible scalability to support the seamless addition of service nodes and the operation of servers in the nodes as the service carrying requirements increase, so as to improve the carrying capacity.

CP-04: Compatibility requirements:

– It is required to have the ability to be compatible with the software version. When the software version is upgraded or revised, it has the ability to be compatible with the cloud VR application content previously based on it.
– It is required to have the ability to be compatible with application content developed based on the general VR framework.

8.3.2 Technology integration

TI-01: It is required to build cloud VR technical services based on the cloud resource pool.

TI-02: It is required to build cloud VR technology services nodes based on edge nodes.

TI-03: It is recommended to have the ability of GPU-based video encoding.

TI-04: It is required to have the functions such as seamless migration of services and data security assurance.

TI-05: It is required to have the ability to interface with the cloud VR operation services to provide cloud VR technical integration services.

TI-06: It is required to have functions such as docking with cloud VR terminals, obtaining control instructions, and calling audio and video decoding capabilities.

TI-07: For VR weak interactive services, it is required to provide functions such as cloud transcoding, content distribution and content delivery network (CDN) resource scheduling.

TI-08: For VR strong interactive services, it is required to provide at least one method based on virtual machines, containers, and application virtualization to build parallel cloud VR instances:

– It is required to support cloud-based drivers, including rendering driver, video low-latency compression coding and video streaming transmission.
– Each cloud rendering server or virtual machine is required to have the capability of multi-application rendering parallelism. For rendering services that can run/stream processing with single-core CPU and single-core GPU, it has the parallel operation capability of the smallest cores between CPU and GPU.
– It is required to achieve a one-to-one correspondence between the number of picture frames and the corresponding picture sound data collection, and the time difference is recommended to not exceed 100 ms.

8.3.3 Content distribution

Cloud VR content distribution has an interface with cloud VR operation, which provides cloud VR content aggregation, recommendation and distribution functions.

CD-01: It is required to provide an effective cloud VR content download or online operation path.

CD-02: It is required to provide a CDN function for cloud VR video service.

CD-03: It is required to provide storage capabilities that match the distribution of cloud VR content.

8.4 Resource layer

CR-01: It is required to provide generic physical or virtual CPU, GPU, storage, network card and other hardware resources.

– It is required to provide generic software systems, including safe operating systems, hardware drivers and general graphics interfaces.
– It is required to provide compliant virtual machines, containers or application virtualizations and other concurrent reuse mechanisms of software and hardware resources.

CR-02: It is required to provide general cloud resource pool configuration, expansion, migration, management and other functions.

CR-03: It is required to provide data storage, and data backup.

CR-04: It is required to provide secure and reliable virtual machines, containers or application virtualizations, one-click migration, and a secure data synchronization mechanism.

8.5 Terminals

8.5.1 Hardware

HW-01: It is required to use general CPU architecture such as X86, ARM and others, with complete computing, rendering, storage and other processing capabilities for cloud VR service.

HW-02: It is required to have enough calculation ability, including CPU and GPU.

HW-03: It is required to have enough storage capacity.

HW-04: It is required to provide 2K or more, dual-screen near-eye display capability.

HW-05: It is required to provide 3DOF capability, and is recommended to provide the above 3DOF capability.

HW-06: It is required to provide one or more effective control devices, including handles and VR helmet buttons.

HW-07: It is recommended to provide relevant optical equipment for accurate spatial positioning.

HW-08: It is required to have network access capability above 100 M.

8.5.2 Software

SW-01: It is recommended to use common operating systems such as Windows, Linux, Android and Harmony.

SW-02: It is required to install hardware drivers.

SW-03: It is required to have the ability to access the different cloud VR layers.

– It is required to support cloud VR user management, authentication, and charging functions through connecting with the different cloud VR layers.
– It is required to support functions such as receiving cloud VR service audio and video streams and uploading control commands.
– It is required to support cloud VR content push, update and release functions through connecting with the different cloud VR layers.

SW-04: It is recommended to support multiple codecs, such as H.264, H.265, AVI, and VP9, and also support two or more at the same time.

SW-05: It is required to support the function of a near-eye 3D display.

