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Future networks

Quality of service assurance-related requirements and framework for virtual reality delivery using mobile edge computing supported by IMT-2020

Recommendation ITU-T Y.3109

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Recommendation ITU-T Y.3109

Quality of service assurance-related requirements and framework for virtual reality delivery using mobile edge computing supported by IMT-2020

Summary

Recommendation ITU-T Y.3109 specifies quality of service (QoS) assurance-related requirements and a framework for virtual reality (VR) delivery using mobile edge computing (MEC) in International Mobile Telecommunications-2020 (IMT-2020).

Recommendation ITU-T Y.3109 first provides an introduction to VR delivery using MEC supported by IMT-2020. It then specifies QoS assurance-related function and mechanism requirements and a framework. The QoS planning for VR services, typical VR user cases and guidelines for deployments of VR services are described in appendices.

History

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Recommendation ITU-T Y.3109

Quality of service assurance-related requirements and framework for virtual reality delivery using mobile edge computing supported by IMT-2020

1 Scope

This Recommendation specifies quality of service (QoS) assurance-related requirements and a framework for virtual reality (VR) delivery using mobile edge computing (MEC) supported by International Mobile Telecommunications-2020 (IMT-2020). It summarizes the QoS assurance-related function and mechanism requirements for VR cloud, VR edge, VR client, VR QoS management and control. A high level framework of VR delivery using MEC supported by IMT-2020 is given to assist the understanding of VR QoS assurance-related functions and mechanisms.

This Recommendation refers to MEC only in the context of VR delivery. Therefore, any other use of MEC lies outside the scope of this Recommendation.

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 E.860] Recommendation ITU-T E.860 (2002), *Framework of a service level agreement*.

[ITU-T F.743.10] Recommendation ITU-T F.743.10 (2019), *Requirements for mobile edge computing-enabled content delivery networks*.

[ITU-T G.1035] Recommendation ITU-T G.1035 (2020), *Influencing factors on quality of experience for virtual reality services*.

[ITU-T H.264] Recommendation ITU-T H.264 (2019), *Advanced video coding for generic audiovisual services*.

[ITU-T H.265] Recommendation ITU-T H.265 (2019), *High efficiency video coding*.

[ITU-T H.266] Recommendation ITU-T H.266 (2020), *Versatile video coding*.

[ITU-T Y.3102] Recommendation ITU-T Y.3102 (2018), *Framework of the IMT-2020 network*.

[ITU-T Y.3104] Recommendation ITU-T Y.3104 (2018), *Architecture of the IMT-2020 network*.

[ITU-T Y.3106] Recommendation ITU-T Y.3106 (2019), *Quality of service functional requirements for the IMT-2020 network*.

[ITU-T Y.3107] Recommendation ITU-T Y.3107 (2019), *Functional architecture for QoS assurance management in the IMT-2020 network.*

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 assurance [b-ITU-T X.1500]: The degree of confidence that the process or deliverable meets defined characteristics or objectives.

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

3.1.3 IMT-2020 [b-ITU-T Y.3100]: Systems, system components, and related aspects that support to provide far more enhanced capabilities than those described in [b-ITU-R M.1645].

NOTE 1 – [b-ITU-R M.1645] defines the framework and overall objectives of the future development of IMT-2000 and systems beyond IMT-2000 for the radio access network.

NOTE 2 – This definition is based on [b-ITU-R M.2083-0].

3.1.4 mobile edge computing [ITU-T F.743.10]: System which provides an IT service environment and cloud-computing capabilities at the edge of an access network which contains one or more type of access technology, and in close proximity to devices.

NOTE – Based on the definition of multi-access edge computing in [b-ETSI GS MEC 001].

3.1.5 motion-to-photon latency [ITU-T G.1035]: The time it takes between the user moving their head and this motion being reflected on the screen of the head-mounted display (HMD).

NOTE – Definition based on [b-Brandenburg].

3.1.6 network performance [b-ITU-T E.417]: The performance of a portion of a telecommunications network that is measured between a pair of network-user or network-network interfaces using objectively defined and observed performance parameters.

3.1.7 quality of experience (QoE) [b-ITU-T P.10]: The degree of delight or annoyance of the user of an application or service.

NOTE – Recognizing on-going research on this topic, this is a working definition which is expected to evolve for some time. (This note is not part of the definition.)

3.1.8 quality of service (QoS) [b-ITU-T P.10]: The totality of characteristics of a telecommunications service that bear on its ability to satisfy stated and implied needs of the user of the service (see [b-ITU-T E.800]).

3.2 Terms defined in this Recommendation

This Recommendation defines the following term:

3.2.1 quality of service assurance: Functionalities or mechanisms that enable service providers to make statements with a degree of confidence that the service meets the quality characteristics or objectives specified elsewhere.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

3D three Dimensional

AF Application Function

AN Access Network

ASF Authentication Server Function

CDN Content Delivery Network

CEF	Capability Exposure Function
CN	Core Network
DN	Data Network
DoF	Degree of Freedom
E2E	End-to-End
eMBB	enhanced Mobile Broadband
FoV	Field of View
gNB	next generation Node B
HMD	Head-Mounted Display
IMT-2020	International Mobile Telecommunications-2020
MEC	Mobile Edge Computing
MTP	Motion to Photon
NACF	Network Access Control Function
NFR	Network Function Registry
NSSF	Network Slice Selection Function
QoE	Quality of Experience
QoS	Quality of Service
PCF	Policy Control Function
PPD	Pixels per Degree
RP	Reference Point
RTT	Round-Trip Time
SMF	Session Management Function
TCP	Transport Control Protocol
UDP	User Data Protocol
UE	User Equipment
UPF	User Plane Function
USM	Unified Subscription Management
VoD	Video on Demand
VR	Virtual Reality

5 Conventions

None.

