# ETSI GS F5G 015 V1.2.1 (2024-03)

GROUP SPECIFICATION

# Fifth Generation Fixed Network (F5G);
# F5G Residential Services Quality Evaluation and Classification
# Release 2

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# Foreword

This Group Specification (GS) has been produced by ETSI Industry Specification Group (ISG) Fifth Generation Fixed Network (F5G).

# Modal verbs terminology

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# 1 Scope

The present document specifies the service KQIs for evaluating user experience for fixed residential services. The corresponding evaluation criteria and the calculation methodology are specified using MOS values. To achieve a good user experience, network KQIs are specified and dedicated network KQI thresholds are defined for different network services.

# 2 References

## 2.1 Normative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

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NOTE: While any hyperlinks included in this clause were valid at the time of publication, ETSI cannot guarantee their long term validity.

The following referenced documents are necessary for the application of the present document.

[1] ETSI GS F5G 005: "Fifth Generation Fixed Network (F5G) F5G High-Quality Service Experience Factors Release#1".

[2] Recommendation ITU-T P.10: "Vocabulary for performance, quality of service and quality of experience".

[3] European Union EUR 30789 (2021): "Code of Conduct on Energy Consumption of Broadband Equipment".

[4] IEEE 802.11™/1234r0-2018: "Real-time Mobile Game vs Wi-Fi".

[5] ETSI TS 102 250-1: "Speech and multimedia Transmission Quality (STQ); QoS aspects for popular services in mobile networks; Part 1: Assessment of Quality of Service".

## 2.2 Informative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

NOTE: While any hyperlinks included in this clause were valid at the time of publication, ETSI cannot guarantee their long term validity.

The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

[i.1] Recommendation ITU-T P.800: "Methods for subjective determination of transmission quality".

[i.2] Broadband Development Alliance (BDA) 2021: "White paper: QoE classification of Residential network service".

[i.3] BBF TR126: "Triple-play Services Quality of Experience (QoE) Requirements".

[i.4] Broadband Development Alliance (BDA) 2021: "White paper: Gigabit high quality service experience and network optimization".

[i.5] ETSI GS F5G 004: "Fifth Generation Fixed Network (F5G); F5G Network Architecture".

[i.6] CCSA YD/T 1154-2020: "Network Technical Requirements of Cloud VR based on Telecommunication Networks".

[i.7] Recommendation ITU-T G.107: "The E-model: a computational model for use in transmission planning".

[i.8] Recommendation ITU-T P.863: "Perceptual objective listening quality assessment".

[i.9] ISO/IEC 29199-2:2020: "Information technology -- JPEG XR image coding system -- Part 2: Image coding specification".

[i.10] CNNIC 2021: "The 47th China statistical report on internet development".

[i.11] ETSI GR F5G 001: "Fifth generation fixed network (F5G); F5G generation definition release #1".

[i.12] CCSA YD/T 3341-2018: "Scoring method for evaluating the quality of broadband web/video/bandwidth-measurement service and network".

[i.13] CCSA YD/T 1071-2006: "Technical requirements for IP telephony gateway".

[i.14] CCSA YD/T 3778-2020: "The live algorithm and parameter for the user experience assessment of broadband video service".

[i.15] CCSA YD/T 3779-2020: "The VOD algorithm and parameter for the user experience assessment of broadband video service".

[i.16] CCSA YD/T 2026-2009: "The technical requirement and evaluation method for quality of IP telephony".

[i.17] ETSI TS 102 250-2: "Speech and multimedia Transmission Quality (STQ); QoS aspects for popular services in mobile networks; Part 2: Definition of Quality of Service parameters and their computation".

[i.18] ETSI TR 103 702: "Speech and multimedia Transmission Quality (STQ); QoS parameters and test scenarios for assessing network capabilities in 5G performance measurements".

[i.19] ETSI TR 101 578: "Speech and multimedia Transmission Quality (STQ); QoS aspects of TCP-based video services like YouTube™".


# 3 Definition of terms, symbols and abbreviations

## 3.1 Terms

For the purposes of the present document, the following terms apply:

**Key Quality Indicator (KQI):** QoS metrics, which are important and have a major impact on the QoE of applications and networks

**Mean Opinion Score (MOS):** mean of the values on a predefined scale that users assign to their opinion of the performance of a system quality

NOTE: See Recommendation ITU-T P.10 [2].

**network KQI:** quantitative indicator of the functionality and performance of the F5G network

**Quality of Experience (QoE):** subjective measure of performance of applications or services that relies in human opinion on the perceived quality

**Quality of Services (QoS):** assessment of the overall transmission chain from a user's perspective is considered to deliver the Quality of Service in an objective manner

NOTE: See ETSI TS 102 250-1 [5].

**service KQI:** quantitative indicator of service or application quality in F5G network

NOTE: Service KQI defined in the present document is similar to the definition of the QoS indicators in ETSI TS 102 250-1 [5].

**telework:** practice of working from home, making use of residential internet, email, telephone, etc.

**vocoder:** category of speech coding that analyses and synthesizes the human voice signal for audio data compression, multiplexing, voice encryption or voice transformation

## 3.2 Symbols

Void.

## 3.3 Abbreviations

For the purposes of the present document, the following abbreviations apply:

| | |
|---|---|
| AP | Access Point |
| APFF | Average Percentage of Frame Freezing |
| BES | Black Edge and Smearing |
| BNG | Broadband Network Gateway |
| BSAR | Blurred Screen Area Ratio |
| BSR | Blurred Screen Ratio |
| CCR | Call Completion Rate |
| CDN | Content Delivery Network |
| CDR | Call Drop Rate |
| CoC | Code of Conduct |
| CPU | Central Processing Unit |
| CSD | Channel Switching Delay |
| CST | Call Setup Time |
| DDoS | Distributed Denial of Service |
| DNS | Domain Name Server |
| DRR | Download Rate Ratio |
| DTR | Desynchronization Time Ratio |
| E2E | End to End |
| E-ONU | Edge ONU |
| EPG | Electronic Programme Guide |
| ETH | Ethernet |
| FFT | Frame Freezing Times |
| FFTR | Frame Freezing Time Ratio |
| FLT | Full Load Time |
| FOV | Field Of View |
| FSDT | First Screen Display Time |
| FTTR | Fibre-To-The-Room |
| GE | Gigabit Ethernet |
| GI | Guard Interval |
| GUI | Graphical User Interface |
| HD | High Definition |
| IBD | Initial Buffering Duration |
| ID | Interaction Delay |
| IE | Interactive Experience |
| ILD | Initial Loading Duration |
| IP | Internet Protocol |
| IPTV | Internet Protocol Television |
| KQI | Key Quality Indicator |
| LAN | Local Area Network |
| LQID | Low-Quality Image Display |
| MOS | Mean Opinion Score |
| MPEG | Moving Picture Experts Group |
| NCBPS | Number of Coded Bits Per Symbol |

| | |
|---|---|
| NST | Network Start-up Time |
| O&M | Operation & Management |
| OLT | Optical Line Termination |
| ONU | Optical Network Unit |
| ORD | Operation Response Delay |
| POLQA | Perceptual Objective Listening Quality Analysis |
| PON | Passive Optical Network |
| P-ONU | Primary ONU |
| PRT | Page Response Time |
| QoE | Quality of Experience |
| QoS | Quality of Service |
| RGW | Residential Gateway |
| RTT | Round-Trip Time |
| RWV | Relative Weighted Value |
| SD | Standard Definition |
| SDR | Stalling Duration Ratio |
| STA | Station |
| TCP | Transmission Control Protocol |
| TV | Television |
| URL | Uniform Resource Locator |
| URR | Upload Rate Ratio |
| USB | Universal Serial Bus |
| VE | Viewing Experience |
| VOD | Video On Demand |
| VoIP | Voice over Internet Protocol |
| VR | Virtual Reality |
| WAN | Wide Access Network |
| XGPON | 10-Gigabit Passive Optical Network |

# 4 Introduction

## 4.1 Overview

The present document specifies the service KQIs for a set of residential applications and services. Such service KQIs reflect the service quality. To have a quantitative evaluation of service KQIs, a corresponding MOS calculation and evaluation criteria are specified. To achieve good service quality, a certain level of F5G network performance and functionality is necessary. Network KQIs are specified to quantify the network in terms of F5G network performance and functionality. Depending on the service, a certain level of network performance is required.

There are a number of service KQIs indicating QoS [1] specified by other organizations or newly defined in the present document:

a) Voice [1] and [2]: call completion ratio, call setup time, conversational quality, call drop rate.

b) Web browsing [i.2]: page response time, first screen display time, full load time.

c) Data upload/download: download rate ratio, upload rate ratio.

d) IPTV [i.2]: indicators of interactive experience, indicators of viewing experience.

e) On-line game [1] and [i.2]:

- terminal-based rendered game: network start-up time, Operation Response Delay (ORD), desynchronization time;

- cloud-based rendered game: frame freezing time ratio, Operation Response Delay (ORD).

f) On-line education/telework [i.2]: frame freezing times, frame freezing time ratio, interaction delay.

g) Cloud VR [1]:

- Cloud VR video: initial buffering duration, Average Percentage of Frame Freezing (APFF), low-quality image display.
- Cloud VR game: black edge and smearing, Average Percentage of Frame Freezing (APFF), operation response latency.

NOTE: The KQI for data upload/download is newly defined in the present document.

The method to quantify service KQIs is based on MOS values, which reflect the user experience. They are defined in clause 7.

A number of network KQIs are used to support the measurement of the services quality which are as follows:

a) Throughput: the maximum transmission data rate of residential system.

b) Latency: the E2E communication time interval between request and response.

c) Connectivity: the connected number of stations to the access point.

d) Handover: the connection switch between different access points.

e) Green: the power consumption of devices.

f) Security: network security of residential network.

g) Smart O&M: smart operation & management of residential network.

Based on the network demand of different service, the network service has been classified into different levels. For example, typical 100 Mbps throughput is enough for the service in L0 while gigabit throughput is necessary for the service L1 and L2. More strict latency boundary is required in L2 service:

a) Level 0 (L0): voice, web browsing, SD and HD video, upload/download.

b) Level 1 (L1): terminal-based on-line game, 4K video, on-line education/Telework.

c) Level 2 (L2): cloud VR, 8K video, cloud-based on-line game.

The detailed network requirements are specified in clause 8.

The framework of user experience evaluation for residential broadband services is shown in Figure 1. To achieve the evaluation, several aspects are considered as follows:

1) The service KQI for residential services listed above are used to estimate the user experience from a user's perspective, shown in the upper left corner of Figure 1.

2) MOS value as quality scoring mechanism is used to quantify the service KQI, shown in the right-hand side of Figure 1. First, MOS value is calculated for each KQI in a dedicated service. Second, a comprehensive MOS value is created for the dedicated service. Finally, the MOS value for the residential network should be estimated by the combination of the MOS value of different service.

3) To support good user experience as perceived by the users, the network KQI listed above is specified as the basis to ensure enough network capability. The detailed network requirements are discussed for different levels of service classification.

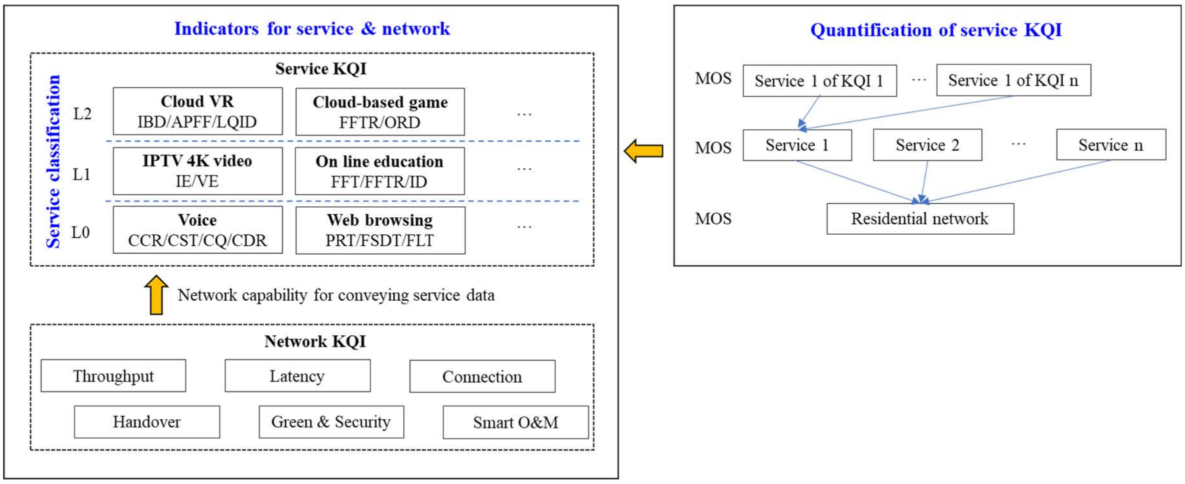



**Figure 1: The framework of user experience evaluation**

## 4.2 Motivation

The present document could be leveraged by the end user to evaluate their residential network and thus improve it by updating the network hardware, optimizing networking topology and so on. According to the service, providing to the end users, the service operator could utilize the present document as a reference to build up a residential network to enable good user experience. To target a good user experience, the system vendor or chipset vendor could develop specific technologies based on the experience issues. Obviously, further measurement methodology or measurement tool could be developed according to the content of the present document.

## 4.3 Document structure

Clause 4 introduces the context of the present document, including the motivation and framework. Clause 5 specifies the individual service KQIs for specific network services while network KQI is specified in clause 6. The evaluation methodology described in clause 7 specifies concrete formulas and algorithms for calculating the MOS value for each service KQI. In clause 8, the classification of network service and corresponding network requirements are then discussed based on the network demand of various service.

# 5 Service KQIs

## 5.1 General description

This clause describes the selected services for evaluation and their associated parameters. The present document focuses on the following types of services, for service quality evaluation:

- Voice.
- Web browsing.
- Upload/download.
- IPTV.
- On-line game:
    - Terminal-based rendered game: it is when the majority of computation of graphics rendering and data processing is conducted by the local terminal device.
    - Cloud-based rendered game: it is when the majority of computation of graphics rendering and data processing is conducted by the cloud server.

- On-line Education/Telework.
- Cloud VR:
  - Cloud VR Video.
  - Cloud VR Game.

The network influences the user experience. When determining service quality indicators, consideration is given to how the network affects the user experience. A number of service KQIs are defined in both ETSI and ITU, the present document refers to these relevant standards. Other service KQIs are defined in the present document in order to specify appropriate evaluation methods.

## 5.2 Telephony

### 5.2.1 Voice service KQIs overview

Quality of Experience (QoE) indicators for telephony are described in various standardization organizations such as ETSI TS 102 250-2 [i.17], and ITU-T P series [2] and [i.1]. The present document describes indicators closely related to the user experience as the basis for service evaluation methods. Telephony Service KQIs include:

- Call completion ratio.
- Call setup time.
- Call drop rate.
- Conversational quality.

### 5.2.2 Call completion ratio

Call completion ratio [i.17] is the percentage of calls that are completed relative to the number of calls initiated by the calling subscriber. The total number of calls initiated by the calling subscriber does not include the calls lost due to the calling subscriber error, such as mis-dialling and quitting midway. The number of completed calls includes the number of calls in which the called subscriber answers, does not answer, is busy, is powered off, rejects the call, and the line is locked.

### 5.2.3 Call setup time

Call setup time [i.17] is the time interval between when a calling subscriber dials the last called number and when the calling subscriber receives a network response. The network response can be a signal tones such as ring tone and busy tone, terminal prompt tone, and recording notification.

### 5.2.4 Call drop rate

The call drop rate [i.17] is the percentage of calls that are dropped after the network connection has been established.

### 5.2.5 Conversational quality

Recommendation ITU-T P10 [2] shows conversational quality as experienced in a bi- or multidirectional conversation. The Telephony Service KQI shall use the Mean Opinion Score (MOS) method as defined in Recommendation ITU-T P.800 [i.1] to evaluate the conversational voice quality. In Recommendation ITU-T P.800 [i.1], a number of participants are invited to listen to the same speech sample and then the conversational quality of this sample is evaluated. Through the MOS method, the conversational quality can be evaluated subjectively, and a specific telephony sample can be scored subjectively.

