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GSTR-MVQ

Quality of service and quality of experience standards related to the metaverse

Technical Report ITU-T GSTR-MVQ

Quality of service and quality of experience standards related to the metaverse

Summary

This Technical Report contains QoS and QoE standards related to the metaverse. It identifies the standards and brings a general overview on the metaverse, and its technologies based, especially on the deliverable of ITU-T Focus Group on Metaverse (FG-MV).

Keywords

AR, digital twins, industrial metaverse, metaverse, QoS, QoE, XR.

Note

This is an informative ITU-T publication. Mandatory provisions, such as those found in ITU-T Recommendations, are outside the scope of this publication. This publication should only be referenced bibliographically in ITU-T Recommendations.

Change Log

This document contains Version 1 of the ITU-T Technical Report GSTR-MVQ on "*QoS and QoE standards related to the metaverse*" approved at the ITU-T Study Group 12 meeting held in Geneva, 9-17 June 2026.

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1 Scope

This Technical Report aims to study the relationship between the metaverse and quality of service (QoS) and quality of experience (QoE), focusing on the main goal of identifying the most important QoS and QoE standards related to the metaverse technologies that will enable high-quality, immersive experiences within the metaverse ecosystem.

As metaverse applications deliver highly immersive and interactive virtual environments, ensuring consistent and measurable QoS/QoE is essential to achieving seamless, realistic and satisfactory user experiences.

This Technical Report presents an overview of the metaverse context, its main concepts and technologies related. It then will cover the relationship between those concepts/technologies and QoS/QoE. Finally, it identifies the most important QoS and QoE standards related to the metaverse and provides guidance for future ITU-T work to ensure that metaverse services are built on a robust, interoperable and high-quality foundation.

2 References

[ITU-T G.1000] Recommendation ITU-T G.1000 (2001), *Communications Quality of Service: A framework and definitions.*

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

[ITU-T G.1036] Recommendation ITU-T G.1036 (2022), *Quality of experience influencing factors for augmented reality services.*

[ITU-T P.10] Recommendation ITU-T P.10/G.100 (2017), *Vocabulary for performance, quality of service and quality of experience.*

[ITU-T P.1320] Recommendation ITU-T P.1320 (2022), *Quality of experience assessment of extended reality meetings.*

3 Definitions

3.1 Terms defined elsewhere

This Technical Report uses the following terms defined elsewhere:

3.1.1 augmented reality (AR) [ITU-T P.1320]: An environment containing both real and virtual sensory components. The augmented reality continuum runs from virtual content that is clearly overlaid on a real environment (assisted reality) to virtual content that is seamlessly integrated and interacts with a real environment (mixed reality).

3.1.2 digital twin [b-ITU-T Y.4600]: A digital representation of an object of interest.

3.1.3 extended reality (XR) [ITU-T P.1320]: An environment containing real or virtual components or a combination thereof, where the variable X serves as a placeholder for any form of new environment (e.g., augmented, assisted, mixed, virtual or diminished reality).

3.1.4 immersion [ITU-T G.1035]: A psychological state characterized by perceiving oneself to be enveloped by, included in and interacting with an environment that provides a continuous stream of stimuli and experiences.

3.1.5 metaverse [b-ITU-T Y.4238]: A collective virtual environment where physical and virtual worlds converge, that enables users to interact with shared digital spaces, objects and services.

3.1.6 presence [ITU-T G.1035]: The subjective experience of being in one place or environment, when one is physically situated in another place or environment.

3.1.7 quality [ITU-T G.1000]: The totality of characteristics of an entity that bear on its ability to satisfy stated and implied needs (ISO 8402).

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

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

3.2 Terms defined in this Technical Report

None.

4 Abbreviations and acronyms

This Technical Report uses the following abbreviations and acronyms:

AI	Artificial Intelligence
AR	Augmented Reality
DFS	Digital Financial Services
eMBB	enhanced Mobile Broadband
FG-MV	ITU-T Focus Group on Metaverse
FPS	Frames Per Second
IoT	Internet of Things
KQI	Key Quality Indicator
MEC	Multi-access Edge Computing
MTP	Motion-To-Photon
NFT	Non-Fungible Token
QoE	Quality of Experience
QoS	Quality of Service
URLLC	Ultrareliable Low-Latency Communications
VR	Virtual Reality
XR	Extended Reality

5 Introduction

Although the metaverse is still at an early stage of development and no internationally agreed definition currently exists, it is widely recognized as a potential driver of the next wave of digital transformation. The metaverse is expected to impact multiple sectors over the coming years, including

entertainment, education, healthcare, manufacturing, transportation, and smart cities services [b-FG-MV D.WG1-01]. In this context, ITU-T Focus Group on Metaverse (FG-MV) was established under the Telecommunication Standardization Advisory Groupon 16 December 2022 to analyse the technical requirements of the metaverse and identify key enabling technologies. The work addresses areas from multimedia and network optimization to digital currencies, Internet of Things (IoT), digital twins, artificial intelligence (AI) and environmental sustainability.

