ITUPublications

International Telecommunication Union

Standardization Sector

ITU Focus Group Technical Report

(06/2024)

ITU Focus Group on metaverse
(FG-MV)

FGMV-52

Metaverse standardization landscape for gap analyses

Working Group 9: Collaboration

Technical Report ITU FGMV-52

Metaverse standardization landscape for gap analyses

Summary

This technical report assists in the development of a gap analysis on metaverse standardization by examining existing standards and standards under development in key standards development organizations (SDOs). Its aim is to facilitate the development of comprehensive and interoperable metaverse-related standards.

Keywords

gap analysis; metaverse; standardization; standards development organizations (SDOs)

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 1.0 of the ITU Technical Report on "*Metaverse standardization landscape for gap analyses*" approved at the 7th meeting of the ITU Focus Group on metaverse (FG-MV) held on 12-13 June 2024.

Acknowledgement

This Technical Report was researched and written by Jungha Hong (ETRI, Korea (Republic of)) as a contribution to the ITU Focus Group on the metaverse. The development of this document was coordinated by Ziqin Sang (CICT, China) and Stella Kipsaita (Communications Authority, Kenya), as Co-Chairs of FG-MV Working Group 9 and Jungha Hong (ETRI, Korea (Republic of)) and Leonidas Anthopoulos (University of Thessaly, Greece), as Co-Chairs of Task Group on gap analysis.

The author would also like to thank the following experts for their assistance: Shane He(Nokia, Finland), Hideo Imanaka (NICT, Japan), Hideki Yamamoto(OKI, Japan), and Kei Kawamura (KDDI, Japan).

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Metaverse standardization landscape for gap analyses

1 Scope

This technical report provides a gap analysis on metaverse standardization. It addresses the following subjects:

− the status of metaverse standards in standards development organizations (SDOs);

− standardization gap analysis.

2 References

None.

3 Terms and definitions

None.

4 Abbreviations

3GPP	3rd Generation Partnership Project
AI	Artificial Intelligence
AR	Augmented Reality
ICT	Information & Communications Technology
ISO	International Organization for Standardization
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IETF	Internet Research Task Force
IoT	Internet of Things
ITU	International Telecommunication Union
ITU-D	ITU Telecommunication Development Sector
ITU-T	ITU Telecommunication Standardization Sector
JTC	Joint Technical Committee
MWG	Metaverse Working Group
PWI	Preliminary Work Item
RFC	Request for Comments
SC	Subcommittee
SDOs	Standards Development Organizations
SG	Study Group
TC	Technical committee
TR	Technical Report
T2TRG	Thing-to-Thing Research Group
VR	Virtual Reality

WG	Working Group
W3C	World Wide Web Consortium

5 Conventions

None.

6 Categories of metaverse standards

This clause provides the categories of metaverse standards that were given in another FG-MV deliverable called “standardization roadmap for metaverse” [b-ITU FGMV-D9.2].

Standards for metaverse can be generally classified into four categories (see figure 6-1):

Category 1: General standards addressing common and general aspects of the metaverse, including:

– Framework, terminology and definitions;
– Evaluation;
– Sustainability;
– Security;
– Accessibility.

Category 2: Application and service standards in various domains that seek to enhance productivity, address global challenges, and contribute to sustainability while providing richer experiences for different users. These include:

– Agriculture
– Power energy
– Tourism and cultural heritage
– Retail and fashion
– Banking
– Medical
– Manufacturing
– Education
– City Governance
– Transportation
– Urban Construction
– Environmental protection

Category 3: Enabling technology standards. Enabling technologies such as VR, AR, digital twins, blockchain, media coding, and AI are pivotal in shaping the metaverse. They offer immersive experiences, real-time synchronization, security, and enhanced interactions. The detailed descriptions of desired standards are provided as follows:

– Virtual reality and augmented reality
– Digital twin
– Blockchain
– Media coding
– Artificial Intelligence
– Digital Human/Avatar

Category 4: Interoperability and ICT-related infrastructure standards. Standardization in this category ensures efficient architectures to support diverse metaverse demands, which include:

– Interoperability protocols
– Data sharing
– Interfacing
– Network infrastructure
– Storage infrastructure
– Computing power infrastructure

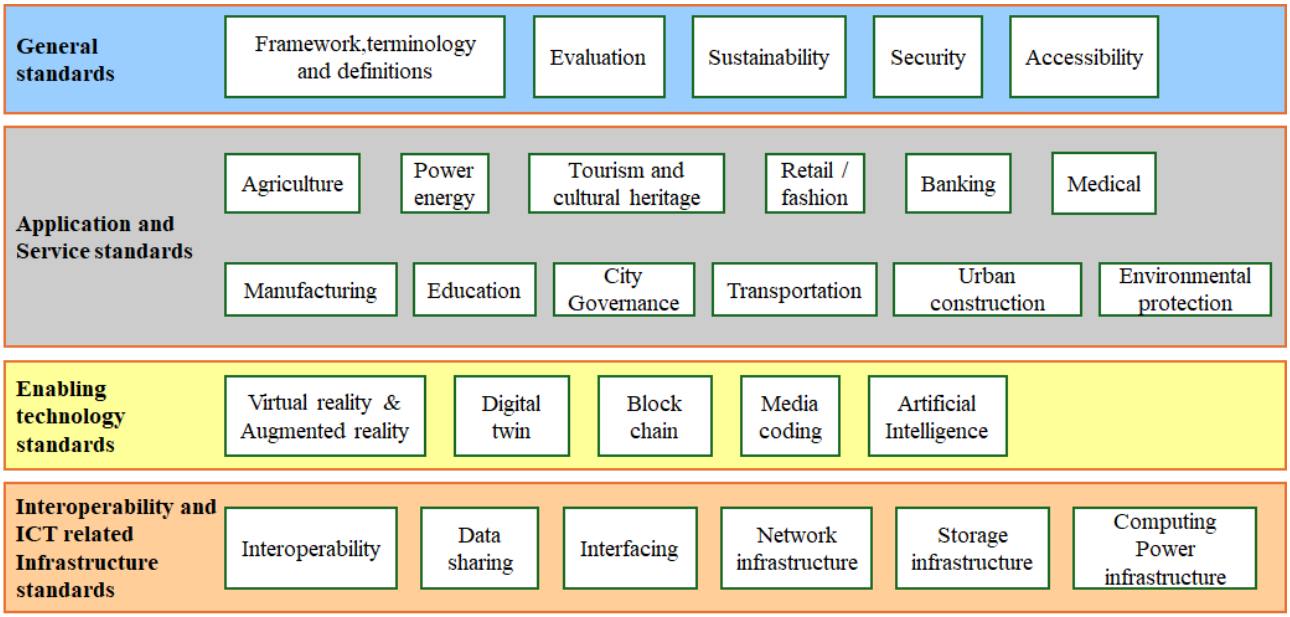

Figure 6-1: Example of metaverse standard categories

7 The status of metaverse standards in SDOs

This clause provides the status of metaverse standards in key standards development organizations (SDOs) by listing of existing standards and standards under development in SDOs.

7.1 General standards

7.1.1 Framework, terminology and definitions

Table 7-1 provides the metaverse standards related to framework, terminology and definitions. SDOs associated with this category of metaverse standards include IEC, IEEE, ISO/IEC, ITU-T, and W3C.

Table 7-1: Metaverse standards related to framework, terminology and definitions

SDO	Study group	Reference	Title	Status	Abstract
IEC	TC 1	IEC 60050-741:2020	International Electrotechnical Vocabulary (IEV) - Part 741: Internet of Things (IoT)	Published	IEC 60050-741:2020 provides a definition of Internet of Things along with related terms and definitions.
IEEE	MWG	IEEE P2048™	Standard for Metaverse: Terminology, Definitions and Taxonomy	Under development	IEEE P2048™ is under development on terminology, definitions and taxonomy for metaverse.
IEEE	MEWG	IEEE P7016™	Standard for Ethically Aligned Design and Operation of Metaverse Systems	Under development	IEEE P7016™ is under development of standard for ethically aligned design and operation of metaverse systems.
ISO/IEC	JTC 1/SC 43	ISO/IEC CD 8663	Information Technology — Brain-computer Interface — Vocabulary	Under development	This document specifies the terms and definitions commonly used in the field of Brain-computer Interface (BCI), including basic concepts and classifications of BCI, hardware, experiment setups and protocols used in BCI, related

					neuroscience concepts of BCI (e.g., coding and decoding, feedback and stimulation), and its applications. etc. This document is applicable to the understanding of Brain-computer Interface concepts and the exchange of information.
ISO/IEC	JTC 1/SC 29	ISO/IEC 23005-6:2019	Information technology - Media context and control - Part 6: Common types and tools	Published	ISO/IEC 23005-6:2019 provides definitions of data types and tools, which are used in other parts of the ISO/IEC 23005 series, but are not specific to a single part. This document specifies syntax and semantics of the data types and tools common to the tools defined in the other parts of the ISO/IEC 23005 series such as basic data types which are used as basic building blocks in more than one of the tools in the ISO/IEC 23005 series, colour-related basic types which are used in light and colour-related tools to help in specifying colour-related characteristics of the devices or commands, and time stamp types which can be used in device commands, and sensed information to specify timing related information. Classification schemes, which provide semantics of words or terms and normative way of referencing them, are also defined in Annex A, if they are used in more than one part of the ISO/IEC 23005 series. The tools defined in this document are not intended to be used alone, but to be used as a part or as a supporting tool of other tools defined in other parts of the ISO/IEC 23005 series, except for the profile and level definitions. This document also contains standard profiles and levels to be used in specific application domains. The profile and level definitions include collection of tools from ISO/IEC 23005-2 and ISO/IEC 23005-5 with necessary constraints.
ISO/IEC	JTC 1/WG 11	ISO/IEC 5087-2	Information technology — City data model — Part 2: City level concepts	Published	This document defines an ontology for city-level concepts using terms specified in ISO/IEC 5087-1. City-level concepts are used to represent data that is shared across multiple services and stakeholders in the city. These concepts are distinguished by their data being read and updated by multiple city services and stakeholders.

ISO/IEC	JTC 1/SC 24	ISO/IEC 18026	Spatial Reference Model (SRM)	Published	ISO/IEC 18026 defines relevant aspects of spatial positioning and related information processing. It allows precise and unambiguous specification of geometric properties such as position (location), direction, distance, and time associated with spatial information.
ISO/IEC	JTC 1/SC 24	ISO/IEC 18041-4	EDCS language bindings – Part 4: C	Published	EDCS (Environmental Data Coding Specification) provides mechanisms to unambiguously specify objects used to model environmental concepts. To accomplish this, a collection of nine EDCS dictionaries of environmental concepts are specified: classifications, attributes, attribute value characteristics, attribute enumerants, units, unit scales, etc.
ISO/IEC	JTC 1/SC 29	ISO/IEC 23005-6	Media context and control - Part 6: Common types and tools	Published	This document provides definitions of data types and tools which are used in other parts of the ISO/IEC 23005 series but are not specific to a single part. It specifies the syntax and semantics of the data types and tools common to the tools defined in the other parts of the ISO/IEC 23005 series. This includes basic data types used as basic building blocks in more than one of the tools in the series, colour-related basic types used in light and colour-related tools to help in specifying colour-related characteristics of devices or commands, and time stamp types that can be used in device commands and sensed information to specify timing-related information.
ISO/IEC	JTC 1/SC 38	ISO/IEC 22123-1	Cloud computing —Part 1: Vocabulary	Published	This document defines terms used in the field of cloud computing including distributed platforms.
ISO/IEC	JTC 1/SC 38	ISO/IEC 22123-2	Cloud computing —Part 2: Concepts	Published	This document specifies concepts used in the field of cloud computing that provide a foundation for other documents associated with cloud computing. It includes detailed descriptions on the application of these concepts in cloud computing, serving as a baseline for understanding and further development in this area. This ensures a consistent framework of terms and definitions, helping to facilitate clearer

					communication and more effective collaboration across different cloud-related projects and research.
ISO/IEC	JTC 1/SC 38	ISO/IEC 19086	Cloud service level agreement (SLA) framework	Published	This document seeks to establish a set of common cloud SLA building blocks (concepts, terms, definitions, contexts) that can be used to create cloud Service Level Agreements (SLAs).
ISO/IEC	JTC 1/SC 38	ISO/IEC 23751	Data sharing agreement (DSA) framework	Published	This document establishes a set of building blocks, i.e., concepts, terms and definitions, including Data Level Objectives (DLOs) and Data Qualitative Objectives (DQOs) that can be used to create Data Sharing Agreements (DSAs). This document is applicable to DSAs where the data is intended to be processed using one or more cloud services or other distributed platforms.
ISO/IEC	JTC 1/SC 38	ISO/IEC AWI 19274	Networking in cloud computing and edge computing	Under development	This document describes the foundational concepts for edge computing and its relationship to cloud computing, including the terminology, models, and functional elements for networking in edge computing and cloud computing systems. This document also applies to distributed platforms, multiple cloud models (including multicloud, hybrid cloud, intercloud, and federated cloud), and related intelligent nodes.
ISO/IEC	JTC 1/SC 38	ISO/IEC TS 5928	Taxonomy for digital platforms	Published	This document specifies a taxonomy related to digital platforms, by providing definitions and supporting information that disambiguates different uses of the term “platform” as it applies to digital services such as cloud computing and other distributed computing systems.
ISO/IEC	JTC 1/SC 32	ISO/IEC TR 15944-14:2020	Information technology - Business operational view - Part 14: Open-edi reference model and cloud computing architecture	Published	ISO/IEC TR 15944-14:2020 examines the basic concepts that have been developed for both cloud computing and Open-edi, identifies key Open-edi concepts relevant to cloud computing, identifies key cloud computing concepts relevant to Open-edi, and compares Open-edi model and cloud computing architecture and identifies mappings (similarities in whole or

					in part) between them using formal semantic modelling techniques.
ISO/IEC	JTC 1/SC 38	ISO/IEC 22123 (series)	Information technology - Cloud computing	Published	ISO/IEC 22123 series provides standards in the field of cloud computing and contains following parts: – ISO/IEC 22123-1:2023 Information technology - Cloud computing - Part 1: Vocabulary
ISO/IEC	JTC 1/SC 38	ISO/IEC 17788:2014	Information technology -- Cloud computing -- Overview and vocabulary	Published	ISO/IEC 17788:2014 provides an overview of cloud computing along with a set of terms and definitions.
ISO/IEC	JTC 1/SC 38	ISO/IEC TR 23951:2020	Information technology - Cloud computing - Guidance for using the cloud SLA metric model	Published	ISO/IEC TR 23951:2020 describes guidance for using the ISO/IEC 19086-2 metric model, illustrated with examples.
ISO/IEC	JTC 1/SC 42	ISO/IEC 22989	Information technology — Artificial intelligence — Artificial intelligence concepts and terminology	Published	This document establishes terminology for AI and describes concepts in the field of AI. This document can be used in the development of other standards and in support of communications among diverse, interested parties or stakeholders. This document is applicable to all types of organizations (e.g., commercial enterprises, government agencies, not-for-profit organizations).
ISO/IEC	JTC 1/SC 42	ISO/IEC 20546:2019	Information technology - Big data - Overview and vocabulary	Published	ISO/IEC 20546:2019 provides a set of terms and definitions needed to promote improved communication and understanding of this area. It provides a terminological foundation for big data-related standards.
ITU	FG-MV	FGMV-02	Metaverse: an analysis of definitions	Approved deliverable	This Technical Report contains a detailed gap analysis in literature of “metaverse” definitions with an explained terminology. This Technical Report studied and analysed approximately 150 existing definitions of metaverse from various sources.

ITU	FG-MV	FGMV-20	Definition of metaverse	Approved deliverable	This Technical Specification provides the definition of the term “metaverse”. It leverages a detailed analysis of 150 existing definitions of metaverse that was undertaken for the development of the ITU Technical Report on “Metaverse: an analysis of definitions”, which was approved at the third meeting of the ITU Focus Group on metaverse (FG-MV), held on 3–5 October 2023, in Geneva, Switzerland.
ITU	FG-MV	FGMV-21	Principles for building concepts and definitions related to metaverse	Approved deliverable	This document establishes the principles for building terms, concepts and definitions related to metaverse, as the foundation for developing technical specification of vocabulary for metaverse.
ITU	FG-MV	FGMV-24	A framework for confidence in the metaverse	Approved deliverable	Still in its nascent phase, even as it rides the downward swing of a highly visible hype curve; the concept of “metaverse” remains undefined. And yet, the metaverse is emerging as a new frontier of social and economic interaction with the potential to transform the way we live, work and play. Given its potential to be highly disruptive, there is some urgency to develop a general understanding of the metaverse in this nascent phase, especially to avoid the pitfalls that continue to afflict its predecessors including Web 2.0 platforms like social media. To address this urgent need, the International Telecommunication Union (ITU) established the first Focus Group on metaverse (FG-MV) in December 2022. A year later, in December 2023, FG-MV experts (brought together from around the world to shape the development of metaverse technology standardization for the benefit of all) proposed a baseline definition for the metaverse. This Technical Report (also a product of FG-MV) outlines an approach to pre-standards of confidence in the metaverse by: • Expanding the “User Confidence Framework” introduced in ITU’s FGMV-06: Technical Report on “Guidelines for

					consideration of ethical issues in standards that build confidence and security in the metaverse" (which was approved at the third meeting of the FG-MV, held on 3–5 October 2023, in Geneva, Switzerland), to include Security and Safety Dimensions in user confidence. • Developing a new framework for metaverse participation that defines new user centric terms related to metaverse use and non-use as an approach to understanding user metaverse engagement. Discussing the concept of personhood for metaverse contexts to contextualize user presence in the metaverse.
ITU	FG-MV	FGMV-25	Near-term and long-term Implications for people in the metaverse	Approved deliverable	Given that the industry has not yet converged on a precise understanding of what is commonly referred to as the "metaverse", there is general confusion between definitions of this term based on Facebook's transformation to Meta in 2021 and definitions that evolved from the concept that was popularized by Neal Stephenson's novel, Snow Crash, in 1992. This has led to conflicting declarations of the metaverse as being both in its nascent phase and already dead. Nevertheless, as the world becomes increasingly digital, the metaverse (no matter the definition ascribed to it) is emerging as a new frontier of social and economic interaction; allowing people to create, connect, and collaborate in ways that were previously thought impossible. The promise of a post-COVID-19 metaverse is rapid acceleration of an already super-charged global digital transformation with the potential to transform our lives, livelihoods, and interactions, in the near-term and long-term, in ways that cannot be overstated. Neither can our lack of clarity around the implications. This Technical Report explores the near-term and long-term implications for people in the metaverse as a framework for

					understanding potential impacts and a guide for maximizing the benefits and minimizing associated risks.
ITU-T	SG13	ITU-T Y.3500	Information technology – Cloud computing – Overview and vocabulary	Published (08/2014)	ITU-T Y.3500 provides an overview of cloud computing, and defines related terms. The terms and definitions provided in this Recommendation | International Standard: cover commonly used terms and definitions in cloud computing standards; – will not cover all terms and definitions used in cloud computing standards; and – do not preclude the definition of additional terms for use in cloud computing standards.
ITU-T	SG13	ITU-T Y.3605	Big data - Reference architecture	Published (09/2020)	ITU-T Y.3605 defines a big data reference architecture (BDRA) that can serve as a fundamental reference point for big data standardization, and which provides an overall framework for the basic concepts and principles of big data. The Recommendation provides a description of reference architecture concepts, two distinct viewpoints including user view and functional view, and also cross cutting aspects. Furthermore, the Recommendation addresses layering framework, functional components within framework and detailed functional descriptions for big data.
ITU-T	SG20	ITU-T Y.4000/Y.2060	Overview of the Internet of things	Published (06/2012)	ITU-T Y.4000 covers the IoT-related terms and definitions, concept and scope of the IoT, characteristics of the IoT, high-level requirements of the IoT, and IoT reference models.
ITU-T	SG20	ITU-T Y.4809	Unified Internet of things identifiers for intelligent transport systems	Published (10/2021)	ITU-T Y.4809 defines field formats for identifying road signs and signals, and identifies specific values for identifiers of such signs and signals.
W3C	W3C Accessible Rich Internet	WAI-ARIA Graphics https://www.w3.org/T	WAI-ARIA Graphics Module	Published (10/2018)	WAI-ARIA Graphics defines a WAI-ARIA 1.1 module of core roles specific to web graphics.

	Applications WG	R/graphics-aria-1.0/			
W3C	W3C Web Real-Time Communications WG	WebRTC Stats https://www.w3.org/TR/webrtc-stats/	Identifiers for WebRTC's Statistics API	Under development	WebRTC Stats defines a set of WebIDL objects that allow access to the statistical information about an RTCPeerConnection. These objects are returned from the getStats API that is specified in [WEBRTC].

7.1.2 Inclusive city development

Table 7-2 provides the metaverse standards related to inclusive city development. SDO associated with this category of metaverse standards includes ITU.

Table 7-2: Metaverse standards related to inclusive city development

SDO	Study group	Reference	Title	Status	Abstract
ITU	FG-MV	FGMV-18	Guidance on how to build a metaverse for all – Part I: Legal Framework	Approved deliverable	This document proposes some guidelines to ensure by default equity, accessibility, and inclusivity in the development of the metaverse. Its primary objective is to offer the context for the legal framework based on the United Nations (UN) mandates and Sustainable Development Goals (SDGs), along the derived standards. This document offers a comprehensive understanding of the current state of the background, which should underlay any metaverse development. The document also identifies the key challenges that hinder the achievement of equity, accessibility and inclusivity within the metaverse, and propose potential roadmaps towards constructing a metaverse leaving no one behind.

7.1.3 Evaluation

Table 7-3 provides the metaverse standards related to evaluation. SDOs associated with this category of metaverse standards include ISO/IEC and ITU-T.

Table 7-3: Metaverse standards related to evaluation

SDO	Study group	Reference	Title	Status	Abstract
ISO/IEC	JTC 1/SC 27	ISO/IEC 15408 series	Information security, cybersecurity, and privacy protection - Evaluation criteria for IT security	Published	These documents include the general concepts and principles of IT security evaluation and the general model of evaluation provided by various parts of the standard; a catalogue of functional components that meets the common security functionality requirements of many IT products; the individual assurance components and other packages, and the criteria for evaluation of Protection Profiles (PPs), PP-Configurations, PP-Modules, and Security Targets (STs); a standardized framework for specifying objective, repeatable and reproducible evaluation methods and evaluation activities; packages of security assurance and security functional requirements.
ISO/IEC	SC 37	ISO/IEC 19794 (series)	Information technology - Biometric data interchange formats	Published	In addition to above requirements, this proposed Recommendation provides evaluation methods for some requirements considering the application in smart mobile devices.
ITU-T	SG 2	ITU-T M.3384	Intelligence levels of artificial intelligence enhanced telecom operation and management	Published	Recommendation ITU-T M.3384 provides definitions, classifications, object selection and an automatic evaluating mechanism for the evaluation of the intelligence levels of artificial intelligence-enhanced telecom operation and management systems that comply with the framework specified in Recommendation ITU-T M.3080.

7.1.4 Sustainability

Table 7-4 provides the metaverse standards related to sustainability. SDO associated with this category of metaverse standards includes ITU.

Table 7-4: Metaverse standards related to sustainability

SDO	Study group	Reference	Title	Status	Abstract
ITU	FG-MV	FGMV-01	Exploring the metaverse: opportunities and challenges	Approved deliverable	This Technical Report explores the opportunities, and challenges, and clarifies the role of international standards and the potential for the metaverse in the achievement of the United Nations Sustainable Development Goals.
ITU	FG-MV	FGMV-08	Design criteria and technical requirements for sustainable metaverse ecosystems	Approved deliverable	The text highlights the potential of the metaverse to advance progress towards the UN Sustainable Development Goals (SDGs) across various sectors like health, education and climate mitigation. However, it warns that digital spaces, including the metaverse, come with inherent costs and risks such as environmental, social, and economic impacts. Without proper governance, the metaverse could exacerbate environmental consequences due to its enabling technologies like AI, augmented reality, blockchains and IoT. Additionally, emerging AI risks such as manipulation and discrimination could be amplified in the metaverse. Economic barriers could hinder access for small businesses and non-profits, deepening power gaps. The document proposes three contributions: defining a sustainable metaverse ecosystem, integrating environmental, social, and economic sustainability criteria into design, and outlining system requirements for sustainable metaverse ecosystems.

7.1.5 Security

Table 7-5 provides the metaverse standards related to security. SDOs associated with this category of metaverse standards include IEEE, IETF, ISO/IEC, ITU, ITU-T and W3C.

Table 7-5: Metaverse standards related to security

SDO	Study group	Reference	Title	Status	Abstract

IEEE	BDBSRAWG	IEEE 2813-2020	IEEE Standard for Big Data Business Security Risk Assessment	Published	IEEE 2813-2020: This standard can be applied to Internet-based business scenarios, and can also be served serve as a practical guide to achieve help assess business security risk control through the big data technology. This standard can be applied in other types of organization, including public or privately-owned or state-owned enterprises, associations, or organizations, or by individuals, to improve assessment of their protection capability against business security risks based on big data technology.
IETF	suit WG	RFC 9124	A Manifest Information Model for Firmware Updates in Internet of Things (IoT) Devices	Published	RFC 9124: Vulnerabilities with Internet of Things (IoT) devices have raised the need for a reliable and secure firmware update mechanism that is also suitable for constrained devices. Ensuring that devices function and remain secure over their service lifetime requires such an update mechanism to fix vulnerabilities, update configuration settings, and add new functionality. One component of such a firmware update is a concise and machine-processable metadata document, or manifest, that describes the firmware image(s) and offers appropriate protection. IETF RFC 9124 describes

					the information that must be present in the manifest.
IETF	T2TRG	RFC 8576	Internet of Things (IoT) Security: State of the Art and Challenges	Published	RFC 8576 discusses the various stages in the lifecycle of a thing, documents the security threats to a thing and the challenges that might be faced to protect against these threats, and discusses the next steps needed to facilitate the deployment of secure IoT systems.
ISO/IEC	JTC 1/SC 27	ISO/IEC TR 5891	Information security, cybersecurity and privacy protection-Hardware monitoring technology for hardware security assessment	Published	This document surveys and summarizes the existing hardware monitoring methods, including research efforts and industrial applications. The explored monitoring technologies are classified by applied area, carrier type, target entity, objective pattern, and method of deployment. Moreover, this document summarizes the possible ways of utilizing monitoring technologies for hardware security assessment with some existing state-of-the-art security assessment approaches. The hardware mentioned in this document refers only to the core processing hardware, such as the central processing unit (CPU), microcontroller unit (MCU), and system on a chip (SoC), in the von Neumann system and does not include single-input or single-output devices such as memory or displays.

ISO/IEC	JTC 1/SC 27	ISO/IEC TR 6114	Cybersecurity-Security considerations throughout the product life cycle	Published	This document describes security considerations throughout the product life cycle (SCLC), which is a framework that spans the entire information and communications technology (ICT) product life cycle. The aim of the framework is to align the industry and bring greater transparency to customers at every point on the ICT product life cycle. This document describes the following items for suppliers, end users (consumers), intermediaries of the ICT supply chain, service providers, and regulators. The target audiences of this document are suppliers and consumers of ICT products, including all participants throughout the supply chain such as silicon chip designers, fabricators, product assemblers, logistics providers, service providers, and information security organizations. Clauses 5 to 11 target an organization’s strategic and risk management teams. This document provides an end-to-end view of the threats in each phase to help the organization shape their plans, procedures and policies.
ISO/IEC	JTC 1/SC 27	ISO/IEC 27001	Information security, cybersecurity, and	Published	This document is the world's best-known standard for information security management systems

			privacy protection-Information security management systems-Requirements		(ISMS). It defines the requirements an ISMS must meet. The ISO/IEC 27001 standard provides companies of any size and from all sectors with guidance for establishing, implementing, maintaining, and continually improving an information security management system. Conformity with ISO/IEC 27001 means that an organization or business has put in place a system to manage risks related to the security of data owned or handled by the company, and that this system respects all the best practices and principles enshrined in this International Standard.
ISO/IEC	JTC 1/SC 38	ISO/IEC PWI (NP) 11034	Trustworthiness in cloud computing	Under development	This document provides an overview, frameworks, and concepts for trustworthiness in cloud computing.
ISO/IEC	JTC 1/SC 38	ISO/IEC PWI (NP) 20996	Cloud service customer business continuity and resilience	Under development	This document provides guidance to cloud service customers on business continuity and resilience when using cloud services.
ITU	FG-MV	FGMV-10	Cyber risks, threats, and harms in the metaverse	Approved deliverable	This Technical Report emphasizes the importance of understanding the cybersecurity landscape in the metaverse. It provides an overview of this emerging digital realm and its potential, highlighting its transformative nature. It also analyses and documents the specific

					cybersecurity risks, threats, and potential harms associated with the metaverse. This Technical Report covers areas such as identity theft, malware, data breaches, and social engineering. Moreover, it explores the background of cybersecurity risks in the metaverse. Additionally, this Technical Report examines the implications of these cybersecurity risks, including their impact on user trust, virtual economies, and assets.
ITU	FG-MV	FGMV-06	Guidelines for consideration of ethical issues in standards that build confidence and security in the metaverse	Approved deliverable	This Technical Report discusses the emergence of the metaverse as a new frontier for social and economic interaction in our increasingly digital world. It emphasizes the need for guidelines to facilitate meaningful engagement and address challenges in the metaverse's infrastructure and ecosystems. Trust and confidence are highlighted as crucial for user interaction and safety in virtual environments, especially considering the vast amounts of personalized data collected. The objective of the report is to develop ethical guidelines grounded in the Universal Declaration of Human Rights and Sustainable Development Goals. It aims to explore user expectations, propose a framework for defining user confidence, and introduce

					guiding principles to foster safety, control, autonomy, fairness, transparency, and access to information within immersive spaces. The document also addresses similarities and unique considerations in fostering confidence within the metaverse compared to existing digital platforms. Overall, it advocates for a user-centric approach to building security and confidence in the metaverse to ensure it evolves sustainably and meets user needs.
ITU	FG-MV	FGMV-11	Embedding safety standards and the user control of Personally Identifiable Information (PII) in the development of the metaverse	Approved deliverable	This Technical Report develops three key areas of a rights-based approach to embedding ethics and safety standards and user control of PII in developing the metaverse that build conceptually on each other: • Data control and agency of users in relation to their service and platform provider, • Human rights test governing workflow design as well as the conduct of service and platform providers as that conduct relates to their public stakeholders, and • Principles for the development of safety standards in line with the SDGs that can effectively govern user conduct within the metaverse spaces such providers offer. The report further maps out key

					lenses in which these three areas interact with one another, with platform design considerations, and other stakeholders. It also offers a practical use-case on an open source and decentralized protocol demonstrating how technical infrastructure can enable user control of PII.
ITU	FG-MV	FGMV-12	Children's age verification in the metaverse	Approved deliverable	The metaverse, encompassing XR technologies like VR, AR, and MR, presents immersive experiences but also intensifies risks to children online. Threats from content, contact, and conduct are amplified in the metaverse, requiring robust child protection measures. Age verification is crucial, with methods like self-declaration, credit cards, biometrics, and digital IDs being utilized. Regulations such as GDPR and California's AADC offer guidelines, but the metaverse offers unique opportunities for bolstering age verification, especially with soft biometrics. Risk assessment frameworks and age verification methods should align with the level of risk, ensuring minimal data collection and utilizing technologies like ZKPs. Trusted third-party verification is advocated for interoperability and data protection.

					Overall, the document highlights challenges and provides guidelines for implementing third-party age verification to safeguard children in the metaverse.
ITU	FG-MV	FGMV-14	Regulatory and economic aspects in the metaverse: Data protection-related	Approved deliverable	The text discusses the emergence of the metaverse as a new frontier in technology, bringing both opportunities and risks, particularly concerning data protection and sovereignty. It explores these concerns from the regulatory and economic perspectives, dividing them into general data protection issues and economic data protection concerns. The report introduces the "Life Cycle of Data Threat Model", which identifies potential threats across seven stages of the data lifecycle. Finally, it proposes a data protection assessment framework to evaluate these challenges and prioritize policy responses accordingly, emphasizing the critical role of data protection in enabling economic activities and regulating the metaverse.
ITU	FG-MV	FGMV-23	Considering online and offline implications in efforts to build confidence and security in the metaverse	Approved deliverable	This Technical Report discusses the evolving concept of the metaverse and its potential implications for both participants and non-participants. It suggests that as the metaverse progresses towards digitally replicating the world, everyone may

					eventually be represented in it, regardless of their active participation. This implies that opting out of the metaverse may not shield individuals from its effects. Early observations indicate various concerns such as security, trust, ethics, and inclusion/exclusion issues. To address these, new frameworks for building confidence and security in the metaverse are presented. These frameworks draw on existing knowledge about trust, safety, and digital inclusion/exclusion, aiming to accommodate diverse populations and their interactions within the metaverse. The Technical Report specifically explores these issues using the "User Confidence Framework" from the ITU FGMV-06 Technical Report on ethical considerations in metaverse standards, highlighting the importance of ensuring confidence and security for all participants.
ITU-T	SG17	TR.cs-sc	Technical Report: Collection of Security Concerns for extracting the Security Requirements for Cyber Security	Under development	The integration of TCP/IP technology with traditional protocols, for all activities has converted/transformed the digital Systems & Digital Infrastructures and Networks into an interconnection of Operations Technology (OT) part of the network and information Technology (IT) Part

			Reference Architecture		of the network. Security risks and concerns are managed differently in IT and OT networks. Security in IT is focused primarily on protecting data confidentiality, ensuring that sensitive information is accessible only to authorized users. OT security; however, it also prioritizes the safety and availability of industrial systems and processes. The integrity and continuous operation of physical equipment are paramount in OT, given that a failure can result in significant safety and financial implications. The security concerns of the OT part and the IT part are to be taken together so as to devise strategy & Mitigation measures towards building a secure and resilient digital Service Provider's network. The Security concerns or threats are used interchangeably but have slightly different connotations and contexts to the OT part and IT part of the Telecommunication Service provider's network, hence they need not necessarily be the same. A Collection of the same for both with the appropriate context will help in identifying the security requirements and the stakeholders to be addressed through the Cyber Security Reference Architecture in X.cs-ra. This work item mainly covers the collection of

					Security concerns with the contexts of use case to derive the appropriate security requirements. The output of this Technical Report will play an important role in developing a comprehensive Cyber Security Reference Architectures by analysing the collected Security concerns and breaking down them into the generic concerns applicable to any network be it based on IT, on OT, or on both.
ITU-T	SG17	TR.cs-uc	Technical Report: Use cases for extracting the security requirements for cybersecurity reference architecture	Under development	The Cyber Security Reference Architecture is aimed at providing a unified, systemic and granular approach for architecting and deploying digital systems, solutions and infrastructures in a comprehensively cybersecure and resilient manner in diverse use cases and application domains, leading to significant improvements in their respective security and resilience along with reducing the vulnerable surface attack areas in the digital systems, solutions and/or infrastructures. However, to be able to understand the diverse security requirements of different use cases and application domains, it is crucial to collect the relevant diverse use cases of digital systems, solutions, infrastructures, and networks to extract all the security requirements

					and concerns. Use cases are means to describe the requirements accurately and completely for any complex systems and functions. This Technical Report develops a common harmonized and standardized approach & Template to describe diverse use cases for their respective context, security concerns and requirements. The output of the Technical Report is crucial in developing a comprehensive Cyber Security Reference Architectures by analysing the collected use cases in the appropriate context, as well as integrating Cyber Security in a structured manner into various digital systems, solutions, infrastructures & Networks Architectures.
ITU-T	SG17	X.cs-ra	Cybersecurity reference architecture	Under development	Strong security controls and practices are foundational elements for building and maintaining stakeholder trust. Security experts no longer can afford to assume that walling off the network would provide the security required to maintain system integrity and customer trust. Recognizing the impact of security breaches on customer trust, enterprises are striving to develop new comprehensive, scalable, and futureproof strategies to protect enterprise systems and data. It is evident that Cyber Security is a

					very complex paradigm, and with evolving new technologies, requirements, and ever-increasing attack Surface, the vulnerabilities are rising many folds with time. In such a dynamic scenario, there is need to develop a Cyber Security Strategy to make our Digital Systems & Infrastructures comprehensively Safe, Secure, Resilient and Trustworthy. Security Architecture is a set of physical and logical security-relevant representations (i.e., views) of system architecture that conveys information about how the system is partitioned into security domains and enforce security policies within and between security domains based on how data and information must be protected. Reference Architecture is a source of information comprising descriptions of generalized architecture concepts, requirements and recommendations that is used to conceptualize architectures and capture architecture descriptions. Reference architectures can be expressed as a set of models, views, model views, processes, elements, their relationships, and rules, etc.
ITU-T	SG17	ITU-T X.1054	Information security, cybersecurity and	Published	Information security is a key issue for organizations, amplified by rapid advances in attack methodologies and

			privacy protection - Governance of information security		technologies, and corresponding increased regulatory pressures. The failure of an organization's information security controls can have many adverse impacts on an organization and its interested parties, including the undermining of trust. Governance of information security is the use of resources to ensure effective implementation of information security, and provides assurances that directives concerning information security will be followed, and that the governing body will receive reliable and relevant reporting about information security-related activities. This assists the governing body to make decisions concerning the strategic objectives for the organization by providing information about information security that may affect these objectives. It also ensures that the information security strategy aligns with the overall objectives of the entity. Managers and others working in organizations need to understand the governance requirements that affect their work, and how to meet governance requirements that require them to take action.
ITU-T	SG17	ITU-T X.1051	Information security,	Published	This Recommendation is designed to establish guidelines and general

			cybersecurity and privacy protection - Information security controls based on ISO/IEC 27002 for telecommunications organizations		principles for initiating, implementing, maintaining and improving information security controls in telecommunications organizations based on ISO/IEC 27002. It also provides an implementation baseline of information security controls within telecommunications organizations to ensure the confidentiality, integrity and availability of telecommunications facilities, services and information handled, processed or stored by the facilities and services.
ITU-T	SG17	X.1058-rev	Information security, cybersecurity and privacy protection — Code of practice for personally identifiable information protection	Under development	This document proposes to revise the draft Recommendation of X.1058 to synchronize the structure and the context with ISO/IEC 27002, which was published in 2022. X.1058 was published in 2017. X.1058 should be restructured text in alignment with the revision of ISO/IEC 27002. ITU-T X.1058 was developed based on the recommendation of ISO/IEC 27002 and the revision of this Recommendation should be considered accordingly. The number of organizations processing personally identifiable information (PII) is increasing, as is the amount of PII that these organizations deal with. At the same time, societal

					expectations for the protection of PII and the security of data relating to individuals are also increasing. A number of countries are augmenting their laws to address the increased number of high profile data breaches. This Recommendation establishes control objectives, controls and guidelines for implementing controls, to meet the requirements identified by a risk and impact assessment related to the protection of PII. In particular, this Specification specifies guidelines based on ISO/IEC 27002, taking into consideration the requirements for processing PII that may be applicable within the context of an organization's information security risk environment(s). This Recommendation is intended to be developed jointly with ISO/IEC JTC 1/SC 27/WG 5 to be a common text with ISO/IEC 29151.
ITU-T	SG17	X.1631rev	Information security, cybersecurity and privacy protection — Information security controls based on ISO/IEC 27002 for cloud services	Under development	Recommendation ITU-T X.1631 | ISO/IEC 27017 provides guidelines for information security controls applicable to the provision and use of cloud services by providing: additional implementation guidance for relevant controls specified in ISO/IEC 27002; and additional controls with implementation guidance that specifically relates to

					cloud services. This Recommendation / International Standard provides controls and implementation guidance for cloud service providers and for cloud service customers.
ITU-T	SG13	ITU-T Y.3539	Cloud computing - Framework of risk management	Published (01/2023)	ITU-T Y.3539 provides a framework of risk management in the cloud computing environment, including risk assessment, risk treatment, risk acceptance, risk communication and consultation, and risk monitoring and review. It also provides a complete set of management processes and effective measures to reduce risks in cloud computing environments.
ITU-T	SG17	ITU-T X.1601	Security framework for cloud computing	Published (10/2015)	ITU-T X.1601 describes the security framework for cloud computing.
ITU-T	SG17	ITU-T X.1603	Data security requirements for the monitoring service of cloud computing	Published (03/2018)	ITU-T X.1603 analyses data security requirements for the monitoring service of cloud computing, which includes monitoring data scope requirements, monitoring data lifecycles, security requirements of monitoring data acquisition, and security requirements of monitoring data storage.
ITU-T	SG17	ITU-T X.1352	Security requirements for Internet of things	Published (09/2022)	ITU-T X.1352 establishes detailed requirements for five security dimensions applicable to Internet of things (IoT) device and gateways.

			devices and gateways		
ITU-T	SG20	ITU-T Y.4102/Y.2074	Requirements for Internet of things devices and operation of Internet of things applications during disaster	Published (01/2015)	ITU-T Y.4102 provides requirements for Internet of things (IoT) devices used for the operation of IoT applications in the context of disasters, in addition to the common requirements of IoT in ITU-T Y.2066. It also provides requirements for the operation of IoT applications during disasters.
ITU-T	SG20	ITU-T Y.4810	Requirements for data security of heterogeneous Internet of things devices	Published (11/2021)	ITU-T Y.4810 describes requirements for data security of heterogeneous Internet of things (IoT) devices under specific scenarios to provide a general reference recommendation and to ensure IoT data safety.
ISO/IEC	JTC 1/SC 29	ISO/IEC 23090-10:2022	Coded representation of immersive media - Part 10: Carriage of visual volumetric video-based coding data	Published	ISO/IEC 23090-10:2022 defines a model for the runtime management of applications within a distributed application environment. It provides a framework for overseeing and controlling the execution, resource allocation, and overall behaviour of applications across various nodes and platforms. The standard outlines mechanisms for tasks such as application deployment, monitoring, scaling, and termination, along with provisions for handling faults and ensuring application health and performance. Additionally, it

					specifies interfaces for interaction between application management components, enabling interoperability and facilitating the integration of management functionalities within distributed systems.
W3C	W3C Web Authentication WG	WebAuthn, https://www.w3.org/TR/webauthn/	Web Authentication: An API for accessing Public Key Credentials	Published (04/2021)	WebAuthn defines an API enabling the creation and use of strong, attested, scoped, public key-based credentials by web applications, for the purpose of strongly authenticating users. This specification also describes the functional model for WebAuthn conformant authenticators, including their signature and attestation functionality.