6 Introduction

Cloud VR may become one of the preferred enhanced mobile broadband (eMBB) service for many IMT-2020 commercial carriers. VR is a rendered version of a delivered video and audio scene in six degrees of freedom (DoF). The rendering is designed to mimic the visual and aural sensory stimuli of the real world as naturally as possible to an observer or user. VR usually, but not necessarily, requires users to wear an HMD to completely replace the user's field of view (FoV) with a simulated visual component and headphones to provide the user with the accompanying audio. Some form of head and motion tracking of the user in VR is usually also necessary to allow the simulated visual and aural components to be updated in order to ensure that, from the user's perspective, items and sound sources remain consistent with the user's movements [b-3GPP TR 26.918]. To maintain a reliable registration of the virtual world, VR applications require highly accurate, low-latency tracking of the device at about 1 kHz sampling frequency [b-ETSI TR 126 928].

The adoption and growth of new VR services requires high performance, reliability and scalability of IMT-2020 systems and their multimedia enablers. It is important for VR service providers and network operators to be aware of the exact VR QoS (clause 3.1.8) requirements before deployment of VR service. From the network operator point of view, the exact QoS requirements can be used for efficient network QoS planning, QoS provisioning, QoS monitoring and QoS optimization [ITU-T Y.3106] and [ITU-T Y.3107]. From the VR service provider point of view, the exact QoS requirements can help to assure end-to-end (E2E) VR service QoS. Both VR service providers and network operators are required to understand the typical VR service use cases and specific QoS requirements, then, based on these requirements, they can further specify QoS assurance-related requirements and a framework for VR service deployment in IMT-2020.

The QoE (clause 3.1.7) is also very important for the success of VR service. [ITU-T G.1035] identifies and describes 12 QoE-influencing factors for VR services. These influencing factors, as illustrated in Figure 1, are divided into three categories: human; system; and context.

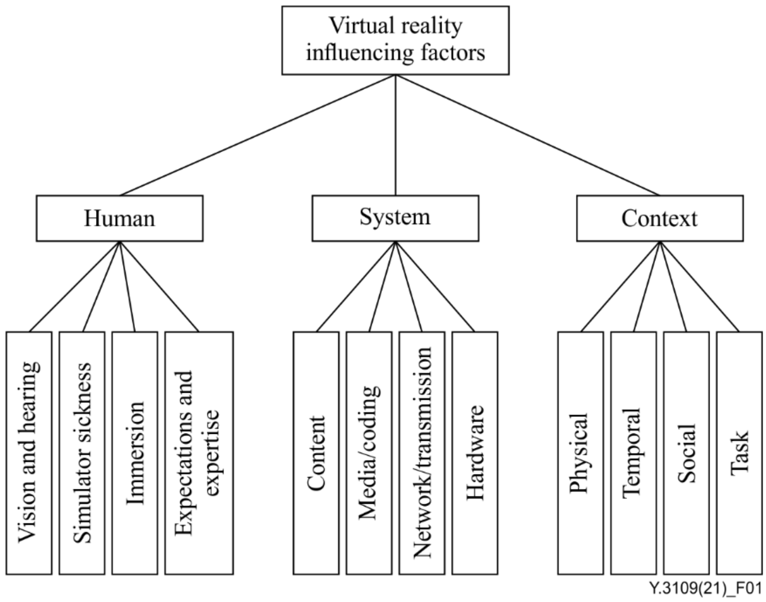


Figure 1 – Virtual reality QoE-influencing factor categories

According to the interaction level, VR services can be classified into those of weak- and strong-interaction [ITU-T G.1035]. The classification of VR services, use cases and service requirements are described in Appendix II.

One of the most important characteristics of IMT-2020/5G is that the cloud and network converge. The basic requirements of cloud and network convergence include: unified definition, orchestration of network resources and cloud resources to form a unified, agile and flexible resource supply, operation and maintenance system. Specific QoS assurance-related functionalities and mechanisms are needed to ensure that the delivered VR service meets the quality characteristics or objectives defined elsewhere.

The following functionalities and mechanisms related to QoS assurance (clause 3.1.1) should be considered when mapping the VR service to the IMT-2020 network:

VR cloud and VR client: Immersive experiences in the human mind require multiple complex scenes rendered at very high frame rates. Traditional VR requires that VR client has strong computing and rendering capabilities to provide a good experience, resulting in high cost. Wireless HMDs allow VR users much greater freedom of movement and will unlock a whole new range of applications in gaming, simulation, education and commerce. However, mobile VR HMDs have limited rendering and computing capabilities and therefore can only support simple VR applications. In this case, maturing real-time cloud rendering technology can transfer the responsibility for complicated rendering and computing processing to the cloud. It also delivers the outputs to users through high-speed low-latency IMT-2020 (clause 3.1.3) networks, greatly lowering requirements for terminal performance, reducing VR terminal costs, protecting VR content intellectual property and improving VR popularization. The most significant factor with cloud VR solutions is the transfer of processing capability from the client to the cloud. A high-capacity, low-latency broadband network allows for responsive interactive feedback, real-time cloud-based perception, rendering and real-time delivery of display content.