The metaverse has been increasingly used to develop new ICT services and digital technologies in both customer-oriented and industrial scenarios. Additionally, cities and countries have been launching metaverse policies and pilot projects as part of broader digital transformation initiatives.

The metaverse represents a convergence of virtual reality (VR), augmented reality (AR), extended reality (XR), digital twins and AI-driven platforms into immersive, persistent and interactive digital environments. These environments are expected to revolutionize entertainment, industrial operations, education and smart city services by providing real-time, multi-user and multi-sensory experiences. However, the success of such services depends critically on their quality of service (QoS) and QoE.

Metaverse applications impose stringent performance requirements that exceed those of traditional multimedia services. Parameters such as motion-to-photon latency, high frame rates, ultralow jitter, and synchronized multimodal outputs (e.g., visual, audio and haptic feedback) are essential to achieving a sense of presence and avoiding user discomfort. For industrial and mission-critical scenarios, including remote robotics, tele-surgery and digital twin operations, requirements related to reliability, deterministic latency, security and real-time synchronization become even more demanding.

In this context, this Technical Report identifies the main QoS and QoE standards related to metaverse technologies and applications, while discussing how existing ITU-T Recommendations can support the development of interoperable, reliable and high-quality metaverse services.

6 Key scenarios of the metaverse

According to [b-FG-MV D.WG1-01], the metaverse can be implemented in three key scenarios (see Figure 1): digitalized lifestyle for inhabitants; industrial metaverse for industries; and digital transformation for cities and communities.

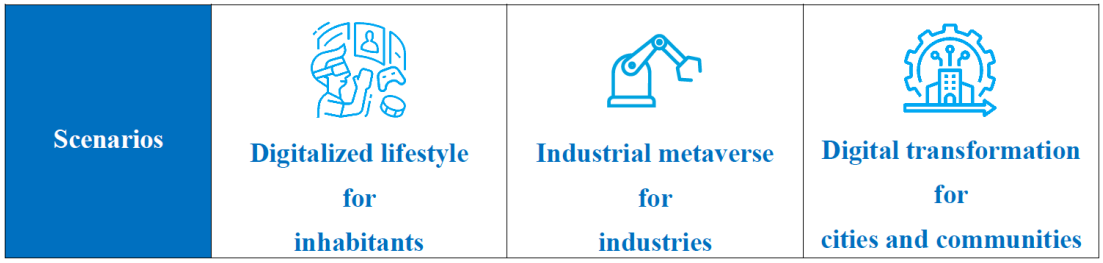

Figure 1 – Three key scenarios of the metaverse [b-FG-MV D.WG1-01]

6.1 Digitalized lifestyle for inhabitants in the metaverse

A digitalized lifestyle scenario can be referred to as a virtual environment in which people can be present in digital spaces with the support of AR, VR, digital twin and other technologies. Specific scenarios include work, games, shopping, online learning, events and fitness activities.

6.2 Industrial metaverse for industries

The second scenario can be broadly called the industrial metaverse. The metaverse arguably offers the greatest potential to sectors such as manufacturing, banking, healthcare and transportation.

6.3 Digital transformation for cities and communities

The third metaverse scenario is focused on cities and communities. The metaverse could provide opportunities to improve urban design, increase citizen participation, improve operational efficiency, optimize energy consumption and enhance the capability of disaster and emergency management. It might even make changes to the forms of governance.

The metaverse will improve urban efficiency and generate new value to cities in the physical world. In addition, it will also enrich the physical experiences of citizens and create new virtual experiences.

7 Technologies related to metaverse

Different models have been proposed by different organizations and individuals to organize the metaverse components, differing on emphasis and granularity [b-FG-MV D.WG1-01]. Five core building elements shown in Figure 2 have been introduced in [b-ITU UNWTO].