7.1.6 Accessibility

Table 7-6 provides the metaverse standards related to accessibility. SDOs associated with this category of metaverse standards include ITU, ITU-D, and W3C.

Table 7-6: Metaverse standards related to accessibility

SDO	Study group	Reference	Title	Status	Abstract
ITU	FG-MV	FGMV-03	Guidelines to assess inclusion and accessibility in metaverse standard development	Approved deliverable	The Technical Report focuses on promoting diversity, equity and inclusion in the metaverse through accessibility implementation. It explores how to realize these principles by integrating accessibility considerations into virtual, augmented, mixed and extended reality

					experiences. The report builds on previous research by examining limitations and validating the United Nations' Sustainable Development Goal (SDG) principles along with six metaverse values. It proposes guidelines for aligning metaverse platforms with the SDGs, emphasizing user experience dimensions such as conception, interaction, interface, information and usability. Universal design principles are highlighted to ensure inclusivity for individuals with diverse abilities, cultures, languages and perspectives. By providing recommendations, the report aims to strengthen the case for incorporating accessibility to achieve inclusion in the development of the metaverse, ultimately contributing to the realization of SDGs through digital transformation.
ITU	FG-MV	FGMV-04	Requirements of accessible products and services in the metaverse: Part I – System design perspective	Approved deliverable	This Technical Specification provides high-level requirements for designers and developers to create an accessible immersive experience in the metaverse. This document considers the common accessibility requirements for the design and development phases of born accessible products and services in the metaverse. The document is related to “Requirements of accessible products and services in the metaverse: Part II –

					User perspective" and provides common accessibility requirements.
ITU	FG-MV	FGMV-05	Requirements of accessible products and services in the metaverse: Part II – User perspective	Approved deliverable	This Technical Specification provides requirements on how to develop an accessible metaverse from a user perspective. This document considers the various metaverse components and the actions that users, regardless of their capabilities, may perform to access the metaverse, create an identity within the metaverse, navigate the metaverse and interact in the metaverse. The document is related to ITU FG-MV Technical Specification on "Requirements of accessible products and services in the metaverse: Part I – System design perspective" and provides requirements on the role of users in creating and assessing accessibility services.
ITU	FG-MV	FGMV-16	Accessibility in a sustainable metaverse	Approved deliverable	This Technical Report promotes and instructs on the adaptation of an integrated approach to accessibility and sustainability in the metaverse. It explores the integration of accessibility products and services in the metaverse and their associated social benefit and environmental impact. Emphasising the need for the early integration of accessibility and sustainability, this document presents information and guidance on how to incorporate sustainable accessibility products and services in the metaverse from the outset.

					Questions related to sustainability and accessibility in the metaverse need to consider the following: • Social benefit of sustainable accessibility products and services in the metaverse. • Challenges and opportunities of an accessible and sustainable metaverse.
ITU	FG-MV	FGMV-17	Guidelines and requirements on interpreting in the metaverse	Approved deliverable	This document provides guidelines and requirements on interpreting in the metaverse. It summarises typical use settings that require interpreting in the metaverse, including conference interpreting, public service interpreting and sign-language interpreting. It describes technical requirements for interpreting in the metaverse. It also provides advice for all parties in interpreted events in the metaverse, including organizers, speakers, interpreters and audience in interpreting facilitated events in the metaverse.
ITU	FG-MV	FGMV-26	Requirements for communication between human-avatar languages in the metaverse	Approved deliverable	This Technical Specification provides requirements on how to develop the architecture for communication between humans, digital humans/avatars, and systems in the metaverse. This document considers language modalities, language writing systems, AI language communication technologies, co-linguistic communication, and language prevalence in terms of use. It provides guidance on a wide array of

					communication workflows for the metaverse. The document also makes recommendations on how communication modalities can be considered in the design of any scenario.
ITU	FG-MV	FGMV-15	Accessibility requirements for metaverse services supporting IoT	Approved deliverable	The virtual world based on real-world data collected through IoT technology and using XR technology as UX is collectively referred to as a metaverse supporting IoT. The ideally constructed metaverse interface should prevent persons with disabilities and those with specific needs who have difficulty using certain senses in the real world from feeling this difficulty in the metaverse. This Technical Specification defines the accessibility requirements that metaverse services supporting IoT should have.
ITU-D	SG1	1/225-E	Brain-computer interface technology facilitates information accessibility for special populations	Under development	The goal of information accessibility is to enable anyone to access, interact and use information equally, conveniently, and safely. Brain-computer interface is an emerging frontier technology that will bring new hope to people with information barriers. This article first introduces the main principle of brain-computer interface technology to help special people with information accessibility and proposes the empowering role for people with motor impairment, consciousness and cognitive impairment, sensory defect impairment and language communication

					impairment. Secondly, it lists the relevant research and practice cases in the global scope. Thirdly, it analyses the challenges faced by the current technology industry, including high research and development costs, long cycles, low-technology maturity and productization level. Finally, it makes a prospect for the development of brain-computer interface to help information accessibility.
W3C	W3C Accessible Platform Architectures WG	SAUR https://www.w3.org/TR/saur/	Synchronization Accessibility User Requirements	Published (06/2023)	SAUR summarizes relevant research, then outlines accessibility-related user needs and associated requirements for the synchronization of audio and visual media. The scope of the discussion includes synchronization of accessibility-related components of multimedia such as captions, sign language interpretation, and descriptions. The requirements identified herein are also applicable to multimedia content in general, as well as real-time communication applications and media occurring in immersive environments.
W3C	W3C Accessible Platform Architectures WG	NAUR https://www.w3.org/TR/naur/	Natural Language Interface Accessibility User Requirements	Under development	NAUR outlines accessibility-related user needs, requirements and scenarios for natural language interfaces.
W3C	W3C Accessible Platform	RAUR https://www.w3.org/TR/raur/	RTC Accessibility User Requirements	Published (05/2021)	RAUR outlines various accessibility related user needs, requirements and

	Architectures WG				scenarios for real-time communication (RTC).
W3C	W3C Accessible Platform Architectures WG	Accessibility of Remote Meetings https://www.w3.org/TR/remote-meetings/	Accessibility of Remote Meetings	Published (07/2022)	Accessibility of Remote Meetings summarizes considerations of accessibility that arise in the conduct of remote and hybrid meetings. Such meetings are mediated, for some or all participants, by real-time communication software typically built upon Web technologies.
W3C	W3C Accessible Platform Architectures WG	CTAUR https://www.w3.org/TR/ctaur/	Collaboration Tools Accessibility User Requirements	Under development	CTAUR outlines various accessibility-related user needs, requirements and scenarios for collaboration tools. The tools of interest are distinguished by their support for one or more specific collaborative features. These features include real-time editing of content by multiple authors, the use of comments or annotations, and revision control.
W3C	W3C Accessible Platform Architectures WG	Making Content Usable for People with Cognitive and Learning Disabilities https://www.w3.org/TR/coga-usable/	Making Content Usable for People with Cognitive and Learning Disabilities	Published (04/2021)	Making Content Usable for People with Cognitive and Learning Disabilities is for people who make web content (web pages) and web applications. It gives advice on how to make content usable for people with cognitive and learning disabilities. This includes, but is not limited to: cognitive disabilities, learning disabilities (LD), neurodiversity, intellectual disabilities, and specific learning disabilities.

W3C	W3C Accessible Platform Architectures WG	MAUR https://www.w3.org/TR/media-accessibility-reqs/	Media Accessibility User Requirements	Published (12/2015)	MAUR presents the accessibility requirements users with disabilities have with respect to audio and video on the web.
W3C	W3C Accessible Platform Architectures WG	WAI-Adapt Symbols https://www.w3.org/TR/adapt-symbols/	WAI-Adapt: Symbols Module	Under development	WAI-Adapt Symbols provides web content authors a standard approach to support web users with various cognitive and learning disabilities who: customarily communicate using symbolic languages generally known as Augmentative and Alternative Communications (AAC); and need more familiar icons (and other graphical symbols) in order to comprehend page content.
W3C	W3C Accessible Rich Internet Applications WG	Core AAM https://www.w3.org/TR/core-aam-1.2/	Core Accessibility API Mappings 1.2	Under development	Core AAM describes how user agents should expose semantics of web content languages to accessibility APIs. This helps users with disabilities to obtain and interact with information using assistive technologies. This specification defines support that applies across multiple content technologies, including general keyboard navigation support and mapping of general-purpose roles, states and properties provided in Web content via WAI-ARIA.
W3C	W3C Accessible Rich Internet	Graphics AAM https://www.w3.org/TR/graphics-aam-1.0/	Graphics Accessibility API Mappings	Published (10/2018)	Graphics AAM defines how user agents map the WAI-ARIA Graphics Module mark-up to platform accessibility APIs. It is intended for user agent developers

	Applications WG				responsible for accessibility in their user agent so that they can support the accessibility of graphics.
W3C	W3C Accessible Rich Internet Applications WG	WAI-ARIA 1.1 https://www.w3.org/TR/wai-aria-1.1/	WAI-ARIA Rich Internet Applications 1.1	Published (12/2017)	WAI-ARIA 1.1 provides an ontology of roles, states, and properties that define accessible user interface elements and can be used to improve the accessibility and interoperability of web content and applications. These semantics are designed to allow an author to properly convey user interface behaviours and structural information to assistive technologies in document-level mark-up.

7.2 Application and service standards

Table 7-7 provides the metaverse standards related to application and service. SDOs associated with this category of metaverse standards include ITU, ITU-T, and ISO/IEC.

Table 7-7: Metaverse standards related to application and service

Subcategory	SDO	Study group	Reference	Title	Status	Abstract
City Governance	ITU	FG-MV	FGMV-07	Policy and regulation opportunities and challenges in the metaverse	Approved deliverable	The text emphasizes the need for policymakers and regulators to carefully balance various societal, environmental, economic, and legal aspects of the emerging metaverse. It discusses the challenges surrounding policy and regulation in the metaverse, including technological advancements, regional/national approaches to development, and the digital divide affecting one third of the global population. Addressing issues like accessibility, energy consumption, and environmental impact is

						crucial, requiring the adoption of energy-efficient practices and standards. Privacy, security, and ethical considerations are also highlighted as essential, necessitating the development of guidelines to ensure responsible behaviour and alignment with societal values. Furthermore, the metaverse presents an opportunity for policymakers to collaborate globally, harmonizing efforts and promoting interoperability while leveraging enabling technologies like AI, blockchain, and cloud computing. This collaboration aims not only to benefit users but also to accelerate sustainable digital transformation and achieve the Sustainable Development Goals.
City Governance	ISO/IEC	JTC 1/SC 24	ISO/IEC TS 5147	Guidelines for Representation and Visualization of Smart Cities	Published	Representation and visualization of smart cities will enable prototyping, demonstration, and analysis of smart city concepts for further development. Physical and geometric and semantic data will both need to be represented and visualized. Representation and visualization of smart cities is a prime application for an integrated approach to leverage standardization since no single standard will address all requirements. This document provides guidelines as to what needs to be represented for smart cities and how this can be achieved.
Education	ITU-T	SG16	ITU-T F.742.1	Requirements for smart class systems based on artificial intelligence	Published	Recommendation ITU-T F.742.1 describes application scenarios and requirements for smart class system based on artificial intelligence, including application scenarios, service requirements, management requirements, and security considerations.

Education	ISO/IEC	JTC 1/SC 29	ISO/IEC 21000-20:2016	Multimedia framework (MPEG 21) - Part 20: Contract Expression Language	Published	ISO/IEC 21000-20:2016 outlines a reference model for Learning, Education, and Training (LET) with the goal to standardize the description and structure of LET systems, including their functions and processes. It provides a common language for various stakeholders involved in LET, such as learners, educators, content developers, and system providers, facilitating interoperability and data exchange between different LET systems. The standard also defines the relationships and interactions between the components of an LET system, including learners, instructors, content, learning context, and learning platforms. This framework aims to help improve the quality and efficiency of LET systems, promote reusability of learning resources, and support the development of innovative LET solutions.
Education	ISO/IEC	JTC 1/SC 29	ISO/IEC 21000-22:2022	Multimedia framework (MPEG 21) - Part 22: User Description	Published	ISO/IEC 21000-22:2022 establishes a framework for the quality assurance and standardization of educational organizations. It outlines a quality management system, including continual improvement processes, to ensure educational services meet learner and other beneficiary needs. This standard specifies requirements for establishing, implementing, maintaining, and continually improving the quality management system, while considering the diverse factors affecting the quality of educational services within an organization's context.
Environmental protection	ISO/IEC	JTC 1/SC 24	ISO/IEC 18023-1	SEDRIS – Part 1: Functional specification	Published	ISO/IEC 18023-1 defines the syntax, semantics, and structure for the representation and interchange

						of environmental data, along with the means to produce and access that data.
Environmental protection	ISO/IEC	JTC 1/SC 24	ISO/IEC 18025	Environment al Data Coding Specification (EDCS)	Published	This International Standard provides mechanisms to unambiguously specify objects used to model environmental concepts. To accomplish this, a collection of nine EDCS dictionaries of environmental concepts are specified; these include: classifications, attributes, attribute value characteristics, attribute enumerants, units, and unit scales.
Environmental protection	ISO/IEC	JTC 1/SC 24	ISO/IEC 18024-4	SEDRIS language bindings – Part 4: C	Published	SEDRIS (Synthetic Environment Data Representation and Interchange Specification) is a system for representing and interchanging environmental data including terrain, oceanographic, atmospheric, and near-space environmental data. SEDRIS includes an application program interface (API) that allows a variety of proprietary systems to consistently interchange and interoperate with the environmental data. Access to the information stored in a SEDRIS transmittal is through the API. This document defines a standard binding for the C programming language.
Environmental protection	ISO/IEC	JTC 1/SC 41	ISO/IEC 30179:2023	Internet of Things (IoT) — Overview and general requirements of IoT system for ecological environment monitoring	Published	ISO/IEC 30179:2023 specifies the Internet of Things system for ecological environment monitoring in terms of the following: system infrastructure and system entities of the IoT system for ecological environment monitoring for natural entities such as air, water, soil, living organisms; and the general requirements of the IoT system for ecological environment monitoring.

Power energy	ITU	FG-MV	FGMV-09	Power metaverse: Use cases relevant to grid side and user side	Approved deliverable	This Technical Report provides steps for the realization and use cases of power metaverse applied in the power system from the perspectives of the user and the grid. Each use case describes the application scenario, the assumptions and the service scenario.
Power energy	ITU	FG-MV	FGMV-27	Guidelines for metaverse application in power system	Approved deliverable	This Technical Report provides the connotation, mapping mode, and implementation logic of the power metaverse, provides the application framework and key technical details. For the convenience of understanding and use, it also lists three typical application scenarios aligned with power system business needs. This Technical Report provides reference for decision-making, technical research and application practice in power metaverse.
Transportation	ISO/IEC	JTC 1/WG 11	ISO/IEC 5087-3	Information technology — City data model — Part 3: Service level concepts - Transportation planning	Published	This is part 3 of the multipart standard that specifies a common data model for cities. Part 3 is a standard for a service-level data model, focusing on transportation planning.
-	3GPP	SA1	TR 22.856	Study on Localized Mobile Metaverse Services (Release 19)	Under change control	TR 22.856 provides a study on localized mobile metaverse services and is under change control.
-	ISO/IEC	JTC 1/SC 24	ISO/IEC 19775-2: 2015	Extensible 3D (X3D) — Part 2: Scene access interface (SAI)	Published	X3D is a file format and related access services for describing interactive 3D objects and worlds. X3D is also a universal interchange format for integrated 3D graphics and multimedia. X3D may be used in a variety of application areas such as engineering and scientific visualization, multimedia presentations, entertainment and educational titles, web pages,

						and shared virtual worlds. This part of ISO/IEC 19775 defines a scene access interface that can be used to interact with X3D worlds both from within the worlds themselves or from external programs.
-	ITU-T	SG16	ITU-T H.430.3	Service scenario of immersive live experience (ILE)	Published (08/2018)	This identifies service scenarios by analysing several use cases on immersive live experience (ILE) services, in order to classify ILE services and to clarify a reference model of ILE. This Recommendation also summarises several use cases and identifies candidate technologies for implementing ILE, including standards gap analysis related to ILE technologies.

7.3 Enabling technology standards

7.3.1 Virtual reality & Augmented reality

Table 7-8 provides the metaverse standards related to virtual reality and augmented reality. SDOs associated with this category of metaverse standards include 3GPP, IEC, IEEE, ISO/IEC, ITU, ITU-T and W3C.

Table 7-8: Metaverse standards related to virtual reality and augmented reality

SDO	Study group	Reference	Title	Status	Abstract
3GPP	SA4	TR 26.998	Support of 5G glass-type Augmented Reality / Mixed Reality (AR/MR) devices	Under change control	TR 22.856 provides a support of 5G glass-type Augmented Reality / Mixed Reality (AR/MR) devices and is under change control.
IEC	TC 100	IEC TR 63308:2021	Virtual reality equipment and systems - Market, technology and standards requirements	Published	IEC TR 63308 discusses the market of virtual reality (VR) and the technical domains pertaining to a VR system. This document provides clarity on how existing

					standards can be used and highlights further requirements for standards within the scope of TC 100.
IEC	TC 110	IEC 63145-20-20:2019	Eyewear display - Part 20-20: Fundamental measurement methods - Image quality	Published	IEC 63145-20-20:2019 specifies the standard measurement conditions and measurement methods for determining the image quality of eyewear displays. This document is applicable to non-see-through type (virtual reality “VR” goggle) and see-through type (augmented reality “AR” glasses) eyewear displays using virtual image optics.
IEEE	3079_WG	IEEE 3079-2020	IEEE Standard for Head-Mounted Display (HMD)-Based Virtual Reality (VR) Sickness Reduction Technology	Published	IEEE 3079-2020: Head-mounted display-based virtual reality sickness-reducing technology is defined.
IEEE	AR-LEM WG	IEEE 1589-2020	IEEE Standard for Augmented Reality Learning Experience Model	Published	IEEE 1589-2020: Augmented Reality (AR) promises to provide significant boosts in operational efficiency by making information available to employees needing task support in context in real time. To support according implementations of AR training systems, this document proposes an overarching integrated conceptual model that describes interactions between the physical world, the user, and digital information, the context for AR-assisted learning and other parameters of the environment. It defines two data models and their binding to XML and JSON for representing learning activities (also known as employee tasks and procedures) and the learning environment in which these tasks are performed (also known as the workplace). The interoperability specification and standard are presented in support of an open market where interchangeable component products provide alternatives to monolithic Augmented Reality-assisted learning systems. Moreover,

					it facilitates the creation of experience repositories and online marketplaces for Augmented Reality-enabled learning content. Specific attention was given to reuse and repurposing of existing learning content and catering to mixed experiences combining real world learner guidance with the consumption (or production) of traditional contents such as instructional video material or learning apps and widgets
ISO/IEC	JTC 1/SC 24	ISO/IEC 14772-1:1997	Information technology - Computer graphics and image processing - The Virtual Reality Modeling Language - Part 1: Functional specification and UTF-8 encoding	Published	ISO/IEC 14772, the Virtual Reality Modeling Language (VRML), defines a file format that integrates 3D graphics and multimedia. Conceptually, each VRML file is a 3D, time-based space that contains graphic and aural objects that can be dynamically modified through a variety of mechanisms. ISO/IEC 14772-1:1997 of ISO/IEC 14772 defines a primary set of objects and mechanisms that encourage composition, encapsulation, and extension.
ISO/IEC	JTC 1/SC 24	ISO/IEC 14772-2:2004	Information technology - Computer graphics and image processing - The Virtual Reality Modeling Language (VRML) - Part 2: External authoring interface (EAI)	Published	ISO/IEC 14772-2:2004 defines the interface that applications external to the VRML browser may use to access and manipulate the objects defined in ISO/IEC 14772-1.
ISO/IEC	JTC 1/SC 24	ISO/IEC 18038:2020	Information technology - Computer graphics, image processing and environmental representation - Sensor representation in mixed and augmented reality	Published	ISO/IEC 18038:2020 defines the framework and information reference model for representing sensor-based 3D mixed-reality worlds. It defines concepts, an information model, architecture, system functions, and how to integrate 3D virtual worlds and physical sensors in order to provide mixed-reality applications with physical sensor interfaces. It defines an exchange format

					necessary for transferring and storing data between physical sensor-based mixed-reality applications.
ISO/IEC	JTC 1/SC 24	ISO/IEC TS 23884:2021	Information technology - Computer graphics, image processing and environmental data representation -Material property and parameter representation for model-based haptic simulation of objects in virtual, mixed and augmented reality (VR/MAR)	Published	ISO/IEC TS 23884:2021 specifies: (1) physical and material parameters of virtual or real objects expressed to support comprehensive haptic rendering methods, such as stiffness, friction and micro-textures; (2) a flexible specification of the haptic rendering algorithm itself.
ISO/IEC	JTC 1/SC 24	ISO/IEC 23488:2022	Information technology - Computer graphics, image processing and environment data representation - Object/environmental representation for image-based rendering in virtual/mixed and augmented reality (VR/MAR)	Published	ISO/IEC 23488:2022 specifies an image-based representation model that represents target objects/environments using a set of images and optionally the underlying 3D model for accurate and efficient objects/environments representation at an arbitrary viewpoint. It is applicable to a wide range of graphic, virtual reality and mixed reality applications which require the method of representing a scene with various objects and environments.
ISO/IEC	JTC 1/SC 24	ISO/IEC 18520:2019	Information technology - Computer graphics, image processing and environmental data representation - Benchmarking of vision-based spatial registration and tracking methods for	Published	ISO/IEC 18520:2019 identifies the reference framework for the benchmarking of vision-based spatial registration and tracking (vSRT) methods for mixed and augmented reality (MAR). The framework provides typical benchmarking processes, benchmark indicators and trial set elements that are necessary to successfully identify, define, design, select and apply benchmarking of vSRT methods for MAR. It also provides definitions for terms

			mixed and augmented reality (MAR)		on benchmarking of vSRT methods for MAR. In addition, this document provides a conformance checklist as a tool to clarify how each benchmarking activity conforms to this document in a compact form by declaring which benchmarking processes and benchmark indicators are included and what types of trial sets are used in each benchmarking activity.
ISO/IEC	JTC 1/SC 24	ISO/IEC 19775-1:2013	Information technology - Computer graphics, image processing and environmental data representation - Extensible 3D (X3D) - Part 1: Architecture and base components	Published	ISO/IEC 19775-1:2013 defines a software system that integrates network-enabled 3D graphics and multimedia. Conceptually, each X3D application is a 3D time-based space that contains graphic and aural objects that can be dynamically modified through a variety of mechanisms.
ISO/IEC	JTC 1/SC 36	ISO/IEC TR 23842 (series)	Information technology for learning, education and training - Human factor guidelines for virtual reality content	Published	ISO/IEC TR 23842 presents considerations for using VR content in the learning, education and training (LET) domain for reducing reality and virtual reality crossover confusion among users and assisting users to effectively use these emerging technologies, and addresses VR content that uses a head-mounted display (HMD) in the LET domain. ISO/IEC TR 23842 series contains following parts: – ISO/IEC TR 23842-1:2020 Information technology for learning, education and training - Human factor guidelines for virtual reality content - Part 1: Considerations when using VR content – ISO/IEC TR 23842-2:2020 Information technology for learning, education, and training - Human factor guidelines for virtual reality content - Part 2: Considerations when making VR content

ISO/IEC	JTC 1/SC 36	ISO/IEC TR 23843:2020	Information technology for learning, education and training - Catalogue model for virtual, augmented and mixed reality content	Published	ISO/IEC TR 23843:2020 describes how to search for virtual reality (VR), augmented reality (AR) and mixed reality (MR) content through a curriculum catalogue based on curriculum and achievement standards information. The curriculum catalogue metadata is defined in order to search for educational VR and MR content information
ISO/IEC	JTC 1/SC 24	ISO/IEC 3721:2023	Information technology — Computer graphics, image processing and environmental data representation — Information model for mixed and augmented reality content — Core objects and attributes	Published	ISO/IEC 3721:2023 specifies the information model for representing the mixed and augmented reality (MAR) scene/contents description, namely, information constructs for: a) representing the virtual reality scene graph and structure such that a comprehensive range of mixed and augmented reality contents can also be represented; b) representing physical objects in the mixed and augmented reality scene targeted for augmentation; c) representing physical objects as augmentation to other (virtual or physical) objects in the mixed and augmented reality scene; d) providing ways to spatially associate aforementioned physical objects with the corresponding target objects (virtual or physical) in the mixed and augmented reality scene; e) providing other necessary functionalities and abstractions that will support the dynamic MAR scene description such as event/data mapping, and dynamic augmentation behaviours; f) describing the association between these constructs and the MAR system which is responsible for taking and interpreting this information model and rendering/presenting it out through the MAR display device.
ISO/IEC	JTC 1/SC 24	ISO/IEC AWI TR 16088	Constructs for visual positioning systems in	Under development	ISO/IEC AWI TR 16088 is under development and provides a TR on constructs for visual positioning systems in mixed and augmented reality (MAR).

			mixed and augmented reality (MAR)		
ISO/IEC	JTC 1/SC 24	ISO/IEC 19775-1	Extensible 3D (X3D) — Part 1: Architecture and base components	Published	X3D is a 3-dimensional data model that defines an object in a virtual environment. The object can consist of graphics, image, and/or video data, and a virtual world is obtained by the collection of the objects. It provides interactive multimedia information and 3D virtual worlds using computer graphics and animation technologies. ISO/IEC 19775-1 can be used to generate 3D virtual worlds that represent metaverse environments. Metaverse objects that should be represented in a virtual environment can be created using X3D.
ISO/IEC	JTC 1/SC 24	ISO/IEC 18038	Sensor representation in MAR (Mixed and Augmented Reality)	Published	This International Standard defines a framework and information reference model for representing sensor-based 3D mixed reality worlds. It outlines concepts, an information model, architecture, system functions, and how to integrate 3D virtual worlds and physical sensors to provide mixed reality applications with physical sensor interfaces. It also defines an exchange format necessary for transferring and storing data between physical sensor-based mixed reality applications.
ISO/IEC	JTC 1/SC 24	ISO/IEC 18039	MAR reference model	Published	This International Standard defines the scope and key concepts of mixed and augmented reality (MAR), the relevant terms and their definitions, and a generalized system architecture that together serve as a reference model for MAR applications, components, systems, services, and specifications. This architectural reference model establishes the set of required submodules and their minimum functions, the associated information content, and the information models that shall be provided and/or supported by a compliant MAR system.

ISO/IEC	JTC 1/SC 24	ISO/IEC 18040	Live actor and entity representation in MAR	Published	This International Standard, Live Actor and Entity (LAE) Representation in Mixed and Augmented Reality, defines a reference model and base components for representing and controlling a single LAE or multiple LAEs in a MAR scene. It defines concepts, a reference model, system framework, functions, and how to integrate a 2D/3D virtual world and LAEs, and their interfaces, in order to provide MAR applications with interfaces of LAEs. It also defines an exchange format necessary for transferring and storing LAE-related data between LAE-based MAR applications.
ISO/IEC	JTC 1/SC 24	ISO/IEC 3721	Information Model for Mixed and Augmented Reality (MAR) Contents	Published	This standard describes an information model for representing mixed and augmented reality scene/contents description: extending the existing and conventional constructs for representing the virtual reality scene graph and structure; representing physical objects in the mixed and augmented reality scene targeted for augmentation; providing ways to spatially associate the aforementioned physical objects, and so on.
ISO/IEC	JTC 1/SC 24	ISO/IEC 18520	Benchmarking of vision-based spatial registration and tracking methods for mixed and augmented reality (MAR)	Published	This standard identifies a reference framework for the benchmarking of vision-based spatial registration and tracking (vSRT) methods for mixed and augmented reality (MAR). It provides typical benchmarking processes, benchmark indicators, and trial set elements that are necessary to successfully identify, define, design, select, and apply benchmarking of vSRT methods for MAR.
ISO/IEC	JTC 1/SC 24	ISO/IEC 21145	Style representation for mixed and augmented reality	Published	This standard describes a set of information constructs for stylizing MAR content and its objects. ISO/IEC 3721 specifies a MAR scene with core objects and their attributes. This standard further refines ISO/IEC 3721 similarly to how CSS (Cascading Style Sheets) augments

					HTML-5 for web document stylization. Virtual objects that augment real world objects may be subject to further stylization. Stylization refers to the act of making certain information follow a particular form for various purposes.
ISO/IEC	JTC 1/SC 24	ISO/IEC TS 23884	Material property and parameter representation for model-based haptic simulation of objects in virtual, mixed, and augmented reality (VR/MAR)	Published	The objective of this specification is to propose an extension to the existing standard for virtual and mixed reality scene/contents description and information models. This extension includes: (1) the expression of physical and material parameters of virtual/real objects to support comprehensive haptic rendering methods, such as stiffness, friction, and micro-textures, and (2) a flexible specification of a rendering algorithm. The specification also provides definitions for terms related to various material properties, physical simulation, and haptic rendering and algorithm.
ITU-T	SG11	ITU-T Q.4066	Testing procedures of augmented reality applications	Published (09/2020)	This defines approaches for testing for various applications of AR.
ITU-T	SG12	ITU-T G.1035	Influencing factors on quality of experience for virtual reality services	Published (11/2021)	This categorizes and summarizes the factors affecting the user-perceived experience of a virtual reality (VR) service, with the intention of helping to identify the methodologies for assessing VR quality. Gaming, social, shopping are mentioned in use cases of VR services.
ITU-T	SG12	ITU-T P.1320	Quality of experience assessment of extended reality meetings	Published (07/2022)	This advises on aspects of importance for quality of experience (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.
ITU-T	SG12	ITU-T G.1036	Quality of experience influencing factors for augmented reality services	Published (07/2022)	This lists typical use cases of augmented reality (AR) services and identifies the key quality of experience (QoE) factors within them, and also gives a suggested scheme for AR QoE assessment in future work.
ITU-T	SG13	ITU-T Y.3109	Quality of service assurance-related requirements and framework for virtual reality delivery using mobile edge computing supported by IMT-2020	Published (04/2021)	This specifies quality of service (QoS) assurance-related requirements and a framework for virtual reality (VR) delivery using mobile edge computing (MEC) in International Mobile Telecommunications-2020 (IMT-2020).
ITU-T	SG16	ITU-T F.746.14	Requirements and reference framework for cloud virtual reality systems	Published (12/2022)	This focuses on the overall requirements of cloud virtual reality systems and the related requirements of each layer including content requirements, network requirements, control requirements, resource requirements and terminal requirements, as well as the reference framework for related high-level functions.
ITU-T	SG16	ITU-T F.740.2	Requirements and reference framework for digital representation of cultural relics and artworks using augmented reality	Published (06/2021)	This describes the requirements, application scenarios and reference framework for the digital representation of cultural relics and artworks using augmented reality (AR), which is known as an augmented reality cultural service system (ARCSS).
ITU-T	SG16	ITU-T F.IPTV-VRSReqs	Requirements of enabling VR service based on IPTV Architecture	Under development	This draft Recommendation identifies the requirements and functions of enabling VR service base on IPTV architecture. This draft Recommendation discussed the VR services based on IPTV terminal devices. This draft Recommendation also describes the related use cases of VR service based on IPTV architecture.

ITU-T	SG9	ITU-T J.301	Requirements for augmented reality smart television systems	Published (10/2014)	This specifies requirements that should be considered for augmented reality (AR) smart television system (AR-STV).
ITU-T	SG9	ITU-T J.302 Amd 1	System specifications of augmented reality smart television service	Published (01/2019)	This specifies the related technologies that should be implemented for augmented reality smart television system.
ITU-T	SG9	ITU-T J.cloud-vr-arch	Architecture of E2E network platforms to enhance the delivery of cloud-VR services over integrated broadband cable networks	Under development	ITU-T J.cloud-vr-arch: This focuses on architecture of the end-to-end (E2E) network platform to deliver 360°/Virtual Reality (VR) video services from the video cloud to terminal devices, as well as the network requirements of cloud VR services, over integrated broadband cable networks. NOTE – Integrated broadband cable networks can be referred to as a cable network, e.g., coaxial cable, optical fibre, and hybrid fibre coaxial (HFC), that also has capability to provide broadband services integrated with television services over the same network.
ISO/IEC	JTC 1/SC 29	ISO/IEC 21000-23:2022	Multimedia framework (MPEG 21) - Part 23: Smart Contracts for Media	Published	ISO/IEC 21000-23:2022, titled “Information technology — Multimedia framework (MPEG-21) — Part 23: Spatial Web Model,” outlines a standardized model for representing and interacting with the spatial web. This model facilitates the integration of real and virtual environments, enabling users to access and interact with digital content overlaid onto the physical world. It achieves this by defining a common framework for spatial computing, encompassing aspects such as spatial mapping, object recognition and user interaction. This standard fosters interoperability between different spatial web applications and devices, promoting a seamless user experience. Moreover, it addresses crucial factors like privacy, security and trust within the spatial web environment.