SW-06: The overall terminal operation delay and processing delay are recommended to be less than 40 ms, of which the asynchronous time warp (ATW) is required to be less than 20 ms, and the graphics and audio data decoding is recommended to be less than 20 ms.

8.6 Network

CN-01: The bandwidth is required to reference standard [ITU-T J.1631] FEP related requirements.

CN-02: The latency is required to be less than or equal to 100 ms. For strong-interaction VR service, it is recommended that the manipulation latency is less than or equal to 50 ms.

CN-03: The packet loss rate is required to less than or equal to 10^{-4} ([ITU-T J.1631] FEP). For strong-interaction VR service, the packet loss rate is recommended to be less than or equal to 10^{-5}.

CN-04: For wired access, it is recommended to use fibre to the home (FTTH) access technology.

CN-05: For wireless cellular access, it is recommended to use 5G and above network access standards.

CN-06: Access delay is required to be less than or equal to 5 ms, and is recommended to be less than or equal to 2 ms.

CN-07: It is recommended to support deterministic network access guarantees for cloud VR services such as bandwidth and delay.

CN-08: It is recommended to provide network guarantee mechanisms such as link path selection and network acceleration.

CN-09: It is recommended to use optical fibre or wavelength division multiplexing (WDM) direct connection between cloud VR edge computing nodes to reduce the delay of multi-person remote interaction.

CN-10: Inside the cloud data centre, a 1 Gbit/s or more network interconnection is required, and 10 Gbit/s or more is recommended.

8.7 Operation, administration and management

CO-01: It is required to have the ability to provide cloud VR operation and management based on a cloud basic resource pool or general server.

CO-02: It is required to have the ability to centralize the management and scheduling of resources in the underlying cloud resource pool.

CO-03: It is required to have the ability to interface with various VR applications, including the ability to import and release VR applications.

CO-04: It is required to have the ability to connect the cloud VR technology integration service.

CO-05: It is required to have service authentication and service invocation/removal capabilities of different cloud VR technical integration services.

CO-06: It is required to have complete user authentication, service billing, data analysis, operation and maintenance, etc.

CO-07: It is required to have the ability to interface with cloud VR terminals, complete user authentication, content synchronization, and charging functions.

CO-08: It is recommended to adopt software development kit (SDK), application programming interface (API) and other forms to provide the capability of a built-in cloud VR terminal for operational capability.

8.8 Security

SR-01: It is required to have the ability to divide security domains according to service nodes, deploy firewalls, intrusion detection, abnormal traffic detection and filtering and other measures.

SR-02: It is required to have anti-virus capabilities and process (logical) security assurance, including access rights restrictions, security audits and other functions.

SR-03: It is required to have the ability to ensure the service security through user management, authority management, log management, etc.

SR-04: It is required to have security protection capabilities for metadata, user access data, business operation data, etc., and use encryption technology to encrypt important data transmitted on the Internet.

SR-05: It is required to have corresponding measures to prevent and deal with simulator sickness, including fatigue, sweating, vertigo and nausea.

Appendix I

Use cases

(This appendix does not form an integral part of this Recommendation.)

Through cloud computing, compared with the VR terminal mode, cloud VR has the advantages of enhanced service capability, reduced terminal operation pressure and centralized distribution of content, so as to deduce a variety of rich and colourful use case types.

In order to show the characteristics of cloud VR strong interaction scenarios and cloud VR weak interaction scenarios, this appendix selects typical use cases such as cloud VR games and cloud VR live broadcasts. At the same time, cloud VR education with strong and weak interaction attributes is selected as a typical use case.

Cloud VR game and cloud VR live broadcast serve as as personal consumption-level service representatives, while cloud VR education serves as as an enterprise-level service representative.

I.1 Cloud VR game

Figure I.1 shows a schematic diagram of cloud VR game. A cloud VR game is a typical use case of cloud VR due to its smooth control experience and multi-person real-time interaction mechanism. Unlike cloud VR video that can use the terminal, CDN and other caching mechanisms to alleviate the experience of problems caused by network instability, cloud VR game needs to complete the transmission of high-capacity media streams and remote control commands from the cloud to the terminal in real time and efficiently.

