5G Service Experience–Based Network Planning Criteria

In partnership with

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Contents

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Overview

In brief

5G encompasses many different technologies, network build options, and services. The decisions an operator makes when it comes to technologies and build options will greatly impact service performance. Because of this relationship, mobile operators need a set of network performance standards to help them select the right technologies and build options to make sure their 5G networks support the services they want to deliver.

Ovum view

The commercial 5G experience will be an evolutionary one. Mobile operators will start with basic connectivity services, enhanced mobile broadband (eMBB), and fixed wireless access (FWA). As technology and markets evolve, 5G will enable those operators to deliver even more advanced and value-added services. Network planning and deployments must be done in a way that matches the service ambition; this includes understanding performance requirements and building to network standards that support those requirements.

The standards process should begin before starting to build the 5G network. Operators should make it part of their service strategy process and work on enabling as many of those standards as possible on their existing LTE network before deploying the 5G access network. Network performance standards, however, are not static. They will evolve during the lifecycle of the 5G network to meet new use cases and customer performance expectations.

Key messages

- 5G services are in the early stages of development, and service providers need to continue to invest, collaborate, and partner to ensure they develop the kinds of tailored services that make the most of 5G's expanded capabilities.
- Mobile operators need to build their network to support different quantifiable performance standards to ensure they can support different 5G use cases and provide a high quality of experience with those services.
- Operators should develop a 5G service strategy prior to deploying their 5G network. This way, they can build the network to the correct performance standards instead of trying to retrofit their 5G later on to meet service requirements.

5G service opportunities

Streaming video, including cloud-based DVR

Among the main use cases that 5G is set to significantly improve is how customers experience their networks, especially around video services – not simply as currently experienced but also including enhanced video experiences that incorporate augmented reality (AR), virtual reality (VR), and the ability to switch from multiple cameras in real time.

Video performance is the most critical focus area for 5G, mainly because mobile video has grown to represent 67% of total cellular traffic in 2017 and is set to increase to 83% of total mobile data traffic by end-2023, according to Ovum research. Unsurprisingly, service providers and their partners are working toward improving the video experience to take advantage of 5G's speed and capacity benefits over 4G.

AR and VR

AR and VR are among services that 5G's capabilities will make more attractive to end users because of its lower latency than 4G as well as its greater capacity and faster speeds. Indeed, this potential is already being made real. South Korea's LG Uplus is seeing AR and VR services drive usage on 5G networks, with average data usage of 1.3GB per day compared with 400MB per day on LTE, an increase driven in part by an increase in the use of AR and VR services.

Online gaming

Online gaming has already seen significant activity among service providers looking to demonstrate the advantages of 5G over 4G, particularly its lower latency, which online gaming is ideally suited to showcase. Indeed, some 5G operators, such as Sprint, Verizon, Vodafone, and EE, have launched or plan to launch online gaming services from leading gaming developers including Hatch and Niantec to both differentiate in the market around exclusive content and give consumers a clear reason to move to 5G. Partnerships around 5G gaming will give service providers the opportunity to reinforce their brand in the online gaming and esports community, for instance around tournament sponsorship, a route Vodafone has already gone down with its ESL esports partnership. Moreover, moves from major companies such as Google and Apple into subscription mobile gaming services are set to propel online gaming further into the mainstream and accelerate 5G uptake.

The need for network standards

Where to apply standards

There are several network areas where operators need to enforce basic levels of performance standards. Meeting these standards gives operators quantitative network key performance indicators to help them build a better understanding of service key quality indicators, which help operators improve the overall quality of experience. Areas where operators need to apply a minimum level of performance are

- latency
- stall
- packet loss
- bandwidth
- minimum speeds.

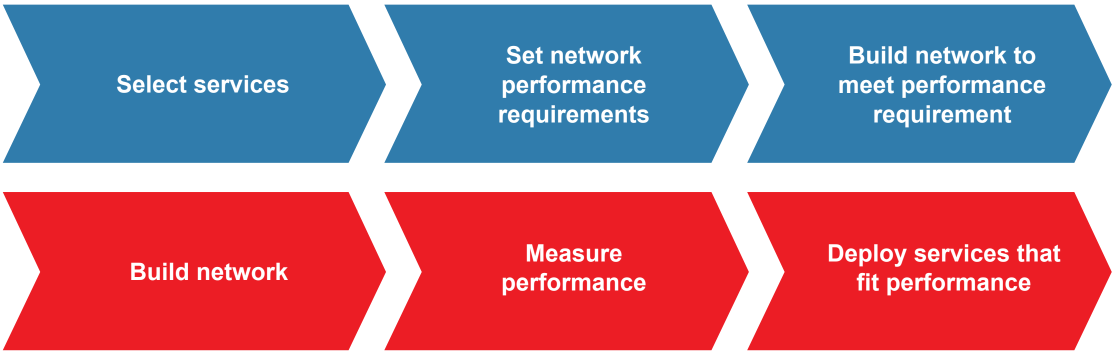
Of course, performance standards vary by service or application. Streaming video will have different network performance requirements than a more interactive experience such as online gaming or virtual reality will. There should be a tight relationship between an operator's network performance and its service strategy.

Role of standards in network build and service selection

There are two approaches operators can take in offering services using network performance standards. An operator can start with developing its 5G service strategy, set network requirements based on performance standards, and then build network to meet those requirements. The other approach is the exact opposite. The operator builds the network, measures network performance, and then deploys services where the network meets performance standards.

Ovum advises taking the first approach, because it gives the operator more control and helps to maximize the network investment. However, network performance and service offering are not locked in with the second approach. An operator can continue to evolve network performance to support new services. Figure 1 below illustrates this relationship.

Figure 1: Relationship between standards, network build, and service selection



Source: Ovum

Benefits of standards

The overall benefit of building a mobile network to a set of performance standards is that it ensures a high quality of service for the end user. This will keep end users happy and discourage subscriber churn to competing operators. It will also create a positive reputation for the mobile operator and its 5G services, which will encourage new end users to subscribe. Ultimately, this will help in monetization of 5G investments.

Building to quantifiable standards also benefits the operator in a multivendor environment. Commonly, operators choose more than one radio, backhaul, and core vendor. Making all these vendors meet a common performance standard will ensure a consistent end-user experience throughout the operator's footprint. This concept can be extended internationally as well. An operator wanting to offer multinational service to enterprise customers can partner with other global operators that also build to a common standard. This will allow for strong performance-based multinational SLAs.

Note: The following sections of this white paper are supplied by Huawei and may not reflect the views of Ovum.

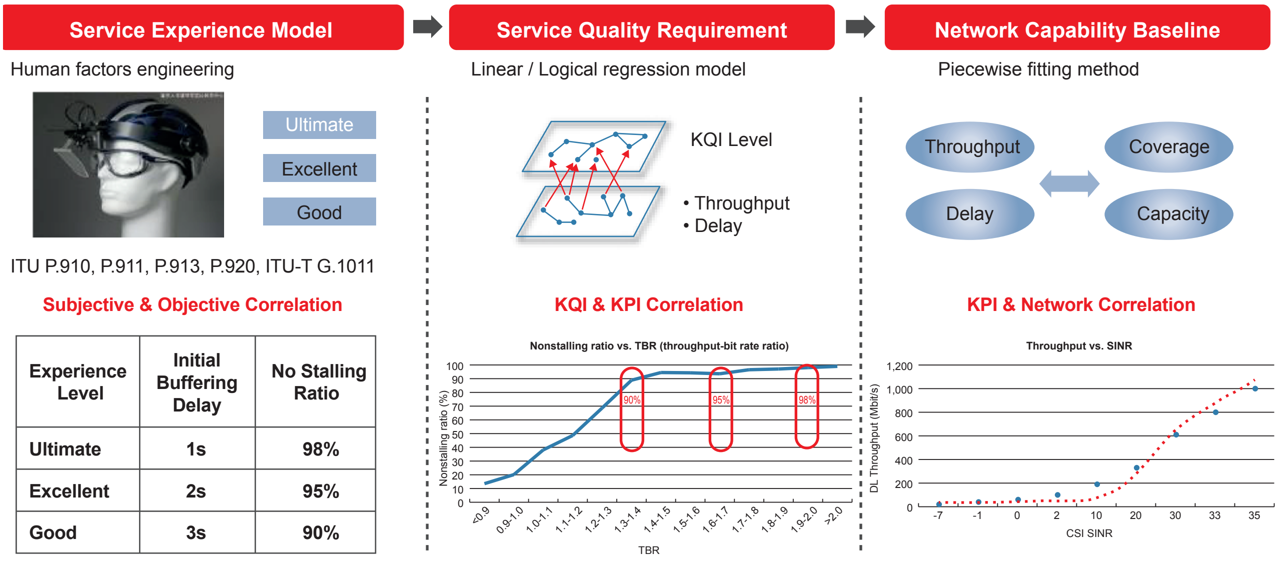
Service experience–based 5G network planning criteria introduction