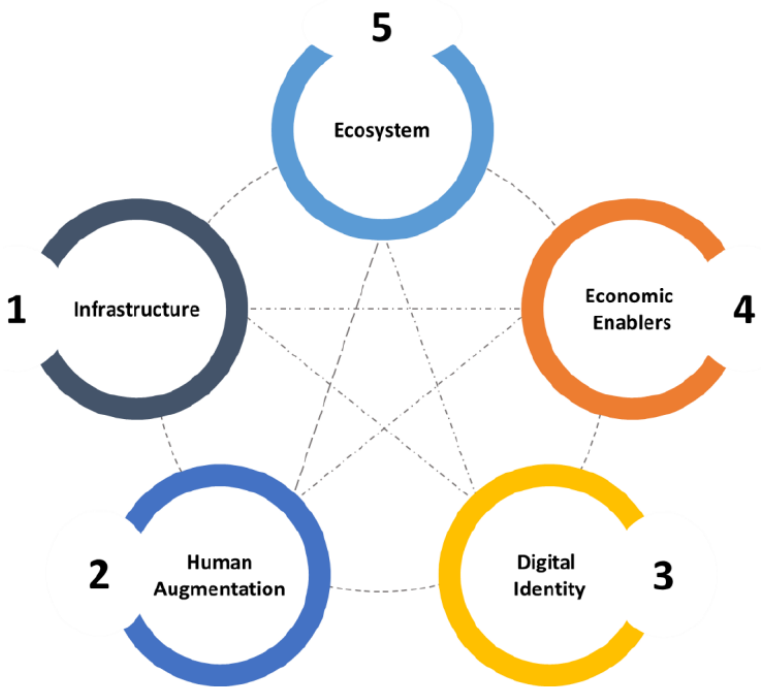

Figure 2 – Five elements model of the metaverse [b-FG-MV D.WG1-01]

The five building elements of the metaverse consist of the following concepts and technologies [b-FG-MV D.WG1-01]:

Infrastructure: networks and connectivity, computing power, graphic processing units, storage capacity, sensing or perception, cloud or edge infrastructure, semiconductor (chips or processors).

Human augmentation:

– mobile devices: headsets (VR), smart glasses (AR), other wearables, haptics, holographic, brain-machine interface;

– creation platform: interaction platform, content moderation platform, 3D design or modelling, game engines, AI or machine learning services, creator tools, search/visual search;

– asset: 3D interoperable assets, asset market.

Digital identity: avatar, agent, multiuser and multitasking, social graphs, rating, social curation, security, privacy.

Economic enablers: decentralized, blockchain, cryptocurrency, NFT, commerce, advertising, payment, transactions.

Ecosystem: entertainment, shopping, education, games, e-sports, industrial applications, regulation, governance, ethics.

Considering the scenarios and the five elements model presented, it is feasible to say that the development of metaverse is based on a combination of technologies. Some of the identified technologies related to metaverse are:

- Augmented reality (AR);
- Virtual reality (VR);
- Cloud computing;
- Artificial intelligence (AI);
- Digital twin;
- Internet of things (IoT);
- Blockchain.

The relationship between QoS/QoE and the metaverse can be observed across multiple building elements and enabling technologies.

8 Relationships between QoS, QoE and the metaverse

The metaverse is envisioned as a cutting-edge digital environment, where the convergence of technologies such as VR, AR, AI, and digital twins will enable new forms of interaction and deeply immersive experiences. Reaching this vision requires not only advanced technological enablers but also the assurance of high-quality user experiences, grounded in well-defined QoS and QoE parameters.

Unlike conventional multimedia services, metaverse applications frequently combine multiple synchronized sensory and interaction channels, including audiovisual rendering, spatial audio, haptic feedback, motion tracking and real-time user interaction.

These emerging requirements may also motivate future enhancements to QoS/QoE assessment methodologies and interoperability frameworks.

When it comes to quality perception in metaverse environments, QoE is increasingly influenced by the combined interaction of network performance, device capabilities, rendering systems and human perception factors.

When analysing the main building elements of the metaverse, clear relationships with QoS and QoE can be established. Examples include:

- **Infrastructure**: network performance (latency, jitter, throughput, synchronization) is directly tied to immersive continuity, reflecting requirements already considered in ITU-T Recommendations such as G.1010 and E.430.
- **Human augmentation**: applications like VR and AR depend on ultralow latency, high frame rate and accurate motion tracking, as described in [ITU-T G.1035], [ITU-T G.1036] and [ITU-T P.1320].
- **Economic enablers**: digital financial services in the metaverse must ensure reliability, security and usability, areas covered by Recommendation ITU-T G.1033.
- **Ecosystem**: interactive applications such as gaming demand stringent QoE requirements, with SG12 standards including G.1032 and G.1072 providing specific models for cloud gaming and real-time interactivity.