W3C	W3C Accessible Platform Architectures WG	XAUR https://www.w3.org/TR/xaur/	XR Accessibility User Requirements	Published (08/2021)	XAUR lists user needs and requirements for people with disabilities when using virtual reality or immersive environments, augmented or mixed reality and other related technologies (XR).
W3C	W3C GPU for the Web WG	WGSL https://www.w3.org/TR/WGSL/	WebGPU Shading Language	Under development	WGSL defines the Shading language for WebGPU.
W3C	W3C Immersive Web CG	WebXR Raw Camera Access https://immersive-web.github.io/raw-camera-access/	WebXR Raw Camera Access Module	Proposed	WebXR Raw Camera Access provides a means to access the raw camera image displayed behind an immersive AR session, when the device is responsible for rendering that camera image.
W3C	W3C Immersive Web CG	The <model> Element https://immersive-web.github.io/model-element/	The <model> Element	Proposed	The <model> Element allows embedding 3D graphical content into a [HTML] document. The HTMLModelElement interface then provides a means to interface with the embedded resource.
W3C	W3C Immersive Web WG	WebXR https://www.w3.org/TR/webxr/	WebXR Device API	Under development	WebXR describes support for accessing virtual reality (VR) and augmented reality (AR) devices, including sensors and head-mounted displays, on the Web.
W3C	W3C Immersiv	WebXR-AR https://www.w3.	WebXR Augmented Reality Module - Level 1	Under development	WebXR-AR expands the WebXR Device API with the functionality available on AR hardware.

	e Web WG	org/TR/webxr-ar-module-1/			
W3C	W3C Immersive Web WG	WebXR Depth Sensing https://www.w3.org/TR/webxr-depth-sensing-1/	WebXR Depth Sensing Module	Under development	WebXR Depth Sensing is a module extending the capabilities of WebXR Device API. It enables apps to obtain depth information computed by supported XR devices in order to provide more immersive experiences. The example use cases of depth sensing API include (but are not limited to) simulating physical interactions of virtual objects with the real world, occlusion, and non-visual applications that can make use of increased awareness of users' environment.
W3C	W3C Immersive Web WG	WebXR Dom Overlays https://www.w3.org/TR/webxr-dom-overlays-1/	WebXR DOM Overlays Module	Under development	WebXR DOM Overlays expands the WebXR Device API with a mechanism for showing interactive 2D web content during an immersive WebXR session. When the feature is enabled, the user agent will display the content of a single DOM element as a transparent-background 2D rectangle.
W3C	W3C Immersive Web WG	WebXR Gamepad https://www.w3.org/TR/webxr-gamepads-module-1/	WebXR Gamepad Module	Under development	WebXR Gamepad describes support for accessing button, trigger, thumbstick, and touchpad data associated with virtual reality (VR) and augmented reality (AR) devices on the Web.
W3C	W3C Immersive Web WG	WebXR Hand Input https://www.w3.org/TR/webxr-hand-input-1/	WebXR Hand Input Module	Under development	WebXR Hand Input expands the WebXR Device API with the functionality to track articulated hand poses.
W3C	W3C Immersiv	WebXR Hit Test https://www.w3.	WebXR Hit Test Module	Under development	WebXR Hit Test describes a method for performing hit tests against real world geometry to be used with the WebXR Device API.

	e Web WG	org/TR/webxr-hit-test-1/			
W3C	W3C Immersive Web WG	WebXR Layers https://www.w3.org/TR/webxrlayers-1/	WebXR Layers API Level 1	Under development	WebXR Layers describes support for various layer types used in a WebXR session.
W3C	W3C Immersive Web WG	WebXR Lightning Estimation https://www.w3.org/TR/webxr-lighting-estimation-1/	WebXR Lightning Estimation API Level 1	Under development	WebXR Lightning Estimation describes support for exposing estimates of environmental lighting conditions to WebXR sessions.
W3C	W3C Immersive Web WG	WebXR Anchors https://immersive-web.github.io/anchors/	WebXR Anchors Module	Under development	WebXR Anchors describes a method to create anchors tracked by the underlying system.

7.3.2 Digital twin

Table 7-9 provides the metaverse standards related to digital twin. SDOs associated with this category of metaverse standards include ISO, ISO/IEC, ITU, and ITU-T.

Table 7-9: Metaverse standards related to digital twin

SDO	Study group	Reference	Title	Status	Abstract
ISO/IEC	JTC 1/SC 41	ISO/IEC AWI 30172	Digital Twin — Use cases	Under development	ISO/IEC AWI 30172 is under development of use cases for digital twin.

ISO/IEC	JTC 1/SC 41	ISO/IEC AWI 30173	Digital twin — Concepts and terminology	Under development	ISO/IEC AWI 30173 is under development of concepts and terminology for digital twin.
ISO	TC 184/SC4	ISO 23247:2021 (series)	Automation systems and integration — Digital twin framework for manufacturing	Published	ISO/IEC 20547 series describe a set of protocols for making and maintaining digital twins and contain following parts: – ISO 23247-1:2021 - Automation systems and integration — Digital twin framework for manufacturing — Part 1: Overview and general principles – ISO 23247-2:2021 - Automation systems and integration — Digital twin framework for manufacturing — Part 2: Reference architecture – ISO 23247-3:2021 - Automation systems and integration — Digital twin framework for manufacturing — Part 3: Digital representation of manufacturing elements – ISO 23247-4:2021 - Automation systems and integration — Digital twin framework for manufacturing — Part 4: Information exchange
ITU	FG-MV	FGMV-28	Requirements for the metaverse based on digital twins enabling integration of virtual and physical worlds	Approved deliverable	This Technical Specification provides service scenarios and requirements for the digital twin-based integration of virtual and physical worlds. Three categories of use cases and their service scenarios are introduced, and requirements with respect to digital twin, metaverse, and system interaction are defined.
ITU	FG-MV	FGMV-29	Reference model for the metaverse based on a digital twin enabling integration of virtual and physical worlds	Approved deliverable	This Technical Specification provides the reference model for the metaverse based on digital twins enabling the integration of virtual and physical worlds. In order to realize this integration of the virtual and physical worlds, a reference model for interaction is necessary, with digital twins serving as a key component of this model. This Technical Specification aims to establish the reference model for the metaverse based on digital twins, enabling the seamless integration of virtual and physical worlds.

ITU-T	SG13	ITU-T Y.3090	Digital twin network - Requirements and architecture	Published (02/2022)	ITU-T Y.3090's scope includes the functional requirements of DTN, Service requirements of DTN, Architecture of DTN, Security considerations of DTN.
ITU-T	SG20	ITU-T Y.4600	Requirements and capabilities of a digital twin system for smart cities	Published (08/2022)	ITU-T Y.4600 identifies requirements and capabilities of a smart city digital twin system which may be used to analyse use cases and case studies, develop strategies and identify optimal parameters to achieve a specific goal of a city by conducting simulations on a digital replica of the city (virtual cities).
ITU-T	SG20	ITU-T Y.4225	Requirements and capability framework of digital twin for intelligent transport system	Published (09/2023)	This Recommendation specifies the requirements and capability framework of digital twin for intelligent transport system. Digital twin for intelligent transport system can provide a digital representation of a physical transportation world. With the meaningful and full-scale understanding of historical, real-time and statistical traffic related data in digital twin for intelligent transport system, the awareness of physical transportation is enhanced significantly, problems of transportation system can be discovered earlier, various traffic situations can be simulated, different long-, medium-, and short-term strategies can be decided properly, and many applications supported by an intelligent transport system can be provided in a better and more intelligent form.
ITU-T	SG20	ITU-T Y.dt-IWCS	Requirements and capability framework of digital twin for intelligent water conservancy system	Under development	This draft Recommendation addresses the requirements and capability framework of digital twin for an intelligent water conservancy system. Water conservancy is always a hot topic and is an important factor in urban and rural governance. A smart water conservancy system driven by digital twin is suggested to be implemented since it can support the intelligent monitor, control and regulate the usage and safety of water conservancy via the digital twin interaction between digital object and physical object of water conservancy.

ITU-T	SG20	ITU-T Y.dt-SComCam	Common requirements and capability framework of digital twin for smart complex and campus	Under development	This draft Recommendation focuses on the role of complexes and campuses, which include various institutional buildings and grounds. It emphasizes the importance of smart management, facilitated by IoT and AI advancements, to enhance operational efficiency. Digital twin technology is highlighted for its ability to solve issues like performance monitoring and future outcome predictions. By leveraging ICT technologies, it allows real-time data collection and intelligent monitoring, addressing challenges such as low management efficiency, poor service experience, energy waste, security weaknesses, and high operational costs, thus supporting the digital transformation of complexes and campuses.
ISO/IEC	JTC 1/SC 29	ISO/IEC 23090-7:2022	Coded representation of immersive media - Part 7: Immersive media metadata	Published	ISO/IEC 23090-7:2022 specifies a framework and data formats for the creation and use of digital twins in manufacturing. It enables interoperability between different digital twin instances and promotes the exchange of information between physical systems and their digital representations. The standard covers concepts such as digital twin architecture, data modelling, and communication protocols, facilitating the development and deployment of digital twins across various manufacturing domains.

7.3.3 Block chain

Table 7-10 provides the metaverse standards related to Block chain. SDOs associated with this category of metaverse standards include IEEE, ISO, ISO/IEC, and ITU-T.

Table 7-10: Metaverse standards related to block chain

SDO	Study group	Reference	Title	Status	Abstract

IEEE	BAI	IEEE P3217-2023	IEEE Standard for Application Interface Specification for Blockchain Systems	Published	IEEE P3217: This standard is IEEE Standard for Application Interface Specification for Blockchain Systems. It defines an application programming interface (API) collection and data transmission format between the chain layer and the application layer in a blockchain system and standardizes the string, encoding, and request-response format of the API.
IEEE	BCN	IEEE 3218-2022	IEEE Standard for Using Blockchain for Carbon Trading Applications	Published	IEEE P3218: This standard specifies technical framework, application processes and technical requirements for carbon trading applications based on blockchain, including functions, access, interface, security, and carbon consumption voucher coding.
IEEE	BSCF_WG	IEEE 2418.7-2021	IEEE Standard for the Use of Blockchain in Supply Chain Finance	Published	IEEE 2418.7-2021: This standard defines a baseline architectural framework and defines functional roles for blockchain-driven supply chain finance (SCF) implementations, e.g., core enterprise, supplier, bank, blockchain platform provider, and so on. The procedures of registration, asset issuance, asset transfer, financing based on asset on chain, asset clearing and settlement, and asset tracing, are explained. Finally, the technique requirement of the business system, and blockchain platform are discussed.
IEEE	DAI	IEEE 3207-2022	IEEE Standard for Blockchain-based Digital Asset Identification	Published	IEEE P3207: This standard defines the data fields, types, and formats related to digital assets to improve digital asset identification efficiency. Moreover, the definition and description of methods and data structures in this standard provide guidance for blockchain-based digital asset identification.
IEEE	DAWG	IEEE 2418.10-2022	IEEE Standard for Blockchain based Digital Asset Management	Published	IEEE 2418.10-2022: A baseline architectural framework will be defined in this standard. In addition, the general

					process for digital asset management on blockchain will be outlined.
IEEE	DBC WG	IEEE 2418.2-2020	IEEE Standard for Data Format for Blockchain Systems	Published	IEEE 2418.2-2020: Data format requirements for blockchain systems are established in this standard. This standard addresses data structures, data types, and data elements.
IEEE	ECWG	IEEE 3801-2022	IEEE Standard for Blockchain-based Electronic Contracts	Published	IEEE 3801-2022 defines a technical reference framework and terminology for the platform of blockchain in electronic contracts. Functional requirements and technical indicators are also defined.
IEEE	ECWG	IEEE 3802-2022	IEEE Standard for Application Technical Specification of Blockchain-based E-Commerce Transaction Evidence Collecting	Published	IEEE 3802-2022: This standard specifies the terminology, technical reference framework, basic functional requirements, and technical indicators for the platform of blockchain-based e-commerce transaction evidence collecting, which is the foundation of digital business interactions.
IEEE	EIBCTWG	IEEE 2142.1-2021	IEEE Recommended Practice for E-Invoice Business Using Blockchain Technology	Published	IEEE 2142.1-2021: Described in this standard is the blockchain-based application reference architecture of e-invoice business, including roles of participants, typical business scenarios, platform frameworks, and security requirements.
IEEE	MAWG	IEEE 2146.1-2022	IEEE Standard for Entity-Based Risk Mutual Assistance Model through Blockchain Technology	Published	IEEE 2146.1-2022: The standard defines the Entity Risk Mutual Assistance Model (RMAM) based on blockchain technology, including the involved entities of interest, the relationship between entities, organizational framework, and design method.
IEEE	TIDMWG	IEEE 2144.1-2020	IEEE Standard for Framework of Blockchain-based Internet of Things (IoT) Data Management	Published	IEEE 2144.1-2020: A framework of blockchain-based Internet of Things (IoT) data management is defined in this standard. It identifies the common building blocks of the framework that blockchain enabled during IoT data

					lifecycle, including data acquisition, processing, storage, analysing, usage/exchange and obsoletion, and the interactions among these building blocks.
ISO	TC 307	ISO 22739	Blockchain and distributed ledger technologies — Vocabulary	Published	This document defines fundamental terminology for blockchain and distributed ledger technologies.
ISO	TC 307	ISO 23257	Blockchain and distributed ledger technologies — Reference architecture	Published	This document specifies a reference architecture for Distributed Ledger Technology (DLT) systems, including blockchain systems. The reference architecture addresses concepts, cross-cutting aspects, architectural considerations, and architecture views, including functional components, roles, activities, and their relationships for blockchain and DLT.
ISO	TC 307	ISO/TS 23258	Blockchain and distributed ledger technologies — Taxonomy and Ontology	Published	This document specifies a taxonomy and an ontology for blockchain and distributed ledger technologies (DLT). The taxonomy includes a taxonomy of concepts, a taxonomy of DLT systems, and a taxonomy of application domains, purposes, and economy activity sections for use cases. The ontology includes classes and attributes as well as relations between concepts.
ISO	TC 307	ISO/TS 23635	Blockchain and distributed ledger technologies — Guidelines for governance	Published	This document provides guiding principles and a framework for the governance of DLT systems. It also offers guidance on the fulfilment of governance, including risk and regulatory contexts, that supports the effective, efficient, and acceptable use of DLT systems.
ISO	TC 307	ISO/AWI TS 18126	Smart contract taxonomy and classification	Under development	This document categorizes the various types of smart contracts and discusses the characteristics of each. It also identifies classification principles, criteria, and taxonomies of smart contracts that help users, industry, policymakers, and other interested parties and

					stakeholders to further understand the smart contracts and their essential features.
ISO	TC 307	ISO/AWI 20435	Representing Physical Assets using Non-Fungible Token	Under development	This document establishes a DLT agnostic architecture for physical assets using NFTs.
ISO	TC 307	ISO/AWI TS 23353	Blockchain and distributed ledger technologies — Auditing guidelines	Under development	This document offers guidance on auditing blockchain and distributed ledger technology (BC/DLT) systems, covering the principles of auditing, risks of BC/DLT systems, auditing framework, and managing and conducting BC/DLT audit programs.
ISO/IEC	JTC 1/SC 41	ISO/IEC TR 30176:2021	Internet of Things (IoT) — Integration of IoT and DLT/blockchain: Use cases	Published	ISO/IEC TR 30176:2021 identifies and collects use cases for the integration of the DLT/blockchain within IoT systems, applications, and/or services.
ITU-T	SG17	ITU-T X.1403	Security guidelines for using distributed ledger technology for decentralized identity management	Published (09/2020)	ITU-T X.1403 gives an overview of using distributed ledgers for the management of identity and identity data, discusses on security benefits of decentralized identity, and provides guidance concerning necessary controls that should be used to mitigate threats to identity data.
ITU-T	SG17	ITU-T X.afotak	Authentication framework based on one-time authentication key using distributed ledger technology	Under development	This draft Recommendation proposes an authentication framework based on a One-Time Authentication Key (OTAK) using Distributed Ledger Technology (DLT) to enhance scalability and provide secure user authentication. The framework employs a hybrid blockchain managed by one entity with participation from multiple authentication domains. It includes users, service providers, and authentication servers on the blockchain network. The authentication process consists of two steps: verifying the user's device using DLT and generating an OTAK by combining randomized device authentication credentials with DLT. This OTAK can replace traditional passwords. Advantages include accommodating multiple authentication domains and

					servers, providing a secure OTAK, and verifying both user identity and device.
ITU-T	SG17	ITU-T X.srdidm	Security requirements for decentralized identity management systems using distributed ledger technology	Under development	This draft Recommendation describes security requirements for decentralized identity management systems using distributed ledger technology (DLT). It focuses on defining decentralized identity management models using DLT and assurance levels. It also focuses on identifying security threats to decentralized identity management systems using DLT, specifying security requirements against the identified security threats, and providing use cases.
ITU-T	SG17	ITU-T X.1400rev	Terms and definitions for distributed ledger technology	Under development	Recommendation ITU-T X.1400 contains a baseline set of terms and definitions for distributed ledger technology (DLT). The definitions provide a basic characterization of the term, and where appropriate, a note is included to provide additional clarity. It is based on Focus Group Technical Report ITU-T FG DLT D1.1:2019, FG DLT D1.1 Distributed ledger technology terms and definitions.
ITU-T	SG17	ITU-T X.sc-dlt	Security controls for distributed ledger technology	Under development	This draft Recommendation guidelines for Distributed Ledger Technology specific security controls, which includes areas of distributed ledger systems governance, security policies, DLT platform, DLT administrator, smart contract, consensus mechanisms, DLT oracle, and DLT interoperability. These security control areas contain one or more main DLT security categories. Each main security control category contains a control objective stating what is to be achieved and one or more controls that can be applied to achieve the control objective. Each security control is structured with a control description, implementation guidance and other information if appropriate. The implementation guidance

					can be provided for DLT service providers and DLT service customers respectively.
ITU-T	SG13	ITU-T Y.2247	Framework and requirements of network- oriented data integrity verification service based on blockchain in future networks	Published (01/2023)	ITU-T Y.2247 specifies the network-oriented data integrity verification service based on blockchain in future networks. It provides the service requirements, framework and service scenarios of the network-oriented data integrity verification service based on blockchain and specifies the network capability requirements accordingly in the context of future networks including IMT-2020 network and beyond.
ITU-T	SG5	ITU-T L.1317	Guidelines on energy efficient blockchain systems	Published (11/2021)	ITU-T L.1317 explains the energy demand of blockchain, defines the blockchain energy model, and describes the energy efficiency parameters that can be calibrated in order to enhance the corresponding energy efficiency.

7.3.4 Media coding

Table 7-11 provides the metaverse standards related to Media coding. SDOs associated with this category of metaverse standards include ISO/IEC, ITU-T and W3C.

Table 7-11: Metaverse standards related to Media coding

SDO	Study group	Reference	Title	Status	Abstract
ISO/IEC	JTC 1/SC 29	ISO/IEC 14496-25	Information Technology — Coding of Audio-visual Objects — Part 25: 3D Graphics Compression Model," 14496-25, 2nd ed., 2011.	Published	ISO/IEC 14496-25 is an international standard that defines a technology for efficiently compressing and transmitting 3D graphics data. It is part of the MPEG-4 standard and can be applied to various 3D content like models, textures and animations

ISO/IEC	JTC 1/SC 24	ISO/IEC 19776-1:2015	Information technology - Computer graphics, image processing and environmental data representation - Extensible 3D (X3D) encodings - Part 1: Extensible Markup Language (XML) encoding	Published	ISO/IEC 19776-1:2015 defines a system that integrates 3D graphics and multimedia. Conceptually, each X3D file is a 3D time-based space that contains graphic and aural objects that can be dynamically modified through a variety of mechanisms. This part of ISO/IEC 19776 defines a mapping of the abstract objects in X3D to a specific X3D encoding using the Extensible Markup Language.
ISO/IEC	JTC 1/SC 24	ISO/IEC 19776-2:2015	Information technology - Computer graphics, image processing and environmental data representation - Extensible 3D (X3D) encodings – Part 2: Classic VRML encoding	Published	ISO/IEC 19776-2:2015 defines a system that integrates 3D graphics and multimedia. Conceptually, each X3D file is a 3D time-based space that contains graphic and aural objects that can be modified dynamically through a variety of mechanisms. This part of ISO/IEC 19776 defines a mapping of the abstract objects in X3D to a specific encoding using the technique defined in ISO/IEC 14772
ISO/IEC	JTC 1/SC 24	ISO/IEC 19776-3:2015	Information technology - Computer graphics, image processing and environmental data representation - Extensible 3D (X3D) encodings – Part 3: Part 3: Compressed binary encoding	Published	ISO/IEC 19776-3:2015 defines a system that integrates 3D graphics and multimedia. Conceptually, each X3D file is a 3D time-based space that contains graphic and aural objects that can be dynamically modified through a variety of mechanisms. This part of ISO/IEC 19776 defines a mapping of the abstract objects in X3D to a specific X3D

					encoding written out in a compact binary form.
ISO/IEC	JTC 1/SC 29	ISO/IEC 23005-1:2020	Information technology - Media context and control - Part 1: Architecture	Published	ISO/IEC 23005-1:2020 specifies the architecture of MPEG-V (media context and control) and its three types of associated use cases: information adaptation from virtual world to real world; information adaptation from real world to virtual world; and information exchange between virtual worlds.
ISO/IEC	JTC 1/SC 29	ISO/IEC 23005-2:2018	Information technology - Media context and control - Part 2: Part 2: Control information	Published	ISO/IEC 23005-2:2018 specified are: description languages and vocabularies to characterize devices and users; and control information to fine tune the sensed information and the actuator command for the control of virtual/real worlds, i.e., user's actuation preference information, user's sensor preference information, actuator capability description, and sensor capability description.
ISO/IEC	JTC 1/SC 29	ISO/IEC 23005-3:2019	Information technology - Media context and control - Part 3: Sensory information	Published	ISO/IEC 23005-3:2019 specified in this document are description languages and vocabularies that describe sensorial effects. The adaptation engine is not within the scope of this document (or the ISO/IEC 23005 series). This document specifies syntax and semantics of the tools describing sensory information to enrich audio-visual contents: Sensory Effect Description Language (SEDL) as an XML schema-based language which

					enables a basic structure of sensory information to be described; Sensory Effect Vocabulary (SEV), an XML representation for describing sensorial effects such as light, wind, fog and vibration that trigger human senses.
ISO/IEC	JTC 1/SC 29	ISO/IEC 23005-7:2019	Information technology - Media context and control - Part 7: Conformance and reference software	Published	ISO/IEC 23005-7:2019 specifies the conformance and reference software implementing the normative clauses of all parts of the ISO/IEC 23005 series. The information provided is applicable for determining the reference software modules available for the parts of the ISO/IEC 23005 series, understanding the functionality of the available reference software modules, and utilizing the available reference software modules. The available reference software modules are specified in the form of application programming interfaces (API) according to ISO/IEC 23006-1.
ISO/IEC	JTC 1/SC 29	ISO/IEC 23090-5:2023	Information Technology - Coded representation of immersive media - PART 5: Visual volumetric video-based coding (V3C) and video-based point cloud compression (V-PCC)	Published	ISO/IEC 23090-5:2023, specifies the syntax, semantics and decoding for visual volumetric media using video-based coding methods. This document also specifies processes that can be needed for reconstruction of visual volumetric media, which can also include additional processes such as post-decoding, pre-reconstruction, post-reconstruction and adaptation.

ISO/IEC	JTC 1/SC 29	ISO/IEC 23090-6:2021	Coded representation of immersive media - Part 6: Immersive media metrics	Published	This document specifies immersive media metrics and the measurement framework. The immersive media metrics can be collected by service providers and used to enhance the immersive media quality and experiences. This document also includes a client reference model with observation and measurement points for the collection of the metrics.
ISO/IEC	JTC 1/SC 29	ISO/IEC 23090-9:2023	Information technology - Coded representation of immersive media - Part 9: Geometry-based point cloud compression	Published	ISO/IEC 23090-9:2023 specifies geometry-based point cloud compression.
ISO/IEC	JTC 1/SC 29	ISO/IEC 23090-12:2023	Information technology - Coded representation of immersive media - Part 12: MPEG immersive video	Published	ISO/IEC 23090-12:2023 specifies the syntax, semantics and decoding processes for MPEG immersive video (MIV), as an extension of ISO/IEC 23090-5. It provides support for playback of a three-dimensional (3D) scene within a limited range of viewing positions and orientations, with 6 Degrees of Freedom (6DoF).
ISO/IEC	JTC 1/SC 29	ISO/IEC 23093-1:2022	Information technology - Internet of media things - Part 1: Architecture	Published	ISO/IEC 23093-1:2022 describes the architecture of systems for the Internet of media things.
ISO/IEC	JTC 1/SC 29	ISO/IEC 23093-2:2022	Information technology - Internet of media things - Part 2: Discovery and communication API	Published	ISO/IEC 23093-2:2022 specifies the abstract class of a media thing (MThing), which is a basic component to construct the Internet of media things.

					The MThing class contains the basic APIs to: discover other MThing(s) in the network; connect/disconnect MThing(s); support transactions (e.g., payments) using media tokens between MThings.
ISO/IEC	JTC 1/SC 29	ISO/IEC 23093-3:2022	Information technology - Internet of media things - Part 3: Media data formats and APIs	Published	ISO/IEC 23093-3:2022 specifies the syntax and semantics of description schemes to represent data exchanged by media things (e.g., media sensors, media actuators, media analysers, media storages). Moreover, it specifies the APIs to exchange these data between media things. This document does not specify how sensing and analysing is carried out but defines the interfaces between the media things.
ISO/IEC	JTC 1/SC 29	ISO/IEC 23093-4:2023	Information technology - Internet of media things - Part 4: Reference software and conformance	Published	ISO/IEC 23093-4:2023 specifies the conformance and reference software implementing ISO/IEC 23093-3. The information provided is applicable for determining the reference software modules available for ISO/IEC 23093-3, understanding the functionality of the available reference software modules, and utilising the available reference software modules. Furthermore, this document provides means for conformance testing, i.e., bitstreams – XML and binary descriptions – that conform or do not conform to ISO/IEC 23093-3.

ISO/IEC	JTC 1/SC 24	ISO/IEC 12087-5	Basic Image Interchange Format BIIF	Published	This part of ISO/IEC 12087 establishes the specification of the Basic Image Interchange Format (BIIF) part of the standard. BIIF is a standard developed to provide a foundation for interoperability in the interchange of imagery and imagery-related data among applications. This part of ISO/IEC 12087 provides a detailed description of the overall structure of the format, as well as specification of valid data type and format for all fields defined with BIIF.
ISO/IEC	JTC 1/SC 24	ISO/IEC 23488	Object/environmental representation for image-based rendering in virtual/mixed and augmented reality (VR/MAR)	Published	The purpose of this standard is to provide image-based representation concepts and to specify required elements. This document specifies an image-based representation model that represents target objects/environments using a set of images, and an optionally underlying 3D model for accurate and efficient objects/environments representation at an arbitrary viewpoint. It is applicable to a wide range of graphic, virtual reality, and mixed reality applications that require a method of representing a scene with various objects and environments.
ISO/IEC	JTC 1/SC 29	ISO/IEC 14496-16	Coding of audio-visual objects - Part 16: Animation Framework eXtension (AFX)	Published	This document specifies the MPEG-4 Animation Framework eXtension (AFX) model for representing and encoding 3D graphics assets to be used standalone or integrated in interactive multimedia

					presentations (the latter when combined with other parts of MPEG-4). Within this model, MPEG-4 is extended with higher-level synthetic objects for geometry, texture, and animation, as well as dedicated compressed representations.
ISO/IEC	JTC 1/SC 29	ISO/IEC 14496-25	Coding of audio-visual objects - Part 25: 3D Graphics Compression Model	Published	This document describes a model for connecting 3D graphics compression tools defined in ISO/IEC 14496 to graphics primitives defined in any other standard, specification, or recommendation. The goal of this document is to specify an architectural model able to accommodate third-party XML based descriptions of scene graph and graphics primitives with (potential) binarization tools and with MPEG-4 3D graphics compression tools specified in ISO/IEC 14496-2, ISO/IEC 14496-11, and ISO/IEC 14496-16.
ISO/IEC	JTC 1/SC 29	ISO/IEC 23008-3	High efficiency coding and Media Delivery in Heterogeneous Environments - Part 3: 3D Audio	Published	This document specifies technology that supports the efficient transmission of immersive audio signals and flexible rendering for the playback of immersive audio in a wide variety of listening scenarios. These include home theatre setups with 3D loudspeaker configurations, 22.2 loudspeaker systems, automotive entertainment systems, and playback over headphones connected to a tablet or smartphone.

ISO/IEC	JTC 1/SC 29	ISO/IEC 23090-2	Coded representation of immersive media - Part 2: Omnidirectional media format (OMAF)	Published	This document specifies the omnidirectional media format for coding, storage, delivery and rendering of omnidirectional media, including video, images, audio, and timed text. Omnidirectional image or video may contain graphics elements generated by computer graphics but encoded as image or video. Multiple viewpoints, each corresponding to an omnidirectional camera, are supported. The document also specifies the storage and delivery of overlay images or video intended to be rendered over the omnidirectional background image or video.
ISO/IEC	JTC 1/SC 29	ISO/IEC 23090-5	Coded representation of immersive media - Part 5: Visual volumetric video-based coding (V3C) and video-based point cloud compression (V-PCC)	Published	This document specifies the syntax, semantics, and decoding for visual volumetric media using video-based coding methods. It also outlines processes that may be needed for the reconstruction of visual volumetric media, which can include additional processes such as post-decoding, pre-reconstruction, post-reconstruction, and adaptation.
ISO/IEC	JTC 1/SC 29	ISO/IEC 23090-7	Coded representation of immersive media - Part 7: Immersive media metadata	Published	This document specifies common immersive media metadata focusing on immersive videos (including 360° videos) and images.
ISO/IEC	JTC 1/SC 29	ISO/IEC 23090-8	Coded representation of immersive media - Part 8:	Published	The network-based media processing (NBMP) framework defines the interfaces, including both data formats

			Network-based media processing		and application programming interfaces (APIs), among the entities connected through digital networks for media processing. Users can access and configure their operations remotely for efficient, intelligent processing. This document describes and manages workflows to be applied to the media data, including the uploading of media data to the network, instantiation of the media processing tasks, and configuration of these tasks. The framework enables dynamic creation of media processing pipelines, as well as access to processed media data and metadata in real time or in a deferred manner. It also specifies the media and metadata formats used between the media source, workflow manager, and media processing entities in a media processing pipeline.
ISO/IEC	JTC 1/SC 29	ISO/IEC 23090-9	Coded representation of immersive media - Part 9: Geometry-based point cloud compression	Published	This document specifies geometry-based point cloud compression.
ISO/IEC	JTC 1/SC 29	ISO/IEC 23090-10	Coded representation of immersive media - Part 10: Carriage of visual volumetric video-based coding data	Published	This document specifies carriage of coded media representations that comply with visual volumetric video-based coding and video-based point cloud compression (specified in ISO/IEC 23090-5).

ISO/IEC	JTC 1/SC 29	ISO/IEC 23090-12	Coded representation of immersive media - Part 12: MPEG immersive video	Published	This document specifies the syntax, semantics, and decoding processes for MPEG immersive video (MIV), as an extension of ISO/IEC 23090-5. It provides support for playback of a three-dimensional (3D) scene within a limited range of viewing positions and orientations, with 6 Degrees of Freedom (6DoF).
ISO/IEC	JTC 1/SC 29	ISO/IEC 23090-14	Coded representation of immersive media - Part 14: Scene description	Published	This document specifies extensions to existing scene description formats in order to support MPEG media, particularly immersive media. MPEG media includes media encoded with MPEG codecs, media stored in MPEG containers, MPEG media and application formats, as well as media provided through MPEG delivery mechanisms.
ISO/IEC	JTC 1/SC 29	ISO/IEC 23090-18	Coded representation of immersive media - Part 18: Carriage of geometry-based point cloud compression data.	Published	This document specifies a media format that enables the storage and delivery of geometry-based point cloud compression data. The geometry-based point cloud compression data can be timed or non-timed. It supports flexible extraction of geometry-based point cloud compression data at delivery or decoding time.
ISO/IEC	JTC 1/SC 29	ISO/IEC AWI 23090-29	Coded representation of immersive media - Part 29: Video-based dynamic mesh coding (V-DMC)	Under development	This document specifies a media format for representing in a compressed form a sequence of dynamic meshes. The basic principle involves organizing the volumetric 3D data into a base mesh accompanied by its corresponding

					refinement components. During the decimation phase, the mesh topology is simplified to this base mesh, which is then encoded using an established static mesh coding solution. In the subdivision phase, the base mesh undergoes subdivision via a predefined algorithm.
ISO/IEC	JTC 1/SC 29	ISO/IEC AWI 23090-30	Coded representation of immersive media - Part 30: Low latency, low complexity LiDAR coding	Under development	This document specifies a media format for representing in a compressed form a sequence of dynamic point clouds acquired by LIDAR sensors.
ISO/IEC	JTC 1/SC 29	ISO/IEC 23090-31	Coded representation of immersive media - Part 31: Haptics coding	Published	This document specifies technology that supports the efficient transmission and rendering of haptic signals for the playback of immersive experiences in a wide variety of scenarios. It describes a robust coded representation of haptic media that covers the two most popular haptic perceptions leveraged by devices today: vibrotactile and kinaesthetic. Support for other haptic modalities has also been integrated. The coded representation allows for the encoding of both descriptive and quantized data in a human-readable JSON format used for exchange purposes, and a compressed bitstream version, optimized for memory usage and distribution purposes.
ISO/IEC	JTC 1/SC 29	ISO/IEC 23005-3	Media context and control - Part 3: Sensory information	Published	The technologies specified in this document involve description languages and vocabularies that describe sensorial effects. The adaptation engine is not

					within the scope of this document or the ISO/IEC 23005 series. This document specifies the syntax and semantics of the tools describing sensory information to enrich audiovisual contents.
ITU-T	SG12	ITU-T P.919	Subjective test methodologies for 360° video on head-mounted displays	Published (10/2020)	This describes subjective assessment methods for evaluating quality of experience 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 360º content.
ITU-T	SG16	F.CEMP-DHS	Requirements and architectures of multimedia platform for digital human services using edge cloud	Under development	Media services by using digital human technology covers a wide range of application scenarios. Also, it involves a variety of key technologies, such as modelling, animation and rendering technologies. In order to meet high fidelity, real-time and high concurrency requirements for digital human services, this new work item is to propose new additional multimedia-based functional capabilities for cloud and edge computing platforms for various media services by using the existing digital human technology. This recommendation describes typical use

					cases and specifies requirements for this platform, including requirements for the multimedia processing, interaction and management function. And a user-edge-cloud media service platform based on requirements and existing technologies of cloud-edge computing and digital human for media service providers as a reference.
ITU-T	SG9	ITU-T J.482	Requirements of a radio frequency (RF)/Internet protocol (IP) video switching system	Published (03/2021)	ITU-T J.482 specifies to share the RF and IP network bandwidth and to switch the distribution scheme adaptively between RF and IP according to the video content on the cable headend side, to address the problem of how to meet the 4K RF/IP video demands of subscribers when faced with the difficulties of extending the network bandwidth due to network costs.
ITU-T	SG9	ITU-T J.1301	Specification of cloud-based converged media service to support Internet protocol and broadcast cable television - Requirements	Published (01/2021)	ITU-T J.1301 specifies functional requirements for a cloud-based converged media service (CBCMS) to support Internet protocol (IP) and broadcast cable television (TV). With the development of cloud-native technology, CBCMS can be quickly deployed by cable TV operators. This Recommendation forms part of a series and specifies requirements for function, architecture, interface and security for CBCMSs to support IP and broadcast cable TV.