Overview of service experience–based 5G network planning criteria

With the evolution of the 5G technology and mobile networks, mobile networks need to be transformed from the traditional telecoms service–based network construction model to the service experience–based network construction model (e-planning model) that meets the new digital service experience requirements.

The core of the e-planning model is the six-order logic, including service feature analysis, experience modeling and standardization, experience inflection point and baseline, network impact analysis, experience-based network planning criteria, and experience management (visualized, manageable, and guaranteed). The e-planning model helps implement modeling based on three-layer mapping, that is, from user experience model (experience) to service quality requirement (quality) and then to network capability baseline (network).

Figure 2: Experience-based network planning criteria based on the e-planning model



Experience Level	Initial Buffering Delay	No Stalling Ratio
Ultimate	1s	98%
Excellent	2s	95%
Good	3s	90%

Source: Huawei

The following network planning criteria are established for typical 5G service scenarios based on

- feature analysis and experience modeling of mainstream 2C services (cloud VR and 4K videos) and 2B services (4K live broadcast pushing and video surveillance) of 5G
- a large amount of lab and live-network test data
- three-layer EQN mapping model from service experience to network capabilities.

Table 1: Overview of network planning criteria for typical 5G service scenarios

Service scenario	Network planning criteria							
Scenario	Typical application instance	Device requirements (typical bit rate)	Throughput	Packet loss rate	Millisecond-level peak value	Delay	Coverage level CSI RSRP	Coverage quality CSI SINR
2C	4K on-demand video	5G CPE+large TV screen (VBR: 15Mbps)	30Mbps (downlink)	10^{-3}	N/A (without affecting services)	RTT <100ms	-113dBm	-2dB
	4K live video	5G CPE+large TV screen (VBR: 20Mbps)	40Mbps (downlink)	10^{-3} (with FEC) 10^{-5} (without FEC)	N/A (without affecting services)	RTT <100ms	-110dBm	-1dB
	4K 360-degree VR panoramic video (VR IMAX and VR concert)	All-in-one VR machine (VBR: 40Mbps)	80Mbps (downlink)	10^{-3}	N/A (without affecting services)	RTT <100ms	-108dBm	1dB
		Mobile phone+mini-VR/ glasses (VBR: 15Mbps)	30Mbps (downlink)	10^{-3}	N/A (without affecting services)	RTT <100ms	-113dBm	-2dB
	8K FOV VR video (2D)	All-in-one VR machine Mobile phone+mini-VR (VBR: 50Mbps)	100Mbps (downlink)	10^{-5} (TCP) 10^{-4} (UDP)	N/A (without affecting services)	RTT <25ms	-107dBm	2dB
	3K cloud VR (Game)	All-in-one VR machine (CBR: 50Mbps)	100Mbps (downlink)	10^{-5} (TCP) 10^{-4} (UDP)	500–700Mbps	RTT <25ms	-107dBm	2dB
2B	Surveillance/ UAV pushing (1080p)	HD camera+ pushing device (VBR: 2.5Mbps)	5Mbps (uplink)	10^{-3} (with FEC) 10^{-5} (without FEC)	16–20× burst throughput	RTT <50ms	-105dBm	3dB
	4K live news pushing (30fps)	LiveU pushing backpack (VBR: 20Mbps)	40Mbps (uplink)	10^{-2} (with SRT) 10^{-5} (without SRT)	16–20× burst throughput	RTT <50ms	-95dBm	5dB
	4K live broadcast pushing at CCTV Spring Festival Gala (50fps)	Cogent and digital video pushing backpack (CBR: 42Mbps)	63Mbps (uplink)	10^{-2} (with SRT) 10^{-5} (without SRT)	16–20× burst throughput About 700–800Mbps	RTT <50ms	-91dBm	8dB
	8K live broadcast pushing	OSDE (CBR: 120Mbps)	To be constructed	–	–	–	–	–
	5G campus	–	To be constructed	–	–	–	–	–
	FWA private line	–	To be constructed	–	–	–	–	–
	Cloud PC	–	To be constructed	–	–	–	–	–
	Telemedicine/ education	–	To be constructed	–	–	–	–	–

Source: Huawei

Remarks:

- Table 1 lists the network planning criteria formulated for the air interface that is the key bottleneck. For details about the end-to-end (E2E) planning principles, see "E2E planning principles based on service experience."

- These network planning criteria are based on the air interface load below 20% (light load scenario). The standards for medium-load and heavy-load scenarios will be continuously improved after the 5G network is developed to a certain scale and the live-network data of such scenarios can be obtained.
- In this table, VR 360-degree videos are tested at a fixed point, with a 98% stalling-free rate. Because of platform problems, 8K FOV VR videos have not been tested.

E2E planning principles based on service experience

Unified planning and domain-based design is the core principle, which implements effective cross-domain collaboration and domain-based design.

In E2E planning of service experience–based network construction, the requirements of user experience on the network can be mapped to the baseline requirements such as the E2E throughput, delay, and packet loss rate. Therefore, the E2E planning of service experience–based network construction uses the unified core quality of service (QoS) parameters (throughput, delay, and packet loss rate) as the baseline, and the planning of the wireless network, bearer network, and cloud core network are associated with each other to implement unified planning and domain-based design of the E2E throughput, delay, and packet loss rate.