## 5.3 Web browsing

### 5.3.1 Web browsing service KQIs overview

Web browsing is one of the basic Internet applications from a user perspective. Page response time, first screen display time and full load time are the key indicators [i.17], [i.2] in F5G network.

### 5.3.2 Page response time

The page response time of the user accessing a web page (DNS resolution is required) is calculated between the time that the user initiates an access instruction on the terminal (i.e. for desktop/mobile browser (via Wi-Fi®): entering the URL address and pressing Enter) and the time the user receives the first response packet with a content payload.

### 5.3.3 First screen display time

The first screen display time is defined as follows. The user accesses the page (DNS resolution is required). The user initiates an access instruction on the terminal. (Enter the URL address in the desktop browser and pressing Enter, or Enter the URL address in the mobile browser (via Wi-Fi®) and pressing Enter.) The time period from when the browser sends a request message to when the data returned by the website fills the screen of the user terminal for the first time.

NOTE: For comparing measurements of this KQI, the same terminal device is recommended to be used.

### 5.3.4 Full load time

The full load time of a user accessing a webpage (DNS resolution is required) is calculated between the time that user initiates an access instruction on the terminal (i.e. for desktop/mobile browser (via Wi-Fi®): entering the URL address and pressing enter) and the time that it takes for the entire page to be fully loaded on the browser.

NOTE: User may be interested in viewing any part of the webpage. Therefore, the webpage should be fully loaded as soon as possible.

## 5.4 Data upload/download

### 5.4.1 Upload/download service KQI overview.

Upload/download is one of the basic Internet applications. Both average download rate ratio and upload rate ratio are key indicators that directly affect the user experience [i.17].

### 5.4.2 Download rate ratio

This measures the ratio of the average download rate to the subscription bandwidth when speed testing software is used to access a specified server.

### 5.4.3 Upload rate ratio

This measures the ratio of the average upload rate to the subscription bandwidth when speed testing software is used to access a specified server.

## 5.5 IPTV

### 5.5.1 IPTV service KQI overview

ETSI TR 101 578 [i.19] and the BDA white paper [i.2] shows key factors affecting IPTV user experience which include video/TV program source quality, interactive user experience, and viewing user experience.

The user experience of video viewing depends on the resolution, smoothness, and fidelity (tone and contrast) of the video. The service KQI is determined by the following parameters, resolution, frame rate, network bit rate, content type, encoding, and the end device (such as TV, laptop, pad with different screen resolution).

NOTE: IPTV includes watching videos/TV programs on any end devices, such as television, laptops or hand-held device.

The interactive experience depends on the response time of the video/TV system to TV channel switching or video selection. It also depends on the performance of the cloud platform, communication network, and the end device. It can be measured by a few key performance indicators such as response time to Electronic Programme Guide (EPG) interaction, initial video/TV program loading duration, channel switching duration, fast forward and rewind response.

The viewing experience depends on the quality of the program signals during display of video/TV programs. The factors affecting the viewing user experience include screen artefact and frame freezing. Such factors can be measured by objective indicators such as the transmission performance and quality impairment of the video.

Generally service operators do not directly produce video/TV programs. Therefore, it is recommended to focus on interactive user experience and viewing user experience for IPTV service.

Figure 2 shows the key factors for video/TV program user experience in different experience categories.

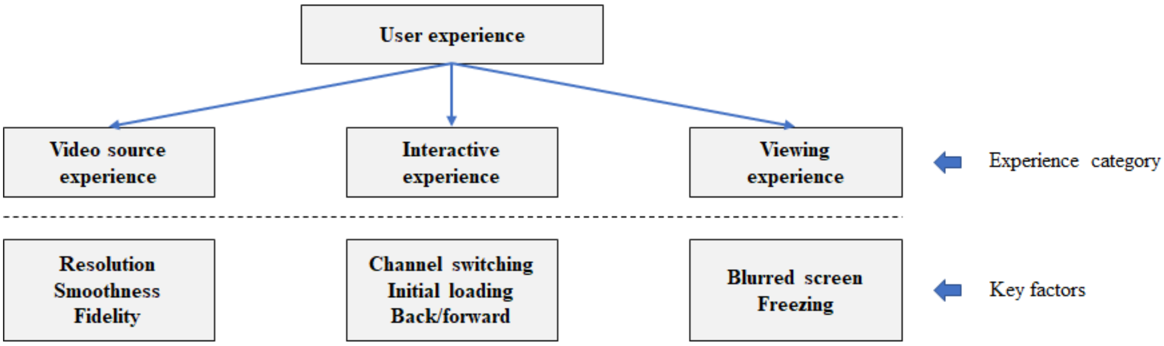



**Figure 2: Experience category and key factors affecting user experience**

## 5.5.2 Interactive experience

**Interactive indicators of live TV service** include live TV channel switching delay, i.e. the time between closure of the previous channel and that the new channel is played.

**Interactive indicators of VOD service include** VOD initial loading duration [i.19], i.e. the time between that the VOD service request is initiated and that the video frame is resolved (e.g. I frame in MPEG is decoded).

The initial loading duration is the key indicator for VOD. Other factors, such as fast-forwarding and fast-rewinding for VOD or pre-recorded TV programs may use the initial loading duration definition and details are left for further study.

## 5.5.3 Viewing experience

**The viewing indicators of Live TV** include blurred screen duration ratio and blurred screen area ratio:

1) Blurred screen duration ratio: the duration of blurred screen over the total play time of the live TV.

2) Blurred screen area ratio: average blurred screen area over the whole screen area when the blurred screen occurs.

NOTE 1: The blurred screen duration is determined by the duration of continuously received damaged frames. The blurred screen area is determined by the averaged over time of the accumulated damaged received frames.

**The viewing indicator of the VOD service** includes freezing duration ratio [i.19], i.e. video pause duration caused by an empty buffer over the total play or playback duration of the video.

NOTE 2: When evaluating user experience, a fixed video source (for VOD) and viewing video resolution (for live TV and VOD) is recommended.

## 5.6 On-line game

### 5.6.1 Overview

ETSI GS F5G 005 [1] shows the game user experience is classified and explained in terms of graphics, sound, playability, difficulty, originality. For users who play on-line game over residential network, the quality of the broadband network can directly affect the game's playability. Good playability can give users a better on-line game visual and interactive user experience. The visual user experience will be affected by problems such as network transmission latency and server processing load (see clause 6 for more details). The interactive user experience is affected by real-time response due to the network transmission latency. The present document lists the key indicators of on-line game service related to the residential network.

### 5.6.2 Terminal-based rendered game

#### 5.6.2.1 Overview of terminal-based rendered game KQIs

In terminal based rendered game, the computation of graphics rendering and data processing are conducted on the player's local terminal device. The terminal device transmits the basic state information of the game by interacting with the game server. The terminal device here includes a mobile phone, laptop, etc. When running such games over residential network, network start-up time, game Operation Response Delay (ORD), and game desynchronization time are key indicators that are closely related to the network quality and will affect the user's experience. The key performance indicators for terminal-based rendered game are described in BDA white paper [i.2].

#### 5.6.2.2 Game start-up time

Game start-up time is the time from when the user clicks to start of the game until the user can operate the game interface. The lower the start-up time, the better. The game start-up time consists of terminal start-up time affected by terminal performance and network start-up time affected by network conditions. The present document focuses on the impact of network start-up time on game. The network start-up time is the delay from when the user clicks the login page of the game to the time when the user enters the operation page of the game.

#### 5.6.2.3 Operation response delay

Operation response delay is also known as game responsiveness which is described in BBF TR126 [i.3]. In networked games, this term is related to the delay for an update event to be registered by the affected media players. In other words, the game need to react quickly to the player's inputs and rapidly showing their effects. With a networked game, the responsiveness will depend on the network delay experienced.

For mobile games, the Operation Response Delay (ORD) is the average time difference between when the player clicks on the mobile phone screen and when the game client's graphics/sound effects change. The Operation Response Delay (ORD) is defined as the time from upload the user operation instruction to the server to the time that the server sends the calculation result to the terminal and displays it. The user has high expectations on the Operation Response Delay (ORD). The longer the Operation Response Delay (ORD) is, the worse the user's game experience will be.

#### 5.6.2.4 Desynchronization time ratio

For terminal-based rendered games, desynchronization is the phenomenon that the game client loses synchronization due to abnormal data interaction with the server. As a result, the previous image will be repeatedly displayed causing the ghost image to occur on the terminal. When playing the game, the duration of a certain ghost image event is recorded as the desynchronization duration. The sum of the desynchronization durations is the total desynchronization time. The Desynchronization Time Ratio (DTR) is the ratio of the total desynchronization time to the total game time.

### 5.6.3 Cloud-based rendered game

#### 5.6.3.1 Overview of cloud-based rendered game KQIs

In cloud-based rendered game, the computation of graphics rendering and data processing are conducted in the remote server. When playing cloud-based rendered games using the residential network, the frame freezing time ratio and the game Operation Response Delay (ORD) are the key indicators that are closely related to the network quality and will affect the user's experience.

#### 5.6.3.2 Frame freezing time ratio

For cloud-based rendered games, the frame freezing of the cloud-based rendered game client is due to insufficient data received for real-time video decoding, as a result, the previous data will be repeatedly displayed which causing the picture to freeze. When playing the game, the duration of a certain (assuming the i-th) frame freezing event is recorded as the i-th frame freezing duration. The sum of the frame freezing time is recorded as the total frame freezing time, and the frame freezing time ratio indicator is defined as the total frame freezing time compared to the total game time t. The calculation formula is as below:

$$\text{Frame freezing time ratio} = \frac{\sum_{i=1}^{t} freezingtime_i}{t} \tag{1}$$

#### 5.6.3.3 Operation response delay

For the definition of Operation Response Delay (ORD), refer to clause 5.6.2.3.

## 5.7 On-line education/telework

### 5.7.1 Overview of on-line education/telework KQI

On-line education is mainly implemented through mobile phones, tablets, and computers to transmit educational images and interact with audio and video. Telework is mainly implemented by using computers to perform remote video conferences and desktop sharing to implement voice and video interaction and transmission of content images. User-perceived on-line education/remote office service KQIs include the number of frame freezing times, frame freezing ratio, and interaction delay. The key performance indicators for on-line education/telework are described in BDA white paper [i.2].

### 5.7.2 Frame freezing times

For on-line education/telework, frame freezing times is defined as the number of times that video cannot be played in time due to poor network conditions, frame freezing, screen flicker, or skipping occurs during loading on the GUI within a measurement period.

NOTE: Interruptions caused by the user or high CPU load are not considered.

### 5.7.3 Frame freezing time ratio

For on-line education/telework service, frame freezing time ratio is defined as the ratio of the frame freezing time observed on the user side to the total measurement period.

NOTE: Interruptions caused by the user or high CPU load are not considered.

### 5.7.4 Interaction delay

When client A and client B interact such as video interaction and desktop control, the interaction delay is defined as the time from transmission of picture information from client A to display on client B, or controlling client B through client A, the delay from operation to response.

# 5.8 Cloud VR

## 5.8.1 Overview

The definition and QoE factors of cloud VR service are described in ETSI GS F5G 005 [1]. The present document refers to the cloud VR application scenarios of operators, and proposes typical KQI indicators for cloud VR video and cloud VR games to evaluate user experience.

## 5.8.2 Cloud VR video

### 5.8.2.1 Overview

Cloud VR video is a typical weak-interaction cloud VR service. The user experience KQI indicators of cloud VR video include initial buffering duration, Average Percentage of Frame Freezing (APFF), and low-quality image display. Low-quality image display is only applicable to Field Of View (FOV) video services.

### 5.8.2.2 Initial buffering duration

As with traditional on-line video, after the user clicks the Cloud VR video play button, there is a loading process for performing CDN scheduling, index downloading, and data caching. For this process, users generally only see the loading progress bar. The shorter the loading time, the sooner the user sees the video content and the better the user experience.

**Initial buffering duration:** is the time from when the user clicks the Cloud VR video play button to when the user sees the normal play screen.

### 5.8.2.3 Average percentage of frames freezing

During full view VR video playing, if the media players download data buffer is empty it cannot meet the real-time play-out requirements, the terminal will stop playing and will wait until the newly buffered video data reaches a certain buffer fill-level, then restarts playing. The phenomenon of buffering and playing after stopping is called a freeze frame. Because it will interrupt the user's viewing process, it has a greater impact on the user's experience. In general, the lower the number of freeze frames and the shorter their duration, the better the user's experience.

**Average percentage of frames freezing:** is the ratio of the total freezing time to the total playing time per time window during VR video playing.

### 5.8.2.4 Low-quality image display (the indicator definition is only for videos that use the FOV transmission solution)

ETSI GS F5G 005 [1] states that in low-quality image display mode, the VR video source file is divided into multiple segments for storage in the cloud. Each segment corresponds to a different Field Of View (FOV). Based on the head motion of the user, the terminal locally calculates the current FOV. The terminal requests the corresponding high-definition segment. The cloud server responds by sending the requested segment and a low-definition full-view background video. The terminal displays the high-definition segments when available and fills the remaining portion of the screen with background video.

NOTE: If these dynamic processes suffer network or application delay, the user will only see low-definition content.

**Average percentage of the low-quality image area:** is the average value of the low-definition content in the user's viewing area during the playing process.

**Percentage of low-quality image duration:** is the proportion of playing time of low-definition content during the playing process.

### 5.8.3 Cloud VR Game

#### 5.8.3.1 Overview

Cloud VR game is a typical a strong-interaction cloud VR service. The user experience KQI indicators of cloud VR game include black edge and smearing, average percentage of frame freezing and Operation Response Delay (ORD).

#### 5.8.3.2 Black edge and smearing

To save cloud rendering resources and shorten E2E latency, Cloud VR game servers generally only render and transmit images within the user's view angle. Therefore, the new viewing areas that are not rendered on time are displayed as black edges or smearing. The faster the head motion, the longer the cloud rendering and streaming latency, and the more pronounced the black edge and smearing are.

**Average percentage of the black edge area:** is the average value of the black edge/smearing in the user's viewing angle during the game.

**Percentage of the black edge duration:** is the proportion of the time duration with black edge effect to the total time duration of the game.

#### 5.8.3.3 Average percentage of frame freezing

When the terminal program does not receive the new data frame for a long time, it will repeatedly display the last received data frame until the new data frame is received (most cloud VR game platforms use the TCP protocol to transmit game video streams, it can ensure the integrity and ordering of application layer data). When the terminal receives the previous lost data frame and the new data frame, it will use the new data frame to update the content on the display (to ensure the real-time and synchronization of the game).

**Average percentage of frames freezing:** calculates the average percentage of frame freezing to the total game duration during VR games.

#### 5.8.3.4 Operation response delay

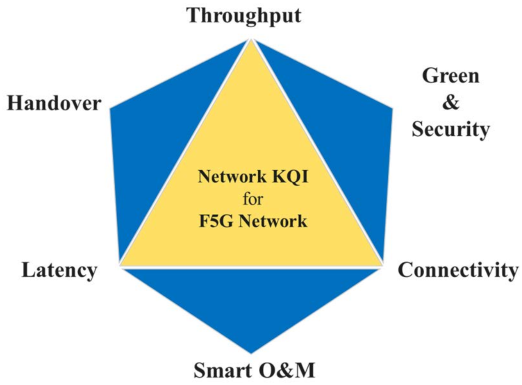
In strong-interaction application scenarios, such as Cloud VR game, users expect immediate audio-visual responses when they move, pull a trigger, or wave a hand. If the response takes longer than they expect, they feel interactive delay. Operation response delay is caused by the asynchronous collaboration between the cloud rendering and streaming process and the local playout process.

**Operation response delay:** is the average time from the action of the user detected by the terminal to the corresponding game screen display.