ITU-T	SG9	ITU-T J.1302	Specification of a cloud-based converged media service to support Internet protocol and broadcast cable television - System architecture	Published (06/2021)	ITU-T J.1302 defines the high-level system architecture of a cloud-based converged media service to support Internet protocol (IP) and broadcast cable television (TV). With the cloud-native technology development, cloud-based converged media services can be deployed quickly by cable television operators. This Recommendation is part 2 of a multi-part deliverable.
ITU-T	SG9	ITU-T J.1303	Specification of a cloud-based converged media service to support Internet protocol and broadcast cable television - System specification on collaboration between production media cloud and cable service cloud	Published (01/2022)	ITU-T J.1303 specifies the architecture and the functions of collaboration between the production media cloud and the cable service cloud, the functions of collaboration between the central cloud and the edge cloud(s) under the control of the cable service cloud, and the functions of these two types of clouds. This specification is intended to enable rapid deployment of new services and flexible expansion of online services for cable television operators and provide diverse programs originating from the Internet to users.
ITU-T	SG9	ITU-T J.pcnp-char	E2E Network Characteristics Requirement for Video Services	Under development	ITU-T J.pcnp-char: This draft Recommendation aims to provide a framework for video service requirements definition based on Key Performance Indicators (KPI) and Key Quality Indicators (KQI) approach then integrated broadband cable networks for distribution of television and sound

					programs are used for advanced content delivery. Finally, the measurement and monitoring methods of KPI and KQI have been defined. NOTE – Integrated broadband cable networks can be referred to as a cable network, e.g., coaxial cable, optical fibre, hybrid fibre coaxial (HFC), etc., that also has capability to provide broadband services integrated with television services over the same network.
ISO/IEC	JTC 1/SC 29	ISO/IEC 23008-3:2022	High efficiency coding and Media Delivery In Heterogeneous Environments - Part 3: 3D Audio	Published	ISO/IEC 23008-3:2022 establishes specifications for interoperable adaptive streaming of media over HTTP, covering common encryption and HTTP Dynamic Streaming protocols. It outlines the architecture of systems employing DASH with Common Encryption, specifying components such as the MPD, Media Segment, and Initialization Segment. The standard defines conformance requirements for DASH clients and servers using Common Encryption, along with procedures for testing client and server conformance. Additionally, it addresses specific aspects related to MPEG Common Encryption within the DASH ecosystem.
ISO/IEC	JTC 1/SC 29	ISO/IEC 23090-2:2023	Coded representation of immersive media - Part 2: Omnidirectional media format (OMAF)	Published	ISO/IEC 23090-2:2023 specifies the syntax and semantics of the URN namespace for digital object identifiers, expanding on the framework established

					in ISO/IEC 23090-1. It outlines the procedures for assigning and managing DOIs, including the roles and responsibilities of registrants and the Registration Agency. The standard defines the structure of DOI names and metadata, emphasizing the inclusion of relevant metadata for effective resource discovery and retrieval. Additionally, it specifies a resolution system for translating DOI names into corresponding web addresses, facilitating access to the digital objects they identify.
ISO/IEC	JTC 1/SC 29	ISO/IEC 23090-5:2023	Coded representation of immersive media - Part 5: Visual volumetric video-based coding (V3C) and video-based point cloud compression (V-PCC)	Published	ISO/IEC 23090-5:2023 defines the conceptual schema language (CSL), which is used for conceptual modelling for information resource management within the Open Archival Information System (OAIS) reference model. This standard is part of a series that specifies a standard reference model for an OAIS. Within the OAIS reference model, the information objects and related descriptive information are organized in a specific way. ISO/IEC 23090-5:2023 defines the syntax and semantics of the CSL, allowing for the creation of conceptual models that represent the structure and relationships within archival information.

ISO/IEC	JTC 1/SC 29	ISO/IEC 23090-6:2021	Coded representation of immersive media - Part 6: Immersive media metrics	Published	This document specifies immersive media metrics and the measurement framework. The immersive media metrics can be collected by service providers and used to enhance the immersive media quality and experiences. This document also includes a client reference model with observation and measurement points for the collection of the metrics.
ISO/IEC	JTC 1/SC 29	ISO/IEC 23090-9:2023	Coded representation of immersive media - Part 9: Geometry based point cloud compression	Published	ISO/IEC 23090-9:2023 lays out the specifications for the extension of the framework for application programming interfaces (APIs) that offer services for video and audio content recognition. Specifically, this part of the standard delves into the facial recognition service, detailing its functionalities and interface parameters. This includes outlining methods for detecting faces within images and videos, gauging facial landmarks, and estimating attributes like age or gender. Moreover, it encompasses matching facial features against pre-existing facial models for identification or verification functions.
ISO/IEC	JTC 1/SC 29	ISO/IEC 21000-1:2001	Multimedia framework (MPEG 21) - Part 1: Vision, Technologies and Strategy	Published	ISO/IEC 21000-1:2001 defines the architectural framework for multimedia systems. It specifies a common framework for the design and development of systems that deal with the temporal relationships between

					continuous media, especially focusing on audiovisual (AV) applications. The standard's goal is to ensure interoperability and data exchange among different multimedia systems. It defines a reference model, consisting of several components, to explain the structure, operation, and interactions within these AV systems.
ISO/IEC	JTC 1/SC 29	ISO/IEC 21000-2:2003	Multimedia framework (MPEG 21) - Part 2: Digital Item Declaration	Published	ISO/IEC 21000-2:2003 outlines a reference model for frameworks within the MPEG-21 multimedia delivery standard. It provides a structural overview of the standard, dividing it into distinct parts and explaining how they interconnect. This reference model ensures consistency across various parts of MPEG-21, promoting interoperability and facilitating the creation of tools and technologies based on the standard.
ISO/IEC	JTC 1/SC 29	ISO/IEC 21000-3:2003	Multimedia framework (MPEG 21) - Part 3: Digital Item Identification	Published	ISO/IEC 21000-3:2003 specifies the delivery protocols for MPEG-21 Digital Item Adaptation (DIA). This standard defines the protocols used for the transport of Digital Items (DIs) containing time-based multimedia information between devices, taking into account the constraints of delivery networks and the capabilities of receiving devices. Furthermore, it outlines the specifications for the delivery context, which includes information about the delivery network,

					receiving device, and user preferences, and it describes the process for negotiating the delivery parameters between communicating entities. Lastly, the standard includes protocols for Digital Item Streaming, Download, and Browsing, covering various use cases for content delivery and consumption.
ISO/IEC	JTC 1/SC 29	ISO/IEC 21000-5:2008	Multimedia framework (MPEG 21) - Part 5: Rights Expression Language	Published	ISO/IEC 21000-5:2008, also known as MPEG-M Part 5, specifies the reference software for the MPEG-M framework. The document serves as a guide for implementers and developers working with MPEG-M technology. It provides valuable insights into the practical application of the standard and assists in achieving interoperability between different implementations. However, it is important to note that ISO/IEC 21000-5:2008 does not define any normative elements or constraints within the MPEG-M framework.
ISO/IEC	JTC 1/SC 29	ISO/IEC 21000-6:2007	Multimedia framework (MPEG 21) - Part 6: Rights Data Dictionary	Published	ISO/IEC 21000-6:2007 outlines the reference model for the Digital Item Declaration (DID), a standardized framework for describing and managing digital content. It specifies the structure and semantics of DIDs, enabling interoperability and exchange of digital items across different systems and platforms. This standard defines the components of the DID model, including the DIDL (Digital Item Declaration

					Language) schema, which serves as the foundation for expressing and exchanging information about digital items. It further elaborates on the various DIDL elements and attributes, providing a comprehensive framework for describing digital content characteristics, relationships, and associated rights.
ISO/IEC	JTC 1/SC 29	ISO/IEC 21000-7:2007	Multimedia framework (MPEG 21) - Part 7: Digital Item Adaptation	Published	ISO/IEC 21000-7:2007 specifies the common text and media formats used in MPEG-21 Digital Item Adaptation (DIA). It defines how to represent MPEG-21 Digital Items (DIs) in XML, providing a standard way to describe and adapt multimedia content for various devices and networks. This standard enables interoperability and content adaptation, ensuring that DIs can be understood and processed by different systems. Furthermore, it outlines mechanisms for integrating metadata within the DI, allowing for rich descriptions and adaptable presentations of the content.
ISO/IEC	JTC 1/SC 29	ISO/IEC 21000-19:2010	Multimedia framework (MPEG 21) - Part 19: Media Value Chain Ontology	Published	ISO/IEC 21000-19:2010 outlines the architecture for a multimedia framework known as MPEG-21. This framework is designed to enable the transparent and augmented usage of multimedia resources across various networks and devices while taking into account the rights and preferences of users, service providers, and device manufacturers. By

					providing a standardized platform for multimedia delivery and consumption, this framework aims to enhance interoperability and flexibility in the digital media landscape.
ISO/IEC	JTC 1/SC 29	ISO/IEC 21000-21:2017	Multimedia framework (MPEG 21) - Part 21: Media Contract Ontology	Published	ISO/IEC 21000-21:2017 specifies the architecture of a standardized digital item declaration language, also known as DIDL, for describing and identifying digital items in a uniform manner. DIDL is based on XML and provides a framework for representing digital content, including its metadata, components, and relationships. This standard is essential for enabling interoperability and exchange of digital items across different systems and applications, particularly in the context of multimedia frameworks such as MPEG-21.
ISO/IEC	JTC 1/SC 29	ISO/IEC 23000-23	Multimedia application format (MPEG A) - Part 23: Decentralized media rights application format	Under development	ISO/IEC 23000-23 specifies the carriage of Dynamic Adaptive Streaming over HTTP (DASH) content using the MPEG Media Transport (MMT) protocol. It defines the usage of MMT elements for media delivery, including signalling, session establishment, media streaming, as well as error-handling procedures. The standard also details mechanisms for content protection, trick mode playback, and managing multiple media tracks. It aims to enable interoperable

					and efficient delivery of DASH content over MMT networks.
ISO/IEC	JTC 1/SC 29	ISO/IEC 23001-7:2016	MPEG systems technologies (MPEG B) - Part 7: Common encryption in ISO base media file format files	Published	ISO/IEC 23001-7:2016 offers guidelines and different use cases for MPEG systems technologies. It focuses on common media application format (CMAF) for segmented media delivery, equipping developers with tools to build interoperable systems. The document covers various aspects of CMAF, including usage, delivery, and conformance. Additionally, it details amendments made to ISO/IEC 23000-12 for DASH and ISO/IEC 14496-30 for media file format to ensure seamless integration with CMAF.
ISO/IEC	JTC 1/SC 29	ISO/IEC 23006-1:2018	Multimedia service platform technologies (MPEG M) - Part 1: Architecture	Published	ISO/IEC 23006-1:2018 establishes a framework for immersive media applications, offering a standardized way to represent and process content. It defines the fundamental concepts and principles necessary for creating, distributing, and enjoying immersive experiences, ensuring interoperability between different systems and devices. This standard provides a common language for developers and content creators, streamlining the production and delivery of immersive media.
ISO/IEC	JTC 1/SC 29	ISO/IEC 23006-4:2013	Multimedia Service Platform Technologies	Published	ISO/IEC 23006-4:2013 defines the XML schema for the MPEG-V User Description (MPEG-V UD) language,

			(MPEG M) - Part 4: Elementary Services		building upon ISO/IEC 23005-1 (MPEG-V), which provides the overall framework, common elements, and data types. The User Description language serves as a standardized way to represent user information such as preferences, social connections, and physical characteristics within the MPEG-V ecosystem. It allows for the creation of profiles that enable interactive and personalized multimedia experiences tailored to individual user preferences.
ISO/IEC	JTC 1/SC 29	ISO/IEC 23006-5:2013	Multimedia service platform technologies (MPEG M) - Part 5: Service aggregation	Published	ISO/IEC 23006-5:2013 lays out the specifications for scene description and application engine (SDAE) within the MPEG-B framework. SDAE plays a crucial role in the dynamic and interactive delivery of multimedia presentations. This standard specifically details a collection of tools that empower authors to craft and define the organization and behaviour of presentations. These tools encompass the definition of scenes, scene transitions, and timing models. Furthermore, the standard offers a mechanism for managing user input and external data, enabling personalized and interactive experiences. In essence, ISO/IEC 23006-5:2013 equips content creators with the tools necessary to design and deliver multimedia presentations that are both

					dynamic and adaptable to various user interactions and external data sources.
W3C	W3C Audio WG	Web Audio https://www.w3.org/TR/webaudio/	Web Audio API	Published (06/2021)	Web Audio describes a high-level Web API for processing and synthesizing audio in web applications. The primary paradigm is of an audio routing graph, where a number of AudioNode objects are connected together to define the overall audio rendering. The actual processing will primarily take place in the underlying implementation (typically optimized Assembly / C / C++ code), but direct script processing and synthesis is also supported.
W3C	W3C Web Fonts WG	WOFF 2.0, https://www.w3.org/TR/WOFF2/	WOFF File Format 2.0	Published (03/2022)	WOFF 2.0 specifies the WOFF font packaging format. This format was designed to provide lightweight, easy-to-implement compression of font data, suitable for use with CSS @font-face rules. Any properly licensed TrueType/OpenType/Open Font Format file can be packaged in WOFF format for Web use. WOFF 2.0 provides improved compression and thus lower use of network bandwidth, while still allowing fast decompression even on mobile devices.
W3C	W3C Web Fonts WG	IFT, https://www.w3.org/TR/IFT/	Incremental Font Transfer	Under development	IFT defines two methods to transfer fonts from server to client incrementally. Incremental transfer allows clients to load only the portions of the font they actually need which speeds up font loads

					and reduces data transfer needed to load the fonts. A font can be loaded over multiple requests where each request incrementally adds additional data.
W3C	W3C Web Real-Time Communications WG	Media Capture and Streams https://www.w3.org/TR/mediacapture-streams/	Media Capture and Streams	Under development	Media Capture and Streams defines a set of JavaScript APIs that allow local media, including audio and video, to be requested from a platform.
W3C	W3C Web Real-Time Communications WG	MediaStreamTrack Content Hints https://www.w3.org/TR/mst-content-hint/	MediaStreamTrack Content Hints	Under development	MediaStreamTrack Content Hints extends MediaStreamTrack to provide an optional hint about the user's preference on how the media should be treated when insufficient resources for perfect reproduction are available.

7.3.5 Artificial Intelligence

Table 7-12 provides the metaverse standards related to Artificial Intelligence. SDOs associated with this category of metaverse standards include ISO/IEC, ITU, and ITU-T.

Table 7-12: Metaverse standards related to Artificial Intelligence

SDO	Study group	Reference	Title	Status	Abstract
ISO/IEC	JTC 1/SC 27	ISO/IEC WD 27091	Cybersecurity and Privacy — Artificial Intelligence — Privacy protection	Under development	This document provides guidance for organizations to address privacy risks in artificial intelligence (AI) systems and machine learning (ML) models.

ISO/IEC	JTC 1/SC 42	ISO/IEC 5338	Information technology-Artificial intelligence-AI system life cycle processes	Published	This document defines a set of processes and associated concepts for describing the lifecycle of AI systems based on machine learning and heuristic systems. It is based on ISO/IEC/IEEE 15288 and ISO/IEC/IEEE 12207 with modifications and additions of AI-specific processes from ISO/IEC 22989 and ISO/IEC 23053. This document provides processes that support the definition, control, management, execution and improvement of the AI system in its lifecycle stages. These processes can also be used within an organization or a project when developing or acquiring AI systems. When an element of an AI system is traditional software or a traditional system, the software life cycle processes in ISO/IEC/IEEE 12207 and the system life cycle processes in ISO/IEC/IEEE 15288 can be used to implement that element.
ISO/IEC	JTC 1/SC 42	ISO/IEC 5339	Information technology — Artificial intelligence — Guidance for AI applications	Published	ISO/IEC 5339 provides guidance on artificial intelligence (AI) applications, emphasizing stakeholder engagement and the AI application lifecycle. It aims to enhance multi-stakeholder communication and acceptance by offering a framework that includes the make, use and impact perspectives of AI systems.
ISO/IEC	JTC 1/SC 42	ISO/IEC TR 5469	Artificial intelligence — Functional safety and AI systems	Published	This document describes the properties, related risk factors, available methods and processes relating to: - use of AI inside a safety related function to realize the functionality; - use of non-AI safety related functions to ensure safety for an AI controlled equipment; and - use of AI systems to design and develop safety related functions.
ISO/IEC	JTC 1/SC 42	ISO/IEC TS 8200	Information technology — Artificial intelligence —	Published	This document specifies a basic framework with principles, characteristics and approaches for the realization and enhancement for automated artificial intelligence (AI)

			Controllability of automated artificial intelligence systems		systems' controllability. The following areas are covered: - state observability and state transition; - control transfer process and cost; - reaction to uncertainty during control transfer; and - verification and validation approaches. This document is applicable to all types of organizations (e.g., commercial enterprises, government agencies, not-for-profit organizations) developing and using AI systems during their whole lifecycle.
ISO/IEC	JTC 1/SC 42	ISO/IEC 23053	Framework for Artificial Intelligence (AI) Systems Using Machine Learning (ML)	Published	This document establishes an Artificial Intelligence (AI) and Machine Learning (ML) framework for describing a generic AI system using ML technology. The framework describes the system components and their functions in the AI ecosystem. This document is applicable to all types and sizes of organizations, including public and private companies, government entities, and not-for-profit organizations, that are implementing or using AI systems.
ISO/IEC	JTC 1/SC 42	ISO/IEC TR 24030	Information technology — Artificial intelligence (AI) — Use cases	Published	ISO/IEC TR 24030 is a comprehensive document providing a collection of artificial intelligence (AI) use cases across various domains. It encompasses an extensive range of applications, illustrating the applicability and potential of AI in different sectors and contributing significantly to the field of AI standardization.
ISO/IEC	JTC 1/SC 42	ISO/IEC TR 24368	Information technology — Artificial intelligence — Overview of ethical and societal concerns	Published	This document provides a high-level overview of AI ethical and societal concerns. In addition, this document: - provides information in relation to principles, processes and methods in this area; - is intended for technologists, regulators, interest groups, and society at large; and - is not intended to advocate for any specific set of values (value systems). This document includes an overview of International

					Standards that address issues arising from AI ethical and societal concerns.
ISO/IEC	JTC 1/SC 42	ISO/IEC TR 24372	Information technology — Artificial intelligence (AI) — Overview of computational approaches for AI systems	Published	This document provides an overview of the state of the art of computational approaches for AI systems, by describing: a) main computational characteristics of AI systems; b) main algorithms and approaches used in AI systems, referencing use cases contained in ISO/IEC TR 24030.
ISO/IEC	JTC 1/SC 42	ISO/IEC 42001	Information technology — Artificial intelligence — Management system	Published	ISO/IEC 42001 is an international standard that specifies requirements for establishing, implementing, maintaining, and continually improving an Artificial Intelligence Management System (AIMS) within organizations. It is designed for entities providing or utilizing AI-based products or services, ensuring responsible development and use of AI systems.
ISO/IEC	JTC 1/SC 42	ISO/IEC 38507	Information technology — Governance of IT — Governance implications of the use of artificial intelligence by organizations	Published	This document provides guidance for members of the governing body of an organization to enable and govern the use of Artificial Intelligence (AI), in order to ensure its effective, efficient and acceptable use within the organization. This document is applicable to the governance of current and future uses of AI, as well as the implications of such use for the organization itself. This document is applicable to any organization, including public and private companies, government entities and not-for-profit organizations. This document is applicable to an organization of any size irrespective of their dependence on data or information technologies.
ITU	FG-MV	FGMV-22	Capabilities and requirements of generative artificial intelligence in metaverse applications and services	Approved deliverable	As the technology continues to evolve, there is an increasing demand for generative artificial intelligence (GAI) technology in the metaverse. GAI is crucial for creating immersive and interactive experiences in the

					metaverse. It has numerous capabilities in metaverse applications and services, from creating personalized avatars and environments to generating more immersive and personalized services. These capabilities can enrich the content of metaverse in more forms and significantly enhance the user experience within the metaverse, providing a more engaging and immersive environment. This Technical Specification provides capabilities and requirements of Generative Artificial Intelligence in metaverse applications and services. This document specifies four common capabilities of Generative Artificial Intelligence in metaverse applications and services and analyses the description, assumption, service scenario. And it specifies the requirements of Generative Artificial Intelligence in metaverse applications and services.
ITU	FG-MV	FGMV-13	Responsible Use of AI for Child Protection in the metaverse	Approved deliverable	This Technical Report explores the scope for the responsible use of A1 for child protection in the metaverse as a contribution in this area to assist in the achievement of the United Nations Sustainable Development Goals.
ITU-T	SG 11	ITU-T Q.5008	Signalling requirements and architecture to support artificial intelligence-based vertical services in future networks including IMT-2020 and beyond	Published	Recommendation ITU-T Q.5008 provides the signalling requirements and architecture to support artificial intelligence (AI) based vertical services in future networks including IMT-2020 and beyond. These requirements include the signalling information over each of the reference points and service procedures for a high-level AI platform.
ITU-T	SG 13	ITU-T Y.3177	Architectural framework for artificial intelligence-based network automation for resource and fault management in future networks including IMT-2020	Published	Recommendation ITU-T Y.3177 specifies an architectural framework for network automation based on artificial intelligence (AI) for resource and fault management in future networks, including international mobile telecommunications-2020. The purpose of the framework is to improve network efficiency and performance by

					continuously monitoring the network and promptly determining appropriate actions for resource adaptation and fault recovery with the help of AI, including machine learning.
ITU-T	SG 13	ITU-T Y.3178	Functional framework of artificial intelligence-based network service provisioning in future networks including IMT-2020	Published	Recommendation ITU-T Y.3178 specifies a functional framework for network service provisioning based on artificial intelligence (AI) in future networks, including international mobile telecommunication-2020 (IMT-2020). This Recommendation addresses the following aspects: – a business role-based model for AI-based network service provisioning; – high-level requirements for the roles and their interactions from an AI-based operational perspective; – functional components and their interactions for AI-based operations for network service provisioning.
ITU-T	SG 13	ITU-T Y.3550	Cloud computing – Requirements for artificial intelligence based cloud service development and operation management	Published	Recommendation ITU-T Y.3550 aims to provide an overview of artificial intelligence (AI)-based cloud service development and operation management based on Recommendation ITU-T Y.3525. It impacts four lifecycle stages of cloud service development and operation management with AI capabilities to improve software development and operation management efficiency. Additionally, this Recommendation specifies the functional requirements of AI-based cloud service development and operation management derived from the corresponding use cases.
ITU-T	SG 16	ITU-T F Suppl. 4	Overview of convergence of artificial intelligence and blockchain	Published	Artificial intelligence (AI) is one of core essential driving forces of a new round of industrial reform, which can affect the promotion of the upgrading of traditional industries. Blockchain presents opportunities for disruptive innovations, which enables global businesses to transact business with less friction and more trust. AI and

					blockchain promote and influence each other, and their convergence could provide major driving forces for industries and great creativity across a wide range of business applications in many fields. There are many benefits and challenges to combining AI and blockchain. This Supplement focuses on the research on the convergence of AI and blockchain, specifically analyses the mutual promotion between AI and blockchain, and provides a technical reference for the application of AI and blockchain. In addition, Supplement 4 to ITU-T F-series Recommendations also provides application analysis of the convergence of AI and blockchain.
ITU-T	SG 2	ITU-T M.3385	Intelligence levels evaluation framework of artificial intelligence enhanced telecom operation and management	Published	Recommendation ITU-T M.3385 provides a detailed evaluation framework, evaluation rating method and automatic evaluating process for intelligence levels of systems which follow the framework of artificial intelligence enhanced telecom operation and management (AITOM). This Recommendation is included in the series of Recommendations about intelligence levels of artificial intelligence enhanced telecom operation and management (IL-AITOM).
ITU-T	SG 20	ITU-T Y.4470	Reference architecture of artificial intelligence service exposure for smart sustainable cities	Published	Recommendation ITU-T Y.4470 establishes artificial intelligence service exposure (AISE) for smart sustainable cities (SSCs), and provides the common characteristics and high-level requirements, reference architecture and relevant common capabilities of AISE. AISE is one of the basic supporting functional entities for SSCs, with which SSC services can use uniform reference points (exposed by AISE) to integrate and access the artificial intelligence (AI) capabilities of AI services (e.g., machine learning services for image recognition, natural language processing services and traffic prediction services). In addition, AISE can

					collect and open SSC data, and it supports AI services to train and supply AI capabilities in AISE in SSCs.
ITU-T	SG13	ITU-T Suppl 72 to ITU-T Y-3000 series	Artificial Intelligence Standardization Roadmap	Published	This Supplement provides the standardization roadmap for artificial intelligence (AI) in the information and communication technologies area. This AI standardization roadmap has been developed to assist in the development of AI-related standards in the ICT fields by providing information about existing standards and standards under development in key standards development organizations (SDOs). In addition, it provides the overviews of AI and AI-related technical areas from standards perspective, AI-related activities in standards development organizations (SDOs), and gap analysis.
ITU-T	SG13	ITU-T Y.3115	AI enabled cross-domain network architectural requirements and framework for future networks including IMT-2020	Published	Recommendation ITU-T Y.3115 addresses the problem of the lack of an architecture to coordinate the artificial intelligence (AI) capabilities among the current network domains, and specifies architectural requirements and framework of AI-enabled cross-domain networks for future networks including IMT-2020, which aim to achieve overall network intelligence.
ITU-T	SG16	ITU-T F.748.17	Technical specification for artificial intelligence cloud platform – Artificial intelligence model development	Published	Recommendation ITU-T F.748.17 provides a framework for the cloud-based development of artificial intelligence (AI) models. It covers the terminology, features and reference design of an AI cloud platform to enable the development of AI models. It establishes the technical specifications of the platform's supporting functional modules, core functional modules, and auxiliary functional modules.
ITU-T	SG16	ITU-T F.748.26	Technical specification for artificial intelligence cloud	Published	This Recommendation provides a comprehensive performance evaluation framework for an artificial intelligence cloud platform. It covers the overview of the

			platforms: Performance evaluation		evaluation framework, configuration specification, workloads, metrics, requirements on evaluation results and evaluation suggestions. It can be a unified guideline for developers, users, third-party test agency, and researchers to analyse and access the performance of AI cloud platforms.
ISO/IEC	JTC 1/SC 29	ISO/IEC 23090-14:2023	Coded representation of immersive media - Part 14: Scene description	Published	ISO/IEC 23090-14:2023 provides guidance on the technical aspects of AI trustworthiness regarding risk management. It defines trustworthiness in the context of AI systems and outlines key concepts related to risk and trustworthiness. The standard emphasizes a socio-technical approach, acknowledging the interplay between technical and societal factors in AI systems. It explores the relationship between AI trustworthiness and existing risk management methodologies, adapting them to the specific challenges posed by AI. Additionally, the document offers recommendations for establishing and maintaining trustworthiness throughout the AI system lifecycle, covering aspects like design, development, deployment and monitoring.

7.3.6 Digital Human/Avatar

Table 7-13 provides the metaverse standards related to Digital Human/Avatar. SDOs associated with this category of metaverse standards include ISO, ISO/IEC, ITU-T, and VRM Consortium.

Table 7-13: Metaverse standards related to Digital Human/Avatar

SDO	Study group	Reference	Title	Status	Abstract
ISO	TC 184/SC4	ISO/TR 24464:2020	Automation systems and integration — Industrial data —	Published	ISO/TR 24464:2020 analyses visualization elements that are key components of the interface between the

			Visualization elements of digital twins		physical asset and the avatar (digital replica of the physical asset).
ISO/IEC	JTC 1/SC 24	ISO/IEC 19774-1	Humanoid animation — Part 1: Architecture	Published	ISO/IEC 19774-1 specifies a data structure for a humanoid with its skeleton and skin data models. A basic humanoid data model is defined by segments and joints using four levels of articulation depending on the complexity of the humanoid structure. In addition, HAnim site and displacer nodes can define clothing and accessories for human bodies.
ISO/IEC	JTC 1/SC 24	ISO/IEC 19774-2	Humanoid animation — Part 1: Motion data animation	Published	ISO/IEC 19774-2 HAnim motion data animation can be used to generate and exchange humanoid animation using motion data. Based on the ISO/IEC 19774-1 humanoid structure, animation sequences of a humanoid avatar are generated using keyframe parameters, algorithms, or motion capture data, depending on the levels of articulation.
ISO/IEC	JTC 1/SC 29	ISO/IEC 23005-4:2018	Information technology - Media context and control - Part 4: Virtual world object characteristics	Published	The technologies of this document specified are description languages and vocabularies to describe virtual world objects. The adaptation engine is not within the scope of this document. This document specifies syntax and semantics of the tools used to characterize a virtual world object related metadata: Virtual World Object Characteristics (VWOC) as an XML Schema-based language which enables a basic structure of avatars and virtual world objects in virtual environments to be described.
ITU-T	SG16	ITU-T F.748.15	Framework and metrics for digital human application systems	Published (03/2022)	ITU-T F.748.15: This specifies a framework and metrics for digital human (i.e., intelligent-driven digital human) application systems, and addresses metrics for image, speech, animation, interactive processing, multimodal

					input/output. Use case mentions a virtual consumer service system.
ITU-T	SG16	ITU-T F.748.14	Requirements and evaluation methods of non-interactive 2D real-person digital human application systems	Published (03/2022)	ITU-T F.748.14: This specifies requirements and evaluation methods for non-interactive two-dimensional (2D) real-person digital human application systems, in terms of image, voice, movement and display, etc. It can be used to guide relevant parties to test, select or evaluate a non-interactive, 2D real-person digital human application system.
ITU-T	SG16	ITU-T F.748.27	Framework and requirements for the construction of 3D intelligent driven digital human application systems	Published (01/2024)	With the advancement of modelling, driving, rendering and interactive technologies, an increasing number of new services and applications involving 3D intelligent driven digital humans are emerging. This Recommendation outlines the framework and requirements for the construction of 3D intelligent driven digital human application systems. It defines the concept, related terms and fundamental functions of 3D intelligent driven digital human to specify the framework of 3D intelligent driven digital human application systems, including image generation, speech generation, animation generation, interaction processing, multimodal input and output modules with its specified functions and construction requirements. In addition, the appendix presents some use cases of workflow of 3D intelligent driven digital human.
ITU-T	SG16	F.DH-PE	Requirements and evaluation methods of digital human platform	Under development	The purpose of this Recommendation is to provide technical guidance and technical specification support for the research and development, selection and testing of digital human platform, to achieve a fair, just, scientific and objective evaluation of digital human platform, and to promote the progress of digital human technology products. This Recommendation provides

					the requirements and evaluation methods for the digital human platform from the aspects of function, compatibility, reliability, scalability, time response and ease of use.
ITU-T	SG16	F.DHPIE	Metrics and Evaluation Methods for the Presentation and Interactive Effect of 3D Digital Human	Under development	With the development of artificial intelligence, computer graphics and animation technologies, 3D digital human has become increasingly popular in industries such as film and television, media, games, finance, culture and tourism, education, medical treatment, retail and other fields. Digital human application shows a vigorous development trend, of which scalable and replicable business value is increasingly prominent. Currently 3D digital human can not only simulate human appearance and movement, but also interact with users in a more natural and intelligent way. However, there is great variability in the quality of presentation and interactive effect among digital humans, which restricts the commercialization and implementation of digital people, and to some extent hinders the high-quality development of the digital people industry. Therefore, evaluating the presentation and interaction effect of 3D digital human has become an important part of promoting the development of digital human technology. It is necessary to develop comprehensive methods and standards to evaluate the user experience of 3D digital humans to ensure their high quality and usability, and provide a scientific and reasonable evaluation system for digital human developers, users, and companies. This will promote the development of the digital human industry and enhance user experience in various applications. At present, the research on digital human standards by the International Telecommunication Union focuses mainly on the requirements, evaluation indicators, and methods

					related to digital human application systems or production platforms. The published F.748.15 (ex F.DH-FM) specifies framework and metrics for digital human application system and F.748.14 (ex F.DH-2D) specifies evaluation method of non-interactive virtual human (2D real-person image) application system. There is no relevant standard to evaluate the presentation and interaction effect of digital human from the user experience side. By using the metrics and methods in the Recommendation, a comprehensive evaluation and analysis of digital humans can be conducted in terms of user experience, promoting technology innovation to improve the quality and effectiveness of digital humans. This standard is applicable to the development, testing and application of digital humans in fields such as cultural tourism, integrated media, education and training, sports and health, business and creativity, performing arts and entertainment, disability assistance, and smart cities, and it is of great significance for the healthy development of the digital human industry.
ITU-T	SG16	F.DHSMD	Technical requirements and evaluation methods of 3D digital human system based on smart mobile devices	Under development	This proposed Recommendation clarifies requirements of 3D digital human system based on smart mobile devices(SMD) from three dimensions: 1) Functional requirements: Focus on the technical capabilities of SMD-based 3D digital humans in the dimensions of image, voice, action, interaction, multimodal input and output, etc. 2) Performance requirements: Focus on the memory occupied by the 3D digital human in SMD, the power consumption of the 3D digital human running in different states and the interaction fluency of the 3D digital human with the SMD users.

					3) System requirements: Focus on the reliability and robustness of SMD-based 3D digital human systems.
ITU-T	SG16	F.CSDH	Requirements of communication services for digital humans	Under development	A digital human is a virtual human created in a digital space to have the appearance and voice of a human and act like a human. A digital human can communicate with humans such as human-like facial expressions and gestures, and allow them to have more realistic conversations than the past chatbots. This draft recommendation provides use cases and requirements of the communication services for digital human.
ITU-T	SG16	F.FDHC	Factors and framework for digital human customization	Under development	The advancement in digital human technology is enabling natural movements in various fields. Effective control requires considering factors like text, voice, images and emotions, and defining interfaces between multiple models. As digital humans mirror real humans, defining movement control parameters during modelling is crucial for establishing interfaces between different models.
VRM Consortium	-	https://github.com/vrm-c/vrm-specification	VRM 2.0	Completed	VRM is a platform-independent file format designed for use with 3D characters and avatars in the modern VR landscape. In addition to conventional information such as textures and bones for 3D models, the file format can also handle information necessary for first-person avatars such as gaze settings, etc. By unifying the different scales and coordinate systems depending on the environment, we believe that 3D avatars will be more useable on all platforms such as distribution and games. Taking into account the characteristics of avatars and how people use them to bring out their personalities, we

					believe it is possible to embed rights specific to avatars in the file, such as usage permissions for the avatar for violent content. In the future, we aim to combine the function of protecting the rights of 3D models with the creation of a new standard format for the distribution of 3D models, such as sales and modifications.

7.4 Interoperability and ICT related infrastructure standards

7.4.1 Interoperability protocols

Table 7-14 provides the metaverse standards related to interoperability protocols. SDOs associated with this category of metaverse standards include IEEE, IETF, ISO, ISO/IEC, ITU, ITU-T and W3C.