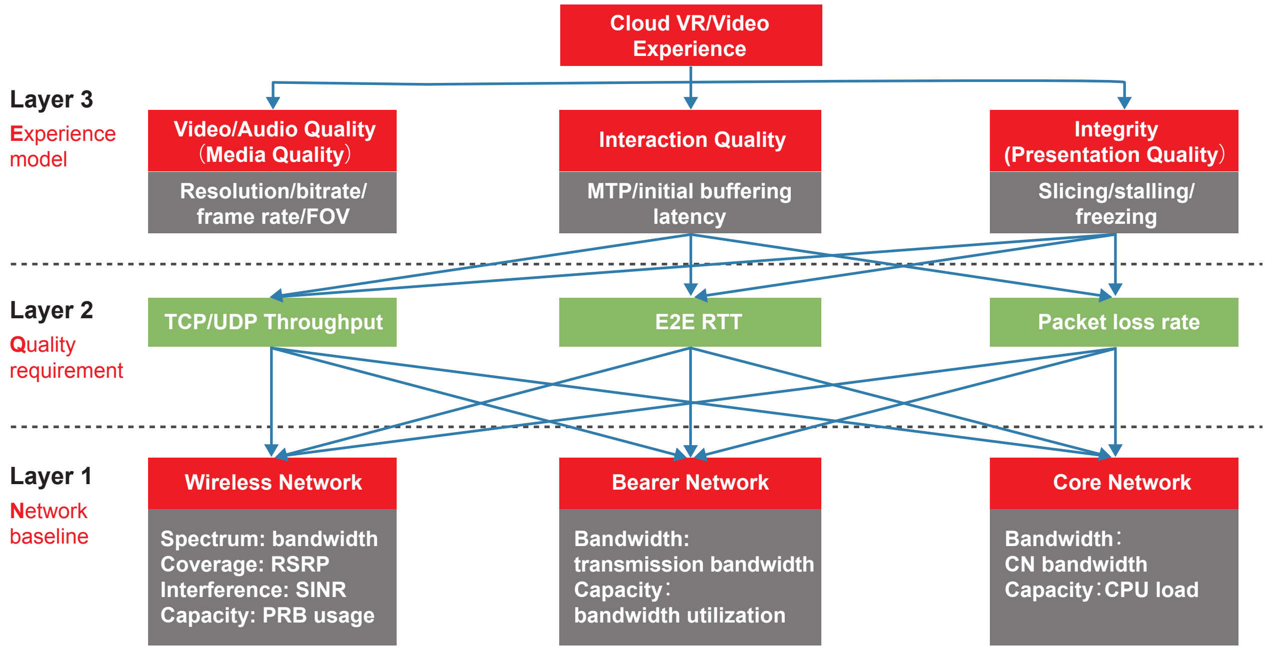
Three-layer EQN mapping modeling from user experience to network capabilities

This chapter describes the modeling methodology from 5G service experience objectives to network capabilities, including mapping methods and examples.

The three-layer EQN mapping modeling from the user experience model to the network capability baseline is completed through the two-step hierarchical mapping modeling process from experience to quality and then to networks. Because of the service experience model and differences between layers, mapping methods between different layers may be independent from each other.

Figure 3 shows the three-layer EQN mapping modeling from the user-experience model to the network-capability baseline.

Figure 3: Three-layer EQN mapping modeling



Source: Huawei

Layer 3: User experience model

Cloud VR experience

The following three key indicators are used to comprehensively evaluate cloud VR user experience based on the VR experience evaluation model suggestions provided in ITU-T G.QOE-VR and 3GPP TR 26.929: media quality index (MQI), interaction quality index (IQI), and presentation quality index (PQI).

- **MQI: Media quality score (0–100).** This indicates whether the sensory stimulation to users brought by the VR content, including the audio, video, and content degrees of freedom (DOF), has been close to the sensory effect in the real world.
  Factors that affect media quality include resolution, frame rate, bit rate, FOV, and PPD. These factors are related to VR content sources and VR devices.
- **IQI: Interaction quality score (0–100).** This indicates the experience of interaction between a user and VR content operations when the user uses the VR service. Interaction delay can cause dizziness, nausea, and isolation from the feeling in the real world.
  The DOF is related to the VR game content sources and devices and is irrelevant to networks. The MTP latency is closely related to networks and needs to be mapped to the lower layer.

Table 2: Key factors affecting the IQI

Factor	Impact
MTP latency	MTP latency refers to the response duration of the video and audio after a user performs an action during VR experience.
DOF	DOF indicates the mode in which an object can move in space. It is a key factor that helps users create an immersive environment.

Source: Huawei

- **PQI: Presentation quality score (0–100).** This indicates the continuous and smooth sensory experience of users when they use the VR service. Poor user experience refers to artifacts and stalling.
  Factors that affect the VR presentation quality include stalling, artifacts, and frame skipping. These factors are related to network capabilities and need to be mapped to the lower layer.

Relationship between the IQI and MTP latency

If the MTP latency is less than or equal to 50ms, the score (96 points) of the IQI is close to the full score. If the MTP latency is less than or equal to 70ms, the score of the IQI is 88 points. If the MTP latency is less than or equal to 80ms, the score of the IQI is 85 points, indicating good user experience. If the MTP latency is greater than 100ms, user experience is poor. It is recommended that the MTP latency be less than 80ms and good user experience be considered as a basic requirement.

4K video experience

The mobile U-vMOS standard defined by Huawei also applies to 4K videos.

Mobile U-vMOS = f(sQuality, sLoading, sStalling)

where
- sQuality = f(resolution, bit rate, encoding mode, encoding level)
- sLoading = f(initial video buffering delay)
- sStalling = f(video-stalling rate).

The video resolution, bit rate, encoding mode, and encoding level are obtained from the negotiation result between the video server and the user device. Therefore, they are irrelevant to network capabilities.

The initial video buffering delay and video-stalling rate depend on the matching between video-quality requirements and network capabilities.

The mapping from the U-vMOS to sQuality, sLoading, and sStalling and then to the initial video buffering delay and video-stalling rate is defined by U-vMOS. The mapping can be obtained by visiting the mLAB website: *http://www.mbblab.com:9090/mobilemos.*

Layer 2: Service quality requirements

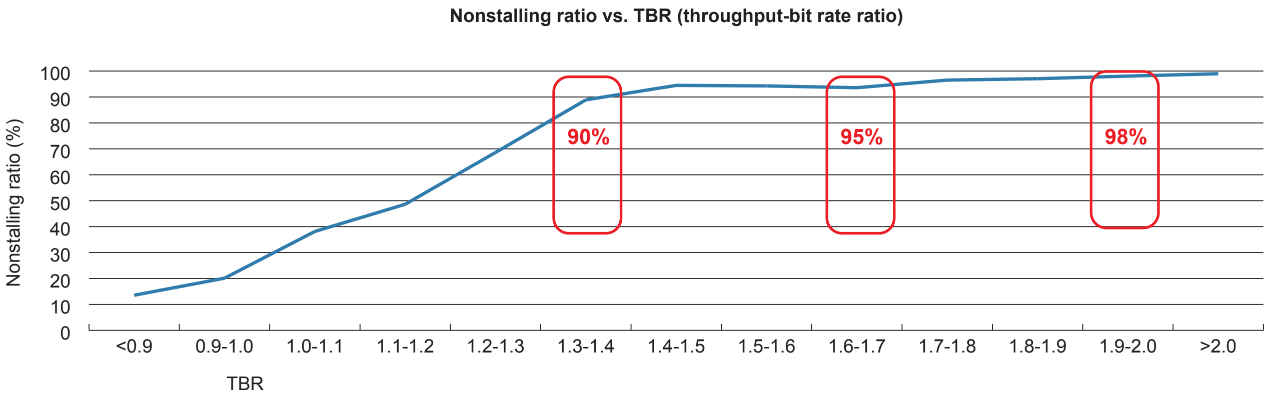
This section describes how to map the initial video-buffering delay/stalling and interactive VR game MTP latency to the E2E RTT/data transmission throughput.

Video TBR model

"TBR model" refers to the throughput-to-bit rate ratio model. According to lab and live-network data analysis, the bandwidth required for video playback depends on the video bit rate. In addition, the bandwidth is the root factor that affects the buffering delay and stalling.

Based on the analysis of a large number of video-play samples (about 700,000) on the live network, it is found that the network bandwidth for a type of video meets a certain throughput-to-bit rate ratio to ensure a certain stalling-free rate.

Figure 4: Mapping between the typical throughput-to-bit rate ratios and stalling-free rates



Source: Huawei

Video services can be considered as throughput-sensitive services.