# 6 Network KQI

## 6.1 Overview

To improve the Quality of Experience (QoE) for residential users of network services, the F5G network should provide the appropriate network functionality and performance to carry service and application data. Six dimensions  are used to categorize the network KQIs [i.18]. These six dimensions are throughput, latency, connectivity, handover, green & security and smart O&M as illustrated in Figure 3.




NOTE: Handover refers to the handover time defined in clause 6.5.

**Figure 3: Network KQI Dimensions**

The network KQI dimensions are either network performance related or network functionality related.

The network KQI quantifies the network characteristic from different angles to support specific application services. The Mean Opinion Score (MOS) value is quantifying the user experience. To achieve a high MOS value, an application service specific network performance is required. The requirements are defined in terms of six network-level KQI dimensions discussed in following clauses so as to support at least good user experience, which means a MOS value of 3,5 or above (see clause 7.1.2 on the concept of a MOS value).

# 6.2 Throughput

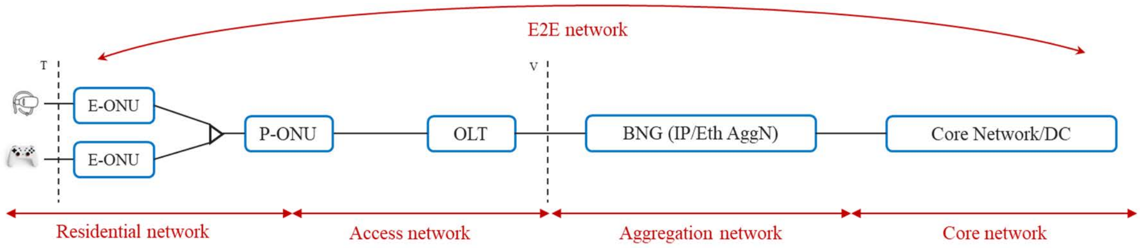
Table 1 lists the recommended throughput requirements for various residential broadband services to enable the end users to have a good experience.

**Table 1: Recommended throughput requirements ([i.2] and [i.4])**

| Service Type | | Throughput Requirements |
|---|---|---|
| Voice | | ≥ 64 Kbps |
| Web browsing | | ≥ 5 Mbps |
| Data upload/download | | ≥ 30 Mbps |
| Terminal-based rendered game | | ≥ 2 Mbps |
| Cloud-based rendered game | | ≥ 200 Mbps |
| IPTV | SD and HD video | ≥ 20 Mbps |
| | 4K video | ≥ 70 Mbps |
| | 8K video | ≥ 200 Mbps |
| On-line education/telework | | ≥ 5 Mbps |
| Cloud VR (see note) | | ≥ 80 Mbps |
| NOTE: Weak-interaction Cloud VR with 4K resolution and 360°FOV. | | |

# 6.3 Latency

Figure 4 shows the network segmentation of the E2E network for latency analysis. In addition, Table 2 lists the round-trip latency requirements for various residential broadband services.




NOTE: Figure 4 is modified from Figure 2 (F5G Network Topology) of ETSI GS F5G 004 [i.5].

**Figure 4: An example of E2E Network for latency analysis**

To ensure the appropriate level of user experience for various types of services, the total latency of each type of service shall meet Table 2 values. The decoupled requirement of residential network and access network are also listed, respectively.

NOTE: The decoupled requirement of latency in Cloud VR is referred to in [i.6]. The distribution of latency requirements (the percentage of latency per segment is similar to Cloud VR) to different network segment also apply to other services. The remainder of the end-to-end latency minus the residential and the access network latency is attributed to the aggregation and core network segments and are not further discussed.

**Table 2: Latency requirements for different network segments ([i.2] and [i.4])**

| | | E2E latency Requirement | Latency requirement for residential network | Latency requirement for access network |
|---|---|---|---|---|
| Voice | | ≤ 220 ms | ≤ 77 ms | ≤ 22 ms |
| Web browsing | | ≤ 100 ms | ≤ 35 ms | ≤ 10 ms |
| Data upload/download | | / | / | / |
| Terminal-based rendered game | | ≤ 60 ms | ≤ 21 ms | ≤ 6 ms |
| Cloud-based rendered game | | ≤ 20 ms | ≤ 7 ms | ≤ 2 ms |
| IPTV | SD and HD video | ≤ 100 ms | ≤ 35 ms | ≤ 10 ms |
| | 4K video | ≤ 50 ms | ≤ 19 ms | ≤ 4 ms |
| | 8K video | ≤ 20 ms | ≤ 7 ms | ≤ 2 ms |
| On-line education/telework | | ≤ 150 ms | ≤ 53 ms | ≤ 15 ms |
| Cloud VR | | ≤ 30 ms | ≤ 11 ms | ≤ 3 ms |

Since end users directly connect to the residential network, the network latency of the residential network is measured from the end user device to the network terminal of the access network, like PON interface of ONU. Residential network latency is mainly composed of signal transmission delay between user device and Residential Gateway (RGW) and packet receiving & processing delay in the hardware of RGW. For the wireline interface the end devices, like a fixed workstation generally use short ETH cable to connect the RGW, and the latency is usually less than 1 ms. In most cases, the end devices, like smart phone, laptop, etc., connect to the RGW through Wi-Fi®, which is the most significant factor impacting the latency of E2E transmission.

For IPTV service, besides the video transmission requirements, the user behaviour such as channel switching will trigger the loading a new live video stream.

# 6.4 Connectivity

Connecting various types of end devices is a characteristic of residential networks. Different QoS requirements of network services impose additional complexity to the residential network. Especially, when multiple services are running simultaneously. The connectivity is the key network KQI and is determined by the number of connected devices and the number of simultaneously active devices:

*1)* Number of connected devices is the maximum number of devices that can connect to the network.

*2)* Number of simultaneously active devices is the number of devices that simultaneously connected and active using the network service.

In residential networks, Wi-Fi® is the most commonly used technology and therefore the effect of higher number of simultaneously active Wi-Fi® devices on the user experience is described.

As background information, the mathematical model of the Wi-Fi® duty cycle (the utilization of the air interface) is defined in formula (2):

$$\text{Duty Cycle} = \frac{\sum_1^n R_{nrate}}{N_{SS} \times (N_{CBPS} * R) \times (1/(T_S + T_{GI}))} \quad (2)$$

where:

- $N_{SS}$: the number of spatial streams in Wi-Fi® transmission.
- $N_{CBPS}$: the number of coded bits per symbol.
- R: code rate.
- $T_{GI}$: guard interval.
- $T_S$: symbol length.
- $R_{nrate}$: the actual data rate of the Wi-Fi® terminal.
- n: number of Wi-Fi® terminals.

With more simultaneously connected devices sharing the residential network, the numerator of the above formula has a larger value due to the increased number n with a given rate $R_{nrate}$. This leads to a larger duty cycle. Therefore, with the larger the number of simultaneously active connected devices, the air interface will be heavily utilized, leading to serious congestion due to competition of transmission opportunities, leading to a reduction of user experience.

NOTE: The effects of this is basically adding to the throughput and latency dimensions. The per-service allowed number of simultaneously active connected devices to achieve good user experience is for further study.

## 6.5 Handover

In residential networks, Wi-Fi® is the most commonly used technology and therefore the effect on handover of Wi-Fi® devices across Access Points (APs) impact the user experience. The handover time is the time interval between a wireless Station (STA) moves from the connecting AP and re-connecting to another AP.

Table 3 lists the requirements of various residential broadband services for handover time [i.2].

**Table 3: Requirements for handover time**

| Service Type | | Handover time requirements |
|---|---|---|
| Voice | | / |
| Web browsing | | ≤ 100 ms |
| Data upload/download | | / |
| Terminal-based rendered game | | ≤ 50 ms |
| Cloud-based rendered game | | ≤ 10 ms |
| IPTV | SD & HD video | ≤ 100 ms |
| | 4K video | ≤ 50 ms |
| | 8K video | ≤ 10 ms |
| On-line Education/telework | | ≤ 50 ms |
| Cloud VR | | ≤ 10 ms |
| NOTE: The voice service type is a fixed line telephone connected to a home router only. So Wi-Fi® handover is not relevant. Other voice services are for further study. | | |

Handover time indicates the network capability to maintain service continuity under mobility scenarios.

NOTE: Depending on the handover mechanisms, it affects packet loss, throughput and latency dimensions.

## 6.6 Green & security

### 6.6.1 Introduction

The network KQI dimension of green and security are not traditionally associated with Quality of Experience. However, it is a peace of mind (giving a good feeling) kind of quality. Therefore, this network KQIs are relevant for an overall user experience about F5G network services and applications.

### 6.6.2 Green (power consumption)

In networks, power consumption is the most commonly associated green factor and therefore the effect of power consumption impacts the user experience. Other green aspects are for further study.

In F5G residential networks, FTTR, Wi-Fi® and XGS-PON based access networks are the most commonly used technologies and therefore affects the power consumption and user experience.

The power consumption of individual ONUs is specified in Code of Conduct (CoC) standard [3]. The practical power consumption of an ONU varies due to the communication hardware interfaces and actual workload.

The present document defines three scenarios for evaluating power consumption, including full loading, light loading and standby. The light loading scenario is equivalent to the on-stage status of CoC standard, while the standby scenario is equivalent to the idle-stage status of CoC standard.

To objectively evaluate the power consumption of an ONU, the power per Mbit (mW/Mbit) is used. The related definition is shown in formula (3):

$$P = P_a / D_a \qquad (3)$$

$P_a$ is the power consumption, while $D_a$ is the data traffic. To have a comprehensive calculation of $P_a$ and $D_a$, three typical working scenarios (full loading, light loading and standby) are considered, as described in Table 4.

**Table 4: Definition of power consumption in scenarios**

| Scenario | Full loading | Light loading | Standby |
|---|---|---|---|
| Definition | 1. All functional modules are in use. For example, as to a dual band Wi-Fi® 6 device, full loading of data should be running over the 2,4 GHz and 5 GHz frequency band with greater than 80 Mbps and 1 Gbps, respectively.<br>2. The Wi-Fi® configuration should conform to the power transmission requirement of the country code and use 100 % of default transmission power.<br>See note. | 1. Equivalent to the on-stage of CoC standard [3]:<br>10 Mbit/s downlink streaming in the access part, 10 Mbit/s data streaming on the Ethernet port, 10 Mbps streaming in both uplink and downlink for 2,4 GHz and 5 GHz band of Wi-Fi® with one Station (STA) connected, VoIP port (off-hook), and USB port (idle) | 1. Equivalent to the idle-stage of CoC standard [3]:<br>Link stablished without data streaming in access part, ETH ports are not connected, Wi-Fi® is enabled without Station (STA) connected, voice port (on-hook) and USB port (idle) |
| Power consumption | $P_{max}$ | $P_{sm}$ | $P_{idle}$ |
| Proportion | 10 % | 50 % | 40 % |
| NOTE: To have complete example, taking a device with a specific profile (4 GE Ethernet port, 2 spatial streams in 2,4 GHz, 2 spatial streams in 5 GHz, XGPON as access uplink, G.fin/ETH as optional downlink to edge ONU, VoIP port (off-hook), USB port (idle), etc.). | | | |

The Pa value could be calculated based on formula (4):

$$P_a = P_{max} \times 10\% + P_{sm} \times 50\% + P_{idle} \times 40\ \% \qquad (4)$$

where, $P_{max}$ is power consumption under full loading, $P_{sm}$ is power consumption under light loading, and $P_{idle}$ is power consumption under standby, respectively.

In FTTR, the network terminal of the access network is the Primary ONU (P-ONU), and the terminating unit is the Edge-ONU (E-ONU). The evaluation setup is described in Table 5.

**Table 5: Traffic loading of the P-ONU in various scenarios**

| Scenario | Function Module | Traffic (Mbit/s) | Remarks |
|---|---|---|---|
| Full loading | XGPON | 1 000 | Stream direction is from XGPON WAN port of P-ONU to the E-ONU |
| | 4GE | 1 080 | Stream direction is from LAN port 1 (ETH GE) to 2,4 GHz Wi-Fi®; From LAN port 2 (ETH GE) to 5 GHz Wi-Fi® |
| | 2,4 GHz Wi-Fi® | 80 | / |
| | 5 GHz Wi-Fi® | 1 000 | / |
| | Downlink connection of E-ONU | 1 000 | In F5G this link is fibre |
| | $D_{max}$ | 4 160 | 10 %, referred to $P_{max}$ |
| Light loading | XGPON | 10 | / |
| | 4GE | 40 | / |
| | 2,4 GHz Wi-Fi | 10 | / |
| | 5 GHz Wi-Fi | 10 | / |
| | Downlink connection of E-ONU | 10 | In F5G this link is fibre |
| | $D_{sm}$ | 80 | 50 %, referred to $P_{sm}$ |
| Standby | $D_{idle}$ | 0 | / |

The corresponding calculation methodology is as follows:

$$D_a = D_{max} \times 10\ \% + D_{sm} \times 50\ \% + D_{idle} \times 40\ \% \quad (5)$$

where, $D_{max}$ is data traffic under full loading, $D_{sm}$ is data traffic under light loading, and $D_{idle}$ is data traffic under standby, respectively.

Like the traffic requirement in P-ONU, the traffic requirement of E-ONU is shown in Table 6.

**Table 6: Traffic loading of the E-ONU in various scenarios**

| Scenario | Function Module | Traffic (Mbit/s) | Remarks |
|---|---|---|---|
| Full loading | Uplink connection of E-ONU | 1 000 | Stream direction is from E-ONU to 5 GHz Wi-Fi® |
| | 2GE | 80 | Stream direction is from LAN port 1 (ETH GE) to 2,4 GHz Wi-Fi® |
| | 2,4 GHz Wi-Fi® | 80 | / |
| | 5 GHz Wi-Fi® | 1 000 | / |
| | Dmax | 2 160 | 10 %, referred to $P_{max}$ |
| Light loading | Uplink connection of E-ONU | 10 | / |
| | 2GE | 20 | / |
| | 2,4 GHz Wi-Fi® | 10 | / |
| | 5 GHz Wi-Fi® | 10 | / |
| | $D_{sm}$ | 50 | 50 %, referred to $P_{sm}$ |
| Standby | $D_{idle}$ | 0 | / |

Based on the formula and definition, the power consumption of ONUs can be calculated. The average power consumption per ONU is calculated by formula (6):

$$\mathrm{P}_{nor} = (\mathrm{P}_{P-ONU} + \mathrm{P}_{E-ONU\ 1} + \mathrm{P}_{E-ONU\ 2} \dots + \mathrm{P}_{E-ONU\ N})/(\mathrm{N}+1) \quad (6)$$

where, N indicates the number of edge ONUs. Figure 5 shows the full loading traffic scenario for P-ONU and E-ONU.

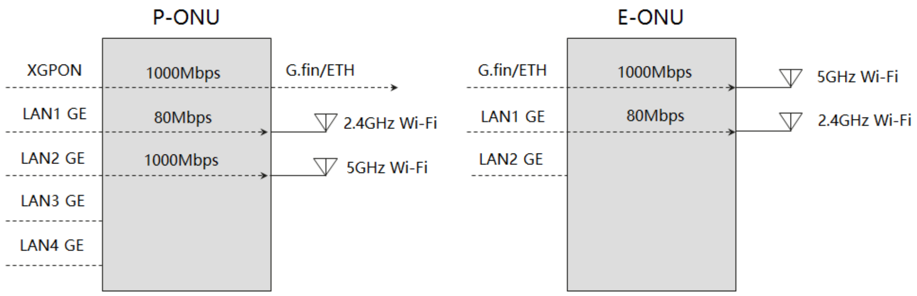



**Figure 5: Full loading traffic scenario**

The full loading traffic scenario allows the measurement of the power consumption of FTTR deployments. It calculates the power consumption in a residential network. It helps to objectively compare FTTR deployments with other residential network deployments under the same load and therefore the same performance provided by the network.

The FTTR lower power consumption helps to save on the energy bill of the users. Defining power consumption limits implies that advanced technologies are preferred.