In terms of content, game content providers are required to inject panoramic game content with exquisite visual effects such as stereoscopic high-definition pictures, etc. In terms of platforms, high-end GPU cluster servers are required to provide functions such as game running, graphics rendering, and audio and video capture/encoding. In the network related to cloud VR game, it is necessary to provide high-bandwidth, low-latency, and low-packet-loss stable data transmission services. In terms of the terminal, it is necessary to accept high-definition graphics data issued by the cloud, and collect corresponding operating instructions data and upload it to the cloud to complete the overall business service process.

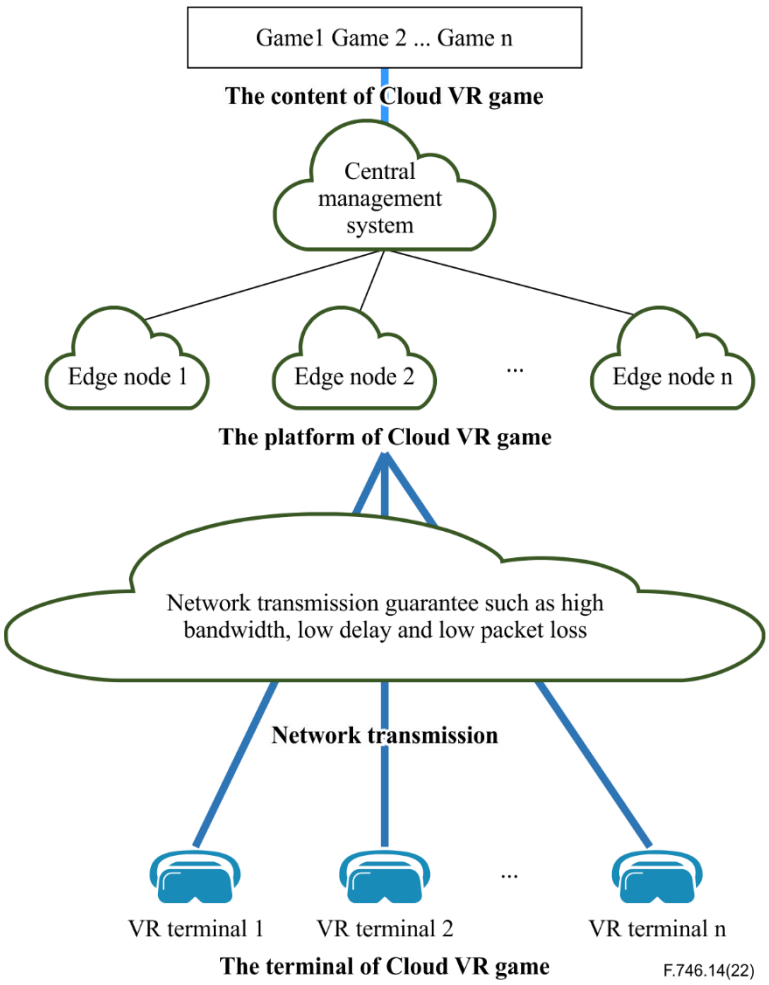

Figure I.1 – Schematic diagram of cloud VR game

Cloud VR game requires high-end GPU servers as the foundation for cloud operations. Through mechanisms such as virtual machines and containers, a server has the ability to carry multiple services. This mechanism has the problem of multiple users repeatedly processing common game graphics data resources, and it also puts pressure on the overall carrying capacity of the cloud. In order to solve the above problems, it is necessary to adopt technological innovations such as multi-user cloud computing resources and multi-dimensional sharing of cloud data resources to avoid the waste of multi-processing of general game graphics.

I.2 Cloud VR live broadcast

Figure I.2 shows a schematic diagram of cloud VR live broadcast. Cloud VR live broadcast, firstly uses VR technology to achieve panoramic view shooting and surround-sound capture of content. It then uses high-performance servers at the edge nodes close to the live broadcast site to complete the stitching and optimization of audio and video streams. Then through the CDN system, with the help of ultra-high bandwidth's network it realizes multi-user-oriented audio and video distribution. The end user completes the online viewing of the corresponding live broadcast through the VR terminal.