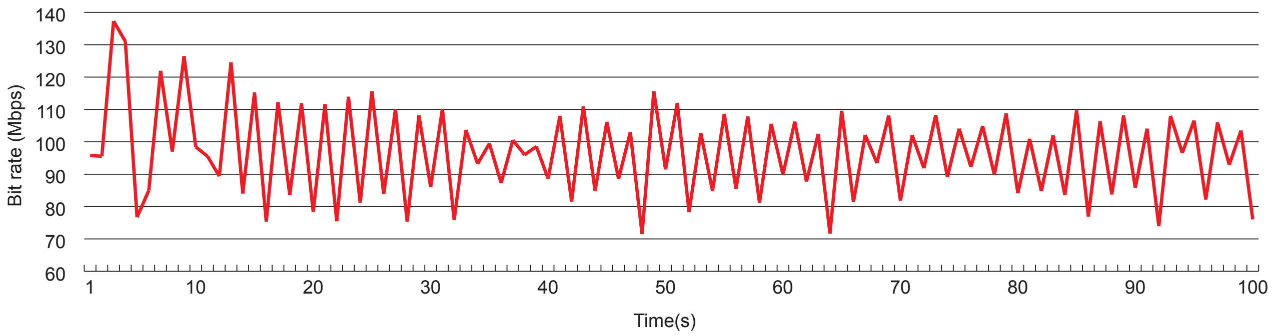
Compared to bit rate with a wide fluctuation range, the mapping between the throughput-to-bit rate ratios and the stalling-free rate is more convergent. Based on this analysis, Huawei proposes the TBR model for throughput-sensitive video services:

$$\text{NonStalling\_Rate} = f\left(\frac{\text{throughput}}{\text{bit rate}}\right)$$

This model framework can be used to study the mapping between different types of videos and network bandwidth requirements. Different types of videos have different requirements on the throughput-to-bit rate ratio. The throughput-to-bit rate ratio required for smooth video playback is determined by the following factors:

- **Fluctuation of the bit rate.** The instantaneous bit rate fluctuates around the average bit rate during video playback. The instantaneous bit rate is high when the video image is rich in details and scenarios are frequently switched. In the contrary case, the instantaneous bit rate is relatively low. In addition, the jitter of the network environment must be considered. Therefore, the bandwidth required for smooth video playback must be higher than the average bit rate of videos.

Figure 5: Typical bit rate for video playback



Source: Huawei

Currently, over-the-top (OTT) and VR videos are encoded based on the VBR, and the bit rate fluctuates greatly. Some live TV programs and VR games are encoded based on the CBR, and the bit rate fluctuates slightly.

- **Video buffering duration.** For on-demand videos, the player has a certain amount of buffer during video playback. When there is no network download, the buffer means normal playback can continue for a certain period (generally 10–30s).

Table 3: Typical features and experience results of on-demand and live broadcast videos

On-demand/ live broadcast	Mode	Live broadcast delay	Perceived initial buffering delay	Stalling duration ratio	Initial buffering time	Maximum prebuffering time during playback	Content fragment duration
On-demand	–	–	1.92s	0.03%	4.2s	125s	5s
Live broadcast	Normal delay	25s	1.85s	0.46%	4.45s	13.6s	5s
	Short delay	9.5s	1.87s	5.50%	2.4s	5.3s	2s
	Ultra-short delay	4.4s	1.89s	19.40%	1.89s	2.6s	1s

Source: Huawei

Remarks:

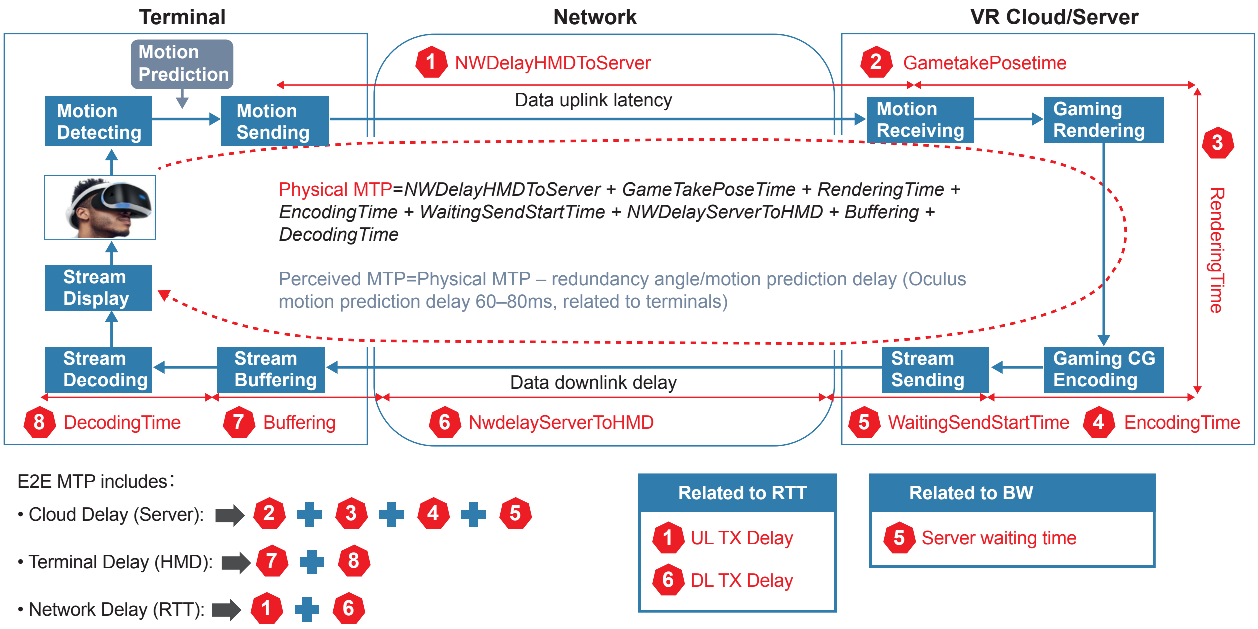
- mLAB obtains the characteristics and experience results of on-demand and live broadcast videos from the live-network test of the top two carriers in country D.
- The three live-broadcast delay modes are defined by YouTube.

During the playback of an on-demand program, inbound traffic is sufficient, and the client can buffer a large amount of video data. This way, temporary insufficient traffic caused by network-quality fluctuation does not affect the playback. During the playback of a live-broadcast program, insufficient inbound traffic and buffering policies on the client side result in less buffered data and higher stalling than during an on-demand program. The initial buffering delay can also be mapped based on the ratio of the stable rate to the bit rate in the initial buffering phase. In addition, the initial buffering delay is related to the network RTT and can be mapped based on different RTT ranges.

Cloud VR game MTP model

According to the lab analysis, the experience on cloud VR real-time interactive rendering games is mainly affected by the action response delay (MTP latency). If the MTP latency is too long, users may feel dizzy and game freezing may occur. MTP latency is an E2E response delay at the application layer, as shown in Figure 6. (Cyber Cloud indicators are used as examples. They are slightly different from Huawei cloud VR indicators.)

Figure 6: MTP latency of a cloud VR game



Source: Huawei

As shown in Figure 6, the E2E MTP model covers the processing delay of three parts, that is, cloud, pipe, and device:

- Cloud processing delay: includes the VR cloud action obtaining delay (2), rendering delay (3), encoding delay (4), and waiting for sending delay (5).
- Pipe processing delay: includes the uplink transmission delay (1) and downlink transmission delay (6). The sum of the two delays is close to the network RTT.
- Device processing delay: includes the buffering delay (7) and device decoding delay (8).

According to the live-network test data, the average value of the total cloud and device-processing delay ((2) + (3) + (4) + (5) + (8)) is about 41ms. The total delay can be considered as a constant A.

Constant A = action obtaining delay + rendering delay + encoding delay +
waiting for sending delay + decoding delay

MTP latency = constant A + uplink transmission delay +downlink transmission delay +
buffering delay = constant A + RTT + *t*

According to the preceding analysis, the following three delays in the MTP latency are directly affected by the pipe capability: uplink transmission delay, downlink transmission delay, and buffering delay. The uplink transmission delay and downlink transmission delay are close to the network RTT, but the buffering delay *t* (stream buffering) is inversely proportional to the data transmission throughput, as shown in Figure 7.