NOTE: The power consumption is compared according to the traffic requirements defined above. Different devices (such as the RGW) which are composed of different set of functional components (e.g. WAN interface, LAN interface, Wi-Fi® interface) could achieve the same traffic target.

### 6.6.3 Security

In residential network, security is the capability to ensure secure utilization (i.e. availability) of service and applications. The end-to-end network security ensures that user data is not disclosed (i.e. confidentiality) or tampered (i.e. integrity).

Residential network devices should ensure that user services are not affected when a network attack occurs. In addition, the devices should be capable to notify the users of potential security risks if necessary. Especially in residential broadband network, that are meeting the requirements of broadband services, the network system shall have the capability to defend against attacks.

Securing the F5G network and specifically the residential network lets the user feel save and protected, which is part of the overall user experience. If the user knows that privacy is ensured, the comfort is enhanced while using the services and application.

## 6.7 Smart O&M

Smart O&M is intended to enable new services and achieve ideal user experience, by using big data and intelligent mechanism, in order to maximize the utilization efficiency of resource and power, and achieve automatic, self-optimized, and self-healing network, and finally achieving an autonomous network:

- Automatic: Services are automatically deployed based on user objectives.
- Self-healing: Predicts faults and automatically recovers based on events.
- Self-optimization: Adaptive optimization based on user experience.
- Autonomous: The network functions are self-evolved on the basis of automatic, self-healing, and self-optimization.

With smart O&M, many network issues could be predicted or solved before the user detects the problems. This indirectly improves the user experience in long term usage of the residential network. Fast and autonomous recovery of network failures also reduces user complains.

The capability of smart O&M is described by several level of sophistication (Controllable, Controllable/Manageable, Controllable/Manageable/Analytical), shown in Table 7.

**Table 7: Smart O&M definition of functionality**

| Network O&M | "Controllable" | "Controllable/Manageable" | "Controllable/Manageable/Analytical" |
|---|---|---|---|
| Definition | 1) Accurate service provisioning and network configuration. | 1) Accurate service provisioning and network configuration.<br>2) Fault management and diagnostic. | 1) Accurate service provisioning and network configuration.<br>2) Fault management and diagnostic.<br>3) Big data analytics and autonomous reaction. |

With good smart O&M capability, the service operator could identify network failure and implement network recovery before the user detects it. Manageable provides committed process while analytical gives accurate prediction for network failure recovery. This helps stabilize the network performance, and enable good user experience in the long term.

# 7 User experience evaluation

## 7.1 General description

### 7.1.1 Introduction

User experience evaluation identifies the service quality as perceived by the user, collects statistical service data, identifies network failure, etc. The result of the evaluation is utilized by the service operator to improve the network service. The clauses below specify the quantification methodology to determine the service KQI. The method is using the concept of Mean Opinion Score (MOS) values. MOS value and corresponding MOS formulas are provided to score the service KQIs on a per-KQI, and per-service level.

### 7.1.2 The Concept of a MOS value

The MOS value is the general concept to quantify the subjective perceptions of the end user. The MOS value is service dependent. The MOS value can be derived through a mapping function from network or service indicators to the MOS value. The detailed procedure will be described in the following clauses. The MOS value for the evaluation of user experience is divided into five score levels [i.12]. Table 8 describes the mapping between MOS value and QoE.

**Table 8: Mapping between MOS value and QoE in residential area**

| MOS value | Quality of Experience (QoE) | |
|---|---|---|
| 4,5 - 5 | Excellent | Ideal experience: no impairment |
| 3,5 - 4,5 | Good | Minor impairment of Experience |
| 2,5 - 3,5 | Fair | Acceptable experience impairment |
| 1,5 - 2,5 | Poor | Serious experience impairment |
| 0 - 1,5 | Bad | Unbearable experience damage |

According to the MOS concept mentioned above, the mapping creates a quantitative relationship between service KQI (listed in clause 5) and the MOS values. If the KQI measurement process fails for a specific service, then the corresponding MOS value is indeterminate and the MOS value is set to zero and not considered in the final calculation.

## 7.2 Telephony

### 7.2.1 MOS mapping of Call Completion Ratio (CCR)

Table 9 summarizes the requirements of the call completion ratio(CCR)[%] between different calling subscribers and called subscribers [i.16].

**Table 9: Call completion ratio requirements**

| Calling subscriber | Called subscriber | 2-hop relay | 3-hop relay |
|---|---|---|---|
| Fixed line subscriber | Fixed line subscriber | 92 % | 90 % |
| Fixed line subscriber | Mobile subscriber | 88 % | 85 % |

Since the present document is focusing on fixed networks, Table 10 provides the mapping between CCR[%] and MOS values for fixed subscriber in both calling and called direction by referring to the 2-hop relay. 92 % of the 2-hop relay is considered to be a fair experience with a MOS value of 3.

**Table 10: Mapping between CCR[%] and MOS**

| Call completion ratio(CCR)[%] | MOS |
|---|---|
| 99 | 5 |
| 95 | 4 |
| 92 | 3 |
| 80 | 2 |
| 60 | 1 |

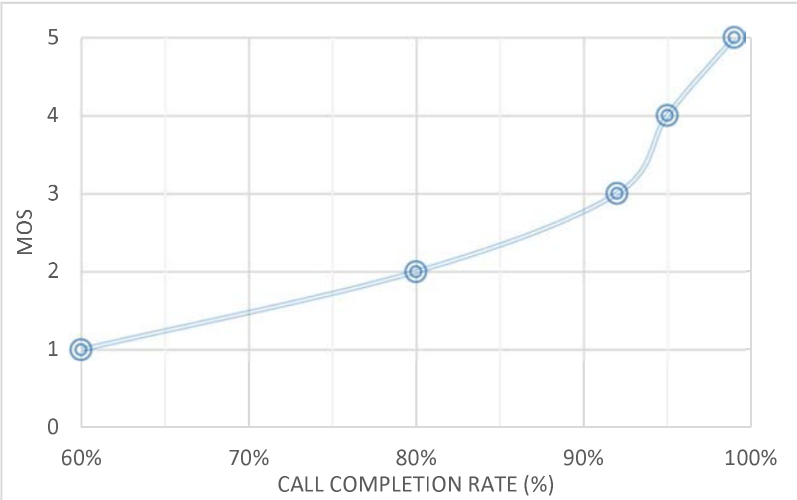



**Figure 6: Mapping between call completion ratio and MOS**

Regression analysis based on the values in Table 10, the mapping relationship is depicted in Figure 6 and the mapping function is described by formula (7).

$$MOS_{CCR} = \begin{cases} 5 & CCR \geq 99\ \% \\ 0{,}0872 \times e^{3{,}9869 \times CCR} & 0 < CCR < 99\ \% \\ 0 & CCR = 0 \\ 0 & Test\ failure \end{cases} \quad (7)$$

## 7.2.2 MOS mapping of Call Setup Time (CST)

The E2E Call Setup Time (CST) is determined by two parts. The first part is the average call setup time between the calling subscriber terminal and the local IP telephony gateway. This is required to be less than 1 s for fixed line network. The second part is the average call setup time between the local gateway of both sides (caller and called gateways) plus the call setup time between the called IP telephony gateway and the called subscriber terminal. This should be less than 5 s for fixed network. Therefore, the E2E call setup time should be less than 6 s [i.16].

By considering 6 s as the mean value for the MOS as Fair. The mapping between Call Setup Time (CST) and MOS value is shown in Table 11.

**Table 11: Mapping between call setup time and MOS**

| Call setup time(CST) [s] | MOS |
|---|---|
| 3 | 5 |
| 4,5 | 4 |
| 6 | 3 |
| 8 | 2 |
| 10 | 1 |

Regression analysis based on the values in Table 11, the mapping relationship is depicted in Figure 7 and the mapping function is described by formula (8).

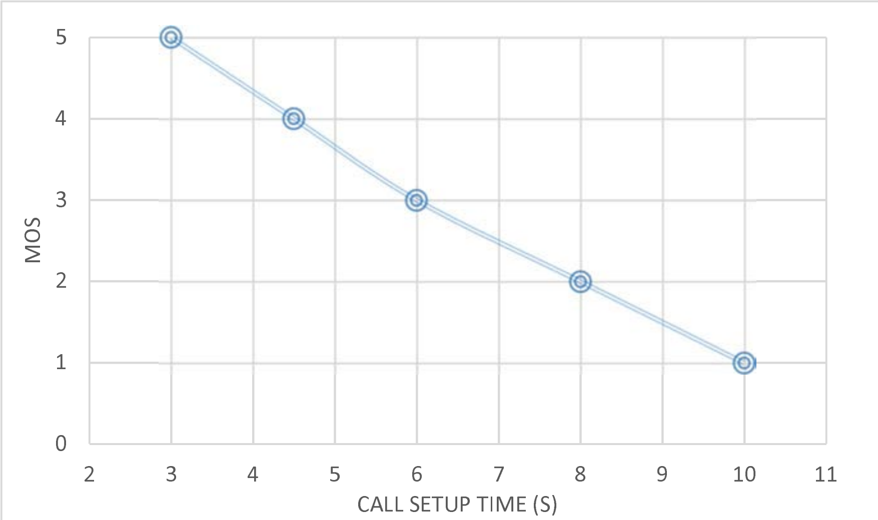



**Figure 7: Mapping between call setup time and MOS**

$$MOS_{CST} = \begin{cases} 5 & CST \leq 3\,s \\ -0{,}5682 \times CST + 6{,}5795 & 3\,s < CST < 11\,s \\ 0 & CST \geq 11\,s \\ 0 & Test\ failure \end{cases} \quad (8)$$

## 7.2.3 MOS mapping of Call Drop Rate (CDR)

The expected call drop rate(CDR) for fixed network should be less than 2/1 000 [i.16]. Considering actual network conditions, the total call drop rate of the telephony service between fixed line terminals should be less than 5/1 000 [i.13].

The above values are used as the fair MOS, and the typical values set in the present document are shown in Table 12.

**Table 12: Mapping between telephony call drop rate and MOS**

| Call drop rate(CDR)[%] | MOS |
|---|---|
| 0 | 5 |
| 0,25 | 4 |
| 0,5 | 3 |
| 2 | 2 |
| 5 | 1 |

Regression analysis based on the values in Table 12, the mapping relationship is depicted in Figure 8 and the mapping function is described by formula (11).

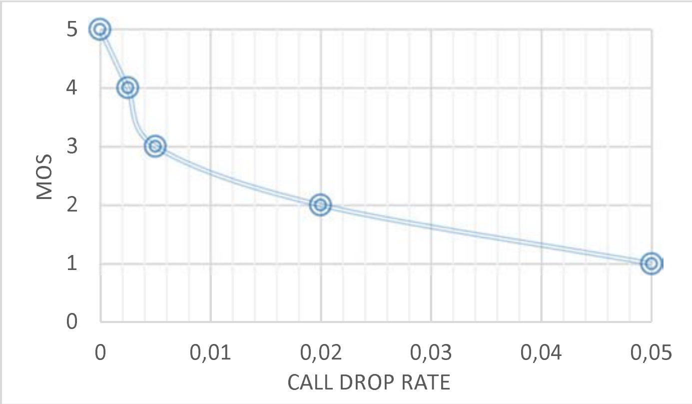



**Figure 8: Mapping between call drop rate and MOS**

$$\mathrm{MOS}_{CDR} = \begin{cases} 2\,291{,}6 \times (\mathrm{CDR})^2 - 184{,}1 \times CDR + 5 & CDR < 10\ \% \\ 0 & CDR \geq 10\ \% \\ 0 & Test\ failure \end{cases} \quad (9)$$

## 7.2.4 MOS mapping of conversational quality

### 7.2.4.1 Introduction

To evaluate conversational quality under successful call setup, Recommendation ITU-T G.107 [i.7] and Recommendation ITU-T P.863 [i.8] provide E-model and POLQA model, respectively. Both models establish the methodology to derive the MOS value in order to quantify conversational quality.

### 7.2.4.2 E-Model

The E-Model model considers transmission condition, telephony terminal, and calling environment for both calling and called subscriber. The E-Model procedure is to independently evaluate the impact of conversational quality through a set of dimensions, including delay impairment, vocoder capability, packet loss and call environment. Therefore, it provides a repeatable methodology for evaluating the quality of telephony. The E-Model is described in Recommendation ITU-T G.107 [i.7], the formula is shown as below:

$$\mathrm{R} = R_0 - I_s - I_d - I_e + \mathrm{A} \quad (10)$$

Where the parameters in the equation are as following:

- R: the transmission rating factor.
- $R_0$: signal-to-noise ratio, including noise sources such as circuit noise and room noise.
- $I_s$: a combination of all impairments which occur more or less simultaneously with the voice signal.
- $I_d$: the impairments caused by delay.
- $I_e$: the effective equipment impairment factor, representing impairments induced by low bit-rate codecs. It also includes impairment due to randomly distributed packet losses.
- A: the advantage factor, allowing for compensation of impairment factors when the user benefits from other types of access to the user.

NOTE: The detailed definition of the parameters mentioned above can be found in Recommendation ITU-T G.107 [i.7].

An estimated MOS value for the conversation quality can be obtained for the R factor using formula (10):

$$\mathrm{MOS}_{VQ} = \begin{cases} 1 & R < 0 \\ 1 + (0{,}035 \times \mathrm{R}) + \mathrm{R} \times (\mathrm{R} - 60) \times (100 - \mathrm{R}) \times 7 \times 10^{-6} & 0 \leq R \leq 100 \\ 4{,}5 & R > 100 \end{cases} \quad (11)$$

According to formula, MOS values ranging from 1 to 4,5 can be obtained by measuring the basic parameters of the network.

#### 7.2.4.3 POLQA Model

The POLQA model is described in Recommendation ITU-T P.863 [i.8], it provides a method to estimate the MOS value by comparing the reference signal with the decoded degraded signal. Such method also measures the E2E voice quality. In the narrowband mode (300 to 3 400 Hz), the maximum MOS score is 4,5, and in fullband mode (20 to 20 000 Hz), the maximum MOS score is 4,8.

NOTE: Recommendation ITU-T P.863 [i.8] algorithm scores saturate at MOS = 4,80 in fullband mode and at MOS = 4,5 in narrow band mode. This reflects the fact that not all subjective test participants will give the highest rating - even for the undegraded reference.

### 7.2.5 Comprehensive service score

The call completion ratio, call setup time, conversational quality, and call drop rate are the key factors, discussed for evaluating user experience of the telephony service. To have a quantitative evaluation through MOS value, a weighted formula is used:

$$\mathrm{MOS}_{voice} = \mathrm{a} * \mathrm{MOS}_{CCR} + \mathrm{b} \times \mathrm{MOS}_{CST} + \mathrm{c} \times \mathrm{MOS}_{VQ} + \mathrm{d} \times \mathrm{MOS}_{CDR} \qquad (12)$$

The exact weight value (a, b, c, d) can be determined by the service operator. The recommended values are a = 20 %, b = 20 %, c = 40 %, d = 20 %. A large weight indicates great impact on user experience. The value of $\mathrm{MOS}_{\mathrm{voice}}$ could be used to reflect overall user experience of the telephony service.

## 7.3 Web browsing

### 7.3.1 MOS mapping of Page Response Time (PRT)

The evaluation of Page Response Time (PRT) is quantified in CCSA YD/T 3341-2018 [i.12] (< 0,1 s as the MOS score 5: Excellent, ~1,5 s as the MOS score 3: fair and ~15 s as the MOS score 0: Bad). The mapping relationship between MOS and PRT is depicted in Figure 9 and the mapping function is described by formula (13).

NOTE: The PRT measurement is for static web page so that repeatability could be guaranteed. The test failure takes place when the network could not support completing the measurement of the KQI.