VR edge: Motion-to-photon (MTP) [ITU-T G.1035] latency is the time it takes between users moving their heads and this motion being reflected on the screen of the HMD. With the limitation of the long propagation distance from the end user to the remote cloud centre, which will result in excessively long latency for mobile applications, it is required to push computing, network control and storage to the network edges so as to enable computation-intensive and latency-critical applications on resource-limited mobile devices. MEC [ITU-T F.743.10] and edge rendering [b-Mangiante] promise dramatic reductions in latency and energy consumption, tackling the key challenges for materializing IMT-2020 VR applications. Compared to capabilities for computing, storage and intelligence accessed via the core network (CN), MEC enables deployment in proximity to VR users with increased performance and low latency.

VR QoS control and management: The VR cloud and VR edge are mapped to IMT-2020 as application function (AF), and the VR client is mapped to IMT-2020 user equipment (UE). The VR cloud acts as AF and interacts with the IMT-2020 policy control function (PCF) via the service-based interface for QoS management and control. The IMT-2020 QoS management and control for VR service assurance include network slicing, VR QoS planning (see Appendix I), VR QoS provisioning, VR QoS monitoring and VR QoS optimization. The VR edge enables network assistance, proxy caching and consistent QoS operations.

Based on the description in the previous paragraph, clause 7 specifies VR QoS assurance-related functionalities and mechanisms requirements for VR services supported by IMT-2020. To fulfil the requirements, a framework of VR delivery using MEC in IMT-2020 is described in clause 8.

7 QoS assurance-related function and mechanism requirements

7.1 VR cloud

Req_1. The VR cloud is required to act as an IMT-2020 AF and to interact with an IMT-2020 PCF to exchange VR QoS subscription information. The subscription information for a VR service may contain bandwidth, delay, loss rate, etc.

Req_2. The VR cloud is required to support generation of realistic images and sounds to emulate a real environment or create a synthetic one for the VR user with immersive experiences.

Req_3. The VR cloud is recommended to support cloud VR logic processing and cloud VR rendering to ensure the QoS of VR client and to lower requirements for VR client performance and costs.

Req_4. The VR cloud is recommended to support cloud encoding and compression mechanisms such as [ITU-T H.264], [ITU-T H.265] and [ITU-T H.266] to lower the network bandwidth requirement.

Req_5. The VR cloud is required to support MEC coordination, which includes VR content delivery and distribution to VR client and VR edge through the IMT-2020 network.

Req_6. The VR cloud is recommended to monitor and collect VR QoS parameters and report QoS parameters to an IMT-2020 PCF to optimize VR QoS.

7.2 VR edge

Req_7. The VR edge is required to act as an IMT-2020 AF and interact with an IMT-2020 PCF to exchange VR QoS information.

Req_8. The VR edge is required to support caching of VR content received from a VR cloud.

Req_9. The VR edge is required to support edge VR logic processing and cloud VR rendering to ensure the QoS of the VR client and to lower requirements for VR client performance and costs.

Req_10. The VR edge is required to be located closely to the VR client and support VR content delivery to the VR client through the IMT-2020 reference point between the UPF and data network (RP-ud) interface.

Req_11. The VR edge is required to redirect VR content requests to other VR edge nodes or the VR cloud when local content is not available.

Req_12. The VR edge is recommended to monitor and collect VR QoS parameters and report QoS parameters to the IMT-2020 PCF to optimize VR QoS.

7.3 VR client

Req_13. The VR client is required to support local decoding and local rendering to ensure immersive VR experiences.

Req_14. The VR client is required to support motion and position capture and report this information to the VR edge and VR cloud.

Req_15. The VR client is recommended to monitor and collect VR QoS parameters and report QoS parameters to the IMT-2020 PCF to optimize VR QoS.

7.4 VR QoS management and control

Req_16. It is required to support capability exposure function (CEF) and network slice selection or instantiation, e.g., eMBB slice, according to VR QoS subscription information.

Req_17. It is required to support VR QoS planning for VR service, which includes estimation of network coverage, capacity and resource requirements.