In Figure 7, *t* is calculated using the following formula:

t = data amount of a frame/data transmission throughput

where

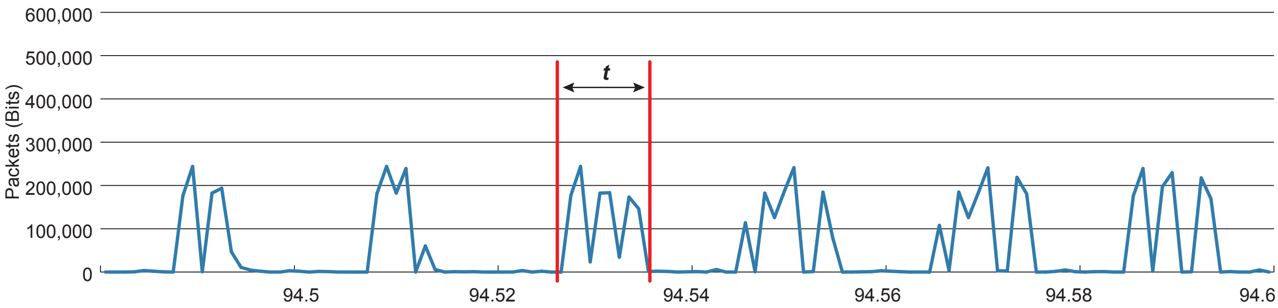
- *t* is the data-receiving delay, that is, buffering delay
- data amount of a frame is the amount of data that needs to be sent after the server encodes each game image frame.

Therefore, in a network, after the server and the device are determined:

MTP latency = constant A (about 41ms for cloud-based devices) + RTT + (game bit rate/frame rate)/network throughput

According to the preceding formula, the MTP latency is directly restricted by the RTT and network bandwidth after the game bit rate and frame rate are fixed. Therefore, optimizing the RTT and throughput is the key to reducing the MTP latency.

Figure 7: Buffering delay *t* and data transmission throughput



Source: Huawei

Layer 1: Network capability baseline

The sections "Layer 3: User experience model" and "Layer 2: Service quality requirements" analyze the requirements of service experience on the throughput and delay. However, the requirements cannot be directly used for radio network planning and must be mapped to coverage and load indicators and used as the direct input for radio network planning.

Currently, most 5G networks mainly analyze the impact of coverage (level and quality) on the throughput and delay.

Throughput requirements on 5G network coverage and interference

- **Analysis of the relationship between the downlink throughput and coverage/interference.** Analyze the downlink throughput scheduling principle. The downlink throughput is directly related to the SINR reported by user equipment (UE). Therefore, the downlink CSI SINR is used as a key indicator for evaluating coverage and interference.

Figure 8 shows the mapping threshold in typical scenarios (3.5GHz, 64T6R, densely populated urban areas, 50% loading load, and 100MHz bandwidth). The mapping threshold is obtained by analyzing the relationship between the downlink edge throughput and SINR based on the actual test data.

- **Analysis of the relationship between the uplink throughput and coverage/interference.** The uplink channel quality of a UE can be indicated by the SINR.

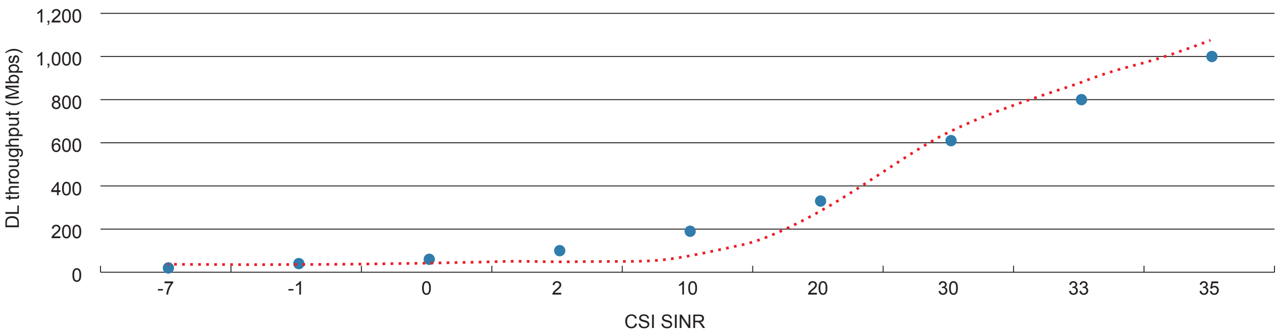
The uplink CSI SINR cannot be tested on the UE side and needs to be replaced by other testable indicators. According to the theoretical calculation and actual test data, the mapping between the uplink CSI SINR and the downlink CSI RSRP is available.

Uplink RSRP = downlink RSRP + UE TxPower - gNodeB TxPower.

That is:

Uplink SINR = downlink RSRP + (UE TxPower - gNodeB TxPower) - (noise + uplink IoT)

Figure 8: Relationship between the downlink throughput and SINR in typical scenarios

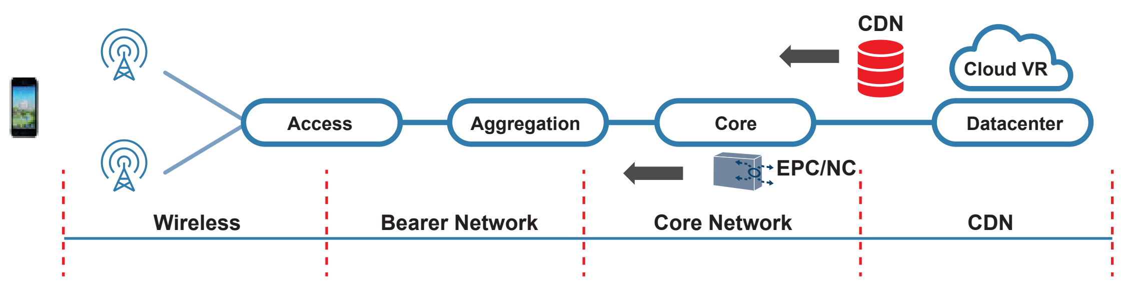


Source: Huawei

Requirements of E2E delay on 5G networks

Based on the 5G network architecture, the E2E delay can be divided into four segments: radio network delay, bearer network delay, core network delay, and server/CDN delay.

Figure 9: E2E delay segmentation on the 5G network



Source: Huawei

In normal cases, the processing delay of the core network and CDN is very short. The delay planning mainly involves the bearer network delay and radio air interface delay.

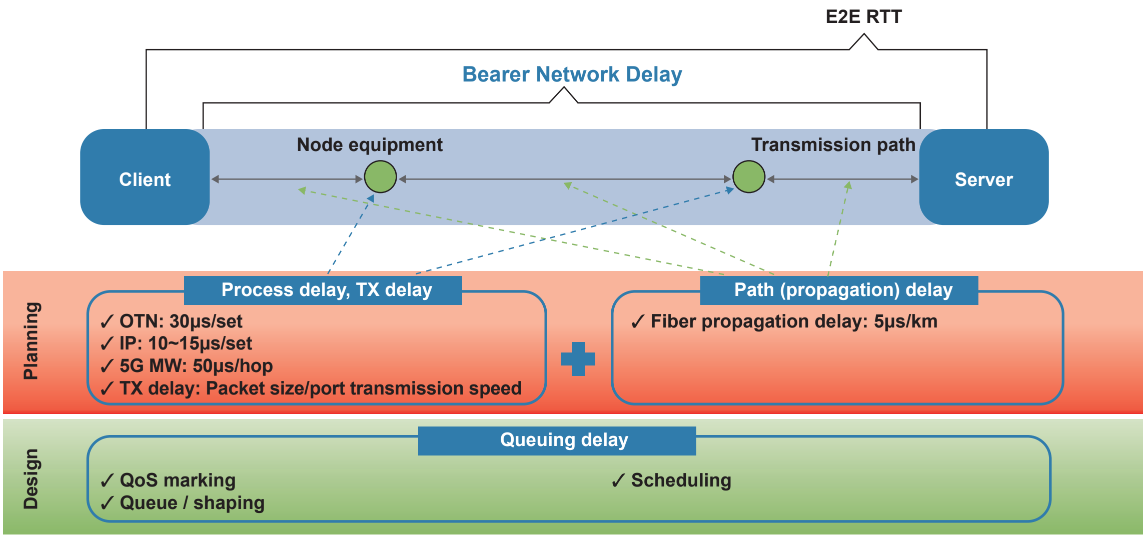
Analysis of the bearer network delay

Figure 10 shows the position where the bearer network delay occurs.