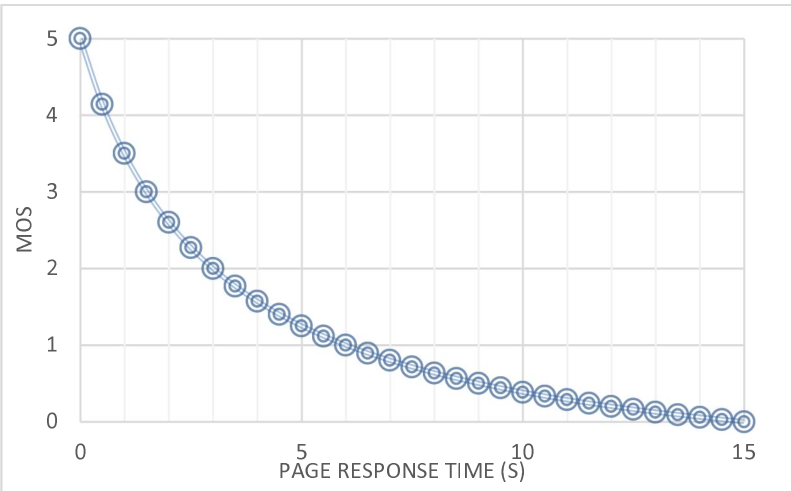



**Figure 9: Mapping between page response time and MOS**

$$MOS_{PRT} = \begin{cases} 5 & 0 \leq PRT < 0{,}1\ s \\ \frac{18}{PRT+3} - 1 & 0{,}1\ s \leq PRT < 15\ s \\ 0 & 15\ s \leq PRT \\ 0 & Test\ failure \end{cases} \quad (13)$$

## 7.3.2 MOS mapping of the First Screen Display Time (FSDT)

The evaluation of first screen display time(FSDT) is quantified in CCSA YD/T 3341-2018 [i.12] (< 0,1 s as the MOS score 5: Excellent, ~3 s as the MOS score 3: fair and ~30 s as the MOS score 0: Bad). The mapping relationship between MOS and FSDT is depicted in Figure 10 and the mapping function is described by formula (14).

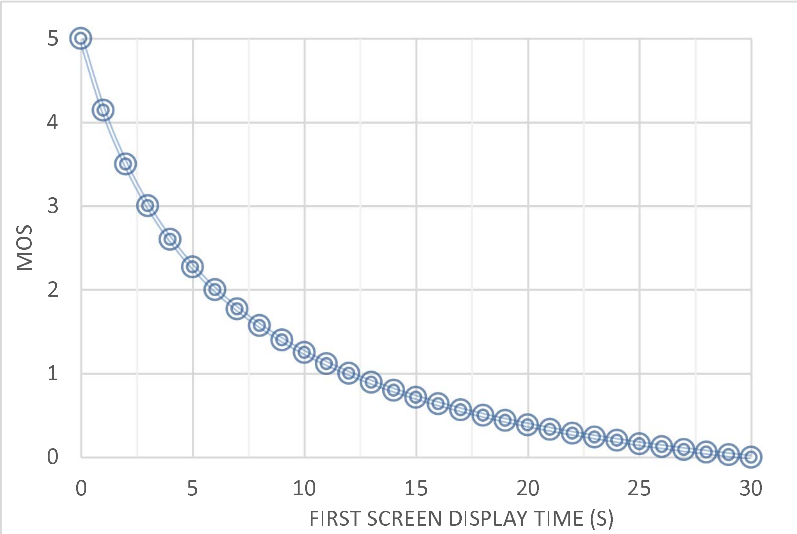



**Figure 10: Mapping between the first screen display time and MOS**

$$MOS_{FSDT} = \begin{cases} 5 & 0 \leq FSDT < 0{,}1\ s \\ \frac{36}{FSDT+6} - 1 & 0{,}1\ s \leq FSDT < 30\ s \\ 0 & 30\ s \leq FSDT \\ 0 & Test\ failure \end{cases} \quad (14)$$

## 7.3.3 MOS mapping of Full Load Time (FLT)

The evaluation of Full Load Time (FLT) is quantified in CCSA YD/T 3341-2018 [i.12] (< 0,1 s as the MOS score 5: Excellent, ~10 s as the MOS score 3: fair and ~100 s as the MOS score 0: Bad). The mapping relationship between MOS and FLT is depicted in Figure 11 and the mapping function is described by formula (15).

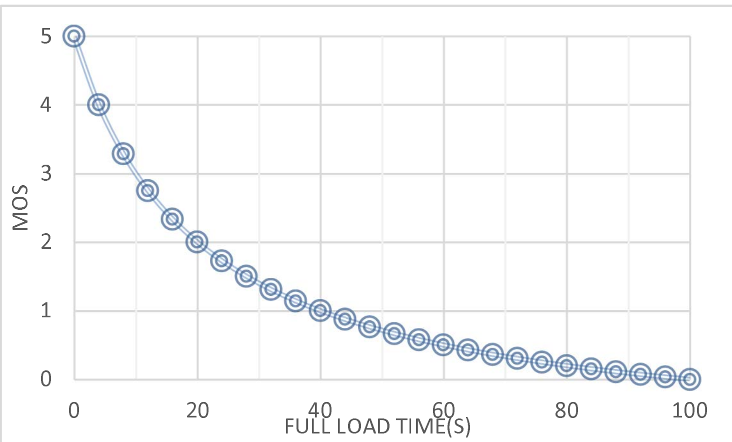



**Figure 11: Mapping between full load time and MOS**

$$MOS_{FLT} = \begin{cases} 5 & 0 \leq FSDT < 0{,}1\ s \\ \frac{120}{FSDT+20} - 1 & 0{,}1\ s \leq FSDT < 100\ s \\ 0 & 100\ s \leq FSDT \\ 0 & Test\ failure \end{cases} \quad (15)$$

### 7.3.4 Comprehensive service score

The page response time, first screen display time, and full load time are the key factors, for evaluating user experience of web browsing. To have a quantitative evaluation through MOS value, a weighted formula is used:

$$\mathrm{MOS}_{web\ browsing} = \mathrm{a} \times \mathrm{MOS}_{PRT} + \mathrm{b} \times \mathrm{MOS}_{FSDT} + \mathrm{c} \times \mathrm{MOS}_{FLT} \quad (16)$$

The exact weight value (a, b, c) can be determined by the service operator. The recommended values are a = 30 %, b = 50 %, c = 20 %. A large weight indicates great impact on user experience. The value of $\mathrm{MOS}_{\text{web browsing}}$ could be used to reflect overall user experience of web browsing.

## 7.4 Data upload/download

### 7.4.1 MOS mapping of Download Rate Ratio (DRR)

The evaluation of Download Rate Ratio (DRR) is quantified in CCSA YD/T 3341-2018 [i.12] (100 % as the MOS score 5: Excellent, ~90 % as the MOS score 3: fair and ~0 % s as the MOS score 0: Bad). The mapping relationship between MOS and DRR [%] is depicted in Figure 12 and the mapping function is described by formula (17).

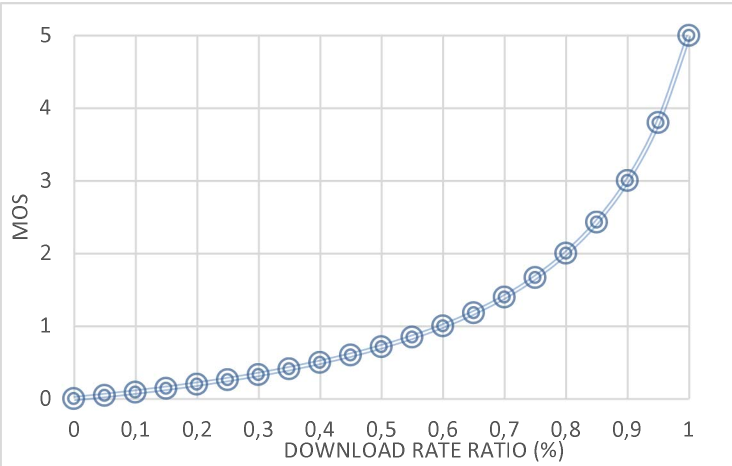



**Figure 12: Mapping between MOS and download rate ratio**

$$\mathrm{MOS}_{DRR} = \begin{cases} \frac{120}{120-100\times DRR} - 1 & DRR \leq 100\ \% \\ 0 & Test\ failure \end{cases} \quad (17)$$

### 7.4.2 MOS mapping of Upload Rate Ratio (URR)

Similarly, the URR[%] mapping function is described by formula (18):

$$\mathrm{MOS}_{URR} = \begin{cases} \frac{120}{120-100\times URR} - 1 & URR \leq 100\ \% \\ 0 & Test\ failure \end{cases} \quad (18)$$

### 7.4.3 Comprehensive service score

The page download and upload rate ratio are key factors, for evaluating experience of download and upload. To have a quantitative evaluation through MOS value, a weighted formula is used:

$$\text{MOS}_{down/upload} = \text{a} \times \text{MOS}_{DRR} + \text{b} \times \text{MOS}_{URR} \tag{19}$$

The exact weight value (a, b) can be determined by service operator. The recommended values are a = 70 %, b = 30 %. A large weight indicates great impact on user experience. The value of $\text{MOS}_{\text{down/upload}}$ could be used to reflect overall user experience of download/upload user experience.

# 7.5 IPTV

## 7.5.1 MOS mapping of Interactive Experience (IE)

For live video/TV program, the Channel Switching Delay (CSD) is considered as one of the key factors that affects user experience. Previous study [i.14] provides a model for quantifying the relationship between MOS and CSD:

$$\text{MOS}_{IE-Live} = C_1 \times \exp(C_2 \times t_{zap}) + C_3 \times \exp(C_4 \times t_{zap}) \tag{20}$$

Table 13 shows a typical relationship between MOS and channel switching delay.

**Table 13: Relationship between MOS and channel switching delay**

| $\text{MOS}_{\text{IE}}$ value of live TV | Channel Switching Delay (s) |
|---|---|
| 5 | ≤ 0,100 |
| 4 | 0,500 |
| 3 | 1,000 |
| 2 | 2,000 |
| 1 | 4,000 |

By fitting the mathematical model, formula (21) shows the mapping between MOS and CSD:

$$MOS_{IE-live} = \begin{cases} 5 & CSD \le 0{,}1\ s \\ 2{,}251 \times e^{-1{,}126 \times CSD} + 3{,}088 \times e^{-0{,}278 \times CSD} & 0{,}1\ s < CSD \le 10\ s \\ 0 & CSD > 10\ s \\ 0 & Test\ failure \end{cases} \tag{21}$$

Figure 13 shows the mapping curve between MOS and CSD for interaction experience of live video/TV program.

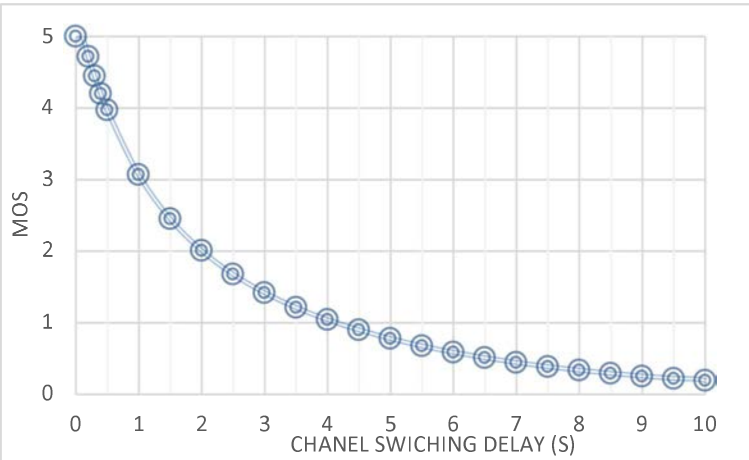



**Figure 13: Mapping between CSD and MOS for interaction experience of live video/TV program**

For VOD service, the Initial Loading Duration (ILD) is considered as one of the key factors that affects user experience [i.19]. Previous study [i.15] provides a model for quantifying the relationship between MOS and ILD:

$$\text{MOS}_{IE-VOD} = C_5 \times \text{t}^3_{\text{loading}} + C_6 \times \text{t}^2_{\text{loading}} + C_7 \times t_{loading} + C_8 \tag{22}$$

Table 14 shows a typical relationship between MOS and ILD.

**Table 14: Relationship between MOS and initial loading duration**

| $MOS_{IE}$ value of live VOD | Initial Loading Duration (s) |
|---|---|
| 5 | ≤ 0,100 |
| 4 | 1,000 |
| 3 | 2,000 |
| 2 | 5,000 |
| 1 | 8,000 |

By fitting the mathematical model, formula (23) shows the mapping between MOS and ILD:

$$MOS_{IE-VOD} = \begin{cases} 5 & ILD \leq 0{,}1\ s \\ -0{,}017 \times \mathrm{ILD}^3 + 0{,}258 \times \mathrm{ILD}^2 - 1{,}508 \times \mathrm{ILD} + 5{,}181 & 0{,}1\ s < ILD < 9\ s \\ 0 & ILD \geq 9\ s \\ 0 & Test\ failure \end{cases} \quad (23)$$

Figure 14 shows the mapping curve between MOS and ILD for interaction experience of VOD.

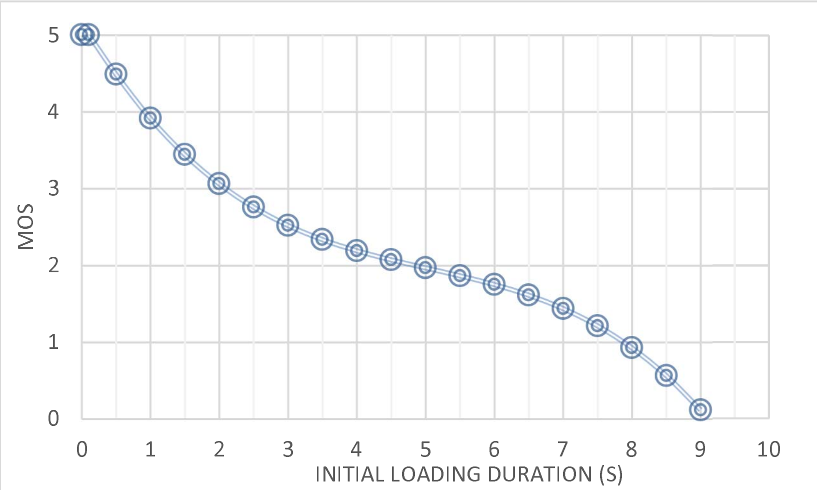



**Figure 14: Mapping between ILD and MOS for interaction experience of VOD**

## 7.5.2 MOS mapping of Viewing Experience (VE)

For live video/TV program, the Blurred Screen Duration Ratio (BSDR) and Blurred Screen Area Ratio (BSAR) are considered as the key factors that affect viewing experience. Previous study [i.14] provides a model for quantifying the relationship between MOS and viewing experience for live video/TV program:

$$\mathrm{MOS}_{VE-Live} = C_1 \times \exp(C_2 \times \mathrm{BSDR} * \mathrm{BSAR}) + C_3 \times \exp(C_4 \times \mathrm{BSDR} \times \mathrm{BSAR}) \quad (24)$$

Table 15 shows a typical relationship between MOS and BSDR[%]/BSAR[%] delay.

**Table 15: Relationship between MOS and BSDR/BSAR**

| Score (MOS) | BSDR(%) | BSAR(%) |
|---|---|---|
| 5 | 0 | 0 |
| 4 | 4 | 35 |
| 3 | 10 | 45 |
| 2 | 15 | 65 |
| 1 | 50 | 95 |

By fitting the mathematical model, formula (25) shows the mapping between MOS and BSDR /BSAR:

$$MOS_{VE-Live} = \begin{cases} 1{,}956 \times e^{-1{,}417 \times BSDR \times BSAR} + 2{,}998 \times e^{-22{,}671 \times BSDR \times BSAR} & BSDR \times BSAR < 0{,}9 \\ 0 & BSDR \times BSAR \geq 0{,}9 \\ 0 & Test\ failure \end{cases} \quad (25)$$

Figure 15 shows the mapping curve between MOS and BSDR/BSAR for viewing experience of live video/TV program.