These links show that the metaverse does not require redefining quality concepts but rather applying and extending existing QoS/QoE frameworks to guarantee immersive, secure and inclusive experiences.

8.1 Metaverse QoS and QoE requirements

The metaverse is underpinned by high-performance communication networks, where low latency, high bandwidth and ultrareliability are critical for delivering immersive experiences. While current QoS requirements address services such as video streaming and gaming, metaverse applications introduce additional complexity due to multimodal and real-time interactions, often requiring end-to-end latency for VR/AR and even lower for haptic feedback.

Key enablers include:

- 5G/6G connectivity with support for URLLC and enhanced mobile broadband (eMBB).
- Network slicing and QoS flows dedicated to specific metaverse services.
- Multi-access edge computing (MEC) to offload rendering, simulation and AI workloads close to users, reducing network delays.

8.1.1 Identifying relevant indicators

Metaverse QoE goes beyond audiovisual quality, encompassing aspects such as presence, immersion, interactivity and multi-sensory fidelity. The relevant indicators may vary depending on the specific service aspects that impact each application. Examples include:

- **Motion-to-photon latency** – critical for preventing motion sickness in VR.
- **Frame rate and visual resolution** – directly affecting perceived realism.
- **Spatial audio quality** – ensuring accurate 3D sound localization.
- **Haptic feedback accuracy** – low latency and jitter thresholds for tactile realism.
- **Task-oriented key quality indicators (KQIs)** – assessing effectiveness in industrial or training simulations.

8.1.2 QoE assessment methodologies

Recommendation ITU-T G.1011 provides general guidance on QoE assessment methodologies, including the selection of appropriate subjective and objective methods according to the application context, user expectations and service characteristics.

In metaverse environments, QoE assessment may involve additional challenges compared with conventional multimedia services, due to the integration of multimodal interactions, spatial perception, real-time responsiveness and user immersion. Factors such as presence, interaction naturalness, audiovisual synchronization, haptic feedback and motion tracking accuracy may significantly influence the perceived quality.

Thus, QoE assessment methodologies for metaverse applications should consider both subjective and objective evaluation approaches, taking into account the specific characteristics of immersive and interactive environments.

QoE assessment will build upon Recommendations ITU-T P.910 and ITU-T P.1320, extending them to incorporate task-based subjective evaluations as well as objective metrics for multimodal interactions. Depending on the application scenario, QoE evaluation may also include measures related to user comfort, cybersickness, task completion effectiveness, collaborative interaction and perceived realism.

8.1.3 Requirements per technology/application

The relevant QoS and QoE aspects may vary depending on the specific metaverse technology or application under consideration. Different services impose distinct requirements related to latency, synchronization, reliability, immersion, interactivity and user perception. Table 1 presents examples of the main quality requirements associated with different metaverse technologies and application scenarios.

Table 1 – Main quality requirements for different technologies and applications in the metaverse

Technology/Application	Main requirements
VR	Low latency, high frame rate, spatial audio, absence of motion sickness
AR	Synchronization between physical and digital world, accurate tracking, low latency
Extended reality (XR)/ immersive meetings	Immersion, natural interaction, audiovisual synchronization, accessibility, spatial synchronization
Gaming/cloud gaming	Ultralow latency, network stability, consistent rendering and interactivity
Telepresence/telemeetings	Realistic presence, real-time interaction, multimodal quality (audio, video, data)
Digital Financial Services (DFS in metaverse)	Reliability, usability, response time.
Multimedia streaming (360° video, virtual events)	Adaptive bitrate, session continuity, audiovisual quality
Avatars	Motion synchronization, natural interaction, rendering consistency, audiovisual synchronization
Digital identity	Identity management, authentication, interoperability
Metaverse economy (blockchain, NFTs, cryptocurrencies)	Transaction reliability, smart contract latency
Network infrastructure (5G/6G, edge, cloud)	End-to-end latency, jitter, bandwidth, scalability
Industrial metaverse	Reliability, deterministic latency, real-time synchronization, operational continuity
Digital twins	Real-time data synchronization, accuracy, low latency, reliability

The main QoS and QoE requirements and assessment aspects associated with different metaverse technologies and applications are further addressed in specific SG12 Recommendations, which are presented in the next clause. Annex B complements this overview by providing examples of QoS and QoE metrics for specific metaverse applications.

9 QoS and QoE standards related to metaverse

The purpose of linking standards and SG12 Recommendations to metaverse applications is to support immersive, interactive, reliable and satisfactory user experiences, fostering the development and adoption of metaverse services and applications. Some standards and Recommendations have already been identified by SG12 in contributions to deliverables developed within FG-MV, as shown in Annex A.