Table 7-14: Metaverse standards related to Interoperability protocols

SDO	Study group	Reference	Title	Status	Abstract
IEEE	IDAC	IEEE 3205-2023	IEEE Standard for Blockchain Interoperability - Data Authentication and Communication Protocol	Published	IEEE P3205: Blockchain interoperability is the ability of two or more blockchain systems or applications to exchange information and to mutually use the information that has been exchanged. The interfaces and protocols play a very important role in realizing interoperability. Therefore, the standard of cross-chain interoperability interfaces and protocols, especially those for data authentication and communication among homogeneous and heterogeneous blockchain systems is needed. Such protocols coordinate blockchains while supporting multiple cross-chain models and levels to meet business demands without the need to customize gateways or exchanges for specific use cases. The standard provides an infrastructure of cross chain interoperability, as well as

					interfaces and protocols of data authentication and communication for homogeneous and heterogeneous blockchain interoperability. The protocols include the distributed identity protocol, metadata protocol, on-chain proof conversion protocol, and cross-chain communication protocol
IEEE	IoT Architecture WG	IEEE 2413-2019	IEEE Standard for an Architectural Framework for the Internet of Things (IoT)	Published	IEEE 2413-2019: New IEEE Standard - Active. An architecture framework description for the Internet of Things (IoT), which conforms to the international standard ISO/IEC/IEEE 42010:2011 is defined. The architecture framework description is motivated by concerns commonly shared by IoT system stakeholders across multiple domains (transportation, health care, Smart Grid, etc.). A conceptual basis for the notion of things in the IoT is provided and the shared concerns as a collection of architecture viewpoints is elaborated to form the body of the framework description
IETF	IAB	RFC 8477	Report from the Internet of Things (IoT) Semantic Interoperability (IOTSI) Workshop 2016	Published	RFC 8477 provides a summary of the “Workshop on Internet of Things (IoT) Semantic Interoperability (IOTSI)”, which took place in Santa Clara, California from 17–18 March 2016.
ISO	TC 307	ISO/WD TS 23516	Blockchain and distributed ledger technologies — Interoperability Framework	Under development	This document specifies a framework, recommendations, and requirements for interoperability between DLT systems, between DLT and entities outside the DLT system, and the relationship and interactions between these, as well as cross-cutting aspects.
ISO/IEC	JTC 1/SC 24	ISO/IEC 19777-1:2006	Information technology - Computer graphics	Published	ISO/IEC 19777-1:2006 specifies such a language-dependent layer for the ECMAScript language. ISO/IEC 19775-2 specifies a language-independent application

			and image processing - Extensible 3D (X3D) language bindings – Part 1: ECMAScript		programmer interface (API) to a set of services and functions.
ISO/IEC	JTC 1/SC 24	ISO/IEC 19777-2:2006	Information technology - Computer graphics and image processing - Extensible 3D (X3D) language bindings – Part 2: JAVA	Published	ISO/IEC 19777-2:2006 specifies such a language-dependent layer for the Java programming language.
ISO/IEC	JTC 1/WG 11	ISO/IEC 5087-1	Information technology — City data model — Part 1: Foundation level concepts	Published	This document is part of the ISO/IEC 5087 series, which specifies a common data model for cities. This document specifies the foundation level concepts.
ISO/IEC	JTC 1/SC 24	ISO/IEC 18042-4	SRM language bindings – Part 4: C	Published	The Spatial Reference Model (SRM) precisely and unambiguously specifies the context in which positions, directions and distances are defined. It also provides the concepts needed to convert locations, directions and distances accurately among multiple spatial reference frames. Access to the data types and concepts defined by this specification is through an application program interface (API). This document defines a standard binding for the C programming language.
ISO/IEC	JTC 1/SC 29	ISO/IEC 23005-2	Media context and control - Part 2: Control information	Published	The technologies specified in this document include description languages and vocabularies to characterize devices and users, as well as control information to fine-tune the sensed information and the actuator command for

					controlling virtual/real worlds. This encompasses user's actuation preference information, user's sensor preference information, actuator capability description and sensor capability description. This document specifies the syntax and semantics of the tools required to provide interoperability in controlling devices (actuators and sensors) in both real and virtual worlds.
ISO/IEC	JTC 1/SC 38	ISO/IEC 5140	Concepts for multi-cloud and the use of multiple cloud services	Published	This document specifies foundational concepts for multiple cloud services including multicloud, hybrid cloud, inter-cloud and federated cloud.
ISO/IEC	JTC 1/SC 38	ISO/IEC 19941	Interoperability and portability	Published	This document specifies cloud computing interoperability and portability types, the relationship and interactions between these two cross-cutting aspects of cloud computing, and common terminology and concepts used to discuss interoperability and portability, particularly relating to cloud services.
ISO/IEC	JTC 1/SC 38	ISO/IEC AWI TS 10866	Framework and concepts for organizational autonomy and digital sovereignty	Under development	This document provides concepts related to the intersection of digital sovereignty, organizational autonomy and digital platforms. It offers a framework enabling organizations to understand the relevant digital sovereignty and autonomy matters, identify the relevant attributes for the organization's potential digital platform and the choices necessary to address the issues, and balance the range of available options to achieve the desired organizational autonomy. This document is applicable to all organizations and policymakers involved in organizational autonomy and digital sovereignty in cloud services and distributed platforms.
ISO/IEC	JTC 1/SC 35	ISO/IEC TR 15440:2016	Information technology - Future	Published	ISO/IEC TR 15440:2016 supported by the history of information technology keyboards during the last three

			keyboards and other input devices and entry methods		decades, lists current and anticipated problem areas as seen by users and tries to pave the way to foreseen work items in JTC 1 for solving issues of the user interface with keyboards, other input devices and input methods.
ISO/IEC	JTC 1/SC 37	ISO/IEC 29794 (series)	Information technology - Biometric sample quality	Published	ISO/IC 39794 series is one of a family of international standards being developed by ISO/IEC]TC 1/ SC 37 that supports interoperability and data interchange among biometric applications and systems. ISO/IEC 39794 series contains following parts: – ISO/IEC 39794-1:2019 Information technology - Extensible biometric data interchange formats - Part 1: Framework – ISO/IEC 39794-4:2019 Information technology - Extensible biometric data interchange formats - Part 4: Finger image data – ISO/IEC 39794-5:2019 Information technology - Extensible biometric data interchange formats - Part 5: Face image data – ISO/IEC 39794-6:2021 Information technology - Extensible biometric data interchange formats - Part 6: Iris image data – ISO/IEC 39794-9:2021 Information technology - Extensible biometric data interchange formats - Part 9: Vascular image data – ISO/IEC 39794-16:2021 Information technology - Extensible biometric data interchange formats - Part 16: Full body image data – ISO/IEC 39794-17:2021 Information technology - Extensible biometric data interchange formats - Part 17: Gait image sequence data
ISO/IEC	JTC 1/SC 37	ISO/IEC 39794 (series)	Information technology - Extensible biometric	Published	ISO/IC 39794 series is one of a family of international standards being developed by ISO/IEC]TC 1/ SC 37 that supports interoperability and data interchange among

			data interchange formats		biometric applications and systems. ISO/IEC 39794 series contains following parts: – ISO/IEC 39794-1:2019 Information technology - Extensible biometric data interchange formats - Part 1: Framework – ISO/IEC 39794-4:2019 Information technology - Extensible biometric data interchange formats - Part 4: Finger image data
ISO/IEC	JTC 1/SC 38	ISO/IEC 17789:2014	Information technology - Cloud computing - Reference architecture	Published	ISO/IEC 17789:2014 specifies the cloud computing reference architecture (CCRA). The reference architecture includes the cloud computing roles, cloud computing activities, and the cloud computing functional components and their relationships.
ISO/IEC	JTC 1/SC 38	ISO/IEC 19941:2017	Information technology - Cloud computing - Interoperability and portability	Published	ISO/IEC 19941 specifies cloud computing interoperability and portability types, the relationship and interactions between these two cross-cutting aspects of cloud computing and common terminology and concepts used to discuss interoperability and portability, particularly relating to cloud services.
ISO/IEC	JTC 1/SC 38	ISO/IEC TR 23187:2020	Information technology - Cloud computing - Interacting with cloud service partners (CSNs)	Published	ISO/IEC TR 23187:2020 provides an overview of and guidance on interactions between cloud service partners (CSNs), specifically cloud service brokers, cloud service developers and cloud auditors, and other cloud service roles.
ISO/IEC	JTC 1/SC 38	ISO/IEC TS 23167:2020	Information technology - Cloud computing - Common technologies and techniques	Published	ISO/IEC TS 23167:2020 provides a description of a set of common technologies and techniques used in conjunction with cloud computing.

ISO/IEC	JTC 1/SC 38	ISO/IEC TR 22678:2019	Information technology - Cloud computing - Guidance for policy development	Published	ISO/IEC TR 22678:2019 provides guidance on the use of international standards as a tool in the development of those policies that govern or regulate cloud service providers (CSPs) and cloud services, and those policies and practices that govern the use of cloud services in organisations.
ITU	FG-MV	FGMV-19	Service scenarios and high-level requirements for metaverse cross-platform interoperability	Approved deliverable	This deliverable specifies the service scenarios and high-level requirements for metaverse cross-platform interoperability. With the increasing number of metaverse platforms being developed, there is a need to create an open and seamless metaverse interoperable environment between metaverse platforms that fosters innovation and collaboration. This deliverable aims to identify the various intended service scenarios and high-level requirements of four types of metaverse cross-platform interoperability: avatar interoperability, asset interoperability, content interoperability, and identity interoperability.
ITU-T	SG 11	ITU-T Q.3055	Signalling protocol for heterogeneous Internet of Things gateways	Published (12/2019)	ITU-T Q.3055 describes the signalling protocol for heterogeneous IoT gateways.
ITU-T	SG13	ITU-T Y.3514	Cloud computing - Trusted inter-cloud computing framework and requirements	Published (05/2017)	ITU-T Y.3515 specifies a framework of trusted inter-cloud computing and relevant use cases. It provides general requirements for trusted inter-cloud and specific ones related to governance, management, resiliency, security and confidentiality of trusted inter-cloud.
ITU-T	SG13	ITU-T Y.3516	Cloud computing - Functional architecture of inter-cloud computing	Published (09/2017)	ITU-T Y.3516 specifies inter-cloud computing functional architecture, including functions and functional components, based on the inter-cloud computing framework specified in Recommendation ITU-T Y.3511.

ITU-T	SG13	ITU-T Y.3536	Cloud computing - Functional architecture for cloud service brokerage	Published (02/2022)	ITU-T Y.3536 describes functional architecture for cloud service brokerage (CSB) based on functional requirements defined in Recommendation ITU-T Y.3506. This Recommendation also provides the reference points among CSB functions, and the relationship between the CSB functional architecture and the cloud computing reference architecture specified in Recommendation ITU-T Y.3502.
ITU-T	SG13	ITU-T Y.3502	Information technology – Reference architecture	Published (08/2014)	ITU-T Y.3502 provides the reference architecture for cloud computing, which includes the cloud computing roles, cloud computing activities, and the cloud computing functional components and their relationships.
ITU-T	SG13	ITU-T Y.3519	Cloud computing - Functional architecture of big data as a service	Published (12/2018)	ITU-T Y.3519 describes the functional architecture for big data as a service (BDaaS). The functional architecture is defined on the basis of the analysis of requirements and activities of cloud computing-based big data described in Recommendation ITU-T Y.3600. Following the methodology of Recommendation ITU-T Y.3502, the BDaaS functional architecture is described from a set of functional components and cross-cutting aspects. The specified functional components consist of sets of functions that are required to perform the BDaaS activities for the roles and sub-roles described in Recommendation ITU-T Y.3600.
ITU-T	SG13	ITU-T Y.3525	Cloud computing - Requirements for cloud service development and operation management	Published (09/2020)	ITU-T Y.3525 describes the overview of cloud service development and operation management and its functional requirements. It provides the lifecycle of cloud service development and operation management based on five processes and eight stages. Additionally, this Recommendation also specifies the functional requirements of cloud service development and operation management derived from the corresponding use cases.

ITU-T	SG20	ITU-T Y.4217	Service requirements and capability framework for Internet of Things-related crowdsourced systems	Published (08/2022)	ITU-T Y.4217 specifies service requirements of Internet of Things (IoT)-related crowdsourced systems, in addition to the requirements of IoT-related crowdsourced systems (Recommendation ITU-T Y.4205); and the common requirements of IoT (Recommendation ITU-T Y.4100). Based on these requirements, a capability framework of IoT-related crowdsourced systems is developed.
ITU-T	SG20	ITU-T Y.4481	Framework for data middle platform in Internet of Things and smart sustainable cities	Published (08/2022)	ITU-T Y.4481 addresses a type of middle platform called the data middle platform (DM), which is expected to provide innovative digital data services to deliver data value. It allows the separation of the fundamental technical support capabilities from business-related services.
ITU-T	SG17	CRAMM Roadmap	SG17 Cyber Security Reference Architectures, Models and Methodologies Strategy and Roadmap	Under development	This document will provide and maintain a small historic context and evolutionary considerations, demonstrate what value this roadmap document brings to SG17, propose a strategy to develop this roadmap, detail each part of its mandate and focus on the program constituencies of, separately, Reference Architectures, Models and Methodologies, reassemble all of them into a cohesive map that will allow to detail the delineations, identify gaps, and set the roadmap and document lessons learnt from other ITU-T Study Groups.
ISO/IEC	JTC 1/SC 29	ISO/IEC 21000-4:2012	Multimedia framework (MPEG 21) - Part 4: Intellectual Property Management and Protection Components	Published	ISO/IEC 21000-4:2012 establishes guidelines for Digital Rights Management (DRM) interoperability, encompassing functional, security, and media format requirements. It aims to facilitate compatibility and information exchange between diverse DRM systems within an open framework. The standard defines DRM components, including content format, packing, transport, usage, and license format, ensuring secure encryption and control over digital content. Additionally, it specifies

					protocols and mechanisms for encryption, key management, and rights expression, promoting interoperability and seamless interaction between different DRM systems while maintaining robust content protection.
W3C	W3C Pointer Events WG	Pointer Events, https://www.w3.org/TR/pointerevents/	Pointer Events	Under development	Pointer Events describes events and related interfaces for handling hardware agnostic pointer input from devices including a mouse, pen, touchscreen, etc. For compatibility with existing mouse-based content, this specification also describes a mapping to fire Mouse Events for other pointer device types.
W3C	W3C Web of Things WG	WoT Thing Description, https://www.w3.org/TR/wot-thing-description/	Web of Things (WoT) Thing Description 1.1	Published (07/2023)	WoT Thing Description describes a formal information model and a common representation for a Web of Things (WoT) Thing Description. A Thing Description describes the metadata and interfaces of Things, where a Thing is an abstraction of a physical or virtual entity that provides interactions to and participates in the Web of Things.
W3C	W3C Web of Things WG	WoT Architecture, https://www.w3.org/TR/wot-architecture/	Web of Things (WoT) Architecture 1.1	Published (07/2023)	WoT Architecture describes the abstract architecture for the W3C Web of Things.
W3C	W3C Web of Things WG	WoT Discovery, https://www.w3.org/TR/wot-discovery/	Web of Things (WoT) Discovery	Published (07/2023)	WoT Discovery describes a process to obtain the Thing Description of a Thing that can run in a variety of use cases. This includes ad-hoc and engineered systems; during development and at runtime; and on both local and global networks. The process also works with existing discovery mechanisms, be secure, protect private information, and efficiently handles updates to WoT Thing Descriptions and the dynamic and diverse nature of the IoT ecosystem.

W3C	W3C Web Payments WG	Payment Handler, https://www.w3.org/TR/payment-handler/	Payment Handler API	Under development	Payment Handler defines capabilities that enable Web applications to handle requests for payment.
W3C	W3C Web Real-Time Communications WG	WebRTC https://www.w3.org/TR/webrtc/	WebRTC: Real-Time Communication in Browsers	Published (03/2023)	WebRTC defines a set of ECMAScript APIs in WebIDL to allow media and generic application data to be sent to and received from another browser or device implementing the appropriate set of real-time protocols.

7.4.2 Data sharing

Table 7-15 provides the metaverse standards related to data sharing. SDOs associated with this category of metaverse standards include ISO/IEC and ITU-T.

Table 7-15: Metaverse standards related to Data sharing

SDO	Study group	Reference	Title	Status	Abstract
ISO/IEC	JTC 1/WG 11	ISO/IEC AWI TR 10267-2	Information technology — Data use in smart cities — Part 2: Use case analysis and common considerations	Under development	This document provides use cases and common considerations for use cases analysis for data use in smart cities.
ISO/IEC	JTC 1/SC 38	ISO/IEC AWI 20151	Dataspace concepts and characteristics	Under development	This document provides the foundational concepts and essential characteristics of dataspaces. This document is applicable to all organizations.
ISO/IEC	JTC 1/SC 38	ISO/IEC 19944-1	Data flow, data categories and data use — Part 1: Fundamentals	Published	This document describes the various types of data flowing within the devices and cloud computing ecosystem, describes the impact of connected devices on the data that flow within the cloud computing ecosystem, describes flows of data between cloud services, cloud service customers, and cloud service users, provides foundational concepts, including a data taxonomy, and identifies the categories of data that flow across the cloud service

					customer devices and cloud services. This document is applicable primarily to cloud service providers, cloud service customers, and cloud service users, but also to any person or organization involved in legal, policy, technical, or other implications of data flows between devices and cloud services.
ISO/IEC	JTC 1/SC 38	ISO/IEC 19944-2	Data flow, data categories and data use — Part 2: Guidance on and extensibility	Published	This document provides guidance on the application of the taxonomy and use statements from ISO/IEC 19944-1 in real-world scenarios, and how to develop extensions to the data taxonomy, data processing and use categories, and data use statements.
ISO/IEC	JTC 1/SC 38	ISO/IEC 22624:2020	Information technology - Cloud computing - Taxonomy based data handling for cloud services	Published	ISO/IEC 22624:2020 describes a framework for the structured expression of data-related policies and practices in the cloud computing environment, based on the data taxonomy in ISO/IEC 19944, provides guidelines on application of the taxonomy for handling of data based on data subcategory and classification, covers expression of data-related policies and practices including, but not limited to data geolocation, cross border flow of data, data access and data portability, data use, data management, and data governance, and describes how the framework can be used in codes of conduct for practices regarding data at rest and in transit, including cross border data transfer, as well as remote access to data.
ISO/IEC	JTC 1/SC 38	ISO/IEC TR 23186:2018	Information technology - Cloud computing - Framework of trust for processing of multi-sourced data	Published	ISO/IEC TR 23186:2018 describes a framework of trust for the processing of multisourced data that includes data use obligations and controls, data provenance, chain of custody, security and immutable proof of compliance as elements of the framework.
ISO/IEC	JTC 1/SC 42	ISO/IEC 20547 (series)	Information technology - Big data reference architecture	Published	ISO/IEC 20547 series describes the framework of the big data reference architecture and contains following parts: – ISO/IEC TR 20547-1:2020 Information technology - Big data reference architecture - Part 1: Framework and application process

					– ISO/IEC TR 20547-2:2018 Information technology - Big data reference architecture - Part 2: Use cases and derived requirements – ISO/IEC 20547-3:2020 Information technology - Big data reference architecture - Part 3: Reference architecture – ISO/IEC 20547-4:2020 Information technology - Big data reference architecture - Part 4: Security and privacy – ISO/IEC TR 20547-5:2018 Information technology - Big data reference architecture - Part 5: Standards roadmap
ITU-T	SG13	ITU-T Y.3601	Big data - Framework and requirements for data exchange	Published (05/2018)	ITU-T Y.3601 provides a framework for data exchange in a big data ecosystem. Big data exchange covers multiple processes for data import and data export within a big data ecosystem. Big data exchange is used for exchanging data of multiple types and multiple formats from a data source to a data target. In this Recommendation, direct and intermediary exchange patterns are introduced. In addition, this Recommendation provides a description of the big data activities for the support of big data exchange by extending the activities defined in Recommendation ITU-T Y.3600. Finally, this Recommendation identifies functional requirements which are derived from relevant use cases.
ITU-T	SG13	ITU-T Y.3602	Big data - Functional requirements for data provenance	Published (09/2022)	ITU-T Y.3602 specifies the functional requirements for data provenance in a big data ecosystem as defined in ITU-T Y.3600, introduces data provenance as well as data provenance in a big data ecosystem, and provides a conceptual model, operations, logical components, and functional requirements for big data provenance.
ITU-T	SG13	ITU-T Y.3603	Big data - Requirements and conceptual model of metadata for data catalogue	Published (12/2019)	ITU-T Y.3603 introduces the metadata concept as well as its usages in a big data lifecycle, and provides requirements and a conceptual model of metadata for a data catalogue to support the big data ecosystem defined in ITU-T Y.3600.

ITU-T	SG13	ITU-T Y.3604	Big data - Overview and requirements for data preservation	Published (02/2020)	ITU-T Y.3604 provides an overview and requirements of big data preservation. It addresses the overview of big data preservation, functional requirements of big data preservation, and use cases of big data preservation.
ITU-T	SG13	ITU-T Y.3607	Big data - Functional architecture for data provenance	Published (01/2023)	ITU-T Y.3607 provides a functional architecture for big data provenance. It specifies the functions for supporting big data provenance, functional architecture of big data provenance, reference points among functions for big data provenance.

7.4.3 Interfacing

Table 7-16 provides the metaverse standards related to interfacing. SDOs associated with this category of metaverse standards include ISO/IEC, ITU-T and W3C.

Table 7-16: Metaverse standards related to Interfacing

SDO	Study group	Reference	Title	Status	Abstract
ISO/IEC	JTC 1/SC 29	ISO/IEC 23005-5:2019	Information technology - Media context and control - Part 5: Data formats for interaction devices	Published	ISO/IEC 23005-5:2019 specifies syntax and semantics of the data formats for interaction devices by providing a standardized format for interfacing actuators and sensors by defining XML schema-based language named Interaction Information Description Language (IIDL). IIDL provides a basic structure with common information for communication with various actuators and sensors in consistency. Device Command Vocabulary (DCV) is defined to provide a standardized format for commanding individual actuator, and Sensed Information Vocabulary (SIV) is defined to provide a standardized format for holding information from individual sensors either to get environmental information from real world or to influence virtual world objects using the acquired information on the basis of IIDL.

ISO/IEC	JTC 1/SC 29	ISO/IEC 23005-5	Media context and control - Part 5: Data formats for interaction devices	Published	This document specifies the syntax and semantics of the data formats for interaction devices by providing a standardized format for interfacing actuators and sensors. It defines an XML schema-based language named Interaction Information Description Language (IIDL), which is used to facilitate communication between various devices in a standardized manner.
ITU-T	SG16	F.DHAI	Framework and requirements of digital human access interfaces	Under development	As one of important elements of Metaverse, digital human application shows a vigorous development trend, of which scalable and replicable business value is increasingly prominent. With the continuous development of artificial intelligence technology and intelligent hardware, digital human not only has more and more functions, but also has more and more extensive application scenarios, such as film and television, media, games, finance, culture and tourism, education, medical treatment, retail and other fields. Different types of digital humans provide different services in multiple application scenarios. The capabilities offered by different vendors vary from each other. The successful application of digital human depends on whether the developers can quickly iterate the capabilities on service demands, or integrate different vendors' offering capabilities. So the unified access interface can facilitate the developers to use plentiful digital human served with higher integration efficiency and greatly expand the application scenarios. At present, there is a lack of unified access interface standards when the developers integrate digital human services to different application. This results in complex adaptation, heavy debugging work, and a lack of portability, which limits cross application access and industrial development of digital human services. In order to promote the technical innovation and expand the application scenarios of digital human, this Recommendation is intended to propose a general access interface framework, relevant interface requirements of digital human services, and provide unified

					access standards for the developers to improve efficiency and reduce cost, based on the sufficient investigation of the technical implementation of digital human access.
ISO/IEC	JTC 1/SC 29	ISO/IEC 23090-8:2020	Coded representation of immersive media - Part 8: Network based media processing	Published	ISO/IEC 23090 8:2020, titled “Information technology — Programming languages, their environments and system software interfaces — Part 8: C++ Extensions for Concepts”, specifies extensions to the C++ programming language to support the definition and use of concepts. Concepts allow programmers to specify requirements for template arguments, improving code readability and enabling better error messages. This standard provides a formal framework for defining concepts and associating them with templates, ensuring type safety and enhancing the expressiveness of C++ templates.
W3C	W3C Browser Testing and Tools WG	WebDriver, https://www.w3.org/TR/webdriver/	WebDriver	Under development	WebDriver is a remote-control interface that enables introspection and control of user agents. It provides a platform- and language-neutral wire protocol as a way for out-of-process programs to remotely instruct the behaviour of web browsers.
W3C	W3C Web	Payment Request, https://ww	Payment Request API	Published (09/2022)	Payment Request standardizes an API to allow merchants (i.e. web sites selling physical or digital goods) to utilize one or more payment methods with minimal integration. User agents (e.g.,

	Payments WG	w.w3.org/TR/payment-request/			browsers) facilitate the payment flow between merchant and user.
W3C	W3C Web Platform Incubator CG	Web Speech, https://wicg.github.io/speech-api/	Web Speech API	Proposed	Web Speech defines a JavaScript API to enable web developers to incorporate speech recognition and synthesis into their web pages. It enables developers to use scripting to generate text-to-speech output and to use speech recognition as an input for forms, continuous dictation and control. The JavaScript API allows web pages to control activation and timing and to handle results and alternatives.
W3C	W3C Web Real-Time Communications WG	Audio Output Devices https://www.w3.org/TR/audio-output/	Audio Output Devices API	Under development	Audio Output Devices defines a set of JavaScript APIs that let a Web application manage how audio is rendered on the user audio output devices.

7.4.4 Network infrastructure

Table 7-17 provides the metaverse standards related to network infrastructure. SDOs associated with this category of metaverse standards include IEEE, IETF and ITU-T.

Table 7-17: Metaverse standards related to Network infrastructure

SDO	Study group	Reference	Title	Status	Abstract
IEEE	P62209-3 WG	IEEE 1528.7-2020	IEEE Guide for EMF Exposure Assessment of Internet of Things (IoT) Technologies and Devices	Published	IEEE 1528.7-2020: In the wireless communication field, 5G and Internet of Things (IoT) solutions are the main emerging technologies and future wireless communication will rely on them. A methodology for classifying IoT devices based on radio frequency (RF) exposure characteristics is provided. Classification is based on frequency, bandwidth, radiated

					power, and typical installation configuration. Links between device class and available measurement/computational standards are provided. A framework criterion for exclusion classes for exposure assessment and criteria for addressing situations where exposure assessment is unavailable are included.
IETF	6tisch WG	RFC 7554	Using IEEE 802.15.4e Time-Slotted Channel Hopping (TSCH) in the Internet of Things (IoT): Problem Statement	Published	RFC 7554 describes the environment, problem statement, and goals for using the Time-Slotted Channel Hopping (TSCH) Medium Access Control (MAC) protocol of IEEE 802.14.4e in the context of Low-Power and Lossy Networks (LLNs).
IETF	IAB	RFC 8240	Report from the Internet of Things Software Update (IoTSU) Workshop 2016	Published	RFC 8240 provides a summary of the Internet of Things Software Update (IoTSU) Workshop that took place at Trinity College Dublin, Ireland on 13 and 14 June, 2016.
IETF	lwig WG	RFC 9006	TCP Usage Guidance in the Internet of Things (IoT)	Published	RFC 9006 provides guidance on how to implement and use the Transmission Control Protocol (TCP) in Constrained-Node Networks (CNNs), which are a characteristic of the Internet of Things (IoT). Such environments require a lightweight TCP implementation and may not make use of optional functionality. IETF RFC 9006 also explains a number of known and deployed techniques to simplify a TCP stack as well as corresponding trade-offs. The objective is to help embedded developers with decisions on which TCP features to use.
ITU-T	SG13	ITU-T Y.3120	Functional architecture for latency guarantee in large scale networks including IMT-2020 and beyond	Published (01/2023)	ITU-T Y.3120 specifies the functional architecture, functional entities, reference points and operational procedures, for the requirements and framework defined in Y.3113, based on the architecture defined in Y.2111. Meanwhile, Y.3113 specifies the use of flow aggregate (FA)-based scheduling and regulators at aggregation domain (AD) boundaries. Y.2111 specifies the resource and admission control functions (RACF) in support of

					end-to-end quality of service (QoS) and necessary transport functions in next generation networks (NGNs).
ITU-T	SG13	ITU-T Y.3138	Unified multiaccess edge computing for supporting fixed mobile convergence in IMT-2020 networks	Published (09/2022)	ITU-T Y.3138 specifies the requirements, architecture and functions of unified multi-access edge computing for supporting FMC in networks.
ITU-T	SG13	ITU-T Y.3325	Framework for high-level AI-based management communicating with external management systems	Published	Recommendation ITU-T Y.3325 describes the requirements for a reference model of such interactions including interface and metadata. After the IMT-2020 technology and network virtualization technology spread, the appearance of emerging services such as multimedia services (high resolution, AR, VR, etc.) and IoT is expected. Since huge amount of traffic of these new coming services will be incurred to the network, the importance of network flexibility and stability will increase. Network operators intend to improve network operations such as provisioning, resource control, failure detection and recovery, and so on. Automatic network management supported by recent AI technologies called AI-based networks will play an essential role in such an era. On the other hand, a service provider needs to manage service dynamically based on service and network status for better quality of service (QoS). In order for service providers to use the information managed by AI-based networks effectively, a common interface between a system of service providers over AI-based networks and AI-based networks is required.
ITU-T	SG16	ITU-T F.746.15	Requirements for smart broadband network gateway in multimedia content transmission	Published (12/2022)	ITU-T F.746.15 specifies requirements for smart broadband network gateway (BNG) in multimedia content transmission, which specifically describes the functional requirements and architecture, security requirements, typical application scenarios and use cases.

ITU-T	SG9	ITU-T J.1631	Functional requirements of E2E network platforms to enhance the delivery of cloud-VR services over integrated broadband cable networks	Published (11/2021)	ITU-T J.1631: This focuses on functional requirements of the end-to-end (E2E) network platform to deliver 360°/Virtual Reality (VR) video services from the video cloud to terminal devices, as well as the network requirements of cloud VR services, over integrated broadband cable networks. NOTE – Integrated broadband cable networks can be referred to as a cable network, e.g., coaxial cable, optical fibre, hybrid fibre coaxial (HFC), etc., that also has capability to provide broadband services integrated with television services over the same network.
ITU-T	SG9	ITU-T J.cloud-game-reg	Functional requirements of E2E network platforms to enhance the delivery of cloud-gaming services over integrated broadband cable networks	Under development	ITU-T J.cloud-game-req: This focuses on functional requirements of the end-to-end (E2E) network platform to deliver cloud-based gaming services from the video cloud to terminal devices over integrated broadband cable networks. NOTE – Integrated broadband cable networks can be referred to as a cable network, e.g., coaxial cable, optical fibre, and hybrid fibre coaxial (HFC), that also has capability to provide broadband services integrated with television services over the same network.
ITU-T	SG9	ITU-T J.cloud-ow	Requirements of E2E network platforms to enhance the delivery of cloud-based holography transmission services over integrated broadband cable networks	Under development	ITU-T J.cloud-ow: This focuses on requirements of the end-to-end (E2E) network platform to deliver object wave transmission to enable holography services from the cloud capability to terminal devices, as well as the network requirements, over integrated broadband cable networks. NOTE – Integrated broadband cable networks can be referred to as a cable network, e.g., coaxial cable, optical fibre, hybrid fibre coaxial (HFC), that also has the capability to provide broadband services integrated with television services over the same network.
ITU-T	SG13	ITU-T Y.3538	Cloud computing - Global management framework of distributed cloud	Published (09/2022)	ITU-T Y.3538 introduces the framework and functional requirements for the global management of distributed cloud.

ITU-T	SG13	ITU-T Y.3606	Big data - Deep packet inspection mechanism for big data in network	Published (12/2021)	ITU-T Y.3606 includes an introduction to the differences between generic deep packet inspection (DPI) and big data DPI, an overview of big data processing procedure and various aspects of DPI applied in big data.

7.4.5 Storage infrastructure

N/A

7.4.6 Computing power infrastructure

Table 7-18 provides the metaverse standards related to computing power infrastructure. SDOs associated with this category of metaverse standards include ISO/IEC, ITU-T and W3C.

Table 7-18: Metaverse standards related to computing power infrastructure

SDO	Study group	Reference	Title	Status	Abstract
ISO/IEC	JTC 1/SC 38	ISO/IEC 19944 (series)	Cloud computing and distributed platforms - Data flow, data categories and data use	Published	ISO/IEC 19944 series provides standards in the field of cloud computing and distributed platforms, and contains following parts: – ISO/IEC 19944-1:2020: Cloud computing and distributed platforms - Data flow, data categories and data use - Part 1: Fundamentals – ISO/IEC 19944-2:2022: Cloud computing and distributed platforms - Data flow, data categories and data use - Part 2: Guidance on application and extensibility
ISO/IEC	JTC 1/SC 38	ISO/IEC TR 23613:2020	Information technology - Cloud computing - Cloud service metering	Published	ISO/IEC TR 23613:2020 describes a sample set of cloud service metering elements and billing modes

			elements and billing modes		
ITU-T	SG13	ITU-T Y.3510	Cloud computing infrastructure requirements	Published (02/2016)	ITU-T Y.3510 provides requirements for cloud computing infrastructure; these include the essential capabilities for processing, storage and networking resources, as well as the capabilities of resource abstraction and control.
ITU-T	SG13	ITU-T Y.3535	Cloud computing - Functional requirements for a container	Published (02/2022)	ITU-T Y.3535 provides an overview and functional requirements for a container in cloud computing. It describes the technical aspects of a container and provides the relationship between containers and cloud computing. It also provides functional requirements for a container in terms of its engine, management system and cloud computing support.
ITU-T	SG13	ITU-T Y.3600	Big data - Cloud computing-based requirements and capabilities	Published (11/2015)	ITU-T Y.3600 provides requirements, capabilities and use cases of cloud computing based big data, as well as its system context. Cloud computing based big data provides the capabilities to collect, store, analyse, visualize and manage varieties of large volume datasets, which cannot be rapidly transferred and analysed using traditional technologies.
ISO/IEC	JTC 1/SC 38	ISO/IEC 22123-3	Cloud computing — Part 3: Reference architecture	Published	This document specifies the Cloud Computing Reference Architecture (CCRA). It outlines a comprehensive framework that describes the essential components and relationships within a cloud computing environment. The CCRA provides a detailed and systematic approach to structuring cloud computing solutions, aiming to ensure interoperability, scalability, and security across various cloud services and infrastructure. This architecture serves as a guideline for

					developers, providers, and users to design, implement, manage, and use cloud computing services effectively.
ISO/IEC	JTC 1/SC 38	ISO/IEC 19086 (series)	Information technology - Cloud computing - Service level agreement (SLA) framework	Published	ISO/IEC 19086 series provides standards related to service level agreement (SLA) framework in cloud computing and contains following parts: – ISO/IEC 19086-1:2016: Information technology - Cloud computing - Service level agreement (SLA) framework - Part 1: Overview and concepts – ISO/IEC 19086-2:2018: Cloud computing - Service level agreement (SLA) framework - Part 2: Metric model – ISO/IEC 19086-3:2017: Information technology - Cloud computing - Service level agreement (SLA) framework - Part 3: Core conformance requirements – ISO/IEC 19086-4:2019: Cloud computing - Service level agreement (SLA) framework - Part 4: Components of security and of protection of PII
ISO/IEC	JTC 1/SC 38	ISO/IEC TR 23188:2020	Information technology - Cloud computing - Edge computing landscape	Published	ISO/IEC TR 23188:2020 examines the concept of edge computing, its relationship to cloud computing and IoT, and the technologies that are key to the implementation of edge computing.
W3C	W3C GPU for the Web WG	WebGPU https://www.w3.org/TR/webgpu/	WebGPU	Under development	WebGPU exposes an API for performing operations, such as rendering and computation, on a Graphics Processing Unit.

8 Analysis of relevance to the metaverse

This clause provides the metaverse standards selected from Clause 7 that are closely related to or can be utilized in the metaverse, along with an analysis of their relevance based on the metaverse definition.

8.1 General standards

8.1.1 Framework, terminology and definitions

Table 8-1 provides the metaverse standards selected from Table 7-1 that are closely related to or can be utilized in the metaverse, along with an analysis of their relevance.

Table 8-1: Selected metaverse standards from Table 7-1 and their relevance to metaverse

SDO	Study group	Reference	Title	Status	Relevance to the metaverse
IEEE	MWG	IEEE P2048™	Standard for Metaverse: Terminology, Definitions and Taxonomy	Under development	This draft standard is applicable to the metaverse as it specifically addresses metaverse terminology, definitions, and taxonomy, which are crucial for understanding and structuring the complex and varied components of the metaverse ecosystem.
IEEE	MEWG	IEEE P7016™	Standard for Ethically Aligned Design and Operation of Metaverse Systems	Under development	This draft standard, IEEE P7016™, is relevant for application in metaverse systems because it explicitly aims to provide guidelines for ethically aligned design and operation of these systems.
ISO/IEC	JTC 1/SC 29	ISO/IEC 23005-6:2019	Information technology - Media context and control - Part 6: Common types and tools	Published	This standard, ISO/IEC 23005-6:2019, is applicable to the metaverse due to its provisions for interoperability and definitions of data types and tools that can be incorporated into virtual environments to enable consistent interaction between devices and systems across different virtual realms.
ISO/IEC	JTC 1/SC 24	ISO/IEC 18026	Spatial Reference Model (SRM)	Published	This standard, ISO/IEC 18026, can be effectively utilized in the development of metaverses, due to its detailed specifications on position, location, and the geometric properties necessary for aligning virtual environments with their physical counterparts. By providing a framework for precise and unambiguous spatial information, it supports the

					creation of interconnected and interoperable virtual worlds that mirror the real world.
ISO/IEC	JTC 1/SC 29	ISO/IEC 23005-6	Media context and control - Part 6: Common types and tools	Published	This standard is relevant to the metaverse as it defines data types and tools that can be used for creating interoperable and consistent virtual environments. By providing a framework for data interaction, it facilitates the development of complex, synchronized virtual worlds, enhancing connectivity and interoperability within these digital spaces.
ISO/IEC	JTC 1/SC 38	ISO/IEC 22123-1	Cloud computing —Part 1: Vocabulary	Published	This standard is applicable to the metaverse as it defines “metaverse” specifically, emphasizing its significance in creating immersive virtual worlds that reflect or are associated with the physical world, which suggests direct relevance to metaverse concepts and applications.
ISO/IEC	JTC 1/SC 38	ISO/IEC 22123-2	Cloud computing —Part 2: Concepts	Published	This standard can be applied to the metaverse because it facilitates a foundation for interoperability and communication across various virtual platforms, essential for building integrated and connected environments..
ISO/IEC	JTC 1/SC 38	ISO/IEC 19086	Cloud service level agreement (SLA) framework	Published	This standard directly relates to the metaverse concept as it provides crucial framework for Service Level Agreements that could govern the quality and reliability of services within the metaverse, implementing consistent and reliable interactions across different virtual environments.
ISO/IEC	JTC 1/SC 38	ISO/IEC 23751	Data sharing agreement (DSA) framework	Published	This standard can be applicable to the metaverse as it involves data sharing agreements which are critical in environments where data is exchanged continuously across different platforms such as the interconnected virtual and augmented worlds within a metaverse.
ISO/IEC	JTC 1/SC 38	ISO/IEC AWI 19274	Networking in cloud computing and edge computing	Under development	This draft standard potentially applies to the metaverse because it outlines foundational concepts for networking and interoperability, which are crucial for the exchange of data

					and interaction within the integrated ecosystems of virtual worlds.
ISO/IEC	JTC 1/SC 38	ISO/IEC TS 5928	Taxonomy for digital platforms	Published	This standard is applicable to the metaverse because it involves a taxonomy for digital platforms, which are foundational to constructing virtual and augmented environments that align with the definitions and components of a metaverse.
ISO/IEC	JTC 1/SC 38	ISO/IEC TR 23951:2020	Information technology - Cloud computing - Guidance for using the cloud SLA metric model	Published	This standard, ISO/IEC TR 23951:2020, may not explicitly focus on the metaverse as it is concerned with using the ISO/IEC 19086-2 metric model; however, if the metaverse applications involve the quantification of performance and service levels within digital transactions, it could potentially be applied.
ISO/IEC	JTC 1/SC 42	ISO/IEC 22989	Information technology — Artificial intelligence — Artificial intelligence concepts and terminology	Published	This standard is applicable to the metaverse as it provides terminology and concepts that are essential for understanding and developing technologies within virtual environments, allowing for a consistent framework crucial for the development and interoperability of different virtual worlds.
ISO/IEC	JTC 1/SC 42	ISO/IEC 20546:2019	Information technology - Big data - Overview and vocabulary	Published	This standard, ISO/IEC 20546:2019, provides terms and definitions pertinent to big data, not directly related to the metaverse concepts, making it a more generalized standard applicable primarily to big data frameworks rather than the specifically detailed and different technological and conceptual underpinnings of the metaverse as defined. Hence, it is marked “X” for this inquiry.
ITU	FG-MV	FGMV-02	Metaverse: an analysis of definitions	Approved deliverable	This pre-standards document is applicable to the metaverse because it analyses the major aspects of metaverse definitions from: (i) the perspective of academics, (ii) the business initiative approach, and (iii) international organization collaborations, with the final aim of establishing a concrete definition for metaverse that can be used worldwide.