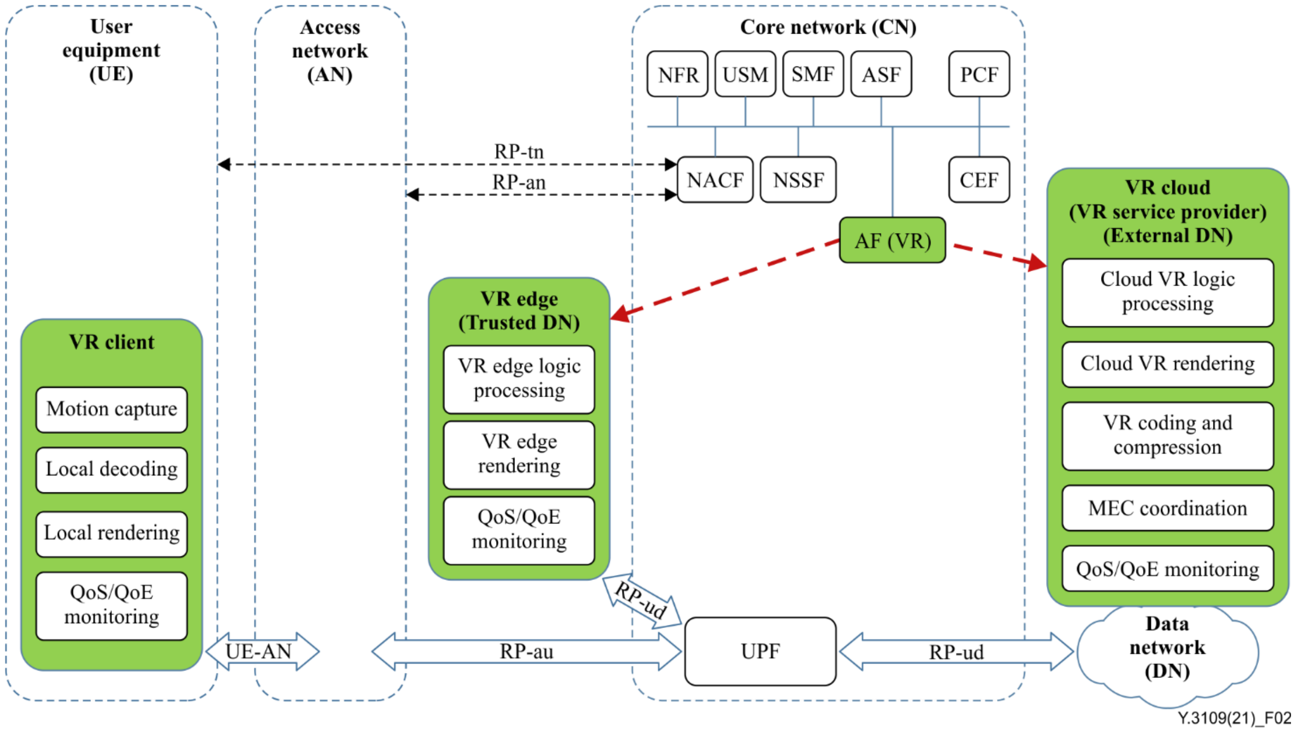
Req_18. It is required to support VR QoS provisioning, which includes translation of a VR service-centric service level agreement [ITU-T E.860] to resource-facing network slice descriptions, unified and E2E QoS control, QoS interworking and mapping, as well as efficient E2E QoS provisioning.

Req_19. It is required to support VR QoS monitoring, which includes collection of the QoS parameters, status and events of the provisioned slice, VR cloud, VR edge and VR client.

Req_20. It is required to support VR QoS optimization, which includes intelligent VR QoS anomaly detection, VR traffic prediction and routing optimization, VR QoS anomaly prediction and VR QoS optimization to provide and assure a desired service performance level during the lifecycle of the service.

8 Framework

The framework of VR delivery using MEC supported by IMT-2020 is shown in Figure 2.



CEF: capability exposure function
USM: unified subscription management
SMF: session management function
UPF: user plane function
RP-au: reference point between AN and UPF
NFR: network function registry
NACF: network access control function
ASF: authentication server function
RP-tn: reference point between UE and NACF
RP-ud: reference point between UPF and data network
PCF: policy control function
NSSF: network slice selection function
AF: application function
RP-an: reference point between AN and NACF

Figure 2 – A conceptual architecture of the VR service framework

A conceptual architecture of the VR service framework consists of a VR cloud (VR service provider), VR edge and VR client. Logical distribution of the VR service into three components assures QoS for VR service delivery to users distributed throughout different locations in the IMT-2020 network. The description of the role of each component is as follows.

– VR services can be seen as AFs in IMT-2020. The QoS requirements of the VR service can be realized by interacting with an IMT-2020 PCF through service-based interfaces [ITU-T Y.3102] and [ITU-T Y.3104]. VR AFs can interact with a CEF to provide session-related information (e.g., QoS requirements) via application signalling. It can also influence traffic routing by providing session-related information to the PCF in support of its rule generation.

– The VR cloud, acting as the VR service provider, may be located in an external data network (DN). It generates the VR media on the fly based on incoming tracking and sensor information. Cloud VR rendering capability is deployed on the cloud so that high-quality three dimensional (3D) rendering effects on lightweight VR terminals and encoding of the full view or FoV media before network transmission can be made. MEC coordination is implemented through IMT-2020 CEF interaction, and the encoded media is transmitted over the IMT-2020 network. The VR cloud can also monitor and collect VR QoS parameters and report QoS parameters to IMT-2020 PCF to optimize VR QoS.

– In the VR client, the tracking and sensor information is delivered in the reverse direction. In the VR HMD device, the VR media decoders decode the media, implement local VR rendering and display to the user. The VR client can also monitor and collect VR QoS parameters and report QoS parameters to IMT-2020 PCF to optimize VR QoS.