Some Recommendations developed within SG12 provide general frameworks, concepts, definitions, methodologies and guidance for QoS/QoE assessment, monitoring and metric selection. The documents listed below are applicable in a transversal manner to telecommunications services and applications and should also be considered in approaches related to QoS and QoE in the metaverse:

- Recommendation ITU-T G.1000 – Communications Quality of Service: A Framework and definitions.
- Recommendation ITU-T E.800 – Definitions of Terms related to Quality of Service.
- Recommendation ITU-T P.10/G.100 – Vocabulary for Performance, Quality of Service and Quality of Experience.
- Recommendation ITU-T G.1011 – Reference Guide to Quality of Experience Assessment Methodologies.
- Recommendation ITU-T P.1401 – Methods, Metrics, and Procedures for Statistical Evaluation, Qualification, and Comparison of Objective Quality Prediction Models.

Additionally, SG12 Recommendations address several aspects relevant to metaverse specific technologies and applications, including:

- Real-time performance requirements: Recommendations set minimum requirements for latency, bandwidth, transfer rate and synchronization to ensure a smooth and immersive metaverse experience.
- Audio and video quality: Quality parameters such as resolution, frame rate, colour depth and spatial audio quality are defined to provide realistic multimedia experience.
- Interactivity and user control: This concerns real-time interaction requirements such as low latency in data input, accurate motion tracking and tactile response, needed to achieve a sense of presence and immersion in the metaverse.
- Accessibility and usability: The Recommendations include guidelines to ensure that metaverse environments are accessible and inclusive for users with different capabilities and preferences.

These are fundamental to the development of interoperable and high-quality metaverse service by providing guidance, methodologies, quality frameworks and best practices for service providers, developers and hardware manufacturers.

Table 2 presents a comparative overview of QoS and QoE Recommendations and standards related to the metaverse.

10 Conclusions

As the technologies and applications associated with the metaverse continue to evolve, ensuring appropriate levels of QoS and QoE remains essential to supporting immersive and reliable user experiences.

This Technical Report has provided an overview of the metaverse context and mapped the main QoS and QoE Recommendations and standards relevant to its technologies and applications. The identified body of work demonstrates that many of the quality aspects associated with current metaverse scenarios are addressed within ITU-T SG12 studies through quality frameworks, terminology, assessment methodologies, influencing factors, performance requirements and application-specific guidance.

The Recommendations identified in this Technical Report show that QoS and QoE aspects of metaverse services are already covered by existing SG12 work, even when the term "metaverse" is not explicitly used. As the sector evolves, additional studies and Recommendations may be developed to address emerging quality-related requirements.

Table 2 – Comparative overview QoS and QoE Recommendations and standards related to the metaverse

Body	Standard	Short description	Publication date	Essential set of information
ITU-T	G.1032	It identifies the main influence factors affecting the QoE in gaming applications, including network performance, responsiveness, rendering quality and user interaction aspects.	29/11/2015	Gaming QoE, Influence factors, Interactive applications
ITU-T	G.1033	It addresses QoS and QoE aspects of digital financial services, including reliability, usability, security and performance considerations.	29/11/2020	Digital financial services, QoS/QoE, Reliability
ITU-T	G.1035	It classifies VR services and identifies the key QoE factors of VR.	29/11/2021	VR, VR QoE, Influencing factors
ITU-T	G.1036	It lists typical use cases of AR services and identifies the key QoE factors within them and also gives a suggested scheme for AR QoE assessment in future work.	29/07/2022	AR, QoE factors and assessment
ITU-T	G.1051	It provides a framework for evaluating the performance of multimedia applications under different network conditions, including interactive and real-time services such as gaming, remote interaction and immersive applications.	29/01/2021	Multimedia performance evaluation, Network impact assessment, Interactive applications
ITU-T	G.1072	It defines an opinion model for predicting the QoE of cloud gaming services based on network and application performance parameters.	29/11/2023	Cloud gaming QoE prediction, Opinion model, Interactive multimedia
ITU-T	G.1091	It specifies QoE requirements for telepresence services, including aspects related to audiovisual quality, interaction naturalness, delay and immersion.	29/09/2011	Telepresence QoE requirements, Immersion, Real-time interaction
ITU-T	G.1092	It provides a taxonomy of telemeeting systems and services from a QoE perspective. The Recommendation classifies telemeeting applications according to their communication characteristics and interaction modes and provides a framework for selecting appropriate QoE assessment methodologies.	29/10/2023	Telemeetings taxonomy, QoE classification, Communication modes, Assessment framework
ITU-T	P.1203	It defines parametric models for monitoring audiovisual quality in adaptive streaming services based on encoded video and network quality parameters.	29/03/2019	Adaptive streaming QoE, Parametric quality assessment, Audiovisual quality monitoring