ITU	FG-MV	FGMV-20	Definition of metaverse	Approved deliverable	This pre-standards document can be utilized for the metaverse as it defines the term “metaverse”, which is vital for metaverse implementation, ensuring technical consistency and interoperability within virtual environments.
ITU	FG-MV	FGMV-21	Principles for building concepts and definitions related to metaverse	Approved deliverable	This pre-standards document is applicable to the metaverse as it outlines methodologies to develop fundamental terms and definitions that form the basis for virtual ecosystems, such as those in the metaverse, facilitating clear communication and collaboration among different entities within this space.
ITU	FG-MV	FGMV-24	A framework for confidence in the metaverse	Approved deliverable	This pre-standards document can be applied to the metaverse as it defines metaverse security and safety in the context of user confidence. It also develops a new framework to establish an understanding of metaverse participation that defines new user-centric terms related to metaverse use and non-use.
ITU	FG-MV	FGMV-25	Near-term and long-term Implications for people in the metaverse	Approved deliverable	This pre-standards document directly relates to the metaverse as it explores the near-term and long-term implications of the metaverse from the perspective of its potential as the future of the Internet through historical and present-day observations. It provides the history of the metaverse as part of the history of the Internet; collects present day perspectives and experiences through in-depth interviews; and presents these insights and analysis as a framework for understanding potential near-term and long-term implications, and a broad guide for maximising the benefits of the metaverse and minimising its associated risks.
ITU-T	SG20	ITU-T Y.4000/Y.2060	Overview of the Internet of Things	Published (06/2012)	This standard ITU-T Y.2060 is applicable to the metaverse as it addresses interconnectivity and interoperability within the Internet of Things (IoT), which are crucial for the seamless integration of virtual and physical systems characterizing

					environments. Additionally, it provides a framework that could support the complex interactions and connectivity required in metaverse ecosystems.

8.1.2 Inclusive city development

Table 8-2 provides the metaverse standards selected from Table 7-2 that are closely related to or can be utilized in the metaverse, along with an analysis of their relevance.

Table 8-2: Selected metaverse standards from Table 7-2 and their relevance to metaverse

SDO	Study group	Reference	Title	Status	Relevance to the metaverse
ITU	FG-MV	FGMV-18	Guidance on how to build a metaverse for all – Part I: Legal Framework	Approved deliverable	This pre-standards document is directly applicable to the metaverse as it identifies key challenges that hinder the achievement of equity, accessibility, and inclusivity within the metaverse, and proposes potential roadmaps towards constructing a metaverse that leaves no one behind.

8.1.3 Evaluation

Table 8-3 provides the metaverse standards selected from Table 7-3 that are closely related to or can be utilized in the metaverse, along with an analysis of their relevance.

Table 8-3: Selected metaverse standards from Table 7-3 and their relevance to metaverse

SDO	Study group	Reference	Title	Status	Relevance to the metaverse
ISO/IEC	JTC 1/SC 37	ISO/IEC 19794 (series)	Information technology - Biometric data interchange formats	Published	This standard is applicable to the metaverse as it supports immersive user experiences and integrates with virtual environments like those required for operating and synchronizing virtual and physical worlds, ensuring connectivity and interoperability among devices and systems.

8.1.4 Sustainability

Table 8-4 provides the metaverse standards selected from Table 7-4 that are closely related to or can be utilized in the metaverse, along with an analysis of their relevance.

Table 8-4: Selected metaverse standards from Table 7-4 and their relevance to metaverse

SDO	Study group	Reference	Title	Status	Relevance to the metaverse
ITU	FG-MV	FGMV-01	Exploring the metaverse: opportunities and challenges	Approved deliverable	This pre-standards document is relevant to the metaverse as it explores the opportunities and challenges and clarifies the role of international standards and the potential for the metaverse in the achievement of the United Nations Sustainable Development Goals.
ITU	FG-MV	FGMV-08	Design criteria and technical requirements for sustainable metaverse ecosystems	Approved deliverable	This pre-standards document appears applicable to the metaverse as it directly references and defines the term "metaverse," suggesting that it pertains to the structural and functional aspects of creating and managing interconnected virtual environments, which align with the overarching concept of a metaverse.

8.1.5 Security

Table 8-5 provides the metaverse standards selected from Table 7-5 that are closely related to or can be utilized in the metaverse, along with an analysis of their relevance.

Table 8-5: Selected metaverse standards from Table 7-5 and their relevance to metaverse

SDO	Study group	Reference	Title	Status	Relevance to the metaverse
IETF	T2TRG	RFC 8576	Internet of Things (IoT) Security: State of the Art and Challenges	Published	This standard, RFC 8576, could be crucial for the metaverse, as it enhances the security of interconnected devices and infrastructure, integral to ensuring a seamless and safe virtual environment synchronized with physical counterparts.

ISO/IEC	JTC 1/SC 27	ISO/IEC TR 5891	Information security, cybersecurity and privacy protection-Hardware monitoring technology for hardware security assessment	Published	This standard can be applied to the metaverse as it deals with core processing hardware like CPUs, MCUs, and SoCs, which are essential for the complex computations and processing required in virtual environments such as metaverses.
ISO/IEC	JTC 1/SC 27	ISO/IEC TR 6114	Cybersecurity-Security considerations throughout the product life cycle	Published	This standard can be applied to the metaverse as it sets a framework for security considerations that are crucial in managing and protecting virtual worlds and their interfaces with the physical world, ensuring a secure and reliable experience.
ISO/IEC	JTC 1/SC 27	ISO/IEC 27001	Information security, cybersecurity, and privacy protection-Information security management systems-Requirements	Published	This standard can be utilized in the metaverse because ISO/IEC 27001 helps ensure the security management of data and systems that underpin the infrastructure of virtual and augmented worlds. It promotes the secure integration of technologies, crucial for the interconnected and interoperable environments.
ISO/IEC	JTC 1/SC 38	ISO/IEC PWI (NP) 11034	Trustworthiness in cloud computing	Under development	This draft standard can be utilized within the metaverse because the term “metaverse” explicitly appears in the description, signifying a direct relevance to virtual environments that integrate into physical counterparts.
ISO/IEC	JTC 1/SC 38	ISO/IEC PWI (NP) 20996	Cloud service customer business continuity and resilience	Under development	This draft standard can be applied to the metaverse as it involves an integrative ecosystem of virtual worlds, which aligns with the principles of connectivity and interoperability essential for creating seamless experiences in metaverses.
ITU	FG-MV	FGMV-10	Cyber risks, threats, and harms in the metaverse	Approved deliverable	This pre-standards document is applicable to the metaverse because it defines an ecosystem of virtual worlds, which includes aspects such as virtual and augmented realities directly related to the metaverse

					concept, emphasizing connectivity and interoperability in a digital realm.
ITU	FG-MV	FGMV-06	Guidelines for consideration of ethical issues in standards that build confidence and security in the metaverse	Approved deliverable	This pre-standards document is applicable to the metaverse because it defines the concept of confidence in the metaverse by introducing a new Confidence Framework for the metaverse. It also identifies existing pillars for building confidence and security in the metaverse and explores new considerations for immersive environments. Finally, it develops user-centric guidelines for inclusion of ethical issues in standards that build confidence and security in the metaverse and establishes the value of global standards including the Universal Declaration of Human Rights and the Sustainable Development Goals in enabling these guidelines.
ITU	FG-MV	FGMV-11	Embedding safety standards and the user control of Personally Identifiable Information (PII) in the development of the metaverse	Approved deliverable	This pre-standards document is applicable to the metaverse as it addresses human rights, data ownership and agency of users in relation to their service and platform provider. It also develops principles for the development of safety standards in line with the SDGs.
ITU	FG-MV	FGMV-12	Children's age verification in the metaverse	Approved deliverable	This pre-standards document explores age verification methods in the context of the metaverse, focusing on the potential enhancement of these methods using metaverse technologies. It reviews existing regulations and provides recommendations. It also proposes general guidelines for third-party age verification solutions to protect children from online threats, while preserving privacy and ensuring interoperability and scalability.

ITU	FG-MV	FGMV-23	Considering online and offline implications in efforts to build confidence and security in the metaverse	Approved deliverable	This pre-standards document is applicable to the metaverse as it explores online and offline implications in efforts to build confidence and security in the metaverse by: • Analysing the evolution of the Internet and corresponding evolution in associated risks and harms related to its use and non-use. • Presenting the metaverse as a paradigm shift in user engagement across a defined bidirectional physical-digital range. • Providing a real-world example illustrating the impact of digital inequalities on user participation.
ITU	FG-MV	FGMV-14	Regulatory and economic aspects in the metaverse: Data protection-related	Approved deliverable	This pre-standards document is applicable to the metaverse because it addresses the critical data protection concerns necessary for the regulatory and economic activities within the metaverse. It provides a structured analysis through the 'Life Cycle of Data Threat Model,' identifying threats at various stages of the data lifecycle—generation, transfer, usage, sharing, storage, archival, and destruction. Additionally, it offers a data protection assessment framework to evaluate threat levels, enabling the prioritization of policy measures to ensure secure and efficient operations in the metaverse.
ITU-T	SG17	TR.cs-sc	Technical Report: Collection of Security Concerns for extracting the Security Requirements for Cyber Security Reference Architecture	Under development	This draft standard directly supports metaverse infrastructures by emphasizing interconnected and secure digital networks, which are fundamental for creating reliable and immersive virtual environments synced with physical counterparts.
ITU-T	SG17	TR.cs-uc	Technical Report: Use cases for extracting the security	Under development	This draft standard is applicable to the metaverse because it addresses the architectural and security challenges

			requirements for cyber security reference architecture		inherent in creating interconnected, virtual environments like those in the metaverse, ensuring these virtual spaces are secure and resilient.
ITU-T	SG17	X.cs-ra	Cyber security reference architecture	Under development	This draft standard can be utilized for the metaverse as it addresses comprehensive security architecture and reference models critical for securing virtual environments, integral to building trustworthy and resilient metaverse ecosystems.
ITU-T	SG17	ITU-T X.1054	Information security, cybersecurity and privacy protection - Governance of information security	Published	This standard can be applied to the metaverse because it emphasizes the need for governance and security, essential in maintaining the integrity and reliability of virtual worlds like the metaverse, where data and user interactions need protection from threats.
ITU-T	SG17	ITU-T X.1051	Information security, cybersecurity and privacy protection - Information security controls based on ISO/IEC 27002 for telecommunications organizations	Published	This standard can be applied to the metaverse because it addresses the security of information systems that could span virtual and augmented environments, ensuring the protection of data within interconnected and immersive digital platforms. By securing these virtual spaces, the standard supports the safe and reliable integration of virtual and physical worlds in the metaverse.
ITU-T	SG17	ITU-T X.1603	Data security requirements for the monitoring service of cloud computing	Published (03/2018)	This standard can be applied to the metaverse because it provides guidelines on securing data, an essential aspect when managing interconnected virtual environments like those in the metaverse, where vast amounts of sensitive monitoring data are generated and exchanged.
ISO/IEC	JTC 1/SC 29	ISO/IEC 23090 10:2022	Coded representation of immersive media - Part 10: Carriage of visual volumetric video-based coding data	Published	This standard is applicable to metaverse environments .because it supports the management of distributed applications, which are crucial in managing the complex interactions and integrations across diverse virtual platforms and physical infrastructures that characterize metaverses. By providing a framework for

					runtime management, it also facilitates the rigorous coordination required in such integrative and expansive digital ecosystems.

8.1.6 Accessibility

Table 8-6 provides the metaverse standards selected from Table 7-6 that are closely related to or can be utilized in the metaverse, along with an analysis of their relevance.

Table 8-6: Selected metaverse standards from Table 7-6 and their relevance to metaverse

SDO	Study group	Reference	Title	Status	Relevance to the metaverse
ITU	FG-MV	FGMV-03	Guidelines to assess inclusion and accessibility in metaverse standard development	Approved deliverable	This pre-standards document is relevant to the metaverse as it directly includes the term “metaverse” and outlines an integrative ecosystem of virtual worlds, which are key components of the metaverse concept, providing a framework for immersive user experiences that align with the definitions and functionalities expected in metaverse environments.
ITU	FG-MV	FGMV-04	Requirements of accessible products and services in the metaverse: Part I – System design perspective	Approved deliverable	This pre-standards document is applicable to the metaverse as it specifically addresses accessibility in virtual and augmented worlds, which are core components of the metaverse ecosystem. The focus on interoperability and connectivity aligns with the dynamic and integrated nature of metaverse environments.
ITU	FG-MV	FGMV-05	Requirements of accessible products and services in the metaverse: Part II – User perspective	Approved deliverable	This pre-standards document is applicable to the metaverse as it defines processes crucial for creating an inclusive virtual environment, directly addressing accessibility, which is essential in ensuring that all users, regardless of their physical or cognitive abilities, can interact within these digital spaces effectively.

ITU	FG-MV	FGMV-16	Accessibility in a sustainable metaverse	Approved deliverable	This pre-standards document can be utilized in the metaverse because it outlines necessary frameworks for integrating accessibility and sustainability within virtual environments, matching the dynamic and complex nature of metaverses which are designed to be integrative and connected ecosystems.
ITU	FG-MV	FGMV-17	Guidelines and requirements on interpreting in the metaverse	Approved deliverable	This pre-standards document is applicable to the metaverse as it explicitly includes the term “metaverse” and outlines interpreting services across various virtual environments, which are integral components of the metaverse ecosystem. The application of such standards ensures effective communication, thereby supporting the immersive and interactive nature of metaverse platforms.
ITU	FG-MV	FGMV-26	Requirements for communication between human-avatar languages in the metaverse	Approved deliverable	This pre-standards document is applicable to the metaverse as it addresses communication architectures that are essential for interactions within virtual worlds, which integrates virtual and physical counterparts seamlessly.
ITU	FG-MV	FGMV-15	Accessibility requirements for metaverse services supporting IoT	Approved deliverable	This pre-standards document is relevant to the metaverse because it specifies accessibility requirements for metaverse services supporting IoT, ensuring inclusivity for users with disabilities, which aligns with the immersive and integrative ecosystem of a metaverse as defined.
ITU-D	SG1	1/225-E	Brain-computer interface technology facilitates information accessibility for special populations	Under development	This draft standard is applicable to the metaverse, which is a type of metaverse with connected virtual and physical worlds, directly relating to the immersive and interconnected environment described in the metaverse definition.
W3C	W3C Accessible Platform	SAUR https://www.w3.org/TR/saur/	Synchronization Accessibility User Requirements	Published (06/2023)	This standard is applicable to the metaverse as it ensures that the multimedia components within these virtual environments, such as audio and visual synchronization, operate seamlessly and inclusively, enhancing the interactive

	Architectures WG				experiences of users from various backgrounds, including those with accessibility needs. Thus, its relevance to the metaverse, particularly immersive platforms, is grounded in its focus on a synchronized and accessible digital interaction.
W3C	W3C Accessible Platform Architectures WG	NAUR https://www.w3.org/TR/naur/	Natural Language Interface Accessibility User Requirements	Under development	This draft standard can be utilized in the metaverse as it outlines interoperability requirements, which are crucial for connecting various systems and devices. By ensuring seamless integration across different platforms, it supports the foundational concept of the metaverse where virtual and physical worlds converge.
W3C	W3C Accessible Platform Architectures WG	RAUR https://www.w3.org/TR/raur/	RTC Accessibility User Requirements	Published (05/2021)	This standard can be applied to the metaverse as it specifically mentions the term “metaverse”, indicating a direct relevance in providing guidelines or frameworks that could shape the development or implementation of metaverse technologies or platforms.
W3C	W3C Accessible Platform Architectures WG	Accessibility of Remote Meetings https://www.w3.org/TR/remote-meetings/	Accessibility of Remote Meetings	Published (07/2022)	This standard is relevant to the metaverse as it focuses on accessibility considerations for remote and hybrid meetings which are essential for integrating inclusive communication channels within virtual environments like those found in a metaverse, ensuring equal participation opportunity.
W3C	W3C Accessible Platform Architectures WG	Making Content Usable for People with Cognitive and Learning	Making Content Usable for People with Cognitive and Learning Disabilities	Published (04/2021)	This standard is applicable to the metaverse, a type of metaverse interconnected with physical counterparts, emphasizing the seamless integration and interoperability of virtual and physical entities, which is central to metaverse environments.

		Disabilities https://www.w3.org/TR/coga-usable/			
W3C	W3C Accessible Platform Architectures WG	MAUR https://www.w3.org/TR/media-accessibility-reqs/	Media Accessibility User Requirements	Published (12/2015)	This standard can be applied to the metaverse because the term “metaverse” itself suggests a connection with emerging virtual environments that require universal design principles to ensure accessibility for users with disabilities.
W3C	W3C Accessible Rich Internet Applications WG	Core AAM https://www.w3.org/TR/core-aam-1.2/	Core Accessibility API Mappings 1.2	Under development	This draft standard is relevant to the metaverse as it ensures accessibility in virtual environments, crucial for inclusivity in the integrative ecosystems described in the metaverse definition, allowing users with disabilities to engage fully in these digital spaces.
W3C	W3C Accessible Rich Internet Applications WG	Graphics AAM https://www.w3.org/TR/graphics-aam-1.0/	Graphics Accessibility API Mappings	Published (10/2018)	This standard could be beneficial for the metaverse as it ensures that virtual environments, which may include complex graphic interactions, are accessible to all users, including those with disabilities. This enhances the universality and inclusivity of metaverse platforms, aligning with the expansive and integrated nature of such digital worlds.
W3C	W3C Accessible Rich Internet Applications WG	WAI-ARIA 1.1 https://www.w3.org/TR/wai-aria-1.1/	WAI-ARIA Rich Internet Applications 1.1	Published (12/2017)	This standard can be utilized in the metaverse as it provides essential guidelines for enhancing user interface accessibility, which is crucial in the immersive, interactive environments of the metaverse platforms. By ensuring that virtual and augmented worlds are accessible, the standard supports the integration of diverse user needs, fostering inclusivity and usability in these advanced digital ecosystems.

8.2 Application and service standards

Table 8-7 provides the metaverse standards selected from Table 7-7 that are closely related to or can be utilized in the metaverse, along with an analysis of their relevance.

Table 8-7: Selected metaverse standards from Table 7-7 and their relevance to metaverse

Subcategory	SDO	Study group	Reference	Title	Status	Relevance to the metaverse
City Governance	ITU	FG-MV	FGMV-07	Policy and regulation opportunities and challenges in the metaverse	Approved deliverable	This pre-standards document directly pertains to the metaverse as it defines the framework and guiding principles for virtual worlds that interact closely with real-world environments, emphasizing connectivity and interoperability essential for the functioning of such complex digital ecosystems.
City Governance	ISO/IEC	JTC 1/SC 24	ISO/IEC TS 5147	Guidelines for Representation and Visualization of Smart Cities	Published	This standard is applicable to the metaverse because it involves the representation and visualization of complex city environments, which align closely with the structures needed in the construction of Smart cities, enhanced through principles of connectivity and interoperability. The standard's focus on integrating both physical and semantic data can directly support the development of metaverse environments that combine real-world elements with augmented features.
Education	ITU-T	SG16	ITU-T F.742.1	Requirements for smart class systems based on artificial intelligence	Published	This standard can be applied to the metaverse because it involves the integration and synchronization of virtual worlds with their physical counterparts.
Education	ISO/IEC	JTC 1/SC 29	ISO/IEC 21000-20:2016	Multimedia framework (MPEG 21) - Part 20:	Published	This standard, ISO/IEC 21000-20:2016, could be beneficially applied to the metaverse concept, as it provides a structured framework for interoperability and data exchange, which are key components in developing

				Contract Expression Language		interconnected virtual environments like those envisaged in metaverses.
Environmental protection	ISO/IEC	JTC 1/SC 24	ISO/IEC 18023-1	SEDRIS – Part 1: Functional specification	Published	This standard can facilitate the metaverse by providing a structured format for the exchange of environmental data, which is essential in constructing dynamic, virtual worlds that accurately reflect or interact with the physical world.
Environmental protection	ISO/IEC	JTC 1/SC 24	ISO/IEC 18024-4	SEDRIS language bindings – Part 4: C	Published	This standard could be utilized in the metaverse as it offers a sophisticated framework for data interchange and representation, which is crucial in the creation and management of interconnected virtual environments like those in the metaverse. Specifically, SEDRIS aids in managing complex environmental data which is fundamental for building realistic and interactive virtual worlds that mirror the physical ones.
Power energy	ITU	FG-MV	FGMV-09	Power metaverse: Use cases relevant to grid side and user side	Approved deliverable	This pre-standards document can be applied to a a metaverse, which is a type of metaverse closely linked to real-world city infrastructures enabling virtual and physical synchronizations, enhancing connectivity, and interoperability among users and systems.
Power energy	ITU	FG-MV	FGMV-27	Guidelines for metaverse application in power system	Approved deliverable	This pre-standards document can be utilized in the metaverse as it outlines an integrative ecosystem of virtual worlds that enrich user experiences, having explicit connections with economic, environmental, social, and cultural dimensions, all of which are core components of the metaverse.
-	3GPP	SA1	TR 22.856	Study on Localized Mobile Metaverse Services (Release 19)	Under change control	This draft standard is applicable to the metaverse because it includes specific references to metaverse technologies and explains the integration of virtual and physical worlds, which aligns with the definitions and functions of a metaverse, emphasizing connectivity and

						interoperability essential for these immersive environments.
-	ISO/IEC	JTC 1/SC 24	ISO/IEC 19775-2	Extensible 3D (X3D) — Part 2: Scene access interface (SAI)	Published	This standard is applicable to the metaverse as it defines a scene access interface for interacting with 3D worlds, which aligns with the concept of immersive virtual environments described in the definition of a metaverse. The interactiveness and universal interchange format supported by X3D can crucially contribute to creating and managing the complex, interconnected virtual spaces that are fundamental to metaverse ecosystems.
-	ITU-T	SG16	ITU-T H.430.3	Service scenario of immersive live experience (ILE)	Published (08/2018)	This standard is applicable to the metaverse as it supports the development of immersive live experience (ILE) services, which are integral to creating engaging, interactive virtual environments similar to those found in a metaverse. Especially with the focus on immersive experiences and the inclusion of environments synchronized with physical counterparts, this standard plays a crucial role in shaping how these virtual experiences are implemented and interconnected.

8.3 Enabling technology standards

8.3.1 Virtual reality & Augmented reality

Table 8-8 provides the metaverse standards selected from Table 7-8 that are closely related to or can be utilized in the metaverse, along with an analysis of their relevance.

Table 8-8: Selected metaverse standards from Table 7-8 and their relevance to metaverse

SDO	Study group	Reference	Title	Status	Relevance to the metaverse
IEC	TC 100	IEC TR 63308:2021	Virtual reality equipment and systems - Market,	Published	This standard can be applicable to the metaverse because it discusses virtual reality systems, which are integral to creating immersive environments in the metaverse.

			technology and standards requirements		
IEC	TC 110	IEC 63145-20-20:2019	Eyewear display - Part 20-20: Fundamental measurement methods - Image quality	Published	This standard, IEC 63145-20-20:2019, is applicable to metaverse technologies as it provides specifications for measuring image quality in eyewear displays used in VR and AR systems. These eyewear technologies are essential for realizing immersive experiences, a core component of metaverses. By ensuring high-quality visual performance, this standard supports the development of more realistic and effective virtual and augmented reality environments, crucial for the embodiment of the metaverse concept.
IEEE	AR-LEM WG	IEEE 1589-2020	IEEE Standard for Augmented Reality Learning Experience Model	Published	This standard, IEEE 1589-2020, can be applied to the metaverse due to its focus on defining interoperable data models for Augmented Reality, which are crucial for creating interconnected and seamless experiences in virtual environments that mimic or link with the physical world. By facilitating the exchange of AR learning content and the integration of real and digital information, IEEE 1589-2020 supports the creation of immersive, real-time learning and operational environments.
ISO/IEC	JTC 1/SC 24	ISO/IEC 14772-1:1997	Information technology - Computer graphics and image processing - The Virtual Reality Modelling Language - Part 1: Functional specification and UTF-8 encoding	Published	This standard, ISO/IEC 14772, can be effectively used in the metaverse as it defines a file format for integrating 3D graphics and multimedia in interactive environments, which are core elements in creating immersive virtual worlds like those found in metaverses.

ISO/IEC	JTC 1/SC 24	ISO/IEC 14772-2:2004	Information technology - Computer graphics and image processing - The Virtual Reality Modelling Language (VRML) - Part 2: External authoring interface (EAI)	Published	This standard, ISO/IEC 14772-2:2004, can be applied to the metaverse as it defines how external applications interact with VRML browsers, which are essential for creating and managing immersive digital environments synonymous with metaverses, where synchronization with physical counterparts is crucial.
ISO/IEC	JTC 1/SC 24	ISO/IEC 18038:2020	Information technology - Computer graphics, image processing and environmental representation - Sensor representation in mixed and augmented reality	Published	This standard, ISO/IEC 18038:2020, can be considered applicable to the metaverse as it facilitates the integration of 3D virtual worlds with physical sensors, helping to bridge digital environments and the real world, which is a core aspect of metaverse ecosystems.
ISO/IEC	JTC 1/SC 24	ISO/IEC TS 23884:2021	Information technology - Computer graphics, image processing and environmental data representation - Material property and parameter representation for model-based haptic simulation of objects in virtual, mixed and augmented reality (VR/MAR)	Published	This standard, ISO/IEC TS 23884:2021, is relevant to the metaverse because it specifies parameters like stiffness, friction, and micro-textures that are crucial for creating realistic and immersive virtual environments, aligning with the interactivity and realism sought in metaverse ecosystems.

ISO/IEC	JTC 1/SC 24	ISO/IEC 23488:2022	Information technology - Computer graphics, image processing and environment data representation - Object/environmental representation for image-based rendering in virtual/mixed and augmented reality (VR/MAR)	Published	This standard, ISO/IEC 23488:2022, can effectively be utilized within the metaverse because it allows for a detailed and accurate representation of objects and environments from various viewpoints, which are essential for creating immersive and interactive virtual worlds that align with physical reality.
ISO/IEC	JTC 1/SC 24	ISO/IEC 19775-1:2013	Information technology - Computer graphics, image processing and environmental data representation - Extensible 3D (X3D) - Part 1: Architecture and base components	Published	ISO/IEC 19775-1:2013 is applicable to the metaverse as it sets a framework for 3D graphics and multimedia in networked environments, making it instrumental in creating immersive virtual worlds that align with metaverse concepts. This standard facilitates the integration of 3D environments with interactive experiences, directly supporting the foundational elements of the metaverse by ensuring dynamic modification and connectivity in virtual spaces.
ISO/IEC	JTC 1/SC 36	ISO/IEC TR 23842 (series)	Information technology for learning, education and training - Human factor guidelines for virtual reality content	Published	This standard, ISO/IEC TR 23842, is directly applicable to the metaverse as it provides guidelines for human factors in VR content used in learning, education, and training. ISO/IEC TR 23842-1 and -2 ensure that VR content minimizes confusion between reality and the virtual world, crucial for immersive metaverse environments where interactions are meant to be seamless and intuitive. By aligning virtual experiences more closely with human perceptual expectations, this standard supports the

					development of more effective and engaging virtual environments, such as those found within a metaverse.
ISO/IEC	JTC 1/SC 24	ISO/IEC 3721:2023	Information technology — Computer graphics, image processing and environmental data representation — Information model for mixed and augmented reality content — Core objects and attributes	Published	This standard, ISO/IEC 3721:2023, directly supports the metaverse by defining an information model essential for creating and managing mixed and augmented reality scenes, which are fundamental components of metaverse environments.
ISO/IEC	JTC 1/SC 24	ISO/IEC AWI TR 16088	Constructs for visual positioning systems in mixed and augmented reality (MAR)	Under development	This draft standard, ISO/IEC AWI TR 16088, can be utilized in the metaverse as it focuses on constructs for visual positioning systems in mixed and augmented reality, essential technologies for creating immersive and integrated experiences in virtual environments.
ISO/IEC	JTC 1/SC 24	ISO/IEC 19775-1	Extensible 3D (X3D) — Part 1: Architecture and base components	Published	This standard, ISO/IEC 19775-1, is applicable to the metaverse as it facilitates the creation of 3D virtual worlds, essential for building immersive, interactive environments described in the metaverse definition. Since the metaverse requires dynamic and interconnected virtual spaces, this standard's ability to define and manage 3D objects and their interactions ensures compatibility and functionality within these complex virtual ecosystems.
ISO/IEC	JTC 1/SC 24	ISO/IEC 18038	Sensor representation in MAR (Mixed and Augmented Reality)	Published	This standard is applicable to the metaverse as it provides a framework for integrating 3D virtual worlds with physical sensors, enhancing the realism and immersion in virtual environments which are core components of metaverses.

ISO/IEC	JTC 1/SC 24	ISO/IEC 18039	MAR reference model	Published	This standard can be applied to the metaverse since it focuses on mixed and augmented reality systems, which are key technologies in creating immersive and integrated digital environments. Additionally, the standard's emphasis on interoperability and connectivity aligns well with the foundational principles of the metaverse that seek seamless interaction between virtual and physical worlds.
ISO/IEC	JTC 1/SC 24	ISO/IEC 18040	Live actor and entity representation in MAR	Published	This standard is applicable to the metaverse as it outlines frameworks and protocols for representing live actors and entities in mixed and augmented realities, integral components for creating immersive and interactive metaverse environments. By providing methods to integrate and manage 2D/3D virtual entities within these augmented spaces, it supports the functionality necessary for the dynamic and interconnected nature of metaverse ecosystems.
ISO/IEC	JTC 1/SC 24	ISO/IEC 3721	Information Model for Mixed and Augmented Reality (MAR) Contents	Published	This standard is applicable to the metaverse as it provides a framework for representing mixed and augmented reality contents that are integral to creating immersive virtual environments resembling or connected to the physical world. It allows for the spatial association and representation of physical objects in virtual settings, which is crucial in developing interconnected virtual and real-world experiences.
ISO/IEC	JTC 1/SC 24	ISO/IEC 18520	Benchmarking of vision-based spatial registration and tracking methods for mixed and augmented reality (MAR)	Published	This standard is applicable to the metaverse as it provides guidelines and benchmarks for vision-based spatial registration and tracking which are crucial in creating immersive, interactive environments integral to the functioning of virtual and augmented realities within the metaverse.

ISO/IEC	JTC 1/SC 24	ISO/IEC 21145	Style representation for mixed and augmented reality	Published	This standard is applicable to the metaverse because it outlines the styling of Mixed Augmented Reality (MAR) content, which is a fundamental component in creating immersive environments within virtual worlds associated with the metaverse. ISO/IEC 3721 specifically aids in defining how virtual objects, which are essential for a robust metaverse experience, are visually integrated and interact with the real world, enhancing the sense of immersion and functionality necessary for metaverse ecosystems.
ISO/IEC	JTC 1/SC 24	ISO/IEC TS 23884	Material property and parameter representation for model-based haptic simulation of objects in virtual, mixed, and augmented reality (VR/MAR)	Published	This standard is applicable to the metaverse as it involves the detailed description and modelling of virtual and mixed reality environments, which are core components of metaversal experiences. By defining material parameters and haptic rendering methods, it directly enhances the realism and interactivity of virtual objects in the metaverse, thus improving user experience and immersion.
ITU-T	SG11	ITU-T Q.4066	Testing procedures of augmented reality applications	Published (09/2020)	This standard directly relates to the metaverse because testing procedures for augmented reality applications are integral to the development and maintenance of the metaverse.
ITU-T	SG12	ITU-T G.1035	Influencing factors on quality of experience for virtual reality services	Published (11/2021)	This standard is relevant to the metaverse because the term “metaverse” is explicitly defined within the document, indicating that the standard considers the unique characteristics and needs of metaverse environments, focusing on immersive virtual experiences that are interconnected with real-world data and infrastructures.
ITU-T	SG12	ITU-T P.1320	Quality of experience assessment of	Published (07/2022)	This standard is applicable to the metaverse due to its focus on assessing quality of experience in telemeetings that employ extended reality technologies, which are

			extended reality meetings		integral to creating immersive and interactive environments in virtual worlds like those found in the metaverse.
ITU-T	SG12	ITU-T G.1036	Quality of experience influencing factors for augmented reality services	Published (07/2022)	This standard is deemed applicable to the metaverse as it explicitly refers to “metaverse” in the definition, suggesting its direct relevance in shaping components like virtual, augmented, and physical interconnected worlds.
ITU-T	SG13	ITU-T Y.3109	Quality of service assurance-related requirements and framework for virtual reality delivery using mobile edge computing supported by IMT-2020	Published (04/2021)	This standard is highly relevant to the metaverse as it outlines the delivery of VR services using mobile edge computing, which can enhance immersive experiences in virtual environments like those found in a metaverse, ensuring high-quality, real-time interactions.
ITU-T	SG16	ITU-T F.746.14	Requirements and reference framework for cloud virtual reality systems	Published (12/2022)	This standard can be utilized in the metaverse as it supports the intricate digital ecosystem described. It enables immersive and interoperable environments, crucial for seamless user experiences in virtual or augmented realities synonymous with metaverse concepts.
ITU-T	SG16	ITU-T F.740.2	Requirements and reference framework for digital representation of cultural relics and artworks using augmented reality	Published (06/2021)	This standard can be utilized in the metaverse because it defines an augmented reality cultural service system, which aligns with the metaverse's capacity for augmenting virtual experiences linked to cultural and historical contexts.
ITU-T	SG9	ITU-T J.301	Requirements for augmented reality smart television systems	Published (10/2014)	This standard specifically mentions and defines “augmented reality”, which implies its applicability to and relevance for metaverse technologies. By defining a system of virtual worlds that can interoperate and interact

					with the physical world, this standard supports the principles and goals of metaverse environments, facilitating integration and enhanced user experiences across virtual and physical realities.
ITU-T	SG9	ITU-T J.302 Amd 1	System specifications of augmented reality smart television service	Published (01/2019)	This standard is applicable to the metaverse because it explicitly includes the term “augmented reality”, indicating a focus on virtual, augmented environments that are interconnected with their physical counterparts. The emphasis on connectivity and interoperability aligns directly with the technological and social requisites of metaversal ecosystems.
ITU-T	SG9	ITU-T J.cloud-vr-arch	Architecture of E2E network platforms to enhance the delivery of cloud-VR services over integrated broadband cable networks	Under development	This draft standard, ITU-T J.cloud-vr-arch, is applicable to the metaverse as it outlines the architecture and network requirements for delivering immersive 360°/VR video services, which can be integral to creating realistic, interactive environments in a metaverse.
ISO/IEC	JTC 1/SC 29	ISO/IEC 21000 23:2022	Multimedia framework (MPEG 21) - Part 23: Smart Contracts for Media	Published	This standard can be utilized in the metaverse as it supports the integration of virtual and physical environments, crucial for creating immersive and interactive virtual worlds like those found in a metaverse. ISO/IEC 21000 23:2022 establishes frameworks for object recognition and spatial mapping, which are essential for syncing and overlaying virtual content on the physical world, thereby enhancing the user experience in metaverses.
W3C	W3C Accessible Platform	XAUR https://www.w3.org/TR/xaur/	XR Accessibility User Requirements	Published (08/2021)	This standard can be utilized in the metaverse because it addresses the integration and interoperability requirements, which are crucial for creating interconnected and harmonious virtual worlds.

	Architectures WG				
W3C	W3C GPU for the Web WG	WGSL https://www.w3.org/TR/WGSL/	WebGPU Shading Language	Under development	This draft standard can be relevant to the metaverse because it defines the shading language WGSL used in WebGPU, which is critical for rendering complex 3D graphics and virtual environments efficiently. Such technology is essential for creating realistic visual experiences in virtual worlds, aligning with the immersive nature of the metaverse where seamless interoperability and connectivity are key.
W3C	W3C Immersive Web WG	WebXR https://www.w3.org/TR/webxr/	WebXR Device API	Under development	This draft standard is applicable to the metaverse as it provides guidelines for creating interconnected, interoperable virtual environments that align with the principles underpinning the metaverse, where virtual and physical realms are integrated and modular experiences are enabled. Additionally, it supports the development of seamless interactions across various systems and devices within these immersive digital worlds.
W3C	W3C Immersive Web WG	WebXR-AR https://www.w3.org/TR/webxr-ar-module-1/	WebXR Augmented Reality Module - Level 1	Under development	This draft standard is applicable to the metaverse because it supports the development of interconnected virtual experiences that are essential for creating immersive environments in metaverses, by facilitating seamless interaction between users and digital content in augmented and virtual reality settings.
W3C	W3C Immersive Web WG	WebXR Depth Sensing https://www.w3.org/TR/webxr-depth-sensing-1/	WebXR Depth Sensing Module	Under development	This draft standard, which enhances the immersion of digital experiences by integrating depth sensing with virtual environments, can be directly applicable in a metaverse context where depth information enriches interaction and realism in virtual worlds,.