– The VR edge is located in a trusted DN and near to the VR client. The VR edge is responsible for interaction with PCF, CEF and MEC coordination, VR edge logic processing, VR edge rendering and media transmission over the IMT-2020 network. The physical deployment guidelines of VR edge location are described in Appendix III. The VR edge can redirect VR content requests to other VR edge nodes or the VR cloud when local content is not available.

9 Security considerations

This Recommendation describes the QoS requirements and frame for VR delivery using MEC in IMT-2020, therefore, general network security requirements and mechanisms in IP-based networks should be applied [b-ITU-T Y.2701] [b-ITU-T Y.3101].

The VR service is an AF instance in IMT-2020 and a VR service provider may interact with the IMT-2020 CN. The security mechanisms such as authentication, authority, accounting and encryption should be adopted to ensure system security.

Appendix I

QoS planning for VR services

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

I.1 Introduction

The development of cloud VR caters for experience: continuous improvement in image quality; interaction; and immersive experience. The synergy between content production, transmission and network technologies determines the level of cloud VR experience. Different VR development levels have different network performance requirements for bandwidth, delay and loss.

There are two main technical directions for transmission of VR video: full-view and FoV. Full-view transmission involves sending 360° images to terminals. When users turn their heads, the images they see are switched according to their FoV, i.e., terminals perform just-in-time processing on images, such as bit stream parsing, video decoding and image rendering. However, the transmission of portions of images that are not seen by users is a severe waste of network resources. In contrast, the FoV transmission solution focuses on the high-quality transmission of images within the current FoV [b-VR-network].

The evolution of cloud VR service experience can be divided into three levels: fair experience; comfortable experience; and ideal experience [b-VR-network].

Fair-experience level: Here, most content is 4K, and the terminal screen resolution is 2K to 4K. The image quality viewed by users is equivalent to the pixels per degree (PPD) effect of 240p/380p on a traditional TV.

Comfortable-experience level: Here, most content is 8K, the terminal screen resolution is 4K to 8K, and chip performance and ergonomics are improved. The image quality viewed by users is equivalent to the PPD effect of 480p video on traditional TV.

In this level, network bandwidth and latency is expected to be significantly improved to ensure good user experience of cloud VR services. For VR video services, full-view transmission will be the first choice to ensure good viewing and interaction experience. However, 360º 8K 3D video expects bandwidths of higher than 100 Mbit/s if full-view transmission is used. The FoV transmission solution lowers the bandwidth requirements, especially relevant for strong-interaction VR services, which require higher resolution and bandwidth.

Ideal-experience level: In the ideal-experience level, most content is 12K or 24K. The terminal screen resolution is 8K to 16K. The image quality viewed by users is equivalent to the PPD effect of 720p video on traditional TV. The development of content and terminals, coupled with technologies such as [ITU-T H.266] video coding standard and light field rendering, provides optimal VR experience.

For VR video services, the full-view transmission solution poses high requirements on network bandwidth. In contrast, the FoV solution poses lower requirements and will be the mainstream solution. In the case of strong-interaction VR services, the resolution is significantly improved, further increasing the required bandwidth. In addition, the user interaction experience requires lower network latency.

I.2 Bandwidth

For VR video services, full-view transmission is used in the fair-experience level. With industry development and increase of resolution, the FoV transmission solution can be used to minimize the required network bandwidth.

The bitrate in the full-view transmission solution is calculated as follows:

Average bitrate = (number of pixels of the image to be transmitted) * (number of bits per pixel) * (frame rate)/(compression ratio) (I-1)

For 2D videos, the number of pixels of the image to be transmitted is the full-view resolution. For 3D videos, it is about twice that number. The number of bits per pixel after sampling is 12 when the colour depth is 8 bits, 15 when it is 10 bits, and 18 when it is 12 bits.

To accommodate traffic bursts, the expected network bandwidth should be 1.5 times the average bitrate:

Expected network bandwidth = 1.5 * average bitrate (I-2)

FoV transmission solution (low-quality full-view transmission and high-quality FoV transmission) would need only 53% of the bandwidth used for full-view transmission [b-5G-VR].

For strong-interaction VR services, real-time rendering is performed based on the current FoV. Strong-interaction services use asynchronous rendering and asynchronous time warping technologies. To minimize the impact of black borders around the new FoV during asynchronous time warping on the user experience, extra-perspective rendering and transmission are needed. An extra 6° in each direction is recommended. Asynchronous rendering between the cloud and terminal adjusts the positions of objects based on depth of field or motion vector. This requires 15% more information about the depth of field and motion vector to be transmitted for each image frame [b-VR-network].

I.3 Delay

Latency in cloud rendering and streaming derives from three factors: processing on the cloud; transmission on the network; and processing on the terminal. Cloud processing includes logic computing, content rendering, coding, MEC coordination and data transmission. Network transmission includes: DNs, CN and access network (AN) transmission. Terminal processing includes motion capture, uplink transmission, downlink transmission, decoding, synchronization and refresh. A round-trip time (RTT) ≤20 ms is acceptable for fair-experience VR [b-VR-network].