Table 2 – Comparative overview QoS and QoE Recommendations and standards related to the metaverse

Body	Standard	Short description	Publication date	Essential set of information
ITU-T	P.1301	It concerns subjective quality assessment of telemeeting systems that provide multiparty communication between distant locations, using audio-only, video-only, audiovisual, text-based or graphical means as communication modes. It also gives an overview of relevant aspects that need to be considered for subjective quality evaluation of multiparty telemeetings and provides guidance to recommendations describing the details of applicable methods and procedures. Aspects in this recommendation are also applicable to two-party telemeetings.	29/10/2017	Subjective quality evaluation of multiparty telemeetings, Telemeeting assessment, Multiparty subjective quality evaluation
ITU-T	P.1305	It describes the impact of echo-free transmission delays on telemeeting QoE. Some analysis based on the alternative technique of conversation surface structures is also included. It also provides guidance on appropriate testing methods for evaluating the effect of delay in telemeetings.	29/07/2016	Subjective Quality Evaluation, Impact of Delay, Factors influencing the impact of pure delay, Testing methods
ITU-T	P.1310	This recommendation concerns the quality assessment of telemeeting systems that apply spatial audio rendering techniques to facilitate communication between parties at remote locations.	01/03/2017	General recommendations concerning assessment of spatial audio, Guidance on appropriate test method
ITU-T	P.1311	It describes a method for conducting a listening test that measures the intelligibility of multiple concurrent talkers in a teleconference. It specifies how to conduct such a test, giving detail on stimulus design, creation of source material, selection of test conditions, calibration, selection and training of listeners, test administration and reporting of results.	22/12/2014	Speech intelligibility, Concurrent talkers, Teleconference listening tests, Subjective assessment methodology
ITU-T	P.1312	It describes a subjective test method for quantifying the effectiveness of telemeeting systems in conveying information in multiparty conversation scenarios. This method utilizes a predefined set of tasks designed to provoke rapid turn-taking and concurrent talking among participants. The goal of these tasks is to stress conferencing systems in order to clearly and measurably demonstrate their limits. The method measures the rate at which multiple participants exchange information to assess the effectiveness of communication systems compared with face-to-face communication.	29/02/2016	Communication effectiveness, Multiparty telemeetings, Task-based QoE assessment, Collaborative interaction evaluation

Table 2 – Comparative overview QoS and QoE Recommendations and standards related to the metaverse

Body	Standard	Short description	Publication date	Essential set of information
ITU-T	P.1320	It advises on aspects of importance for QoE assessment of telemeetings with extended reality elements. The goal is to define the human, context and system factors that affect the choice of the QoE assessment procedure and metrics when extended reality telemeeting systems are under evaluation.	29/07/2022	QoE in XR meetings, Factors influencing QoE, Constituents of QoE
ITU-T	P.1321	It describes interactive test methods for subjective assessment of extended reality (XR) communications. The Recommendation provides practical guidance for evaluating QoE in XR telemeetings, including the selection of tasks, influencing factors, measures and test procedures.	29/10/2025	XR communications, Interactive subjective assessment, QoE evaluation methods, Telemeetings
ITU-T	P.812	It describes principles and considerations for subjective evaluation methods applicable to interactive VR applications and immersive environments, including aspects related to user interaction and perceived quality.	29/07/2016	VR assessment, Subjective QoE evaluation, Interactive immersive applications
ITU-T	P.910	It describes subjective video quality assessment methods for multimedia applications, including test methodologies, assessment procedures and evaluation environments applicable to immersive multimedia services.	29/08/2023	Subjective video quality assessment, Multimedia QoE, Test methodologies
ITU-T	P.919	It describes subjective assessment methods for evaluating QoE of short (between 10 s and 30 s) 360° videos. Recommendation ITU-T P.919 also outlines the characteristics of the source sequences to be used, such as duration, type of content and number of sequences. Details within Recommendation ITU-T P.919 are expected to change in subsequent editions, based on experiments into how best to conduct subjective tests with 360° content.	14/10/2020	Selection of 360° source content, Test methods, Experiment design

Table 2 – Comparative overview QoS and QoE Recommendations and standards related to the metaverse