As shown in Figure 10, the bearer network delay consists of the transmission delay, propagation delay, processing delay, and queuing delay. The characteristics of factors causing delays are as follows:

- **Transmission delay (plannable).** The delay of transmitting data bit by bit through the transmission medium depends on the size of the data packet to be transmitted and the transmission throughput (bps).
- **Propagation delay (plannable).** The transmission delay of an optical fiber depends on the refractive index and length of the optical fiber, that is, the transmission distance.
- **Processing delay (measurable and simulatable).** The processing delay indicates the delay for processing data packets inside network devices. For a typical router, the processing delay of each hop is about 20μs to 30μs when no congestion occurs.

Figure 10: Where the bearer network delay occurs



Source: Huawei

- **Queuing delay (measurable and simulatable).** The delay in a network device queue usually depends on the load and congestion degree of a network link, QoS priority of a data packet, and scheduling algorithm.
- **Bearer network medium selection suggestions.** It is recommended that the 5G bearer network use the all-optical networking mode. If microwave link backhaul must be used in some scenarios, it is recommended that microwave link backhaul be used only for accessing a single gNodeB. It is not recommended that microwave link backhaul be used on aggregation or backbone networks. The E-band 80GHz high-frequency solution is recommended (bandwidth: 10–20GHz; transmission distance: 1–3km/hop).

Requirements of air interface delay (air interface RTT) on wireless network coverage and capacity

According to the analysis of the relationship between the air interface RTT and the CSI RSCP/SINR, the impact on the RTT is not obvious if the RSRP is greater than -110dBm; the RTT will deteriorate if the SINR is smaller than 1dB.

The air interface delay is positively related to the network capacity. Currently, the 5G network is unloaded. Therefore, the heavy-traffic lab test data needs to be provided to obtain the mapping between the network load and air interface delay.

VR video experience–based network planning criteria

Main types and service features of VR videos

Cloud VR service scenarios are classified into cloud VR videos and cloud VR games based on the interaction degree.

Based on the transmission mode and content, on-demand VR panoramic videos use the full-view or FOV transmission solution. In the current VR panoramic videos, 4K videos use the full-view transmission solution to reduce the bit rate. The full-view transmission solution is widely used in the initial phase of cloud VR video services. The cloud pushes all 180- and 360-degree video content to devices, and devices are responsible for tracing the change of the user head posture and parsing, rendering, and displaying the locally cached audio and video data in real time. The process from the header posture change to the display exists only on the device side. This ensures that the MTP latency is shorter than 20ms. Other processes are the same as those of common OTT videos. Stalling caused by insufficient bandwidth is the main problem facing this solution.

Requirements of VR video experience on the throughput and delay

Requirements of 4K 360-degree videos and VR IMAX movies on the throughput and delay

On the 5G commercial network, a series of subjective experience tests are performed for encoding policies with different content according to the subjective evaluation method in the VR experience model.

Currently, 5G VR videos are at the initial stage. The recommended bit rates are as shown in Table 4.

Table 4: Recommended bit rates for 5G VR videos in typical scenarios

Scenario	Resolution	Entry-level bit rate	Frame rate	Encoding format
VR IMAX video	1080p	8Mbps	30fps	H.264
	4K	25Mbps	30fps	H.264
360-degree video	4K	40Mbps	30fps	H.264
	8K FOV	15+35Mbps	30fps	H.265

Source: Huawei

Remarks:

- The data is obtained from the test results of the 5G live network of Zhejiang Mobile and Huawei convergent video platform. The H.264 encoding mode is used.

Based on the recommended bit rates and live-network test results, the required VR throughput-to-bit rate ratio is twice the bit rate (stalling-free rate in the static environment: 98%). Based on this, obtain the required throughput. For details, see "VR video experience–based wireless network planning criteria" below.

VR video experience–based wireless network planning criteria

VR video experience–based wireless network planning criteria (HLS)

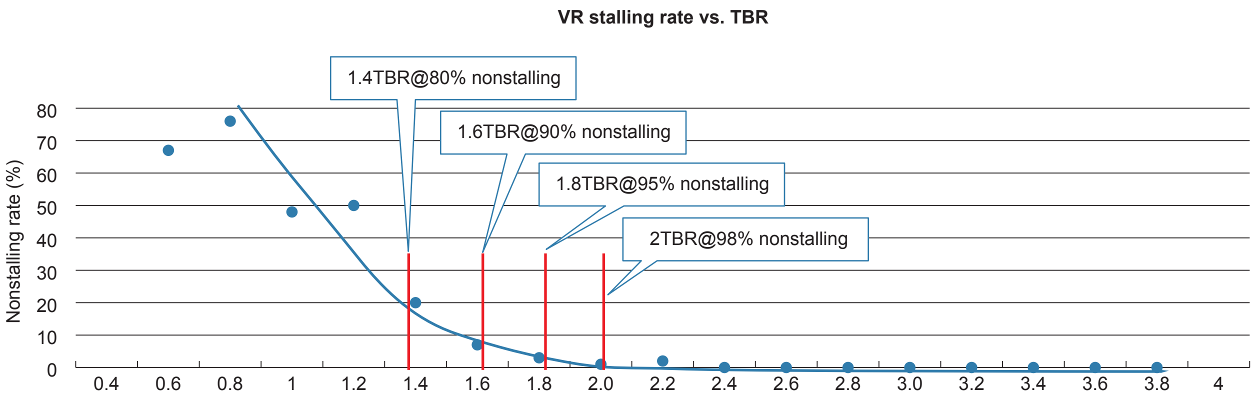
Both 4K 360-degree VR panoramic videos and VR IMAX use the HLS protocol. During playback, service features of such videos are the same on the network side and are the same as those of 4G on-demand videos. Therefore, sample data of these videos is combined and processed together.

Wireless network planning criteria based on lab test data (static and noninterference environment test)

According to the VOD test samples obtained from the live network, when the download throughput is 1.4, 1.6, 1.8, and 2.0 times the average video bit rate, the corresponding stalling-free rate can reach 80%, 90%, 95%, and 98% respectively, at least.

Figure 11 shows the fitted curve of the VR video-stalling rate and the throughput-to-bit rate ratio.

Figure 11: Fitted curve of the VR video-stalling rate and the throughput-to-bit rate ratio in the lab environment



Source: Huawei

Remarks:
- The data is obtained from the indoor distributed lab network, NSA networking, and indoor CQT. The signal is stable. The rate limitation test is performed through the router.
- A total of more than 3,000 samples were collected from April to May in 2019.

According to the previous test results, the recommended bit rate for 4K 360-degree VR videos is 40Mbps. Table 5 lists the recommended bandwidth and coverage requirements.