I.4 Loss

Currently, video on demand (VoD) services use transport control protocol (TCP) transmission. Packet loss reduces TCP throughput and causes frame freezing.

The recommended packet loss ratios for VoD services for given RTT and bandwidth are listed in Table I.1 for weak-interaction VR and in Table I.2 for strong-interaction VR.

Table I.1 – Weak-interaction VR

Parameter	Level		
	Fair experience	Comfortable experience	Ideal experience
RTT	20 ms	20 ms	20 ms
Bandwidth	60 Mbit/s	140 Mbit/s	440 Mbit/s
Packet loss ratio	≤9E-5	≤1.7E-5	≤1.7E-6

The user data protocol (UDP) is recommended for strong-interaction and live video services. However, the UDP is a connectionless protocol and therefore more prone to packet loss than is the TCP, potentially causing problems such as erratic display and black screen.

Table I.2 – Strong-interaction VR

	Level		
	Fair experience	**Comfortable experience**	**Ideal experience**
RTT	20 ms	15 ms	8 ms
Bandwidth	80 Mbit/s	260 Mbit/s	1 Gbit/s
Packet loss ratio	≤1E-5	≤1E-5	≤1E-6

The VR service planning at different levels is shown in Table I.3.

Table I.3 – VR service planning

Parameter		**Level**		
		Fair experience	**Comfortable experience**	**Ideal experience**
Full view resolution		4K (3840*1920)	8K (7680*3840)	12K (11520*5760)
FoV		90° to 110°	120°	120°
Colour depth		8 bits	8 bits	10 bits
Coding		[ITU-T H.264] and [ITU-T H.265]	[ITU-T H.265]	[ITU-T H.266]
Frame rate		30 frames/s	30 frames/s	60 frames/s
Weak-interaction	Bit rate	≥40 Mbit/s	≥90 Mbit/s	≥290 Mbit/s
	Bandwidth	≥ 60 Mbit/s	≥140 Mbit/s	≥440 Mbit/s
	RTT	≤20 ms	≤20 ms	≤20 ms
	Packet loss ratio	≤9E-5	≤1.7E-5	≤1.7E-6
Strong-interaction	Bit rate	≥40 Mbit/s	≥90 Mbit/s	≥360 Mbit/s
	Bandwidth	≥80 Mbit/s	≥260 Mbit/s	≥1 Gbit/s
	RTT	≤20 ms	≤15 ms	≤8ms
	Packet loss ratio	≤1E-5	≤1E-5	≤1E-6

Appendix II

Typical VR use cases

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

II.1 VR service classification

According to the interaction level, VR services can be classified as weak or strong [ITU-T G.1035].

Weak-interaction VR services mainly comprise but are not limited to 360° video, VR theatre and VR live broadcast. In this kind of VR service, users can explore the scene by turning their head; however, they do not interact with the objects present in the scene. For example, touching the entities in the virtual world is not possible.

Strong-interaction VR services include VR games, VR home fitness and VR social networking. Users can interact with these virtual environments through interactive entities (e.g., controllers) in addition to HMD head tracking.

II.2 Use case of cloud VR video

Cloud VR videos refer to VR VoD. The key is cloud-based video content, which is streamed from the cloud to local terminals over networks. Cloud VR videos provide a brand-new watching experience. They are the first type of VR application that most users become familiar with.

Figure II.1 shows the usage scenarios of edge computing-based VR video delivery. Cloud VR services are constructed on both the central and edge clouds. Some of the functions of the rendering and VR engines are deployed on the edge cloud, implementing user-side logic computing and image rendering. The edge cloud is closer to users, meaning lower latency and a more satisfactory real-time interaction experience. VR servers, however, are deployed on the central cloud, implementing other functions of the VR engine and user status synchronization.

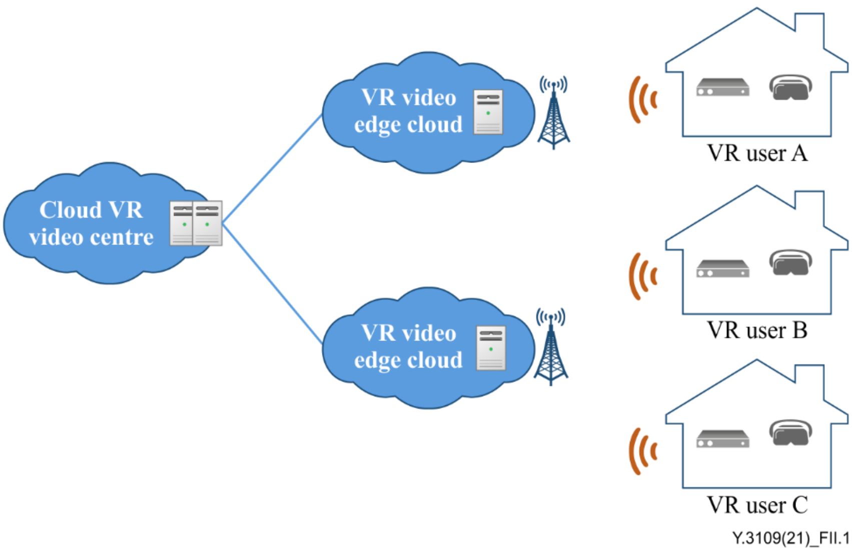


Figure II.1 – Use case of cloud VR video

Parameter examples for typical weak-interaction VR video are listed in Table II.1.