Body	Standard	Short description	Publication date	Essential set of information
ITU-T	Y.4812	It describes identity interoperability for IoT devices across metaverse platforms and provides relevant technical features and reference framework. The identity of an IoT device usually includes a unique identifier and a corresponding identity object (Recommendation ITU-T Y.4811). Although it may take advantage of one IoT device having one unique identity in multiple metaverses, there are challenges; how those metaverses identify, authenticate and authorize the IoT devices when they are roaming across metaverse platforms.	01/03/2025	IoT Metaverse identity, Interoperability framework, Identity management
ETSI	TR 126 928 V16.1.0 (2021-01)	It is a Technical Report that collects information on eXtended Reality (XR) in the context of 5G radio and network services, and baseline technologies for XR type of services and applications are introduced. Use cases and device types are classified, and processing and media centric architectures are introduced.	2021-01	XR in 5G systems, XR architectures, Device types, Media processing and network requirements

Annex A

Recommendations issued by ITU-T SG12 to the deliverables developed with FG-MV

Table A.1 – Mapping of Recommendations issued by SG12 to the deliverables developed with FG-MV

Deliverable no.	Title	Recommendations developed within SG12	
		Covered	Not covered
FGMV-01	Technical report on exploring the metaverse, opportunities and challenges	ITU-T P.1320	E.430 – "Quality of service framework" G.1000 – "Communications quality of service: A framework and definitions" G.1010 – "End-user multimedia QoS categories" G.1011 – "Reference guide to quality of experience assessment methodologies" G.1031 – "QoE factors in web-browsing" G.1032 – "Influence factors on gaming quality of experience" G.1033 – "Quality of service and quality of experience aspects of digital financial services" G.1035 – "Influencing factors on quality of experience for virtual reality services" G.1036 – "Quality of experience influencing factors for augmented reality services" G.1072 – "Opinion model predicting gaming quality of experience for cloud gaming services" G.1091 – "Quality of Experience requirements for telepresence services"
FGMV-04	Technical specification on requirements of accessible products and services in the metaverse, Part I – System design perspective	ITU-T P.1320	
FGMV-05	Technical specification on requirements of accessible products and services in the metaverse, Part II – User perspective	ITU-T P.1320	
FGMV-08	Technical specification on design criteria and technical requirements for sustainable metaverse ecosystems	ITU-T P.1320	
FGMV-21	Technical report on the principles for building concepts and definitions related to metaverse	–	
FGMV-22	Technical report on capabilities and requirements of generative artificial intelligence in metaverse applications and services	ITU-T P.10/G.100	

Table A.1 – Mapping of Recommendations issued by SG12 to the deliverables developed with FG-MV

Deliverable no.	Title	Recommendations developed within SG12	
		Covered	Not covered
			G.1092 – "Taxonomy of telemeetings from a quality of experience perspective" P.10/G.100 – "Vocabulary for performance, quality of service and quality of experience" P.1301 – "Subjective quality evaluation of audio and audiovisual multiparty telemeetings" P.1305 – "Effect of delays on telemeeting quality" P.1310 – "Spatial audio meetings quality evaluation" P.1312 – "Method for the measurement of the communication effectiveness of multiparty telemeetings using task performance" P.1320 – "Quality of experience assessment of extended reality meetings" Y.1550 – "Considerations for realizing virtual measurement systems"

Annex B

QoS/QoE metrics for metaverse applications

This Annex provides an overview of QoS parameters (network-level) and QoE metrics (user experience-level) relevant to metaverse services, organized by use case. The metrics are derived from ITU-T Recommendations (e.g., G.1035, G.1036, P.1320, P.910), 3GPP XR requirements and emerging research on immersive environments.

B.1 General key performance indicator (KPI) categories

B.1.1 Latency

- Motion-to-photon (MTP) latency: Time from user motion to visual update (critical for VR/AR).
- End-to-end round-trip latency: From user device to server/cloud and back.

B.1.2 Jitter

- Variation in packet arrival times affecting real-time rendering and haptic synchronization.

B.1.3 Frame rate (FPS)

- Minimum 60 FPS for AR; ≥90 FPS recommended for VR to avoid motion sickness.

B.1.4 Bandwidth/Throughput

- Data rate requirements for 3D content, multi-stream video and IoT data.

B.1.5 Packet loss and error rates

- For reliable delivery of audiovisual, control and sensor data.

B.1.6 Task-oriented QoE metrics

- Immersion, presence, task completion success and collaborative efficiency.

B.1.7 Multi-sensory feedback metrics

- Latency and accuracy for haptic devices and spatial audio synchronization.