W3C	W3C Immersive Web WG	WebXR Dom Overlays https://www.w3.org/TR/webxr-dom-overlays-1/	WebXR DOM Overlays Module	Under development	This draft standard facilitates the integration of interactive 2D content in immersive environments, which is essential for developing user interfaces and applications in metaverse scenarios, where real-time interaction and information overlay in a simulated or enhanced reality are critical.
W3C	W3C Immersive Web WG	WebXR Gamepad https://www.w3.org/TR/webxr-gamepads-module-1/	WebXR Gamepad Module	Under development	This draft standard is related to the metaverse as it provides the necessary technology to interact with virtual environments through VR and AR devices, crucial for engaging in the immersive experiences that define metaverses.
W3C	W3C Immersive Web WG	WebXR Hand Input https://www.w3.org/TR/webxr-hand-input-1/	WebXR Hand Input Module	Under development	This draft standard, WebXR Hand Input, can be utilized in the metaverse as it supports immersive experiences through articulated hand poses, enhancing user interaction within virtual environments that replicate or augment the real world.
W3C	W3C Immersive Web WG	WebXR Hit Test https://www.w3.org/TR/webxr-hit-test-1/	WebXR Hit Test Module	Under development	This draft standard is applicable to the metaverse as it provides crucial infrastructure for blending virtual and real environments, essential for realistic interactions in metaverse scenarios.
W3C	W3C Immersive Web WG	WebXR Layers https://www.w3.org/TR/webxrlayers-1/	WebXR Layers API Level 1	Under development	This draft standard is relevant to the metaverse because it enhances the immersive experiences by supporting various types of layers in WebXR sessions, crucial for developing interactive and interconnected environments like those found in a metaverse.
W3C	W3C Immersive Web WG	WebXR Lightning Estimation https://www.w3.org/TR/webxr-lighting-estimation-1/	WebXR Lightning Estimation API Level 1	Under development	This draft standard on WebXR Lightning Estimation is applicable to the metaverse as it enhances virtual environments by accurately simulating real-world lighting, allowing these environments to offer more immersive and

					realistic experiences, aligned with the physical attributes of different times and places.
W3C	W3C Immersive Web WG	WebXR Anchors https://immersive-web.github.io/anchors/	WebXR Anchors Module	Under development	This draft standard relating to WebXR Anchors can be utilized in the metaverse as it allows for creating stable, real-time connections between virtual and physical environments, integral for overlaying augmented experiences onto the real world in systems, where virtual and physical synchronicity is essential.

8.3.2 Digital twin

Table 8-9 provides the metaverse standards selected from Table 7-9 that are closely related to or can be utilized in the metaverse, along with an analysis of their relevance.

Table 8-9: Selected metaverse standards from Table 7-9 and their relevance to metaverse

SDO	Study group	Reference	Title	Status	Relevance to the metaverse
ISO/IEC	JTC 1/SC 41	ISO/IEC AWI 30172	Digital Twin — Use cases	Under development	This darft standard, ISO/IEC AWI 30172, is applicable to the metaverse as it targets the development of use cases for digital twins, which are integral to creating synchronized virtual environments as seen in metaverse applications..
ISO/IEC	JTC 1/SC 41	ISO/IEC AWI 30173	Digital twin — Concepts and terminology	Under development	This draft standard can be utilized in the metaverse context because it involves the development of concepts and terminology for digital twins, which are crucial for creating detailed and synchronized virtual representations in both general metaverses and more specialized applications..
ISO/IEC	TC 184/SC 4	ISO 23247:2021 (series)	Automation systems and integration — Digital twin framework for manufacturing	Published	This standard can be utilized for the metaverse as it outlines protocols essential for creating digital twins, which are critical for developing virtual worlds synchronized with physical counterparts.

ITU	FG-MV	FGMV-28	Requirements for the metaverse based on digital twins enabling integration of virtual and physical worlds	Approved deliverable	This pre-standards document directly relates to the metaverse as it outlines the integration of virtual and physical worlds by providing a framework for services scenarios, connectivity, and interoperability essential in metaverse applications.
ITU	FG-MV	FGMV-29	Reference model for the metaverse based on a digital twin enabling integration of virtual and physical worlds	Approved deliverable	This pre-standards document is relevant to the metaverse as it focuses on the integration of virtual and physical worlds through digital twins, aligning closely with the metaverse's definition as a network of virtual worlds linked to the physical realm.
ITU-T	SG20	ITU-T Y.4600	Requirements and capabilities of a digital twin system for smart cities	Published (08/2022)	This standard can be utilized in the metaverse as it outlines the requirements and architecture for a digital twin system of a city, an essential component of the metaverse focusing on synchronized virtual and physical worlds.
ISO/IEC	JTC 1/SC 29	ISO/IEC 23090 7:2022	Coded representation of immersive media - Part 7: Immersive media metadata	Published	This standard can feasibly be applied to the metaverse as it details a framework that supports the development and deployment of digital twins, which are integral to creating synchronized virtual worlds with their physical counterparts. These specifications for interoperability and data formats enable seamless integration of various systems, an essential feature for the complex interactive layers of the metaverse.

8.3.3 Block chain

Table 8-10 provides the metaverse standards selected from Table 7-10 that are closely related to or can be utilized in the metaverse, along with an analysis of their relevance.

Table 8-10: Selected metaverse standards from Table 7-10 and their relevance to metaverse

SDO	Study group	Reference	Title	Status	Relevance to the metaverse

IEEE	DAI	IEEE 3207-2022	IEEE Standard for Blockchain-based Digital Asset Identification	Published	This standard, IEEE P3207, can be beneficial in the metaverse by establishing guidelines for identifying digital assets efficiently within these virtual environments. As metaverses, ,often integrate extensive digital asset interactions, having a standard that improves identification and interoperability across different systems and devices becomes crucial. Hence, IEEE P3207 supports the functionality and connectivity needs of the metaverse infrastructure.
IEEE	DAWG	IEEE 2418.10-2022	IEEE Standard for Blockchain based Digital Asset Management	Published	This standard, IEEE 2418.10-2022, can be utilized in the context of the metaverse by providing a structured approach to digital asset management on blockchain technology, which is crucial for establishing secure and efficient transactions within such virtual ecosystems.
IEEE	DBC WG	IEEE 2418.2-2020	IEEE Standard for Data Format for Blockchain Systems	Published	This standard, IEEE 2418.2-2020, can be applied to the metaverse as it provides structured data format requirements essential for ensuring interoperability and connectivity within digitally created worlds. As these virtual environments require high levels of data exchange and integration, having a defined standard for blockchain systems facilitates the secure, efficient transmission of information across various platforms and devices within the metaverse ecosystem.
ISO	TC 307	ISO 22739	Blockchain and distributed ledger technologies — Vocabulary	Published	This standard includes the term “metaverse” and provides a definition for it, indicating its relevance to any project or study focused on virtual environments interconnected with real-world aspects, making it applicable for understanding and developing metaverse-related technologies.
ISO	TC 307	ISO 23257	Blockchain and distributed ledger technologies — Reference architecture	Published	This standard can be utilized in the metaverse as it offers a structured framework for blockchain systems, which are integral to ensuring secure and reliable transactions in virtual environments like the metaverse. Blockchain technology, as detailed in the standard, provides the essential infrastructure for

					creating transparent, decentralized, and interoperable systems crucial for the economics of the metaverse.
ISO	TC 307	ISO/TS 23258	Blockchain and distributed ledger technologies — Taxonomy and Ontology	Published	This standard is applicable to the metaverse concept as it provides a framework for classifying and understanding the diverse systems and technologies that underpin the metaverse, such as blockchain and distributed ledger technologies, which are integral in creating secure and interoperable virtual ecosystems.
ISO	TC 307	ISO/TS 23635	Blockchain and distributed ledger technologies — Guidelines for governance	Published	This standard is applicable to the metaverse as it provides governance principles for Distributed Ledger Technology (DLT) systems, which can underpin the diverse and interoperable infrastructure necessary for expansive virtual worlds.. Given the metaverse integrates various technological systems and platforms, the governance framework described could ensure optimal and compliant interoperability among them.
ISO	TC 307	ISO/AWI TS 18126	Smart contract taxonomy and classification	Under development	This draft standard can be utilized in the metaverse because it involves smart contracts, which are essential for creating secure and automated transactions in the virtual world’s characteristic of the metaverse. Smart contracts facilitate trust and efficiency in virtual dealings, directly related to economic activities in metaverse environments., where connectivity and interoperability are crucial.
ISO	TC 307	ISO/AWI 20435	Representing Physical Assets using Non-Fungible Token	Under development	This draft standard can be utilized in the metaverse because it is designed to integrate with virtual environments that represent or are associated with the physical world, as seen in the definition of a metaverse. It supports the concepts of connectivity and interoperability, by ensuring that virtual representations sync effectively with their physical counterparts.
ISO	TC 307	ISO/AWI TS 23353	Blockchain and distributed ledger technologies — Auditing guidelines	Under development	This draft standard is applicable to the metaverse because it addresses the principles of connectivity and interoperability, essential for building and managing virtual worlds.

ITU-T	SG17	ITU-T X.1403	Security guidelines for using distributed ledger technology for decentralized identity management	Published (09/2020)	This standard, ITU-T X.1403, focuses on the secure management of identity data using distributed ledgers, a technology that can be crucial in the development and operation of metaverses. As these virtual environments need robust systems for identity verification and data protection to ensure user safety and interoperability, the application of ITU-T X.1403's guidelines can enhance the security and reliability of these digital platforms.
ITU-T	SG13	ITU-T Y.2247	Framework and requirements of network- oriented data integrity verification service based on blockchain in future networks	Published (01/2023)	This standard, ITU-T Y.2247, can be applicable to the metaverse because it focuses on ensuring data integrity through blockchain, which is crucial in maintaining reliable and secure transactions and interactions within virtual environments.

8.3.4 Media coding

Table 8-11 provides the metaverse standards selected from Table 7-11 that are closely related to or can be utilized in the metaverse, along with an analysis of their relevance.

Table 8-11: Selected metaverse standards from Table 7-11 and their relevance to metaverse

SDO	Study group	Reference	Title	Status	Relevance to the metaverse
ISO/IEC	JTC 1/SC 29	ISO/IEC 14496-25	Information Technology — Coding of Audio-visual Objects — Part 25: 3D Graphics Compression Model," 14496-25, 2nd ed., 2011.	Published	This standard, ISO/IEC 14496-25, is relevant to the metaverse because it defines the efficient compression and transmission of 3D graphics data, which are essential for creating immersive environments in virtual worlds. By enabling detailed and interactive 3D models to be effectively transmitted and displayed, this technology underpins the functionality necessary for a seamless and realistic user experience in these expansive digital universes.

ISO/IEC	JTC 1/SC 24	ISO/IEC 19776-1:2015	Information technology - Computer graphics, image processing and environmental data representation - Extensible 3D (X3D) encodings - Part 1: Extensible Markup Language (XML) encoding	Published	This standard, ISO/IEC 19776-1:2015, is applicable to the metaverse as it provides a framework for integrating 3D graphics and multimedia in virtual spaces, which is a fundamental aspect of creating immersive interactive environments typical of metaverse experiences. By defining a mapping for X3D encodings, the standard supports the development of detailed, interactive 3D environments that can dynamically interact with users, aligning with the interconnected and immersive nature of the metaverse concept.
ISO/IEC	JTC 1/SC 24	ISO/IEC 19776-2:2015	Information technology - Computer graphics, image processing and environmental data representation - Extensible 3D (X3D) encodings – Part 2: Classic VRML encoding	Published	This standard, ISO/IEC 19776-2:2015, can be utilized in the development of the metaverse due to its focus on 3D graphics and the interactive multimedia components, which are foundational for creating immersive, virtual environments inherently tied to the concept of a metaverse. It outlines how to encode 3D objects in a manner compatible with widely recognized web standards, ensuring that these environments can be accessed and interacted with from various devices and platforms, crucial for the lifelike experience touted in metaverse ecosystems.
ISO/IEC	JTC 1/SC 24	ISO/IEC 19776-3:2015	Information technology - Computer graphics, image processing and environmental data representation - Extensible 3D (X3D) encodings – Part 3: Part 3: Compressed binary encoding	Published	This standard, ISO/IEC 19776-3:2015, can be applicable to metaverses . due to its role in defining a compact binary form for encoding 3D graphics in X3D, which is vital for creating and managing detailed virtual environments that mirror physical counterparts effectively.
ISO/IEC	JTC 1/SC 29	ISO/IEC 23005-1:2020	Information technology - Media context and	Published	This standard ISO/IEC 23005-1:2020 is relevant to the metaverse as it facilitates interaction between virtual and

			control - Part 1: Architecture		real environments, which is a core component of immersive metaverse ecosystems. It defines how information can be adapted and exchanged between these worlds, enhancing the connectivity and interoperability that are crucial for the seamless integration.
ISO/IEC	JTC 1/SC 29	ISO/IEC 23005-2:2018	Information technology - Media context and control - Part 2: Part 2: Control information	Published	This standard ISO/IEC 23005-2:2018 can be utilized in the context of the metaverse as it is designed to support the integration and control of virtual and real-world environments. By providing frameworks for describing and controlling devices, as well as user preferences related to sensors and actuators, it enables seamless interaction within virtual worlds akin to the metaverse. Thus, ensuring effective connectivity and interoperability that are crucial for constructing synchronized virtual and physical worlds.
ISO/IEC	JTC 1/SC 29	ISO/IEC 23005-3:2019	Information technology - Media context and control - Part 3: Sensory information	Published	This standard, ISO/IEC 23005-3:2019, can be utilized in the metaverse, particularly in creating immersive experiences by facilitating the description of sensorial effects such as light, wind, and vibration, which are crucial for enhancing virtual environments to provide users with a more realistic and engaging interaction.
ISO/IEC	JTC 1/SC 29	ISO/IEC 23005-7:2019	Information technology - Media context and control - Part 7: Conformance and reference software	Published	This standard, ISO/IEC 23005-7:2019, is applicable to the metaverse as it provides frameworks for interoperability and connectivity between virtual environments.
ISO/IEC	JTC 1/SC 29	ISO/IEC 23090-5:2023	Information Technology - Coded representation of immersive media - PART 5: Visual volumetric video-based	Published	This standard, ISO/IEC 23090-5:2023, is relevant to the metaverse as it lays the foundations for creating and decoding visual volumetric media, which can enhance the immersive experiences crucial in virtual worlds. The standard's focus on video-based coding methods supports

			coding (V3C) and video-based point cloud compression (V-PCC)		the development of interactive and realistic environments where users can engage with digital content in a manner akin to real-world interactions, pivotal in constructing synchronized virtual and physical spaces.
ISO/IEC	JTC 1/SC 29	ISO/IEC 23090-6: 2021	Coded representation of immersive media - Part 6: Immersive media metrics	Published	This standard is applicable to the metaverse as it involves metrics and measurement frameworks essential for enhancing user experiences in immersive environments, like those found in virtual or augmented worlds.
ISO/IEC	JTC 1/SC 29	ISO/IEC 23090-9:2023	Information technology - Coded representation of immersive media - Part 9: Geometry-based point cloud compression	Published	ISO/IEC 23090-9:2023, specifying geometry-based point cloud compression, is applicable to the metaverse as it enhances the realism and interactivity of virtual environments by efficiently compressing 3D data. This standard enables detailed and complex virtual worlds like those found in the metaverse to be more accessible and seamlessly integrated, which is essential for creating synchronized virtual experiences.
ISO/IEC	JTC 1/SC 29	ISO/IEC 23090-12:2023	Information technology - Coded representation of immersive media - Part 12: MPEG immersive video	Published	This standard, ISO/IEC 23090-12:2023, can be utilized in metaverse applications because it specifies the syntax and decoding processes for 3D immersive video essential in creating virtual environments that mirror or enhance the physical world as seen in metaverse concepts .. The provision of 6 Degrees of Freedom (6DoF) enables users to experience virtual worlds with realistic navigation and interaction, crucial for the immersive aspect of the metaverse.
ISO/IEC	JTC 1/SC 29	ISO/IEC 23093-2:2022	Information technology - Internet of media things - Part 2: Discovery and communication API	Published	This standard, ISO/IEC 23093-2:2022, is relevant to the metaverse as it defines mechanisms for connectivity and interoperability among media things (MThings), which can facilitate the creation of interconnected and seamless virtual environments, similar to those required in metaverse ecosystems.. These capabilities enable

					enhanced interaction between virtual and physical worlds, aligning with the objectives of metaverses to offer immersive and integrated user experiences.
ISO/IEC	JTC 1/SC 29	ISO/IEC 23093-3:2022	Information technology - Internet of media things - Part 3: Media data formats and APIs	Published	This standard, ISO/IEC 23093-3:2022, is applicable to the metaverse because it defines the APIs and description schemes that facilitate exchange of data between various media things, which can enhance interoperability and connectivity in virtual worlds.
ISO/IEC	JTC 1/SC 29	ISO/IEC 23093-4:2023	Information technology - Internet of media things - Part 4: Reference software and conformance	Published	This standard, ISO/IEC 23093-4:2023, is applicable to the metaverse as it provides a framework for interoperability and connectivity across various virtual environments, key components for the functionality and integration seen in metaverse ecosystems ..
ISO/IEC	JTC 1/SC 24	ISO/IEC 12087-5	Basic Image Interchange Format BIIF	Published	This standard, ISO/IEC 12087, could be highly relevant for the metaverse, as it focuses on interoperability in the exchange of imagery and related data among applications, a crucial aspect for synchronizing virtual and physical worlds effectively.
ISO/IEC	JTC 1/SC 24	ISO/IEC 23488	Object/environmental representation for image-based rendering in virtual/mixed and augmented reality (VR/MAR)	Published	This standard is applicable to the metaverse as it provides an image-based representation model critical for creating immersive, realistic environments that interact seamlessly across virtual and augmented realities, enhancing user experience and engagement in metaverse applications.
ISO/IEC	JTC 1/SC 29	ISO/IEC 14496-16	Coding of audio-visual objects - Part 16: Animation Framework eXtension (AFX)	Published	This standard's framework for 3D graphics and animations aligns with the demands of the metaverse by enabling detailed and immersive digital environments. The integration with interactive multimedia presentations enhances user experiences, crucial for the efficacy of virtual worlds in metaverses ., where synchronized digital and physical realities are central. Thus, its technologies

					are directly applicable to developing immersive and interactive aspects of the metaverse.
ISO/IEC	JTC 1/SC 29	ISO/IEC 14496-25	Coding of audio-visual objects - Part 25: 3D Graphics Compression Model	Published	This standard can be effectively utilized in the metaverse as it specifies how to integrate 3D graphics compression tools with diverse graphic primitives, which is crucial in creating detailed and efficient virtual environments, enhancing user immersion and interaction within the metaverse framework.
ISO/IEC	JTC 1/SC 29	ISO/IEC 23008-3	High efficiency coding and Media Delivery in Heterogeneous Environments - Part 3: 3D Audio	Published	This standard facilitates the transmission and rendering of immersive audio, which is crucial for creating realistic environments in metaverses, enhancing the user's experience by providing spatial audio that mirrors real-world sounds or creates entirely new audio landscapes.
ISO/IEC	JTC 1/SC 29	ISO/IEC 23090-2	Coded representation of immersive media - Part 2: Omnidirectional media format (OMAF)	Published	This standard is applicable to the metaverse as it provides a format for coding, storing, delivering, and rendering omnidirectional media, integral for creating immersive virtual environments that mirror the concept of interconnected and interoperable spaces.
ISO/IEC	JTC 1/SC 29	ISO/IEC 23090-5	Coded representation of immersive media - Part 5: Visual volumetric video-based coding (V3C) and video-based point cloud compression (V-PCC)	Published	This standard is applicable to the metaverse because it details the encoding and decoding processes for visual volumetric media, which are crucial for creating immersive virtual environments. By enabling detailed and responsive environments, this standard supports the advanced interactivity required in metaverses , where synchronization with the physical world enhances user experiences.
ISO/IEC	JTC 1/SC 29	ISO/IEC 23090-8	Coded representation of immersive media - Part 8: Network-based media processing	Published	This standard can be utilized in the metaverse as it defines interfaces for media processing in digital networks, which are fundamental to creating immersive, multimedia experiences in virtual worlds like those found in a metaverse.

ISO/IEC	JTC 1/SC 29	ISO/IEC 23090-9	Coded representation of immersive media - Part 9: Geometry-based point cloud compression	Published	This standard is directly relevant to the metaverse as it outlines methods for the efficient compression of point cloud data, which is crucial for creating and managing detailed virtual environments in both metaverses where real-time data and high-quality visual fidelity are essential.
ISO/IEC	JTC 1/SC 29	ISO/IEC 23090-10	Coded representation of immersive media - Part 10: Carriage of visual volumetric video-based coding data	Published	This standard, which specifies the carriage of coded media representations for volumetric video-based coding and video-based point cloud compression, aligns with metaverse technologies by facilitating the creation of realistic 3D virtual environments that can be integrated into metaverses for immersive user experiences.
ISO/IEC	JTC 1/SC 29	ISO/IEC 23090-12	Coded representation of immersive media - Part 12: MPEG immersive video	Published	This standard facilitates the Metaverse implementation by enabling highly immersive 3D experiences with 6 Degrees of Freedom, essential for creating virtual environments that mimic real-world interactions. It supports the metaverse's need for realistic and seamless user experiences within virtual or augmented worlds, aligning with the broader objectives of immersive digital ecosystems.
ISO/IEC	JTC 1/SC 29	ISO/IEC 23090-14	Coded representation of immersive media - Part 14: Scene description	Published	This standard is relevant to the metaverse as it facilitates immersive experiences through the enhancement of MPEG media integration in virtual environments, crucial for creating seamless and interactive virtual worlds like those envisioned in metaverse concepts.
ISO/IEC	JTC 1/SC 29	ISO/IEC 23090-18	Coded representation of immersive media - Part 18: Carriage of geometry-based point cloud compression data.	Published	This standard is applicable to the metaverse as it supports the delivery and storage of geometry-based point cloud compression data, which is essential for creating and managing detailed, three-dimensional virtual environments that are synchronized with physical counterparts.

ISO/IEC	JTC 1/SC 29	ISO/IEC AWI 23090-29	Coded representation of immersive media - Part 29: Video-based dynamic mesh coding (V-DMC)	Under development	This draft standard can be utilized within the metaverse as it involves organizing and compressing 3D volumetric data, which is essential for creating dynamic and interactive virtual environments synchronizing with their real-world counterparts.
ISO/IEC	JTC 1/SC 29	ISO/IEC AWI 23090-30	Coded representation of immersive media - Part 30: Low latency, low complexity LiDAR coding	Under development	This draft standard for the compressed representation of LIDAR-acquired dynamic point clouds can be pivotal in the creation and rendering of highly detailed and accurate virtual environments in the metaverse, facilitating immersive and interactive experiences that closely mimic the physical world.
ISO/IEC	JTC 1/SC 29	ISO/IEC 23090-31	Coded representation of immersive media - Part 31: Haptics coding	Published	This standard supports immersive experiences in the metaverse by providing a framework for encoding and transmitting haptic signals, which are crucial for creating realistic virtual environments that users can not only see and hear but also feel physically, enhancing the sense of presence and interaction in virtual worlds.
ISO/IEC	JTC 1/SC 29	ISO/IEC 23005-3	Media context and control - Part 3: Sensory information	Published	This standard, which specifies sensory description languages and vocabularies, can greatly enhance metaverse environments by enriching virtual interactions with realistic sensorial experiences. By doing so, it enables a more immersive and interactive experience, aligning closely with the immersive nature of metaverses .
ITU-T	SG12	ITU-T P.919	Subjective test methodologies for 360° video on head-mounted displays	Published (10/2020)	This standard, ITU-T P.919, which focuses on subjective assessment methods for evaluating the quality of experience in 360° videos, can be applicable in metaverse scenarios, particularly in immersive virtual environments . In the context of the metaverse, where users experience simulated realities, the methodologies outlined in this standard could help ensure that 360° video content delivers a high-quality and immersive user experience,

					crucial for the effectiveness of virtual worlds synchronized with physical counterparts.
ITU-T	SG16	F.CEMP-DHS	Requirements and architectures of multimedia platform for digital human services using edge cloud	Under development	This draft standard can be applied to the metaverse because it outlines the technological framework necessary for multimedia-based interaction which is a core component of immersive virtual worlds. By supporting a cloud and edge computing platform that manages high fidelity, real-time interactions, it directly aligns with the operational needs of metaverse environments .., where seamless integration and synchronization with physical counterparts are crucial.
ITU-T	SG9	ITU-T J.1303	Specification of a cloud-based converged media service to support Internet protocol and broadcast cable television - System specification on collaboration between production media cloud and cable service cloud	Published (01/2022)	This standard, ITU-T J.1303, can be considered relevant to the metaverse, specifically to concepts , as it outlines the architecture for integrating multiple cloud services and networks, which could be critical in managing the vast data and interaction requirements of synchronized virtual and physical worlds.
ISO/IEC	JTC 1/SC 29	ISO/IEC 23008-3:2022	High efficiency coding and Media Delivery In Heterogeneous Environments - Part 3: 3D Audio	Published	This standard can be applied to metaverse technologies . due to its focus on interoperable adaptive streaming of media and common encryption over HTTP, which are essential for delivering seamless multimedia experiences in virtual environments aligned with physical counterparts. The standard's emphasis on interoperability and adaptive HTTP streaming directly supports the high-performance, real-time data transmission needs of complex metaverse ecosystems.

ISO/IEC	JTC 1/SC 29	ISO/IEC 23090-5:2023	Coded representation of immersive media - Part 5: Visual volumetric video-based coding (V3C) and video-based point cloud compression (V-PCC)	Published	This standard could be useful in the development of metaverses, ., as it defines a structured schema to systematically manage and represent information within an archival system, which can be crucial for the organized and interoperable exchange of data in virtual environments. ISO/IEC 23090-5:2023's approach to conceptual modelling enhances the ability to create well-defined, interconnected virtual spaces that reflect complex real-world systems and interactions, aligning with the core principles of connectivity and interoperability critical for metaverse ecosystems.
ISO/IEC	JTC 1/SC 29	ISO/IEC 23090-9:2023	Coded representation of immersive media - Part 9: Geometry based point cloud compression	Published	This standard, ISO/IEC 23090-9:2023, is relevant to the metaverse as it defines APIs for video and audio content recognition, which can be integral for creating immersive experiences in virtual worlds. For example, the facial recognition service outlined in this standard could enhance interactive elements by allowing avatars to exhibit realistic and personalized facial expressions or interactions based on real user expressions. Additionally, it could enable security features within the metaverse by verifying user identity through facial recognition, therefore adding layers of both functionality and safety in virtual environments.
ISO/IEC	JTC 1/SC 29	ISO/IEC 21000-1:2001	Multimedia framework (MPEG 21) - Part 1: Vision, Technologies and Strategy	Published	This standard, ISO/IEC 21000-1:2001, can be applied to the metaverse by facilitating interoperability among diverse multimedia systems, which is crucial for creating seamless and immersive environments in virtual worlds. It ensures that different systems can interact, enhancing synchronization between real and virtual cities .
ISO/IEC	JTC 1/SC 29	ISO/IEC 21000-2:2003	Multimedia framework (MPEG 21) - Part 2: Digital Item Declaration	Published	This standard, ISO/IEC 21000-2:2003, enhances the interoperability and connectivity essential in the metaverse by outlining how different parts of digital frameworks should integrate. It ensures that various technologies

					within the metaverse can interact seamlessly, reflecting the necessary cooperation between devices and systems.
ISO/IEC	JTC 1/SC 29	ISO/IEC 21000-3:2003	Multimedia framework (MPEG 21) - Part 3: Digital Item Identification	Published	This standard, ISO/IEC 21000-3:2003, could certainly play a pivotal role in the deployment of metaverse technologies, as its purpose is to ensure robust, scalable delivery of multimedia content across diverse network conditions and devices, which aligns seamlessly with the demands for high-quality, continuous connectivity and interoperability crucial in immersive virtual environments. The standards for negotiation of delivery parameters between entities are essential for seamless interactions.
ISO/IEC	JTC 1/SC 29	ISO/IEC 21000-5:2008	Multimedia framework (MPEG 21) - Part 5: Rights Expression Language	Published	This standard could be applicable to the metaverse as it enhances interoperability and connectivity, essential principles in the complex ecosystems of virtual worlds like metaverses . ISO/IEC 21000-5:2008 supports these features by detailing reference software which can help establish a common framework for various virtual environments to interact effectively.
ISO/IEC	JTC 1/SC 29	ISO/IEC 21000-6:2007	Multimedia framework (MPEG 21) - Part 6: Rights Data Dictionary	Published	This standard, ISO/IEC 21000-6:2007, can be applied effectively to the metaverse, specifically because it outlines a universal framework for the declaration and management of digital items, which are essential components in building an interoperable and immersive virtual ecosystem.
ISO/IEC	JTC 1/SC 29	ISO/IEC 21000-7:2007	Multimedia framework (MPEG 21) - Part 7: Digital Item Adaptation	Published	This standard, ISO/IEC 21000-7:2007, is relevant for application in the metaverse as it provides standardized frameworks for multimedia content adaptation across various devices and networks, essential for creating interoperable and unified experiences in virtual worlds like those in the metaverse .

ISO/IEC	JTC 1/SC 29	ISO/IEC 21000-19:2010	Multimedia framework (MPEG 21) - Part 19: Media Value Chain Ontology	Published	This standard, ISO/IEC 21000-19:2010, can be effectively utilized within the metaverse,. It provides a robust architecture for managing interoperability and seamless integration across different multimedia platforms, which is crucial for the synchronization and interaction between virtual and physical worlds. The framework's focus on ensuring that multimedia resources are used transparently and efficiently across various networks and devices aligns well with the connectivity and interoperability requirements of metaverse environments.
ISO/IEC	JTC 1/SC 29	ISO/IEC 21000-21:2017	Multimedia framework (MPEG 21) - Part 21: Media Contract Ontology	Published	ISO/IEC 21000-21:2017 can be effectively utilized in the metaverse due to its framework for a standardized digital item declaration language, which aids in the uniform description and identification of digital items. This standard ensures that diverse systems within the metaverse can maintain interoperability and connectivity by using a common language for digital content and metadata, facilitating seamless integration and interaction across different virtual environments and platforms.
ISO/IEC	JTC 1/SC 29	ISO/IEC 23001-7:2016	MPEG systems technologies (MPEG B) - Part 7: Common encryption in ISO base media file format files	Published	This standard, ISO/IEC 23001-7:2016, could be relevant to metaverse implementations because it addresses interoperable systems, which are critical in creating connected and consistent experiences across diverse virtual environments. However, it focuses primarily on media delivery aspects rather than on the broader infrastructure needed for a fully integrated metaverse ecosystem. Therefore, its direct applicability to metaverse infrastructure as described might be limited, suggesting it is not specifically designed for metaverse technologies but can support some underlying technology components.
ISO/IEC	JTC 1/SC 29	ISO/IEC 23006-1:2018	Multimedia service platform technologies	Published	This standard, ISO/IEC 23006-1:2018, is applicable to the metaverse by establishing a framework that supports the

			(MPEG M) - Part 1: Architecture		interoperability and connectivity necessary for immersive media applications. ISO/IEC 23006-1:2018 is conducive to creating environments , as it ensures different systems and devices can work together seamlessly, an essential feature for synchronized virtual and physical worlds.
ISO/IEC	JTC 1/SC 29	ISO/IEC 23006-4:2013	Multimedia Service Platform Technologies (MPEG M) - Part 4: Elementary Services	Published	This standard, ISO/IEC 23006-4:2013, can be utilized in metaverse applications because it enables the creation of user profiles that include detailed preferences and characteristics, which are essential for personalized experiences in virtual worlds. Such detailed user descriptions are integral to enhancing user interaction and ensuring seamless interoperability in environments, where virtual and physical worlds converge.
ISO/IEC	JTC 1/SC 29	ISO/IEC 23006-5:2013	Multimedia service platform technologies (MPEG M) - Part 5: Service aggregation	Published	This standard ISO/IEC 23006-5:2013 can be utilized in the metaverse as it supports the creation and organization of interactive and dynamic scenes that can represent or be associated with the physical world, essential for the realization of immersive virtual environments .
W3C	W3C Audio WG	Web Audio https://www.w3.org/TR/webaudio/	Web Audio API	Published (06/2021)	This standard is applicable to the metaverse because it focuses on immersive experiences that can be virtual or augmented, closely aligning with the dynamic and interactive environments of virtual worlds crucial for creating and managing metaverses.
W3C	W3C Web Fonts WG	IFT, https://www.w3.org/TR/IFT/	Incremental Font Transfer	Under development	This draft standard is related to the metaverse concept because it covers the incremental transfer of fonts, which can enhance the visual and textual representation in virtual or augmented environments l, improving load times and user experience in these immersive platforms.
W3C	W3C Web Real-	Media Capture and Streams	Media Capture and Streams	Under development	This draft standard is relevant to the metaverse because it outlines the necessary JavaScript APIs for accessing local media such as audio and video, which are crucial

	Time Communications WG	https://www.w3.org/TR/mediacapture-streams/			components for creating immersive, interactive virtual environments or augmented realities, thereby directly supporting the development and operation of metaverses where real-time media capture and streams enhance user experiences.
W3C	W3C Web Real-Time Communications WG	MediaStreamTrack Content Hints https://www.w3.org/TR/mst-content-hint/	MediaStreamTrack Content Hints	Under development	This draft standard can be beneficial in the metaverse context as it ensures smooth video and audio streaming experiences which are crucial for maintaining immersiveness in virtual worlds like those in a metaverse, thus enhancing user interaction and overall virtual experience.

8.3.5 Artificial Intelligence

Table 8-12 provides the metaverse standards selected from Table 7-12 that are closely related to or can be utilized in the metaverse, along with an analysis of their relevance.

Table 8-12: Selected metaverse standards from Table 7-12 and their relevance to metaverse

SDO	Study group	Reference	Title	Status	Relevance to the metaverse
ISO/IEC	JTC 1/SC 27	ISO/IEC WD 27091	Cybersecurity and Privacy — Artificial Intelligence — Privacy protection	Under development	This draft standard is applicable to the metaverse as it emphasizes principles of connectivity and interoperability, which are crucial for the integrated, virtual environments characteristic of the metaverse.
ISO/IEC	JTC 1/SC 42	ISO/IEC 5339	Information technology — Artificial intelligence — Guidance for AI applications	Published	This standard can be applied to the metaverse as it provides frameworks for AI applications, which are integral to developing interactive and autonomous systems within virtual environments like the metaverse. By enhancing communication and integration among various stakeholders, it ensures that the virtual worlds in the metaverse can be managed and evolved effectively.

ISO/IEC	JTC 1/SC 42	ISO/IEC TR 24030	Information technology — Artificial intelligence (AI) — Use cases	Published	This standard is applicable to the metaverse because it provides AI use cases that can enhance functionalities within virtual environments, fostering better integrations and interactions in immersive platforms .s.
ISO/IEC	JTC 1/SC 42	ISO/IEC TR 24368	Information technology — Artificial intelligence — Overview of ethical and societal concerns	Published	This standard can be applied to the metaverse because it addresses ethical and societal concerns that are pertinent to the development and implementation of metaverses, ., which interact and integrate with diverse societal and technological systems.
ISO/IEC	JTC 1/SC 42	ISO/IEC TR 24372	Information technology — Artificial intelligence (AI) — Overview of computational approaches for AI systems	Published	This standard is applicable to the metaverse since the term “metaverse” is specifically mentioned in its definition, indicating a direct relevance to the technology and concepts associated with virtual and augmented environments.
ISO/IEC	JTC 1/SC 42	ISO/IEC 38507	Information technology — Governance of IT — Governance implications of the use of artificial intelligence by organizations	Published	This standard is applicable to the metaverse as it provides a framework for governing artificial intelligence, which is central to creating and managing interactive and autonomous environments within virtual worlds like the metaverse.
ITU	FG-MV	FGMV-22	Capabilities and requirements of generative artificial intelligence in metaverse applications and services	Approved deliverable	This pre-standards document can be utilized in the metaverse as it provides specifications for Generative Artificial Intelligence, which is essential for creating immersive and interactive experiences in virtual environments like those found in the metaverse.