Table 5: Specifications for network construction based on VR video experience in typical scenarios in the lab environment

Category	Bit rate	Stalling-free rate	Throughput-to-bit rate ratio	Bandwidth	Coverage quality CSI SINR	Coverage level RSRP
4K VR 360 video	40Mbps	90%	1.4	56Mbps	-0.3dB	-110
4K VR 360 video	40Mbps	90%	1.6	64Mbps	0.2dB	-109.5
4K VR 360 video	40Mbps	95%	1.8	72Mbps	0.6dB	-109
4K VR 360 video	40Mbps	98%	2	80Mbps	1dB	-108

Source: Huawei

Remarks:
- For details about the mapping from the bandwidth to SINR, see "Throughput requirements on 5G network coverage and interference."

Cloud VR game experience–based network planning criteria

With the development of a 5G network and industry, cloud VR games are considered to be one of the potential mainstream services in the 5G era. By studying the service features and experience of cloud VR games, we can find the service quality demands (throughput and delay).

There is no sufficient commercial environment for cloud VR games. The sample data used for developing the current network planning criteria is obtained from the OpenLab test environment. After cloud VR games are put into commercial use and popularized on the 5G network, the same modeling mechanism can be used to optimize the experience-based network planning criteria based on the commercial network data.

Key service features of cloud VR games

Cloud VR games are typical cloud-based services. Compared with traditional video services, cloud VR games have higher requirements on the network bandwidth, delay, and packet loss rate. Cloud VR games have the following key features:
- **Millisecond-level pulse.** When the encoding rate is 50Mbps, the millisecond-level peak rate can jump to 200Mbps. Calculate the average number of transmitted packets based on samples collected at the same time point. Two or even 17 packets can be sent per millisecond. The number differs greatly within the same time segment.
- **Fixed packet length.** Game packets are in TCP format, and the length of each packet is fixed at 1,424 bytes.
- **Fixed number of transmitted packets.** There are 4,800 packets sent per second.
- **Fixed encoding rate and frame number.** For example, the encoding rate is 50Mbps, 60 frames are sent per second, and the size of each frame is 0.83Mbps (50Mbps/60).

Requirements of cloud VR game experience on throughput, delay, and packet loss rate

To verify the impact of the throughput and delay on user experience of cloud VR games, two types of tests are performed in the OpenLab: one with limited bandwidth and one with unlimited bandwidth:
- The test with limited bandwidth aims to verify the changes of subjective game experience and MTP latency under different bandwidth configurations and find the inflection point of the impact of the throughput on VR game experience.

- The test with unlimited bandwidth aims to verify the changes of subjective game experience and MTP latency under different packet loss rates and network delays and find the inflection point of the impact of the packet loss and delay on VR game experience.

Figure 12: Network capability vs. MTP and experience

Source: Huawei

The key conclusions of the cloud VR game test on service quality requirements are shown in Table 6.

Table 6: Service quality requirements on cloud VR games

Content	Bandwidth	Packet loss rate	Network delay
Cyber Cloud (TCP)	≥2×bit rate	≤0.001%	<25ms
Cyber Cloud (UDP)	≥2×bit rate	≤0.01%	<25ms

Source: Huawei

Cloud VR game experience–based wireless network planning criteria

Table 7: Key specifications for wireless network construction based on cloud VR game experience							
Service scenarios				Network requirements		Coverage standard	
Service type		Typical application instance	Device requirements	Guaranteed bandwidth	Delay	Coverage level CSI RSRP	Coverage quality CSI SINR
Downlink service	3K cloud VR game bit rate: 50Mbps/ TCP	Cloud VR games and VR education	All-in-one VR machine	100Mbps (downlink)	RTT <25ms	-107dBm	2dB
Source: Huawei							

Remarks:
- The preceding wireless network planning criteria are developed based on data in the OpenLab test environment. The commercial environment will be continuously improved after services are put into commercial use.

4K live broadcast experience–based network planning criteria

Features of the 4K live broadcast service

Resolution and bit rate

The 4K standard is also called "ultra-high definition" or "ultra-HD" and is used for displays that have an aspect ratio of 16:9 or wider and can present native videos at a minimum resolution of 3,840×2,160 pixels.

The bit rate of 4K VOD videos is about 15Mbbps. TV stations and carriers have higher requirements on 4K video service quality during live broadcast. The average bit rate (about 20Mbps) of 4K live broadcast videos is about 20–50% higher than that of internet videos with the same resolution and frame rate. CCTV 4K live broadcast (for example, CCTV Spring Festival Gala live stream) has higher pushing requirements. Generally, the bit rate must be 42Mbps. Table 8 lists the service features in typical 4K live broadcast scenarios.

Live broadcast timeliness (delay)

Live broadcast timeliness (delay) refers to the delay from video image generation to video consumption. No unified standard is available for live broadcast timeliness in the industry. Currently, the commonly used video timeliness rating standards are classified as follows:
- **Pseudo real-time (noninteractive) live broadcast.** The video consumption is delayed for more than 3s.
- **Quasi real-time (weak interactive) live broadcast.** The video consumption is delayed for 1–3s.
- **Real-time (interactive) live broadcast.** The video consumption is delayed for less than 1s, and the average delay is 500ms.

Currently, OTT noninteractive live broadcast is pseudo live broadcast with long delay.

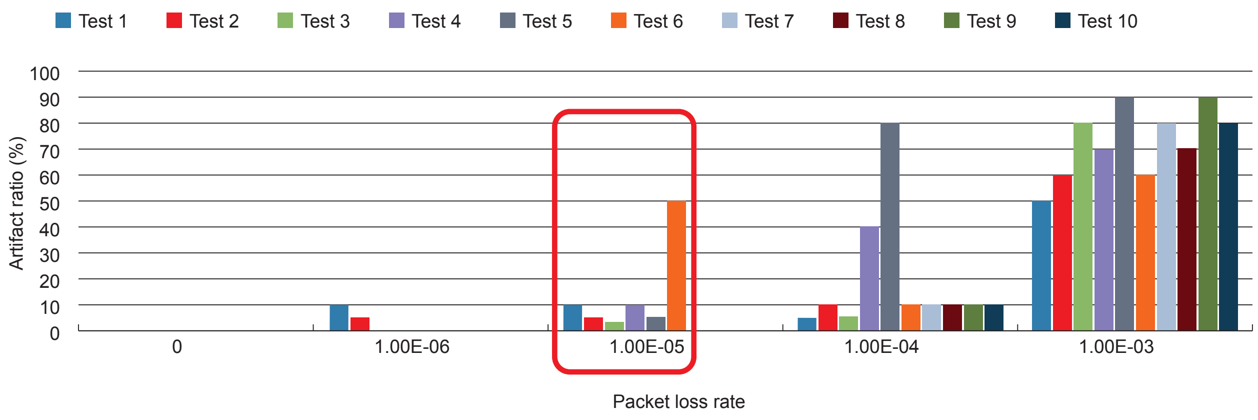
Broadcast and television stations and carriers have higher requirements for noninteractive live broadcast. The delay defined for live broadcast is less than 2s. The delay requirements for CCTV 4K live broadcast are stricter at 1s.

Service quality requirements of 4K live broadcast

4K live broadcast playback (stream pulling)

The 4K live broadcast service uses the UDP transmission mode to meet real-time requirements. If no forward error correction (FEC) redundancy or retransmission (RET) mechanism is available, user experience is sensitive to network fluctuation. When the packet loss rate is greater than 10^{-5}, artifacts occur.

Figure 13: Relationship between the artifact ratio and packet loss rate according to the EDN lab test



Source: Huawei

In addition, the test result shows that the bandwidth required for watching 4K live broadcast programs is 1.5–2× the bit rate. When the network bandwidth is two or more times the bit rate, no artifact or stalling occurs.