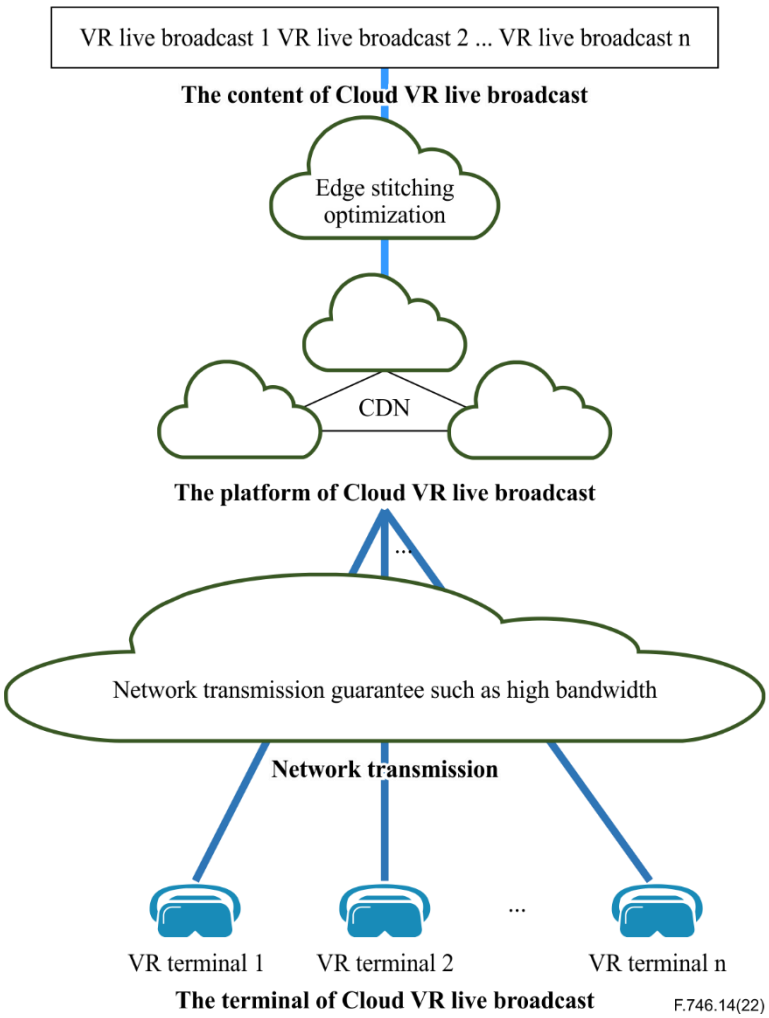

Figure I.2 – Schematic diagram of cloud VR live broadcast

Cloud VR live broadcast is one of the more complex cloud VR video applications. However, because of its online viewing mode, the interaction process only reflects operations such as switching of the focus range and viewing of digital information, and does not involve more complex real-time interaction and so it belongs to cloud VR weak interaction scenarios. At the same time, during the video watching process, modes such as CDN and VR terminal caching can be used to reduce the impact of live broadcast effects caused by network fluctuations, and at the same time reduce the burden of low network latency. If a corresponding virtual image is added to the cloud VR live screen and a real-time interaction mechanism is provided, its attribute is not only a video viewing mode, but a video plus real-time animation interaction mode, which also requires lower network latency.

I.3 Cloud VR education

Figure I.3 shows a schematic diagram of cloud VR education. Cloud VR education is an application of the cloud VR industry. Online distance education is carried out through cloud VR technology, which has attributes such as intuition, fun and fairness. Especially for countries and regions with uneven distribution of educational resources, the cloud VR education method can concentrate high-quality educational resources to provide more school students with the same quality of teaching services, and promote overall education equity.

Cloud VR education has two mutually integrated service modes. One is the mode of directly playing VR education videos online, which belongs to the cloud VR weak interactive service; the other is panoramic simulation education, where the cloud presents a dynamic virtual image based

on the educational content and provides real-time interactive functions which belong to the cloud VR strong interactive service.