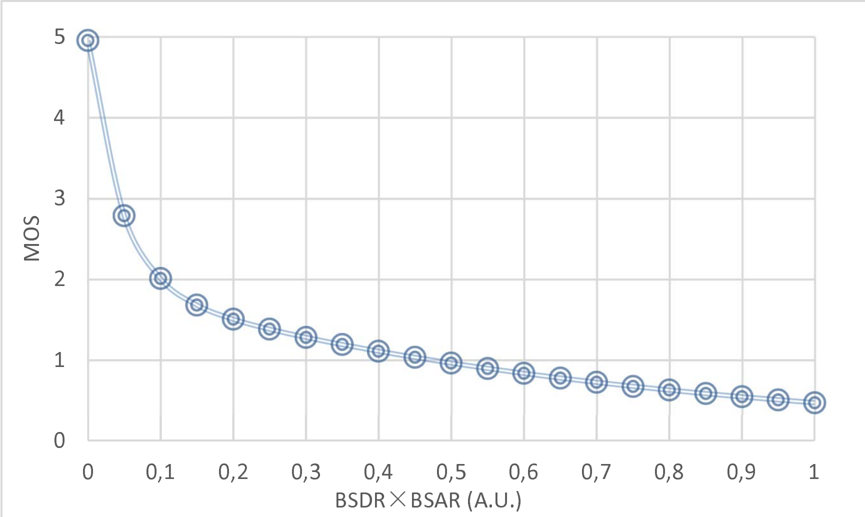



**Figure 15: Mapping between BSDR/BSAR and MOS for interaction experience of live video/TV program**

For VOD, Freezing Duration Ratio (FDR) (i.e. freezing duration ratio= FreezingDuration/TotalPlayTime) is considered as one of the key factors that affects viewing experience of VOD [i.19]. FreezingDuration is the total freezing duration, and TotalPlayTime is the total video playback duration. Previous study [i.15] provides a model for quantifying the relationship between MOS and viewing experience for VOD:

$$\mathrm{MOS}_{VE-VOD} = C_5 \times \exp(C_6 \times \mathrm{FDR}) + C_7 \times \exp(C_8 \times FDR) \quad (26)$$

Table 16 shows a typical relationship between MOS and FDR[%] in VOD.

**Table 16: Relationship between typical MOS values and freezing duration ratio of VOD**

| Score (MOS) | FDR(%) |
|---|---|
| 5 | 0 |
| 4 | 0,1 |
| 3 | 1 |
| 2 | 5 |
| 1 | 10 |

By fitting the mathematical model, formula (27) shows the mapping between MOS and FDR:

$$MOS_{VE-VOD} = \begin{cases} 3{,}403 \times e^{-11{,}555 \times FDR} + 1{,}579 \times e^{-920{,}557 \times FDR} & FDR < 0{,}3 \\ 0 & FDR \geq 0{,}3 \\ 0 & Test\ failure \end{cases} \quad (27)$$

Figure 16 shows the mapping curve between MOS and FDR for viewing experience of VOD.

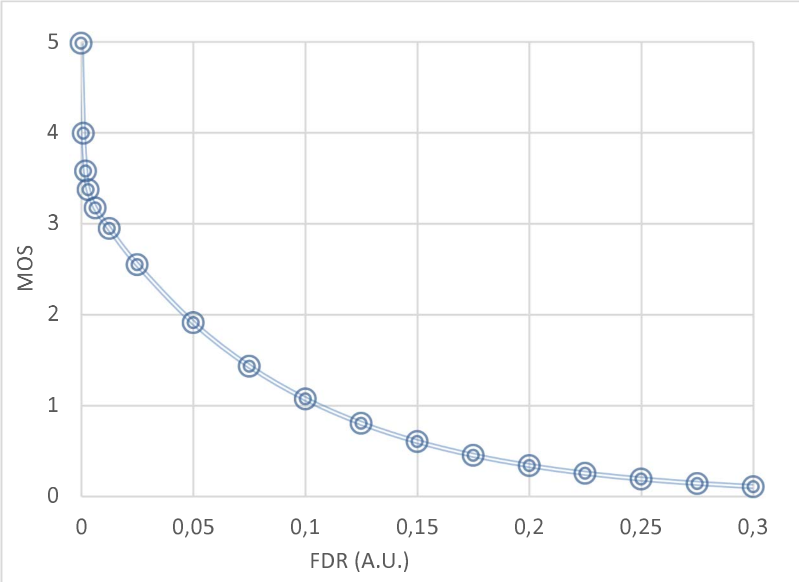



**Figure 16: Mapping between FDR and MOS for interaction experience of VOD**

### 7.5.3 Comprehensive service score

The interactive experience and viewing experience are key factors, for evaluating experience of IPTV (i.e. VOD and live video). To have a quantitative evaluation through MOS value, a weighted formula is used:

$$\mathrm{MOS}_{IPTV} = \mathrm{a} \times \mathrm{MOS}_{IE} + \mathrm{b} \times \mathrm{MOS}_{VE} \quad (28)$$

The exact weight value (a, b) can be determined by service operator. The recommended values are a = 50 %, b = 50 %. A large weight indicates great impact on user experience. The value of $\mathrm{MOS}_{\mathrm{IPTV}}$ could be used to reflect overall user experience of IPTV.

## 7.6 Terminal-based rendered game

### 7.6.1 MOS mapping of Network Start-up Time (NST)

In general, the MOS value of Network Start-up Time (NST) decreases with increasing network Round-Trip Time (RTT). The player has smooth experience with a guaranteed value of the RTT less than 50 ms [4]. This boundary could be set as a MOS value of 5. Some recommended value of MOS = 4 and MOS = 2 are mapped to 225 ms and 450 ms for RTT, respectively. The network start-up time has the following relationship:

$$\mathrm{NST} = 20 \times \mathrm{RTT} \quad (29)$$

The mapping relationship between MOS and NST is depicted in Figure 17 and the mapping function is described by formula (30) shown below.

NOTE: With the evolution of game, the NST requirement may be stricter in the future.

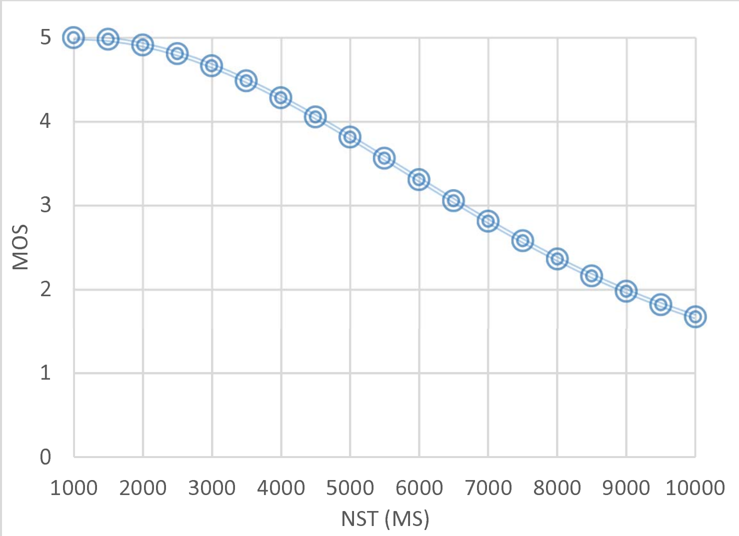



**Figure 17: Mapping between the network start-up time and MOS**

$$MOS_{NST} = \begin{cases} 5 & NST < 1\,000\ ms \\ 4 \times e^{-0{,}02 \times \left(\frac{NST}{1\,000} - 1\right)^2} + 1 & NST \geq 1\,000\ ms \\ 0 & Test\ failure \end{cases} \tag{30}$$

### 7.6.2 MOS mapping of Operation Response Delay (ORD)

The Operation Response Delay (ORD) reflects the interaction experience in the game. Typically, an ORD of 50 ms obtains "perfect" game experience and guarantees the key activities to be conducted in time [4]. 150 ms is for a good QoE (MOS = 4) while 350 ms is a poor QoE (MOS = 2). In general, the MOS value decreases with increasing ORD.

The mapping relationship between MOS and ORD is depicted in Figure 18 and the mapping function is described by formula (31) shown below.

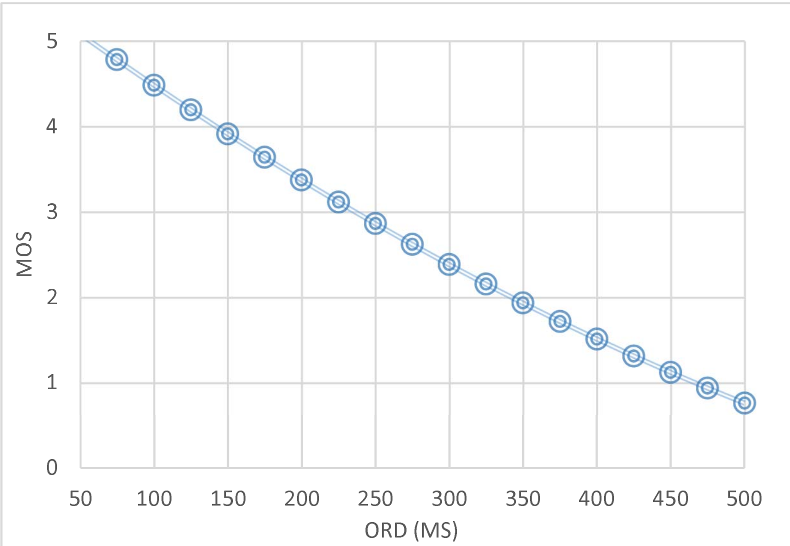



**Figure 18: Mapping between the Operation Response Delay (ORD) and MOS**

$$MOS_{ORD} = \begin{cases} 5 & ORD < 50\ ms \\ 0{,}000006 \times ORD^2 - 0{,}0129 \times ORD + 5{,}7114 & 50\ ms \leq ORD < 400\ ms \\ 0 & ORD \geq 400\ ms \\ 0 & Test\ failure \end{cases} \tag{31}$$

### 7.6.3 MOS mapping of Desynchronization Time Ratio (DTR)

See clause 5.6.2.4 for definition of Desynchronization Time Ratio (DTR). The higher the desynchronization time ratio, the worse the user experience. A MOS value of 5 is given to 0 % of desynchronization time ratio, while value of 3 and 0 are correlated to 0,42 % and 1,8 % respectively.

The mapping relationship between MOS and DTR [%] is depicted in Figure 19 and the mapping function is described by formula (32) shown below.

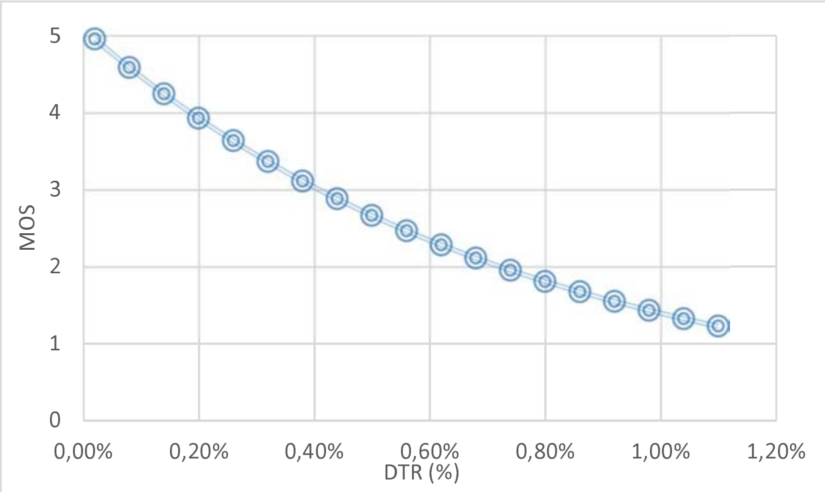



**Figure 19: Mapping between desynchronization time ratio and MOS**

$$MOS_{DTR} = \begin{cases} 5 & DTR \leq 0{,}02\ \% \\ 5{,}0835 \times e^{-129{,}1 \times DTR} & 0{,}02\ \% < DTR < 1{,}8\ \% \\ 0 & DTR \geq 1{,}8\ \% \\ 0 & Test\ failure \end{cases} \quad (32)$$

### 7.6.4 Comprehensive service score

The network start-up time, operation response time, and desynchronization time ratio are the key factors, for evaluating experience of terminal-based rendered game. To have a quantitative evaluation through MOS value, a weighted formula is used:

$$\mathrm{MOS}_{terminal-based\ rendering\ game} = \mathrm{a} \times \mathrm{MOS}_{NTS} + \mathrm{b} \times \mathrm{MOS}_{ORD} + \mathrm{c} \times \mathrm{MOS}_{DTR} \quad (33)$$

The exact weight value (a, b, c) can be determined by the service operator. The recommended values are a = 30 %, b = 50 %, c = 20 %. The larger values the greater the impact on the user experience. The value of $\mathrm{MOS}_{\text{terminal-based rendered game}}$ could be used to reflect overall user experience of terminal-based rendered game.

## 7.7 Cloud-based rendered game

### 7.7.1 MOS mapping of Frame Freezing Time Ratio (FFTR)

The Frame Freezing Time Ratio (FFTR) reflects the percentage of frame freezing phenomenon during the game period. A MOS value of 5 indicates no frame freezing has occurred during the entire playing time, while 0,42 % and 1,8 % are correlated to 3 and 0, respectively.

The mapping relationship between MOS and FFTR [%] is depicted in Figure 20 and the mapping function is described by formula (34) shown below.

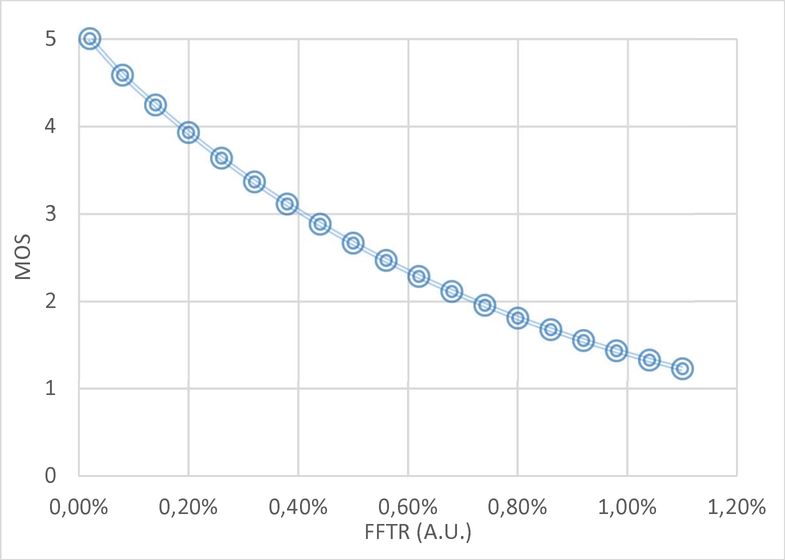



**Figure 20: Mapping between the frame freezing time ratio and MOS**

$$MOS_{FFTR} = \begin{cases} 5 & FFTR < 0{,}02\ \% \\ 5{,}0835 \times e^{-129{,}1 \times FFTR} & 0{,}02\ \% \leq FFTR < 1{,}8\ \% \\ 0 & FFTR \geq 1{,}8\ \% \\ 0 & Test\ failure \end{cases} \quad (34)$$

## 7.7.2 MOS mapping of Operation Response Delay (ORD)

See clause 7.6.2 for the definition of Operation Response Delay (ORD).

The mapping relationship between MOS and ORD is depicted in Figure 21 and the mapping function is described by formula (35) shown below.