Table II.1 – Parameter examples for typical weak-interaction VR video

Item	Parameters
Full view resolution	4K (3840*1920)
Spatial audio	✓
FoV	90° to 110°
DoF	3
Colour depth	8 bits
Coding	[ITU-T H.264] and [ITU-T H.265]
Frame rate	30 frames/s
Load delay	10 s

II.3 Use case of cloud VR games

Cloud VR gaming is the most typical strong-interaction application and introduces cloud computing technology to VR game platforms. The cloud server performs complex computing and image rendering of games, and compresses them into video and audio streams for transmission over high-speed broadband networks to players' headsets. By transferring the computing and rendering capabilities that VR games require to cloud servers, players no longer need to purchase high-end PCs to obtain a good gaming experience.

Figure III.2 shows the application use case of cloud VR games, which is constructed on both the central and edge clouds. Some of the functions of the rendering and game engines are deployed on the edge cloud, implementing user-side gaming logic computing and image rendering. The edge cloud is closer to users, meaning lower latency and a more satisfactory real-time interaction experience. Game servers, however, are deployed on the central cloud, implementing other functions of the game engine and user status synchronization.

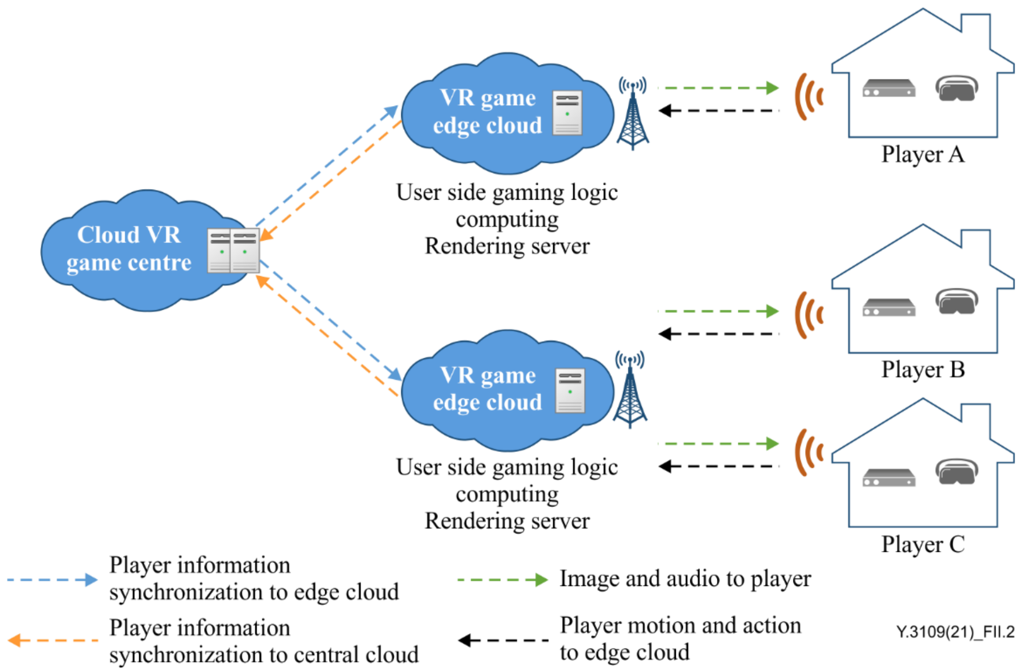


Figure II.2 – Use case of cloud VR games

Parameter examples for typical strong-interaction VR games are listed in Table II.2.

Table II.2 – Example parameters for typical strong-interaction VR games

Item	Parameters
Full view resolution	8K (7680*3840)
Spatial audio	✓
FoV	120°
DoF	6
Colour depth	8 bits
Coding	[ITU-T H.265]
Frame rate	60 frames/s
Load delay	3 s

Appendix III

Guidelines for deployment of VR services using mobile edge computing supported by IMT-2020

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

Logically, VR MEC hosts are deployed in the edge or central DN. The user plane function (UPF) takes care of steering the user plane traffic towards the targeted VR edge in the DN. The locations of DNs and the UPF are a choice of the network operator. The network operator may choose to place physical computing resources based on technical and business parameters, such as available site facilities, supported applications and their requirements, measured or estimated user load [b-ETSI-MEC].

In terms of physical deployment of VR edge, there are multiple options available based on various operational, performance or security-related requirements.

The physical deployment location can be:

1) VR edge and the local UPF collocated with the next generation node B (gNB);
2) VR edge collocated with a transmission node, possibly with a local UPF;
3) VR edge and the local UPF collocated with a network aggregation point;
4) VR edge collocated with the CN.

Figures III.1 to III.4 give some examples of the physical location of the VR edge.