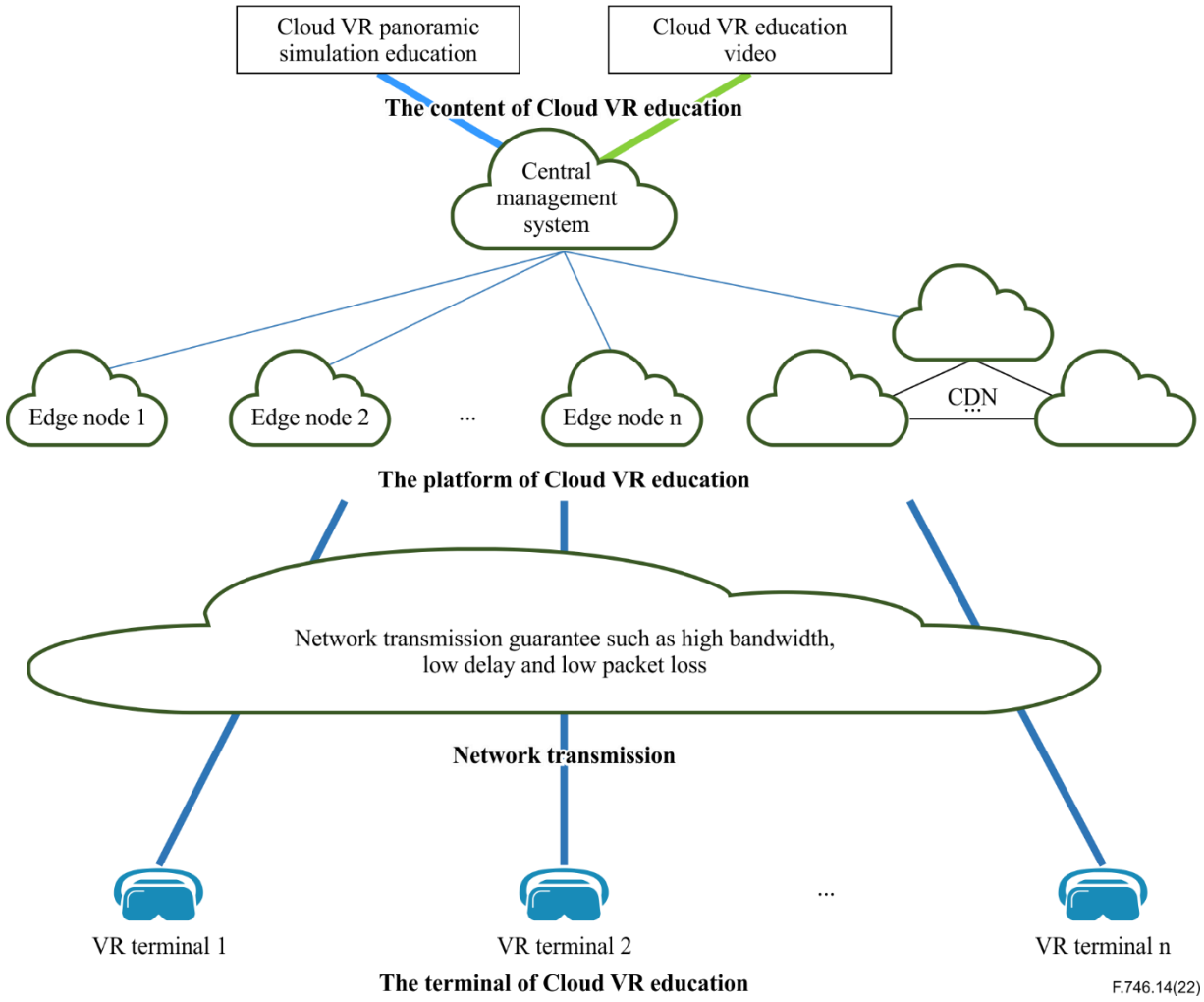

Figure I.3 – Schematic diagram of cloud VR education

In most cloud VR education scenarios, the above two methods exist at the same time, so cloud VR also has the attributes of strong and weak interaction at the same time. For cloud VR education-related technical details, implementation processes, and functional composition, further analysis and clarification of recommendations are needed.

Bibliography

[b-ITU-T G.1035] Recommendation ITU-T G.1035 (2021), *Influencing factors on quality of experience for virtual reality services*.

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