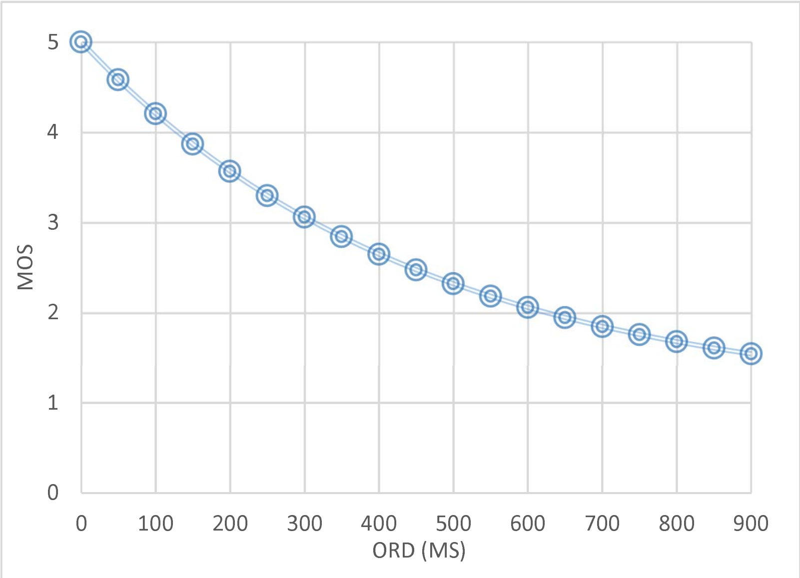



**Figure 21: Mapping between the Operation Response Delay and MOS**

$$MOS_{ORD} = \begin{cases} 4 \times e^{(-0{,}002213 \times ORD)} + 1 & 0 < ORD < 1\ 000\ ms \\ 0 & ORD \geq 1\ 000\ ms \\ 0 & Test\ failure \end{cases} \quad (35)$$

### 7.7.3 Comprehensive service score

The frame freezing time ratio and Operation Response Delay (ORD) are the key factors, for evaluating experience of cloud-based rendered game. To have a quantitative evaluation through MOS value, a weighted formula is used:

$$\mathrm{MOS}_{cloud-based\ rendered\ game} = \mathrm{a} \times \mathrm{MOS}_{FFTR} + \mathrm{b} \times \mathrm{MOS}_{ORD} \tag{36}$$

The exact weight value (a, b) can be determined by service operator. The recommended values are a = 70 %, b = 30 %. The larger the weighting values the greater the impact on the user experience. The value of $\mathrm{MOS}_{\text{cloud-based rendered game}}$ could be used to reflect overall user experience of cloud-based rendered game.

## 7.8 On-line education/telework

### 7.8.1 MOS mapping of Frame Freezing Times (FFT)

See clause 5.7.2 for the definition of Frame Freezing Times (FFT) [times]. For on-line education and telework [i.4], a MOS value of 5 is assigned to 0 number of frame freezing times, while MOS value of 3 and 0 are assigned to 2,5 and 25 frame freezing times respectively.

The mapping relationship between MOS and FFT is depicted in Figure 22 and the mapping function is described by formula (37).

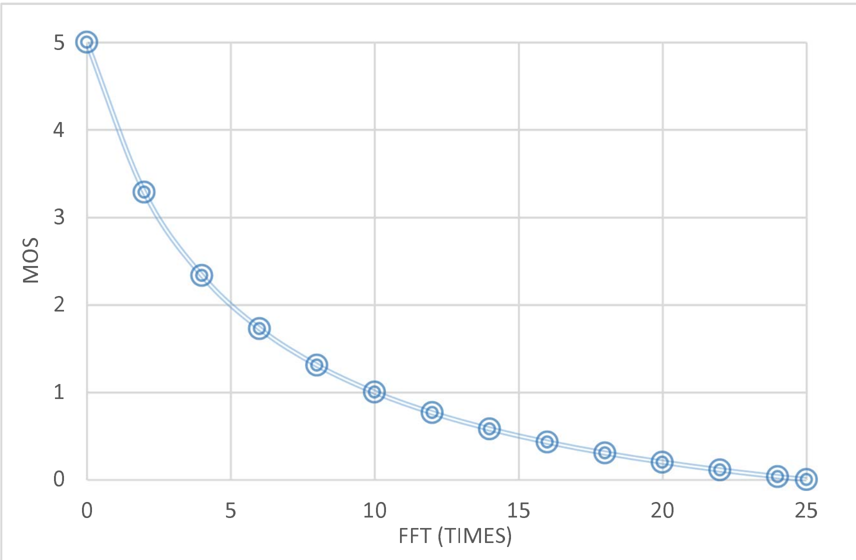



**Figure 22: Mapping between the frame freezing time and MOS**

$$MOS_{FFT} = \begin{cases} \frac{30}{FFT+5} - 1 & FFT \leq 25 \\ 0 & FFT > 25 \\ 0 & Test\ failure \end{cases} \tag{37}$$

### 7.8.2 MOS mapping of Frame Freezing Time Ratio (FFTR)

See clause 7.7.1 for definition of FFTR for cloud-based rendered game. For on-line education and telework [i.4], a MOS value of 5 is assigned to 0 % of frame freezing, while value of 3 and 0 are correlated to 1 % and 10 % respectively.

The mapping relationship between MOS and FFTR[%] is depicted in Figure 23 and the mapping function is described by formula (38).

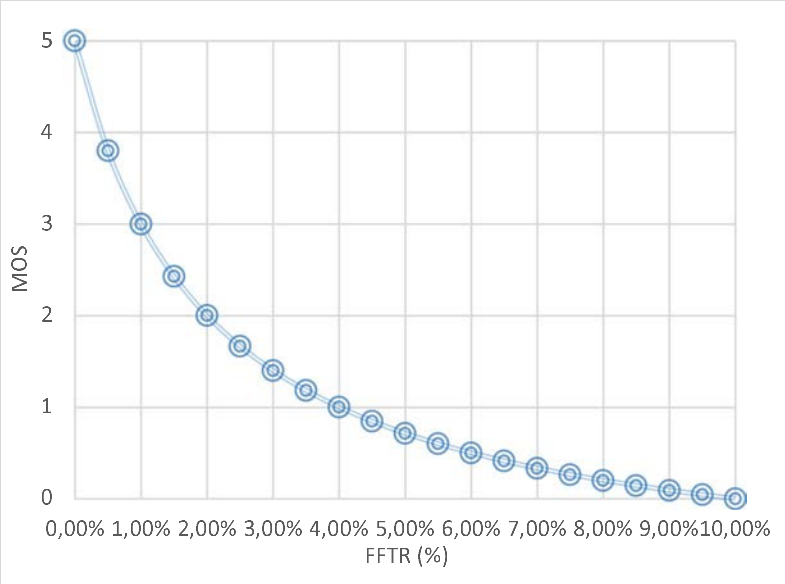



**Figure 23: Mapping between the frame freezing time ratio and MOS**

$$MOS_{FFTR} = \begin{cases} \frac{12}{100 \times FFTR + 2} - 1 & FFTR \leq 10\ \% \\ 0 & FFTR > 10\ \% \\ 0 & Test\ failure \end{cases} \quad (38)$$

### 7.8.3 MOS mapping of Interaction Delay (ID)

For on-line education/telework, the Interaction Delay (ID) indicates the delay of video and audio from the teacher/speaker to the student/listener. The MOS value of 5 indicates the delay is less than or equal to 0,1 s [i.4], which is close to a face-to-face communication. The MOS value of 3 and 0 are given by 0,2 s and 1,1 s, respectively.

The mapping relationship between MOS and ID is depicted in Figure 24 and the mapping function is described by formula (39).

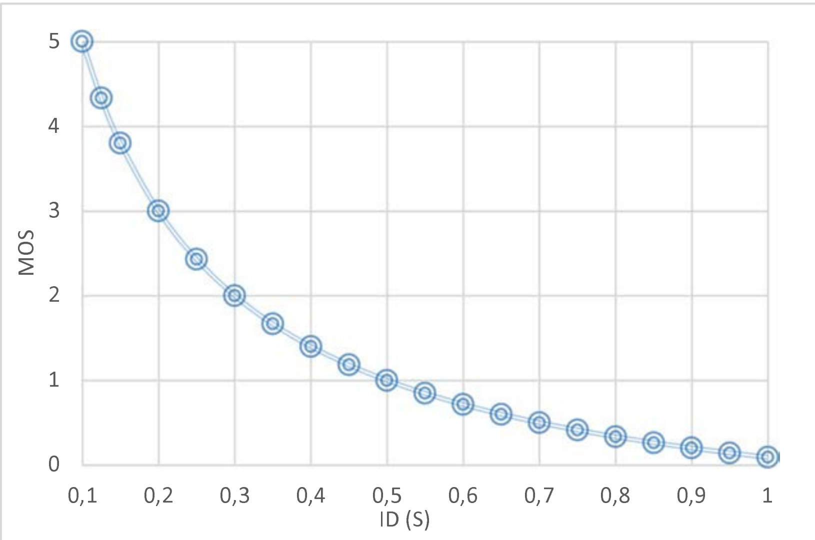



**Figure 24: Mapping between the interaction delay and MOS**

$$MOS_{ID} = \begin{cases} 5 & ID < 0{,}1\ s \\ \frac{12}{10 \times ID + 1} - 1 & 0{,}1\ s \leq ID < 1{,}1\ s \\ 0 & ID \geq 1{,}1\ s \\ 0 & Test\ failure \end{cases} \quad (39)$$

### 7.8.4 Comprehensive service score

The frame freezing time, frame freezing time ratio and interaction delay are the key factors, for evaluating experience of on-line education/telework. To have a quantitative evaluation through MOS value, a weighted formula is used:

$$\mathrm{MOS}_{on-line\ education/telework} = \mathrm{a} \times \mathrm{MOS}_{FFT} + \mathrm{b} \times \mathrm{MOS}_{FFTR} + \mathrm{c} \times \mathrm{MOS}_{ID} \quad (40)$$

The exact weight value (a, b, c) can be determined by the service operator. The recommended values are a = 25 %, b = 25 %, c = 50 %. The larger the weighting values the greater the impact on the user. The value of $\mathrm{MOS}_{\text{on-line education/telework}}$ could be used to reflect overall user experience of on-line education/telework.

## 7.9 Cloud VR video

### 7.9.1 MOS mapping of Initial Buffering Duration (IBD)

The evaluation of Initial Buffering Duration (IBD) is quantified in Table 17, showing a typical relationship between MOS and initial buffering duration. From the statistical analysis, a good experience (MOS = 4) needs the user waiting to be less than 1,9 s. The mapping relationship between MOS and IBD is depicted in Figure 25 and the mapping function is described by formula (41).

**Table 17: Relationship between MOS and initial buffering duration**

| $\mathrm{MOS}_{\mathrm{IBD}}$ value of cloud VR video | Initial buffering duration (s) |
|---|---|
| 5 | 0,07 |
| 4 | 1,9 |
| 3 | 5,8 |
| 2 | 13,7 |
| 1 | 30,0 |

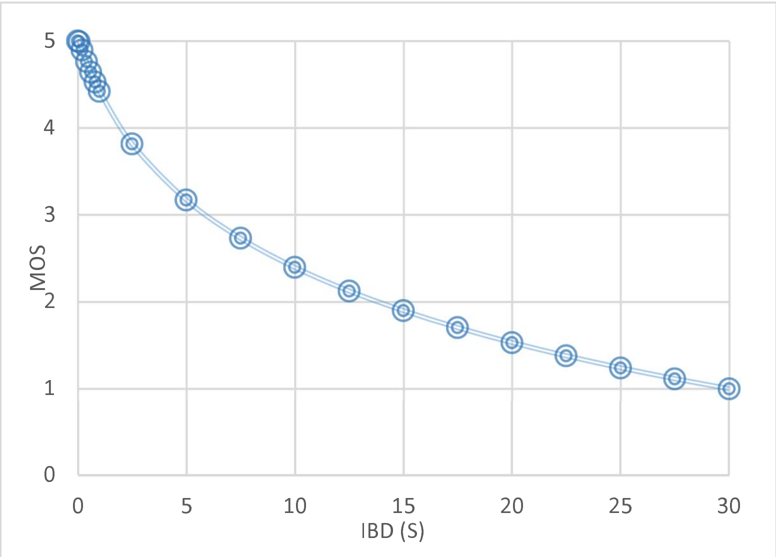



**Figure 25: Mapping between IBD and MOS**

$$MOS_{IBD} = \begin{cases} 5 & 0 < IBD \leq 0{,}07\ s \\ -1{,}407 \times \ln(IBD + 1{,}790) + 5{,}865 & 0{,}07\ s < IBD \leq 30\ s \\ 0 & IBD > 30\ s \\ 0 & Test\ failure \end{cases} \quad (41)$$

## 7.9.2 MOS mapping of Average Percentage of Frame Freezing (APFF)

The Frame Freezing Time Ratio (FFTR) is also discussed in clause 7.7.1 for cloud-based rendered game and in clause 7.8.2 for on-line education/telework. Average Percentage of Frame Freezing (APFF) is the average over a series of FFTR evaluations. For cloud VR video, the evaluation of the APFF is quantified in Table 18, showing a typical relationship between MOS and average percentage of frame freezing. From the statistical analysis, a good experience (MOS = 4) needs APFF to be less than 1,72 %. The mapping relationship between MOS and APFF is depicted in Figure 26 and the mapping function is described by formula (42).

**Table 18: Relationship between MOS and APFF**

| $MOS_{APFF}$ | Average percentage of frame freezing (%) |
|---|---|
| 5 | 0 |
| 4 | 1,72 |
| 3 | 8,3 |
| 2 | 22,1 |
| 1 | 45,8 |

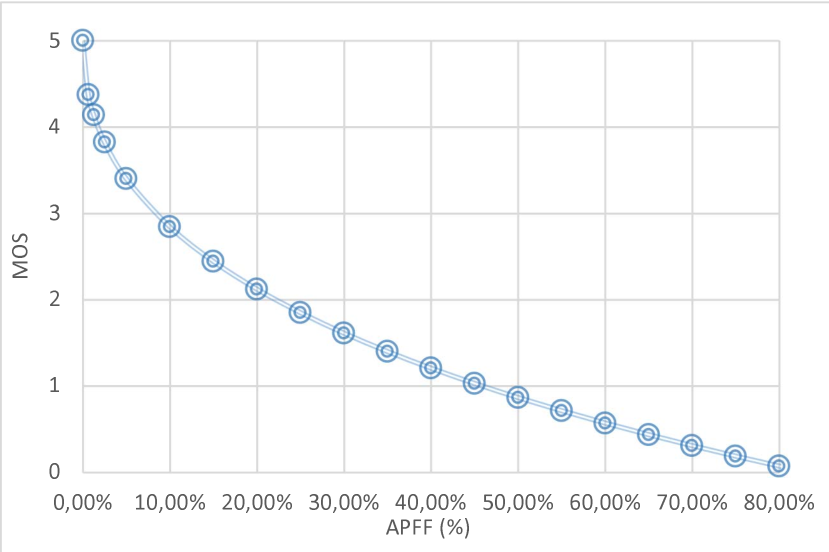



**Figure 26: Mapping between APFF and MOS**

$$MOS_{APFF} = \begin{cases} 5 & APFF = 0\ \% \\ -8{,}766 \times \ln(APFF^{0{,}4782} + 1{,}191) + 6{,}533 & 0\ \% < APFF \leq 83\ \% \\ 0 & APFF > 83\ \% \\ 0 & Test\ failure \end{cases} \quad (42)$$

## 7.9.3 MOS mapping of Low-Quality Image Display (LQID)

Low-quality image displays directly impacts the user feeling of a virtual environment construction. There are a few parameters that are correlated to this evaluation aspect, including average percentage of low-quality image area ($R_{LA}$), percentage of low-quality image duration ($R_{LD}$), the Quantization Parameter (QP) for the low-quality image. The mapping relationship between MOS and the parameters mentioned above is depicted in formula (43).

$$MOS_{LQID} = \min(\max\left(5 - (0{,}1959 \times e^{0{,}04778 \times QP} + 0{,}5934) \times \left(0{,}1959 - \frac{5}{1+(\frac{R_{LA}}{3{,}648 * e^{-17{,}05 \times R_{LD}} + 0{,}3928})^{1{,}487}}\right), 1\right), 5) \quad (43)$$

NOTE: The quantization parameter is a value used to compute the scaling factor for the dequantization of a transform coefficient before the inverse transform process is applied [i.9].