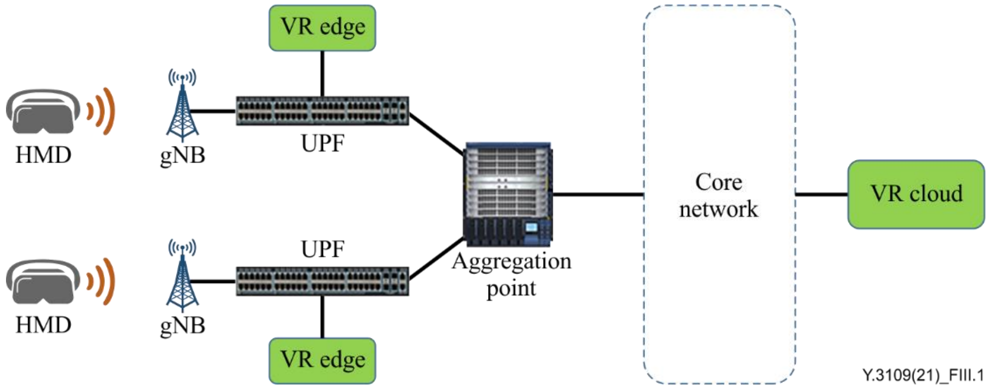


Figure III.1 – Example 1 of VR edge physical deployment

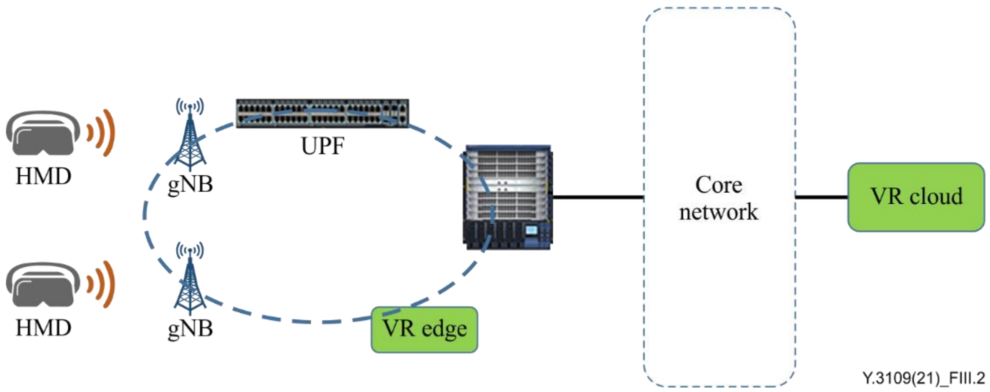


Figure III.2 – Example 2 of VR edge physical deployment

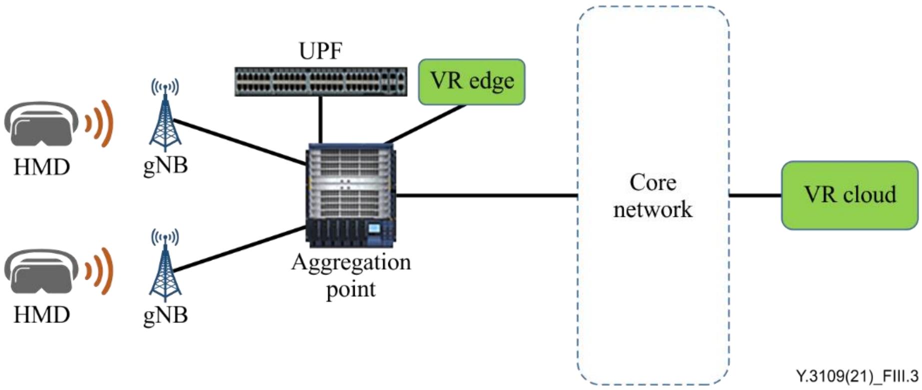


Figure III.3 – Example 3 of VR edge physical deployment

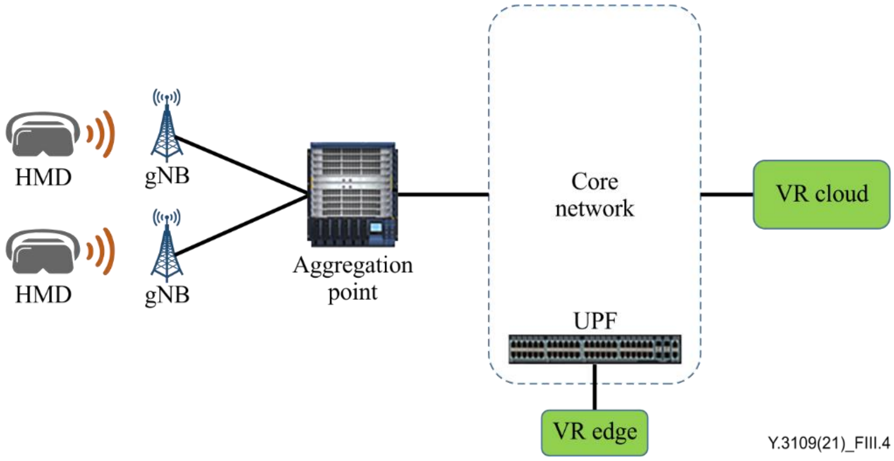


Figure III.4 – Example 4 of VR edge physical deployment

The examples presented in Figures III.1 to III.4 show that the VR edge can be flexibly deployed in different locations from near the gNBs to the central DN. Common for all deployments is the UPF that is deployed and used to steer the traffic towards the targeted VR edge and towards the network.

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