ITU	FG-MV	FGMV-13	Responsible Use of AI for Child Protection in the metaverse	Approved deliverable	This pre-standards document on using AI for child protection in the metaverse is directly related to the metaverse as it addresses the unique challenges and opportunities presented by these virtual spaces. By focusing on child protection, the report aligns with and supports the achievement of various UN Sustainable Development Goals, ensuring that the metaverse evolves into a safe, inclusive, and beneficial environment for all users, especially children.
ITU-T	SG 11	ITU-T Q.5008	Signalling requirements and architecture to support artificial intelligence-based vertical services in future networks including IMT-2020 and beyond	Published	This standard can be utilized in the metaverse, due to its focus on AI-based vertical services, connectivity, and interoperability requirements in future networks, essential for creating seamless integrations between virtual and physical worlds.
ITU-T	SG 13	ITU-T Y.3178	Functional framework of artificial intelligence-based network service provisioning in future networks including IMT-2020	Published	This standard, ITU-T Y.3178, could be effectively utilized in the metaverse given its focus on AI-based network service provisioning, which is crucial for managing the complex, dynamic nature of virtual worlds in a metaverse. This ensures seamless connectivity and interoperability across diverse virtual environments and their physical counterparts, aligning closely with the metaverse's requirements for real-time synchronization and integration.
ITU-T	SG 16	ITU-T F Suppl. 4	Overview of convergence of artificial intelligence and blockchain	Published	This standard can be applied to the metaverse because it discusses the convergence of AI and blockchain, technologies key to managing complex, interoperable environments like those found in metaverses, which require synchronization and seamless interoperability between virtual and physical spaces.
ITU-T	SG13	ITU-T Suppl 72 to ITU-T Y-3000 series	Artificial Intelligence Standardization Roadmap	Published	This standard is relevant to the metaverse as it defines protocols for AI that can underpin the complex, interconnected environments envisioned in metaverse setups, including aspects like virtual interaction, AI-driven simulations, and infrastructural interoperability

					critical for creating a seamless user experience across virtual and physical worlds. AI standardization can drive the functionality and integration necessary for the immersive and interactive experiences that are central to the metaverse concept.
ITU-T	SG13	ITU-T Y.3115	AI enabled cross-domain network architectural requirements and framework for future networks including IMT-2020	Published	This standard, ITU-T Y.3115, can potentially be utilized in the development of metaverse architectures because it outlines how to integrate and manage AI across different network domains. Interoperability and AI functionalities are crucial for creating interconnected virtual environments that mirror physical realities.
ITU-T	SG16	ITU-T F.748.26	Technical specification for artificial intelligence cloud platforms: Performance evaluation	Published	This standard could be applicable to the metaverse since it establishes guidelines for evaluating the performance of AI cloud platforms, which are integral in managing the sophisticated simulations and interoperability required for immersive.
ISO/IEC	JTC 1/SC 29	ISO/IEC 23090 14:2023	Coded representation of immersive media - Part 14: Scene description	Published	This standard can be applied to the metaverse, as ISO/IEC 23090-14:2023 outlines trustworthiness and risk management, which are critical for ensuring secure and reliable interactions within the integrative ecosystems of virtual worlds like the metaverse. Moreover, the emphasis on socio-technical systems aligns well with the metaverse's blending of technology and social interaction.

8.3.6 Digital Human/Avatar

Table 8-13 provides the metaverse standards selected from Table 7-13 that are closely related to or can be utilized in the metaverse, along with an analysis of their relevance.

Table 8-13: Selected metaverse standards from Table 7-13 and their relevance to metaverse

SDO	Study group	Reference	Title	Status	Relevance to the metaverse

ISO	TC 184/SC4	ISO/TR 24464:2020	Automation systems and integration — Industrial data — Visualization elements of digital twins	Published -	This standard, ISO/TR 24464:2020, is applicable to the metaverse because it focuses on the interface between digital avatars and their physical assets, a core component in creating integrated virtual and physical environments .
ISO/IEC	JTC 1/SC 24	ISO/IEC 19774-1	Humanoid animation — Part 1: Architecture	Published	This standard, ISO/IEC 19774-1, is relevant to the metaverse because it specifies a structured model for creating humanoid characters, which can enhance user interaction and representation in virtual environments. By defining a uniform way to represent human figures, the standard supports the creation of more realistic and interactive avatars in virtual spaces, aligning well with the immersive experiences offered in a metaverse.
ISO/IEC	JTC 1/SC 24	ISO/IEC 19774-2	Humanoid animation — Part 1: Motion data animation	Published	This standard, ISO/IEC 19774-2, applies effectively to metaverses .s by ensuring that humanoid animations are smoothly integrated and interoperable across virtual environments. It supports the creation of realistic avatars in these virtual spaces, facilitating enhanced user experiences, critical for immersive interactions in the metaverse where digital human representation is crucial.
ISO/IEC	JTC 1/SC 29	ISO/IEC 23005-4:2018	Information technology - Media context and control - Part 4: Virtual world object characteristics	Published	This standard, ISO/IEC 23005-4:2018, can be effectively utilized in metaverse developments because it provides a framework for describing virtual world objects and avatars. By defining metadata for virtual environment elements through Virtual World Object Characteristics, it facilitates the creation and integration of detailed, realistic elements in virtual worlds, which are essential for immersive experiences in metaverses.

ITU-T	SG16	ITU-T F.748.15	Framework and metrics for digital human application systems	Published (03/2022)	This standard can be applied to the metaverse as it provides guidelines for digital human interaction systems, which are crucial in creating immersive and interactive experiences. ITU-T F.748.15 outlines metrics for image, speech, animation, and multimodal input/output, all of which are essential technologies within metaverse environments ., where synchronous virtual and physical interactions occur. Thus, it directly supports the development of technologically robust and engaging virtual worlds.
ITU-T	SG16	ITU-T F.748.14	Requirements and evaluation methods of non-interactive 2D real-person digital human application systems	Published (03/2022)	This standard is not directly applicable to the metaverse as it focuses on non-interactive 2D digital human application systems, which largely differ from the immersive, interactive 3D environments typical in metaverses. Thus, despite any superficial resemblances due to digital representations, the specific technologies and applications diverge significantly.
ITU-T	SG16	ITU-T F.748.27	Framework and requirements for the construction of 3D intelligent driven digital human application systems	Published (01/2024)	This standard can be utilized in the metaverse because it provides a framework for creating and interacting with 3D intelligent driven digital humans, which are integral to developing immersive, interactive experiences in virtual and augmented worlds, a fundamental aspect of the metaverse.
ITU-T	SG16	F.DH-PE	Requirements and evaluation methods of digital human platform	Under development	This draft standard can be applied to metaverse environments because it involves evaluating digital human platforms, which are essential components in creating immersive and interactive virtual worlds, similar to those in metaverse ecosystems. This makes the standard relevant as it aids in assessing the performance and interoperability necessary for seamless integration within these virtual spaces.

ITU-T	SG16	F.DHPIE	Metrics and Evaluation Methods for the Presentation and Interactive Effect of 3D Digital Human	Under development	This draft standard is applicable to the metaverse as it aims to improve user experience, a critical element in immersive virtual worlds. By establishing evaluation methods for presentation and interaction effects, it directly supports the development and enhancement of lifelike experiences essential for the metaverse environments.
ITU-T	SG16	F.DHSMD	Technical requirements and evaluation methods of 3D digital human system based on smart mobile devices	Under development	This draft standard is applicable in the metaverse because it facilitates the creation and management of 3D digital humans, crucial components for immersive and interactive experiences within virtual environments like those in the metaverse.
ITU-T	SG16	F.CSDH	Requirements of communication services for digital humans	Under development	This draft standard is applicable to the metaverse because it entails creating digital humans that can interact in a highly realistic manner, essential for immersive experiences in virtual worlds, which is a core aspect of metaverse environments.
ITU-T	SG16	F.FDHC	Factors and framework for digital human customization	Under development	This draft standard can be utilized in the metaverse as it defines how virtual environments can be integrative, offering immersive experiences that reflect and interact with the physical world, aligning with the principles of connectivity and interoperability described.
VRM Consortium	-	https://github.com/vrm-c/vrm-specification	VRM 2.0	Completed	This standard is relevant to the metaverse because it ensures that 3D avatars are consistent and interoperable across various virtual environments, which is vital for enhancing the immersive experience in metaverse platforms , where synchronization with physical counterparts is crucial.

8.4 Interoperability and ICT related infrastructure standards

8.4.1 Interoperability protocols

Table 8-14 provides the metaverse standards selected from Table 7-14 that are closely related to or can be utilized in the metaverse, along with an analysis of their relevance.

Table 8-14: Selected metaverse standards from Table 7-14 and their relevance to metaverse

SDO	Study group	Reference	Title	Status	Relevance to the metaverse
IEEE	IDAC	IEEE 3205-2023	IEEE Standard for Blockchain Interoperability - Data Authentication and Communication Protocol	Published	This standard, IEEE P3205, can be particularly useful in the metaverse context, especially in structures , where seamless integration and interoperability between diverse blockchain platforms are crucial. The protocols included in the standard support data authentication and communication across both homogeneous and heterogeneous blockchain systems, which are essential for the interconnected infrastructure of virtual worlds. By enabling different blockchain environments to operate together, this standard helps to ensure that various components of the metaverse can interact without friction, enhancing the user experience and operational efficiency.
IEEE	IoT Architecture WG	IEEE 2413-2019	IEEE Standard for an Architectural Framework for the Internet of Things (IoT)	Published	This standard, IEEE 2413-2019, can be effectively applied to the metaverse as it provides architectural framework guidelines for IoT, ensuring connectivity and interoperability among diverse systems and devices, crucial for developing integrated, responsive virtual worlds.
IETF	IAB	RFC 8477	Report from the Internet of Things (IoT) Semantic Interoperability (IOTSI) Workshop 2016	Published	This standard can be applied to the metaverse because it addresses principles of connectivity and interoperability, essential for developing a networked virtual environment, where physical and digital elements are integrated seamlessly.

ISO	TC 307	ISO/WD TS 23516	Blockchain and distributed ledger technologies — Interoperability Framework	Under development	This draft standard can be utilized in the metaverse as it ensures interoperability, which is crucial for connecting different systems and devices within the virtual worlds of the metaverse, similar to the required connectivity and interoperability.
ISO/IEC	JTC 1/SC 24	ISO/IEC 19777-1:2006	Information technology - Computer graphics and image processing - Extensible 3D (X3D) language bindings – Part 1: ECMAScript	Published	This standard, ISO/IEC 19777-1:2006, is relevant to the metaverse as it provides a specification for integrating the ECMAScript language with virtual reality environments, which are a core component of metaverse platforms. By defining how scripting can interact within these environments, it assists in creating more dynamic and interactive virtual worlds that are essential for the immersive experiences promised by metaverses.
ISO/IEC	JTC 1/SC 29	ISO/IEC 23005-2	Media context and control - Part 2: Control information	Published	This standard is applicable to the metaverse because it outlines technologies for interoperability and control of devices within virtual and real worlds, key components for creating and managing environments like those within a metaverse where seamless interaction and connectivity are crucial.
ISO/IEC	JTC 1/SC 38	ISO/IEC 19941	Interoperability and portability	Published	This standard can be utilized in the metaverse context because it addresses the crucial aspects of interoperability and portability. By establishing guidelines for services to interact seamlessly and data to move efficiently across different platforms, it supports the creation of integrated and cohesive virtual environments that can synchronously operate with physical counterparts.
ISO/IEC	JTC 1/SC 38	ISO/IEC 19941:2017	Information technology - Cloud computing - Interoperability and portability	Published	This standard, ISO/IEC 19941, can be applied beneficially to the metaverse as it offers essential frameworks for interoperability and portability among various cloud services, which are crucial for the seamless integration and operation of diverse systems within a metaverse.

ISO/IEC	JTC 1/SC 38	ISO/IEC AWI TS 10866	Framework and concepts for organizational autonomy and digital sovereignty	Under development	This draft standard is applicable to the metaverse because it addresses digital sovereignty and organizational autonomy, which are critical for managing virtual platforms like metaverses that integrate with real-world systems.
ITU	FG-MV	FGMV-19	Service scenarios and high-level requirements for metaverse cross-platform interoperability	Approved deliverable	This pre-standards document is applicable to the metaverse as it includes specific definitions and concepts related to virtual and augmented environments that are essential for designing interoperable, integrative ecosystems within the metaverse, that sync virtual worlds with physical counterparts.
ITU-T	SG20	ITU-T Y.4217	Service requirements and capability framework for Internet of Things-related crowdsourced systems	Published (08/2022)	This standard, ITU-T Y.4217, could be applicable to the metaverse due to its focus on IoT-related crowdsourced systems, allowing integration and interoperability in environments where physical and virtual elements are interconnected and where diverse systems and devices must function together effectively.
ISO/IEC	JTC 1/SC 29	ISO/IEC 21000 4:2012	Multimedia framework (MPEG 21) - Part 4: Intellectual Property Management and Protection Components	Published	This standard, ISO/IEC 21000-4, can be utilized effectively in the context of the metaverse, including concepts , due to its focus on DRM interoperability, which ensures secure content management across diverse platforms. The standard's emphasis on encryption, rights expression, and secure key management are essential for managing digital rights and user permissions within virtual environments, promoting a secure and robust framework for economic and cultural exchanges in the metaverse.
W3C	W3C Web of Things WG	WoT Thing Description, https://www.w3.org/TR/wot-thing-description/	Web of Things (WoT) Thing Description 1.1	Published (07/2023)	This standard, describing the Web of Things (WoT) Thing Description, can facilitate the development of interconnected and interoperable virtual environments like those in a metaverse. It supports creating systems where various devices and interfaces within a virtual space can efficiently

					communicate and work seamlessly, mirroring the necessities of environments.
W3C	W3C Web of Things WG	WoT Architecture, https://www.w3.org/TR/wot-architecture/	Web of Things (WoT) Architecture 1.1	Published (07/2023)	This standard is applicable to the metaverse as it underscores the essential principles of connectivity and interoperability, which are fundamental to creating interactive and synchronized virtual environments analogous to physical worlds in the metaverse, facilitating a seamless integration between various systems and devices within these virtual spaces.
W3C	W3C Web of Things WG	WoT Discovery, https://www.w3.org/TR/wot-discovery/	Web of Things (WoT) Discovery	Published (07/2023)	This standard can be utilized in the metaverse because it addresses connectivity and interoperability, essential for creating seamless interactions within the synchronized virtual and physical environments.
W3C	W3C Web Real-Time Communications WG	WebRTC https://www.w3.org/TR/webrtc/	WebRTC: Real-Time Communication in Browsers	Published (03/2023)	This standard supports the metaverse by enabling real-time communication between users and synchronization of virtual and physical worlds, key for immersive

8.4.2 Data sharing

Table 8-15 provides the metaverse standards selected from Table 7-15 that are closely related to or can be utilized in the metaverse, along with an analysis of their relevance.

Table 8-15: Selected metaverse standards from Table 7-15 and their relevance to metaverse

SDO	Study group	Reference	Title	Status	Relevance to the metaverse

ISO/IEC	JTC 1/WG 11	ISO/IEC AWI TR 10267-2	Information technology — Data use in smart cities — Part 2: Use case analysis and common considerations	Under development	This draft standard can be applied to the metaverse as it explicitly mentions the term “metaverse” in its definitions, suggesting a direct relevance to the technological ecosystem it seeks to encompass.
ISO/IEC	JTC 1/SC 38	ISO/IEC AWI 20151	Dataspace concepts and characteristics	Under development	This draft standard can be applied to the metaverse as it involves interconnected virtual environments where principles of interoperability are crucial, suggesting its utility in systems . where seamless interaction between diverse digital and physical elements is essential.
ISO/IEC	JTC 1/SC 38	ISO/IEC 19944-2	Data flow, data categories and data use — Part 2: Guidance on and extensibility	Published	This standard can be applied to the metaverse as it involves defining a detailed framework for data usage and processing, which is essential for managing the complex data interactions within virtual environments. ISO/IEC 19944-1 outlines classifications and practices that can enhance interoperability and data usage transparency in these expansive digital ecosystems.
ISO/IEC	JTC 1/SC 38	ISO/IEC 22624:2020	Information technology - Cloud computing - Taxonomy based data handling for cloud services	Published	This standard, ISO/IEC 22624:2020, is not directly applicable to the metaverse as it focuses on data-related policies and practices specifically in the cloud computing environment, without direct references to virtual or augmented worlds that define the metaverse.
ITU-T	SG13	ITU-T Y.3602	Big data - Functional requirements for data provenance	Published (09/2022)	This standard, ITU-T Y.3602, is likely applicable to the metaverse, because it deals with data provenance in big data ecosystems, ensuring data integrity and traceability, which are crucial for creating reliable and interconnected virtual environments that mirror physical counterparts.
ITU-T	SG13	ITU-T Y.3603	Big data - Requirements and conceptual model of metadata for data catalogue	Published (12/2019)	This standard, ITU-T Y.3603, can be utilized in the development of metaverses by defining the use of metadata throughout the big data lifecycle, facilitating improved management and organization of the large, complex data

					structures that virtual and augmented realities in these environments would entail. By providing a structured framework for metadata in a data catalogue, it supports the seamless integration and interoperability needed in sophisticated virtual ecosystems like metaverses.
ITU-T	SG13	ITU-T Y.3607	Big data - Functional architecture for data provenance	Published (01/2023)	This standard, ITU-T Y.3607, can be applicable to the metaverse, particularly for ensuring data accuracy and security within these virtual environments. By utilizing big data provenance architecture, the authenticity and reliability of data operations in the metaverse, such as transactions and user interactions, can be managed effectively.

8.4.3 Interfacing

Table 8-16 provides the metaverse standards selected from Table 7-16 that are closely related to or can be utilized in the metaverse, along with an analysis of their relevance.

Table 8-16: Selected metaverse standards from Table 7-16 and their relevance to metaverse

SDO	Study group	Reference	Title	Status	Relevance to the metaverse
ISO/IEC	JTC 1/SC 29	ISO/IEC 23005-5:2019	Information technology - Media context and control - Part 5: Data formats for interaction devices	Published	This standard, ISO/IEC 23005-5:2019, can be employed effectively in metaverse environments due to its focus on standardizing interfaces for actuators and sensors. By defining the Interaction Information Description Language (IIDL), it facilitates seamless interaction among various devices within virtual worlds, aligning well with the interconnected and interoperable nature of metaverse ecosystems ..
ISO/IEC	JTC 1/SC 29	ISO/IEC 23005-5	Media context and control - Part 5: Data formats for interaction devices	Published	This standard can be effectively utilized in the metaverse because it defines a unified language for communication between devices, enhancing the interoperability and integration necessary in complex virtual environments .

ITU-T	SG16	F.DHAI	Framework and requirements of digital human access interfaces	Under development	This draft standard is applicable to the metaverse as it addresses the integration of digital humans within virtual environments, a core component of immersive experiences in metaverses. By establishing a unified access interface for digital human services, it enhances connectivity and interoperability in these virtual spaces, aligning closely with the principles stated in the definition of the metaverse.
W3C	W3C Browser Testing and Tools WG	WebDriver, https://www.w3.org/TR/webdriver/	WebDriver	Under development	This draft standard is applicable to the metaverse as it addresses seamless interoperability and connectivity, crucial for creating synchronised virtual environments mirroring the physical world.
W3C	W3C Web Platform Incubator CG	Web Speech, https://wicg.github.io/speech-api/	Web Speech API	Proposed	This draft standard is relevant to the metaverse concept as it facilitates the integration and interoperability of different technologies and platforms, which is essential for creating an interconnected digital ecosystem. It aligns with the metaverse's principle of providing immersive experiences through a cohesive virtual space that can interact with the physical world.
W3C	W3C Web Real-Time Communications WG	Audio Output Devices https://www.w3.org/TR/audio-output/	Audio Output Devices API	Under development	This draft standard can be applied to the metaverse as it defines mechanisms for managing audio output, which is crucial for creating immersive audio experiences in virtual environments, thus enhancing the overall interaction and realism within a metaverse.

8.4.4 Network infrastructure

Table 8-17 provides the metaverse standards selected from Table 7-17 that are closely related to or can be utilized in the metaverse, along with an analysis of their relevance.

Table 8-17: Selected metaverse standards from Table 7-17 and their relevance to metaverse

SDO	Study group	Reference	Title	Status	Relevance to the metaverse
IEEE	P62209-3 WG	IEEE 1528.7-2020	IEEE Guide for EMF Exposure Assessment of Internet of Things (IoT) Technologies and Devices	Published	This standard, IEEE 1528.7-2020, does not relate directly to the metaverse as it specifically addresses RF exposure characteristics of IoT devices, rather than environments integrating or representing physical and virtual worlds.
ITU-T	SG13	ITU-T Y.3120	Functional architecture for latency guarantee in large scale networks including IMT-2020 and beyond	Published (01/2023)	This standard, ITU-T Y.3120, along with Y.3113 and Y.2111, may not directly pertain to the development or functioning of metaverses because they focus primarily on flow aggregate-based scheduling, resource, and admission control functions related specifically to network quality services and infrastructure in next generation networks, rather than the immersive, interconnected virtual experiences typical of metaverses. Hence, this standard's relevance to metaverse implementations is marked “X”.
ITU-T	SG13	ITU-T Y.3138	Unified multi-access edge computing for supporting fixed mobile convergence in IMT-2020 networks	Published (09/2022)	ITU-T Y.3138 could be applicable to the metaverse, as it defines architectures for unified multi-access edge computing, which supports seamless interoperability and connectivity essential for integrating virtual environments with physical ones in metaverse applications, fostering more realistic and synchronous virtual and physical city experiences.
ITU-T	SG16	ITU-T F.746.15	Requirements for smart broadband network gateway in multimedia content transmission	Published (12/2022)	This standard ITU-T F.746.15 can be applied to the metaverse because it outlines requirements for the smart broadband network gateway (BNG) essential for multimedia content transmission, a key element in virtual environments such as metaverses to ensure seamless integration and interoperability between virtual and physical entities.

8.4.5 Storage infrastructure

N/A

8.4.6 Computing power infrastructure

Table 8-18 provides the metaverse standards selected from Table 7-18 that are closely related to or can be utilized in the metaverse, along with an analysis of their relevance.

Table 8-18: Selected metaverse standards from Table 7-18 and their relevance to metaverse

SDO	Study group	Reference	Title	Status	Relevance to the metaverse
ISO/IEC	JTC 1/SC 38	ISO/IEC 19944 (series)	Cloud computing and distributed platforms - Data flow, data categories and data use	Published	This standard, ISO/IEC 19944, can be utilized for metaverse applications as it outlines how data flows, is categorized, and is used across cloud computing and distributed platforms. The metaverse often relies on complex data interactions and cloud-based technologies to create immersive, interconnected virtual environments, making the guidance from ISO/IEC 19944 directly relevant.
ITU-T	SG13	ITU-T Y.3600	Big data - Cloud computing-based requirements and capabilities	Published (11/2015)	This standard can be applied to the metaverse because it elaborates on creating and managing large datasets within cloud environments, which are essential for the functioning and development of immersive, data-intensive virtual worlds like those found in the metaverse.
ISO/IEC	JTC 1/SC 38	ISO/IEC 22123-3	Cloud computing — Part 3: Reference architecture	Published	This standard, focusing on interoperability and connectivity, aligns well with the concept of a metaverse, as both emphasize seamless integration and interaction among various systems and entities within digital environments.
W3C	W3C GPU for	WebGPU https://www.w3.org/TR/webgpu/	WebGPU	Under development	This draft standard likely applies to the metaverse as it specifically mentions connectivity and interoperability principles, essentials for creating

	the Web WG				integrated, sustainable virtual environments linked with real-world cities, enhancing user experience and functionality across virtual and physical spaces.

9 Standardization matrix of the metaverse

This clause provides a matrix for gap analysis and the related standardization activities on metaverse to identify standardization gaps. The matrix is populated with the metaverse standards provided in Clause 8, which were selected from Clause 7 as the metaverse standards that are closely related to or can be utilized in the metaverse.

Table 9-1: Standardization matrix of the metaverse

Category	Subcategory	General/ Overview	Use case/Scenario	Requirements	Framework/ Architecture	Protocol
General standards	Framework, terminology and definitions	IEEE P2048™ IEEE P7016™ISO/IEC 18026 ISO/IEC 22123-1 ISO/IEC 22123-2 ISO/IEC 19086 ISO/IEC 23751 ISO/IEC AWI 19274 ISO/IEC TS 5928 ISO/IEC 17788:2014 ISO/IEC 22989 ISO/IEC 20546:2019 FGMV-02	ISO/IEC TR 23951:2020		ITU-T Y.4000/Y.2060	ISO/IEC 23005-6:2019 ISO/IEC 23005-6

		FGMV-20 FGMV-21 FGMV-24 FGMV-25 ITU-T Y.4000/Y.2060				
	Evaluation			ISO/IEC 19794 (series)		
	Inclusive city development	FGMV-18				
	Sustainability	FGMV-01 FGMV-08				
	Security	RFC 8576 ISO/IEC TR 5891 ISO/IEC TR 6114 ISO/IEC PWI (NP) 11034 ISO/IEC PWI (NP) 20996 FGMV-10 FGMV-06 FGMV-11 FGMV-12 FGMV-23 FGMV-14TR.cs-sc X.cs-ra ITU-T X.1054 ITU-T X.1051	TR.cs-sc TR.cs-uc	ISO/IEC 27001 TR.cs-sc TR.cs-ucITU-T X.1051 ITU-T X.1603	TR.cs-uc X.cs-ra ISO/IEC 23090 10:2022	

		CRAMM Roadmap				
	Accessibility	FGMV-03 FGMV-15 FGMV-161/225-E SAUR https://www.w3.org/TR/saur/ NAUR https://www.w3.org/TR/naur/ RAUR https://www.w3.org/TR/raur/ Accessibility of Remote Meetings https://www.w3.org/TR/remote-meetings/ Making Content Usable for People with Cognitive and Learning Disabilities https://www.w3.org/TR/coga-usable/ MAUR https://www.w3.org/TR/media-accessibility-reqs/ Core AAM https://www.w3.or		FGMV-04 FGMV-05 FGMV-17 FGMV-26		

		g/TR/core-aam-1.2/ Graphics AAM https://www.w3.org/TR/graphics-aam-1.0/ WAI-ARIA 1.1 https://www.w3.org/TR/wai-aria-1.1/				
Application and Service standards	Agriculture					
	Power energy	FGMV-27	FGMV-09 FGMV-27		FGMV-27	
	Tourism and cultural heritage					
	Retail and fashion					
	Banking					
	Medical					
	Manufacturing					
	Education		ITU-T F.742.1	ITU-T F.742.1	ISO/IEC 21000-20	
	City Governance	FGMV-07 ISO/IEC TS 5147				
	Transportation					
	Urban Construction					
	Environmental protection	ISO/IEC 18023-1 ISO/IEC 18024-4				
	Etc.		TR 22.856 ISO/IEC 19775-2			

			ITU-T H.430.3			
Enabling technology standards	Virtual reality and augmented reality	IEC TR 63308:2021 IEEE 1589-2020 ISO/IEC 14772-1:1997 ISO/IEC 23488:2022 ISO/IEC TR 23842 (series) ISO/IEC AWI TR 16088 FGMV-17 ITU-T P.1320 ITU-T F.740.2 ISO/IEC 21000 23:2022 XAUR https://www.w3.org/TR/xaur WGSL https://www.w3.org/TR/WGSL/ WebXR https://www.w3.org/TR/webxr/ WebXR-AR https://www.w3.org/TR/webxr-ar-module-1/	IEEE 1589-2020 FGMV-17 ITU-T G.1035 ITU-T G.1036	IEC 63145-20-20:2019 ISO/IEC 14772-2:2004 ISO/IEC TS 23884:2021 ISO/IEC 3721:2023 ISO/IEC TS 23884 ITU-T Q.4066 ITU-T Y.3109 ITU-T F.746.14 ITU-T J.301	IEEE 1589-2020 ISO/IEC 14772-1:1997 ISO/IEC 14772-2:2004 ISO/IEC 18038:2020 ISO/IEC 19775-1:2013 ISO/IEC 3721:2023 ISO/IEC 19775-1 ISO/IEC 18038 ISO/IEC 18039 ISO/IEC 18040 ISO/IEC 3721 ISO/IEC 18520 ISO/IEC 21145 FGMV-23 FGMV-26 ITU-T Y.3109 ITU-T F.746.14 ITU-T J.cloud-vr-arch	IEEE 1589-2020 ISO/IEC 18038:2020 ISO/IEC 18038 ISO/IEC 18040 ISO/IEC 21145

		WebXR Depth Sensing https://www.w3.org/TR/webxr-depth-sensing-1/ WebXR Dom Overlays https://www.w3.org/TR/webxr-dom-overlays-1/ WebXR Gamepad https://www.w3.org/TR/webxr-gamepads-module-1/ WebXR Hand Input https://www.w3.org/TR/webxr-hand-input-1/ WebXR Hit Test https://www.w3.org/TR/webxr-hit-test-1/ WebXR Layers https://www.w3.org/TR/webxrlayers-1/ WebXR Lightning Estimation https://www.w3.org/TR/webxr-				

		lighting-estimation-1/ WebXR Anchors https://immersive-web.github.io/anchors/				
	Digital twin	ISO/IEC AWI 30173 ISO 23247:2021 (series) FGMV-29	ISO/IEC AWI 30172 FGMV-28	FGMV-28 ITU-T Y.4600	ISO/IEC 23090-7	ISO/IEC 23090-7
	Blockchain	ISO 22739 ISO/TS 23258 ISO/TS 23635 ISO/AWI TS 18126 ISO/AWI TS 23353 ITU-T X.1403 ITU-T Y.2247	ITU-T Y.2247	ITU-T Y.2247	IEEE 2418.10-2022 ISO 23257 ISO/TS 23635 ISO/AWI 20435 ITU-T Y.2247	IEEE 3207-2022 IEEE 2418.2-2020
	Media coding	ISO/IEC 19776-2 ISO/IEC 19776-3 ISO/IEC 23090-5 ISO/IEC 23090-9 ISO/IEC 23090-12 ISO/IEC 23488 ISO/IEC 23090-2 ISO/IEC 23090-9 ISO/IEC 23090-12	ISO/IEC 23008-3 ITU-T P.919	ISO/IEC 23005-2 ISO/IEC 23005-7 ISO/IEC 23093-2 ISO/IEC 23093-4 ITU-T P.919 F.CEMP-DHS ISO/IEC 23008-3 ISO/IEC 23090-9	ISO/IEC 19776-1 ISO/IEC 23005-1 ISO/IEC 23005-2 ISO/IEC 23005-7 ISO/IEC 23093-4 ISO/IEC 14496-16 ISO/IEC 14496-25 ISO/IEC 23090-5 ISO/IEC 23090-8	ISO/IEC 19776-1- ISO/IEC 19776-3- ISO/IEC 23005-3- ISO/IEC 23093-3- ISO/IEC 12087-5 ISO/IEC 23090-5 ISO/IEC 23090-8 ISO/IEC 23090-10 ISO/IEC 23090-31

		ISO/IEC 23090-14 ISO/IEC 23090-18 ISO/IEC AWI 23090-30 ISO/IEC 23090-5 ISO/IEC 21000-19 ISO/IEC 23001-7 Web Audio https://www.w3.org/TR/webaudio/ IFT, https://www.w3.org/TR/IFT/ Media Capture and Streams https://www.w3.org/TR/mediacapture-streams/ MediaStreamTrack Content Hints https://www.w3.org/TR/mst-content-hint/			ISO/IEC 23090-12 ISO/IEC AWI 23090-29 F.CEMP-DHS ITU-T J.1303 ISO/IEC 23008-3 ISO/IEC 23090-6 ISO/IEC 23090-9 ISO/IEC 21000-1 ISO/IEC 21000-2 ISO/IEC 21000-3 ISO/IEC 21000-5 ISO/IEC 21000-6 ISO/IEC 21000-7 ISO/IEC 21000-21 ISO/IEC 23006-1 ISO/IEC 23006-5	ISO/IEC 23005-3 ISO/IEC 23090-6- ISO/IEC 21000-3 ISO/IEC 21000-7- ISO/IEC 23006-4-
	Artificial Intelligence	ISO/IEC WD 27091 ISO/IEC 5339 ISO/IEC TR 24368 ISO/IEC TR 24372 ISO/IEC 38507 FGMV-22 FGMV-13	ISO/IEC TR 24030	ITU-T Q.5008	ITU-T Q.5008 ITU-T Y.3178	

		ITU-T F Suppl. 4 ITU-T Suppl 72 to ITU-T Y-3000 series ITU-T Y.3115 ITU-T F.748.26 ISO/IEC 23090-14				
	Digital Human/ Avatar	ISO/TR 24464:2020 ISO/IEC 19774-2 F.DHPIE F.FDHC https://github.com/vrm-c/vrm-specification	ITU-T F.748.15 F.CSDH	ITU-T F.748.14 ITU-T F.748.27 F.DH-PE F.DHSMD F.CSDH	ISO/IEC 19774-1 ISO/IEC 23005-4ITU-T F.748.15 ITU-T F.748.27 F.FDHC	ISO/IEC 23005-4
Interoperability and ICT related infrastructure standards	Interoperability protocols	IEEE 3205-2023 RFC 8477 ISO/IEC 19941 ISO/IEC 19941:2017 WoT Thing Description, https://www.w3.org/TR/wot-thing-description/ WoT Discovery, https://www.w3.org/TR/wot-discovery/	FGMV-19 WoT Discovery, https://www.w3.org/TR/wot-discovery/	ISO/IEC 23005-2 FGMV-19 ITU-T Y.4217 ISO/IEC 21000 4:2012	IEEE 2413-2019 ISO/WD TS 23516 ISO/IEC 19777-1:2006 ISO/IEC 23005-2 ISO/IEC AWI TS 10866 ITU-T Y.4217 ISO/IEC 21000 4:2012 WoT Architecture, https://www.w3.org/TR/wot-architecture/	IEEE 3205-2023 ISO/IEC 19777-1:2006 ISO/IEC 21000 4:2012

		WebRTC https://www.w3.org/TR/webrtc/				
	Data sharing	ISO/IEC AWI 20151	ISO/IEC AWI TR 10267-2 ISO/IEC 19944-2	ITU-T Y.3602 ITU-T Y.3603	ISO/IEC 19944-2 ISO/IEC 22624:2020 ITU-T Y.3603 ITU-T Y.3607	
	Interfacing	F.DHAI WebDriver, https://www.w3.org/TR/webdriver/ Web Speech, https://wicg.github.io/speech-api/ Audio Output Devices https://www.w3.org/TR/audio-output/				ISO/IEC 23005-5
	Network infrastructure	IEEE 1528.7-2020	ITU-T F.746.15	IEEE 1528.7-2020 ITU-T Y.3138 ITU-T F.746.15	IEEE 1528.7-2020 ITU-T Y.3120 ITU-T Y.3138 ITU-T F.746.15	
	Storage infrastructure					
	Computing power	ISO/IEC 19944 (series) ITU-T Y.3600	ITU-T Y.3600	ITU-T Y.3600	ISO/IEC 22123-3	

		WebGPU https://www.w3.org/TR/webgpu/				

Table 9-1 shows the standardization matrix of the metaverse, which is composed of two axes. The horizontal axis describes the steps in the standard as follows:

- General, overview: the standard which provides general descriptions, terms and definitions, and overview of the technology;
- Use case, scenario: the standard which provides use cases and scenario;
- Requirements: the standard that provides derived general/functional requirements;
- Framework, architecture: the standard that provides reference architecture and framework;
- Protocol: the standard that provides a protocol.

The vertical axis describes the metaverse standard categories described in Clause 6 as follows:

- General standards: the standards addressing common and general aspects of the metaverse, which include:
  - Framework, terminology and definitions;
  - Evaluation;
  - Sustainability;
  - Security;
  - Accessibility.
- Application and Service standards: the standards in various domains that seek to enhance productivity, address global challenges, and contribute to sustainability while providing richer experiences for different user.
- Enabling technology standards: the standards play a pivotal role in shaping the metaverse, which include:
  - Virtual reality and augmented reality;
  - Digital twin;
  - Blockchain;
  - Media coding;
  - Artificial Intelligence;
  - Digital Human/Avatar.
- Interoperability and ICT related infrastructure standards: the standards to ensure an efficient architecture that supports diverse metaverse requirements, which include:

- Interoperability protocols;
- Data sharing;
- Interfacing;
- Network infrastructure;
- Storage infrastructure;
- Computing power infrastructure.

Numerous standards related to the metaverse have been investigated in this document. The majority of them fall into the realm of general or overview standards of the horizontal axis in Table 9-1. In particular, in the Enabling Technology Standards category, metaverse-related standards have been developed at all stages of the standards lifecycle. The Interoperability and ICT-related Infrastructure Standards categories also have a relatively even distribution of standards. On the other hand, there are also several blocks for which there are no standards yet, which are colored to distinguish them in the matrix. Therefore, in order to effectively realize the metaverse, it is necessary to develop standards for metaverse-specific use cases, scenarios, requirements, frameworks, architectures and protocols.

Considerations on future gap analysis for the standardization phase of metaverse-related technologies are as follows:

Potential gap analysis for the standardization phase of metaverse-related technologies is as follows:

- General or Overview: Existing standards primarily focus on providing a broad understanding of the metaverse concept and its potential implications. However, there is a lack of comprehensive standards that delve into specific technical requirements and implementation guidelines for various aspects of the metaverse;
- Use Cases, Scenarios: While some use cases and scenarios have been identified and explored, there remains a need for more comprehensive coverage across diverse application domains within the metaverse, as existing examples may not fully capture emerging trends or address niche requirements of different user groups;
- Requirements: While certain requirements have been identified, there is a need for more detailed and standardized specifications that address the diverse needs of metaverse stakeholders. Existing requirements may not fully capture evolving technological capabilities or adequately address issues such as interoperability and security;
- Frameworks, Architectures: Existing frameworks provide valuable guidance on metaverse development, but there is a lack of standardized frameworks that offer comprehensive coverage of all aspects, including architecture, interoperability, and content creation. Additional frameworks may be necessary to address specific challenges and facilitate seamless integration of diverse metaverse components.
- Protocols: While some protocols have been proposed, there is a need for more standardized approaches that ensure interoperability, scalability, and security across different metaverse platforms and technologies. Existing protocols may lack sufficient flexibility to accommodate future advancements or may not adequately address emerging security and privacy concerns.

[Note] The above gap analysis is for the standardization phase provided by the horizontal axis in Table 9-1. The details of task for each related technology standards provided by the vertical axis in Table 9-1 are provided in another FG-MV deliverable called “standardization roadmap for metaverse” [b-ITU FGMV-51].

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[b-ITU FGMV-51] Technical Report on Standardization roadmap for metaverse.

[b-ITU FGMV-20] Technical Specification on Definition of metaverse. Available at: https://www.itu.int/en/ITU-T/focusgroups/mv/Pages/deliverables.aspx