B.2 Detailed metrics table by use case

The values presented in Table B.1 below are provided for illustrative purposes and do not constitute normative requirements. They are intended to provide examples of QoS and QoE metrics and associated threshold values that have been reported for metaverse-related technologies and applications. The values were identified from different sources, including literature reviews, technical publications and experimental studies.

Table B.1 – Detailed metrics by use case

Parameter	Immersive social metaverse (VR/AR events)[1]	Industrial metaverse (digital twins/ remote ops)[1]	Education and training[1]	Urban / smart city applications[1]	Cloud-based streaming (VR)[2]	Cloud-based streaming (social VR)[3]
End-to-end latency	≤ 50 ms (interactive); ≤ 20 ms for MTP latency	≤ 10 ms (closed-loop control); ≤ 100 ms (monitoring)	≤ 80 ms	≤ 200 ms	RTT ≤ 77 ms	RTT ≤ 77 ms
Jitter	≤ 5 ms (to avoid visual-auditory skew)	≤ 2 ms (deterministic networks)	≤ 10 ms	≤ 15 ms	For avg. RTT ≥ 27 ms, jitter ≤ 1std	For avg. RTT ≥ 52 ms, jitter ≤ 1std
Frame rate (FPS)	VR ≥ 90 fps; AR ≥ 60 fps	≥ 30 fps (visualization)	≥ 60 fps	≥ 30 fps	FPS ≥ 75	FPS ≥ 75
Throughput (per user)	50–200 Mbit/s (downlink)	10-100 Mbit/s (video + sensor data)	20–100 Mbit/s	5–50 Mbit/s	65 Mbit/s	40 Mbit/s
Packet loss	≤ 0.1% (critical for immersion)	≤ 0.01% (safety-critical); ≤ 0.1% (others)	≤ 0.1%	≤ 0.5%	For RTT ≥ 25 ms, PL ≤ 4%; For RTT = 4 ms, PL ≤ 6%	For RTT ≥ 77 ms, PL ≤ 2%
Immersion/presence	MOS ≥ 4.0 (1–5 scale)	Not primary; use task success instead	MOS ≥ 3.5	Not primary	QoE (MOS) ≥ 3	QoE (MOS) ≥ 3
Spatial audio latency	≤ 20 ms (relative to video)	≤ 50 ms (if used)	≤ 30 ms	N/A	RTT ≤ 402 ms; RTT and Jitter ≤ 77 ms, 6 std	RTT ≤ 152 ms; RTT and Jitter ≤ 27 ms, 1 std
Haptic feedback latency	≤ 10 ms (visual-haptic skew)	≤ 5 ms (tele-operation)	≤ 20 ms	N/A	Not measured	Not measured
Synchronization	Audio-video-haptic skew ≤ 10 ms	Device-twin state skew ≤ 10 ms	Multi-user avatar sync ≤ 20 ms	IoT-visual sync ≤ 50 ms	Not measured	Not measured

Table B.1 – Detailed metrics by use case

Parameter	Immersive social metaverse (VR/AR events)[1]	Industrial metaverse (digital twins/ remote ops)[1]	Education and training[1]	Urban / smart city applications[1]	Cloud-based streaming (VR)[2]	Cloud-based streaming (social VR)[3]
Task-oriented metrics	N/A (use subjective presence)	Task success ≥ 99% (safety); error rate < 0.1%	Correctness ≥ 90%; time within 120% of baseline	Incident detection accuracy ≥ 95%	QoE (MOS) ≥ 3	QoE (MOS) ≥ 3
Availability/uptime	≥ 99.9%	≥ 99.999% (URLLC class)	≥ 99.9%	≥ 99.99%	99.99%	99.99%

[1] The threshold values presented for immersive social environments, industrial metaverse, education and training, and smart city applications were derived from a review of published literature, including peer-reviewed articles, journals and technical publications.

[2] The threshold values presented for cloud-based streaming (VR) are based on preliminary results presented by Luleå University of Technology (Sweden) to ITU-T SG12 in "Preliminary Results on Subjective Testing of Virtual Reality Cloud Games", Mexico City, 19–28 September 2023 (Doc. T22-SG12-C0155).

[3] The threshold values presented for cloud-based streaming (Social VR) are based on results presented by Luleå University of Technology (Sweden) to ITU-T SG12 in "Results on Subjective Testing of Streamed Social Extended Reality Applications over Heterogeneous Access Networks", Geneva, 9–17 June 2026 (Doc. T25-SG12-C0169).

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