Here are two typical cases:

1) When the low-quality image Quantization Parameter (QP) = 36, the low-quality image area ($R_{LA}$) = 100 %, and according to formula (43), each typical value of $R_{LD}$ can be obtained, and is shown in Table 19. Table 19 shows a typical relationship between MOS and low-quality image duration ($R_{LD}$)). To get a better experience, the low-quality image duration ($R_{LD}$) should be less than 6,9 %.

**Table 19: Relationship between MOS and low-quality image duration ($R_{LD}$)**

| Low quality image duration ($R_{LD}$)(%) | $MOS_{LQID}$ |
|---|---|
| 0 | 5 |
| 6,9 | 4 |
| 40 | 3 |

2) When the low-quality image Quantization Parameter (QP) = 44, low-quality image area ($R_{LA}$) = 100 %, and according to formula (43), each typical value of $R_{LD}$ can be obtained, and is shown in Table 20. Table 20 shows a typical relationship between MOS and low-quality image duration ($R_{LD}$)). To get a better experience, the low-quality image duration ($R_{LD}$) should be less than 1,3 %.

**Table 20: Relationship between MOS and low-quality image duration ($R_{LD}$)**

| Low-quality image duration ($R_{LD}$)(%) | $MOS_{LQID}$ |
|---|---|
| 0 | 5 |
| 1,3 | 4 |
| 6,9 | 3 |
| 12,8 | 2 |
| 34 | 1 |

### 7.9.4 Comprehensive service score

The initial buffering duration, average percentage of frame freezing and low-quality image display are key factors, for evaluating experience of cloud VR video. To have a quantitative evaluation through MOS value, a weighted formula is used:

$$\mathrm{MOS}_{Cloud\ VR\ video} = \mathrm{a} \times \mathrm{MOS}_{IBD} + \mathrm{b} \times \mathrm{MOS}_{APFF} + c \times \mathrm{MOS}_{LQID} \quad (44)$$

The exact weight value (a, b, c) can be determined by the service operator. The recommended values are a = 35 %, b = 15 %, c = 50 %. The larger the weighting values the greater the impact on the user. The value of $MOS_{\text{Cloud VR video}}$ could be used to reflect overall user experience of Cloud VR video.

## 7.10 Cloud VR game

### 7.10.1 MOS mapping of black edge and smearing

The Black Edge and Smearing (BES) reflect the visual quality of VR game. There are two important parameters, the average percentage of the black area ($R_{BA}$) and the percentage of the black edge duration ($R_{BD}$). The mapping relationship between MOS and these two parameters mentioned above is depicted in formula (45):

$$MOS_{BES} = \min(\max\left(5 - \left(5 - \frac{5}{1+(\frac{R_{BA}}{2{,}583 * e^{-20{,}42 \times R_{BD}+0{,}347}})^{1{,}462}}\right), 1\right), 5) \quad (45)$$

Assuming the percentage of the black edge duration $R_{BD}$ = 50 %, the typical relationship between MOS and $R_{BA}$ are as shown in Table 21.

**Table 21: Relationship between MOS and $R_{BA}$**

| $MOS_{BES}$ | $R_{BA}$ (%) |
|---|---|
| 5 | 0 |
| 4 | 13,4 |
| 3 | 26,3 |
| 2 | 45,8 |
| 1 | 89,5 |

## 7.10.2 MOS mapping of Average Percentage of Frame Freezing (APFF)

The Average Percentage of Frame Freezing (APFF) is discussed in clause 7.9.2 for cloud VR video. The mapping relationship between MOS and APFF is depicted in Figure 27 and the mapping function is described by formula (46).

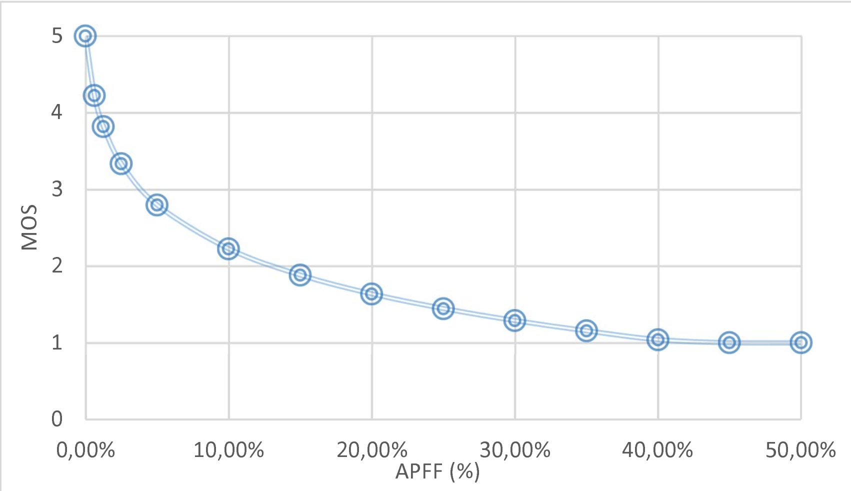



**Figure 27: Mapping between APFF and MOS**

$$MOS_{APFF} = \min(\max(-0{,}8749 \times \ln(APFF + 0{,}004378) + 0{,}2483{,}1), 5) \quad (46)$$

## 7.10.3 MOS mapping of Operation Response Delay (ORD)

The Operation Response Delay (ORD) is discussed in clause 7.6.2 for terminal-based rendered game. The mapping relationship between MOS and ORD is depicted in Figure 28 and the mapping function is described by formula (47).

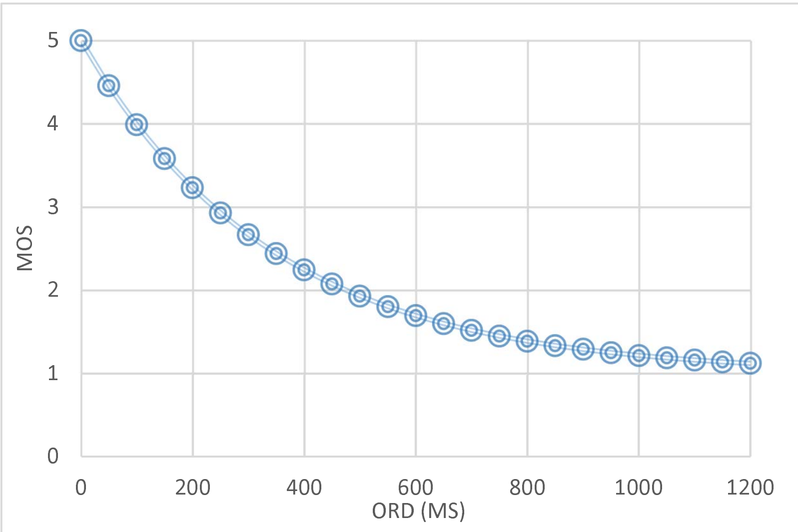



**Figure 28: Mapping between ORD and MOS**

$$MOS_{ORD} = \min(\max(4 \times e^{-0{,}002917 \times ORD} + 1{,}1)\,, 5) \quad (47)$$

### 7.10.4 Comprehensive service score

The Black Edge and Smearing (BES), Average Percentage of Frame Freezing (APFF) and Operation Response Delay (ORD) are key factors, for evaluating experience of cloud VR game. To have a quantitative evaluation through MOS value, a weighted formula is used:

$$\mathrm{MOS}_{cloud\ VR\ game} = \mathrm{a} \times \mathrm{MOS}_{BSE} + \mathrm{b} \times \mathrm{MOS}_{APFF} + \mathrm{c} \times \mathrm{MOS}_{ORL} \quad (48)$$

The exact weight value (a, b, c) can be determined by service operator. The recommended values are a = 50 %, b = 35 %, c = 15 %. The larger the weighting values the greater the impact on the. The value of $\mathrm{MOS}_{\text{cloud VR game}}$ could be used to reflect overall user experience of cloud VR game.

## 7.11 User experience classification and evaluation framework for service bundles

### 7.11.1 Service bundle evaluation framework

Figure 29 shows the service evaluation framework, using detailed KQIs and step-wise aggregates those into an integrated MOS value for a full service bundle. The integrated MOS value is estimating the residential user experience of a service bundle. The MOS values of each residential service defined in the previous clauses are used to calculate the integrated MOS value.

In general, the framework is divided into four steps:

1) KQIs are defined to characterize the user experience for dedicated service (see clause 5). A few KQI parameters are specified according to the service characteristics.

2) The MOS value of each KQI is calculated using the formula defined in the previous clauses.

3) The comprehensive MOS value of each service is then calculated by using a linear weighted function.

4) The integrated MOS value is calculated from the comprehensive MOS values of each service.

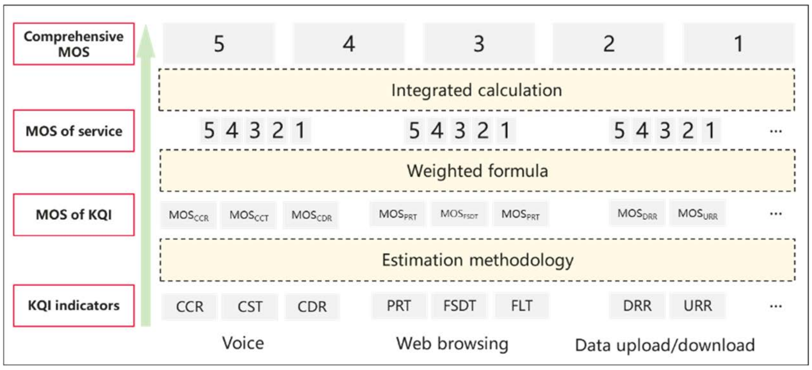



**Figure 29: Illustration of the service evaluation framework for residential network services (not all services are shown)**

### 7.11.2 Calculation of integrated MOS for residential network service bundles

Based on the integrated MOS value, the residential service bundle user experience is evaluated. The integration step is based on the weighted values per service [i.10]. The weighted values are derived from the user utilization rate of the dedicated network service [i.10]. The relative weighted values are a normalization of the weighted values to be a maximum of 10. Table 22 shows the relative weighed value of each residential service.

**Table 22: Relative weighted value of each home broadband service**

| Service \ Weighted value | Relative Weighted Value (RWV) |
|---|---|
| Voice | 1 |
| Web browsing | 9 |
| Data Upload/Download | 3 |
| IPTV | 7 |
| Terminal-based rendered game | 5 |
| Cloud-based rendered game | 5 |
| Video | 9 |
| On-line education | 3 |
| Telework | 4 |
| Cloud VR video | 3 |
| Cloud VR Game | 3 |
| NOTE: The relative weighted values are based on overall usage of service and are therefore the recommendation default value. Individual users might have a different set of relative weighted values. | |

The integrated MOS value is calculated using formula (49):

$$MOS_{integration} = MOS_{voice} \times \frac{RWV_{voice}}{\sum(RWV_{voice}+RWV_{web}+RWV_{upload}+\cdots)} + MOS_{web} \times \frac{RWV_{web}}{\sum(RWV_{voice}+RWV_{web}+RWV_{upload}+\cdots)} + \cdots (49)$$

The $MOS_{integration}$ value can be used to classify the user QoE for a service bundle into categories bad to excellent, see Table 8.

NOTE: The $MOS_{integration}$ value can be on a per-user bases or an average over a set of users. In the latter case the individual service MOS values need to be averaged over that set of users.

# 8 Residential Service classification

## 8.1 Overview

This clause discusses the residential service classification according to the residential service network requirements [i.11]. The residential services are classified into different network characteristics levels. The network characteristics level indicates the network performance and functionality required to satisfy the set of residential services. The higher network characteristics level indicates the greater demand on the network performance and functionality. By quantifying the network characteristics into different levels, operators, users, etc. can choose a suitable subscription and develop the appropriate residential network.

## 8.2 Residential Service classification into network characteristics levels

Table 23 shows the classification of residential services into network characteristics levels based on their network required performance and functionality. Different network characteristics levels (labelled L0, L1, and L2) require dedicated network performance and functionality. Higher network characteristics levels in the future (such as L3, L4, etc.) may be defined according to new services and network capabilities.

**Table 23: Classification of residential service**

| Dimension \ Level | L0 | L1 | L2 |
|---|---|---|---|
| Service | Voice<br>Web browsing<br>SD&HD video<br>Upload/download | Terminal-based on-line game<br>4K video<br>On-line education/office | Cloud VR<br>8K video<br>Cloud-based on-line game |

## 8.3 Network evaluation

### 8.3.1 Introduction

Network capability evaluation can be basic or detailed, depending on the measurement resources. The basic evaluation contains only a simplified subset of network parameters, which could be easily measured by the end user through mobile device. This helps the end user to quickly understand the dynamic status of their network. Such data could be supplied to service operator for improvement of network performance.

For detailed network evaluation, complex testing equipment is necessary to obtain the full set of parameters. This is mainly done by service operator or third-party testing laboratories.

It is expected that the user with network KQIs in a certain level receives good experience (MOS value ≥ 3,5) also for the services of the lower levels.

### 8.3.2 Detailed network evaluation

Detailed network evaluation is a comprehensive way to quantify the residential network capability for different classification levels of residential services. Table 24 lists the recommended network KQIs for each level of the residential services. The values of the network KQI refer to the network requirements of service in clause 6.

**Table 24: Detailed network evaluation of residential services**

| Level | Network KQIs (full set) | | | | | | |
|---|---|---|---|---|---|---|---|
| | **Throughput** | **Latency** | **Connectivity** | **Handover** | **Green** | **Security** | **Smart O&M** |
| L0 | ≥ 100 Mbps | ≤ 35ms | Number of connected devices: 64 | ≤ 100 ms | Power consumption: ≤ 45 mW/Mbit | The hardware shall support secure boot, firmware package encryption, system encryption, and anti-reverse analysis. The system shall have an active/standby capability. When an exception occurs, the system shall be switched to the standby area. | Controllable |
| L1 | ≥ 1 000 Mbps | ≤ 19 ms | Number of connected devices: 128, Number of concurrently active devices: 16, Throughput can be achieved per device: 50 M | ≤ 50 ms | Power consumption: ≤ 30 mW/Mbit | The firewall shall support protection against DDoS attacks up to at least 3 000 attack packets per second. Security tools shall scan the system for unknown vulnerabilities. | Controllable/Manageable |
| L2 | ≥ 2 000 Mbps | ≤ 7 ms | Number of connected devices: 256, Number of concurrently active devices: 16, Throughput can be achieved per device: 100 M | ≤ 10 ms | Power consumption: ≤ 20 mW/Mbit | The firewall shall support protection against DDoS attacks up to at least 10 000 attack packets per second. The system shall log common attacks, prevent brute force cracking of secure information and monitor the security of key files. | Controllable/Manageable/ Analytical |

To build up a residential network, it is important to understand the network requirements for improving the quality of service, and with that improving the user experience for dedicated services. Better quality of service has more stringent requirements on network KQIs, i.e. throughput, latency, connectivity, handover, green, security, and smart O&M. In order to get a good user experience (MOS value ≥ 3,5) for a given network characteristics level (L0, L1, L2) the network shall comply with the corresponding network KQI values. A given network characteristics level supports a certain set of services with good user experience.

### 8.3.3 Basic network evaluation

The basic network evaluation provides relatively simplified network indicators in order to help users be capable to evaluate the network. Table 25 lists the recommended network KQI for the basic network evaluation.

**Table 25: Basic network evaluation of residential service**

| | Network KQIs (basic subset) | | |
|---|---|---|---|
| **Level** | **Throughput** | **Latency of residential network** | **Handover** |
| L0 | ≥ 100 Mbps | ≤ 100 ms | ≤ 100 ms |
| L1 | ≥ 1 000 Mbps | ≤ 50 ms | ≤ 50 ms |
| L2 | ≥ 2 000 Mbps | ≤ 20 ms | ≤ 10 ms |

# History

| Document history | | |
|---|---|---|
| V1.1.1 | April 2023 | Publication |
| V1.2.1 | March 2024 | Publication |
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