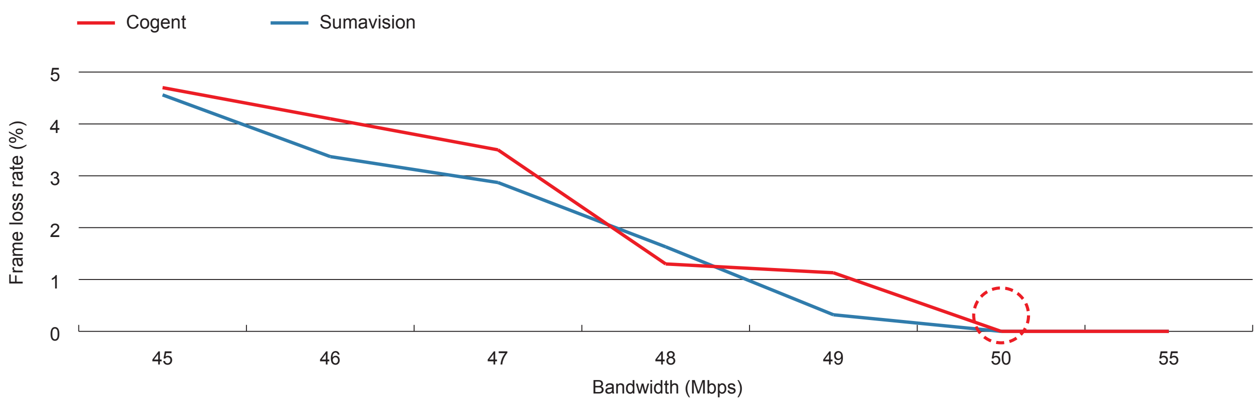
4K live broadcast (stream pushing)

Because of real-time requirements, 4K live broadcast pushing also uses the UDP transmission mode. If no reliability protection mechanism is available, 4K live broadcast pushing is also sensitive to network fluctuation and requires that the packet loss rate be lower than 10^{-5}.

After 2Q19, mainstream 4K pushing backpack vendors, such as Cogent, Sumavision, and LiveU, developed reliable UDP transmission technologies, including FEC and SRT (ARQ):

- **Network bandwidth.** When the bit rate is 42Mbps (CBR), if the uplink bandwidth is lower than 50Mbps, frame loss occurs. If the uplink bandwidth is higher than 50Mbps, frame loss does not occur. Considering the fluctuation of the uplink throughput of the wireless network, it is recommended that the bandwidth be 1.5× the bit rate to ensure the smooth 4K live broadcast pushing experience.
  When the adaptive dynamic bit rate is used, the initial bit rate is 20Mbps. The uplink bandwidth must be higher than 40Mbps (about twice the bit rate).

Figure 14: 4K live broadcast pushing requirement for PLR

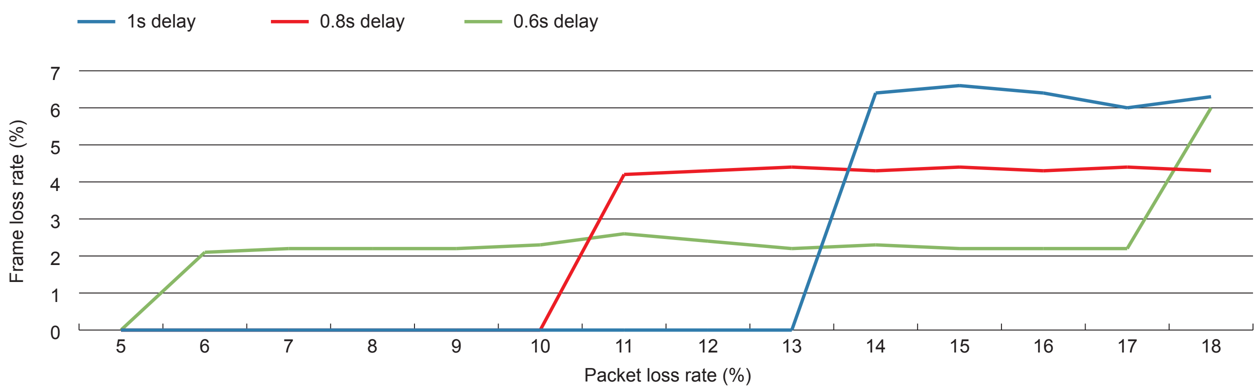


Source: Huawei

• When the uplink bandwidth is higher than 40Mbps, the 4K live broadcast pushing quality is stable. When the uplink bandwidth is lower than 40Mbps, the live broadcast bit rate decreases adaptively and the definition decreases. However, the pushing quality is still stable and no artifact occurs. When the bandwidth is lower than 10Mbps, mosaics occur.

- **Network RTT.** According to the test results of Cogent and Sumavision, the network RTT required by 4K live broadcast pushing is about 110ms when the live broadcast delay is set to 1s. If the live broadcast delay is 0.6s or 0.8s, the RTT is smaller but cannot be smaller than 50ms.
  However, LiveU devices have a higher requirement on the network RTT, that is, 50ms when the delay is 1s.
- **Packet loss rate.** After using reliable UDP transmission technologies such as SRT, Cogent and Sumavision reduce the requirement on the packet loss rate. That is, before such technologies are used, the required packet loss rate must be lower than 10^{-5}. After such technologies are used, the required packet loss rate need only be lower than 10^{-2}. According to the lab test results, the acceptable packet loss rates are 13%, 10%, and 5% respectively when the delay is set to 1s, 0.8s, and 0.6s.
  LiveU uses redundancy coding and has low requirements on the packet loss rate. That is, the packet loss rate only needs to be lower than 8.5%.

Figure 15: 4K live broadcast pushing requirement for PLR



Source: Huawei

4K live broadcast experience–based wireless network planning criteria

Table 8: 4K live broadcast stream pulling requires sufficient downlink bandwidth, and 4K live broadcast pushing requires sufficient uplink bandwidth

Service scenario	Device vendor	Typical bit rate	Frame rate	Network bandwidth	Packet loss rate	Millisecond-level peak value	Delay	Coverage level CSI RSRP	Coverage quality CSI SINR
4K live broadcast video (stream pulling)	Huawei hybrid video platform	20Mbps	30fps	40Mbps, which is 2× the bit rate	10^{-3} (with FEC coding) 10^{-5} (without FEC coding)	N/A (without affecting services)	<100ms	-110dBm	-1dB
4K live news pushing	LiveU	20Mbps	30fps	40Mbps, which is 2× the bit rate	10^{-2} (with FEC coding) 10^{-5} (without assurance)	300–400Mbps, which is 15–20× the bit rate (burst increase) above the base station	<50ms	-95dBm	5dB
CCTV Spring Festival Gala live stream pushing	Cogent and Sumavision	42Mbps	50fps	63Mbps, which is 1.5× the bit rate	10^{-2} (with SRT assurance) 10^{-5} (without assurance)	700–800Mbps, which is 15–20× the bit rate (burst increase) above the base station	<50ms	-91dBm	8dB

Source: Huawei

Remarks:

- The preceding network coverage standards are based on 64T64R, 4:1 timeslot configuration, 100Mbps bandwidth, and 1:1 5G/4G site deployment.

Currently, the 5G wireless network planning criteria are obtained based on the network with light load. After the network data for network planning criteria is obtained based on the network with medium or heavy load, this document will be further optimized.

Appendix

Further reading

Business Consulting Dept. (August 2018) *5G Service Requirement and Business Mode*

User Experience Lab (eLab) (June 2019) *Technical White Paper for 5G VR Service Experience Modeling*

X Labs (June 2019) *Huawei-CN-Cloud VR PI*

Fixed Network Application Scenario Lab (iLab) (June 2018) *Experience-driven Video Bearer Network White Paper (2018)*

X Labs (August 2019) *5G 4K Live Broadcast Service Analysis and Network Impact Report*

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