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Abstract: This document contains the base document of FGMV-D9.1-gap_analysis Technical Report on a gap analysis on metaverse standardization.

This document contains the base document of FGMV-D9.1-gap_analysis Technical Report on a gap analysis on metaverse standardization. This output document has been developed based on the following input document proposed to this 3rd FG-MV meeting and the other 3 input documents submitted to the 1st FG-MV meeting in March 2023. The discussion result about the input document is as follows.

No.	Source	Title	Discussion
FG-MV-I-275-R1	Electronics and Telecommunications Research Institute (ETRI) (Korea (Rep. of))	Proposed document structure of a Technical Report on a gap analysis and standardization roadmap for metaverse	This input document proposed a structure of a Technical Report on a gap analysis and standardization roadmap for metaverse. WG9/FG-MV agreed to the structure but to delete the standardization roadmap.
FGMV-I-023	Electronics and Telecommunications Research Institute (ETRI) (Korea (Rep. of))	Standardization activities on metaverse interoperability	It was requested to merge this into a draft TR on gap analysis on metaverse standardization, but no progress was made.

FGMV-I-025	National Institute of Information and Communications Technology (NICT) (Japan), Oki Electric Industry Company Ltd. (OKI) (Japan)	Proposal for initial gap analysis on metaverse	It was requested to merge this into a draft TR on gap analysis on metaverse standardization, but no progress was made.
FGMV-I-029	Nokia Corporation (Finland)	Draft initial gap analysis on metaverse standardization	It was requested to merge this into a draft TR on gap analysis on metaverse standardization, but no progress was made.

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Technical Report ITU-T FGMV-D9.1-gap-analysis

Gap analysis on metaverse standardization

Summary

This technical report provides a gap analysis on metaverse standardization. It has been developed to assist in the development of metaverse-related standards by providing information on existing standards and standards under development in key standards development organizations (SDOs). In addition, it provides metaverse-related technologies from the standards perspective of SDOs.

Keywords

[if any provided]

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-T Technical Report on "*Title*" approved at the [meeting] held [venue], [date]

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Technical Report ITU-T FGMV-D9.1-gap-analysis

Gap analysis on metaverse standardization

1 Scope

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

- overview of metaverse-related technologies from the perspective of standards development;
- metaverse-related standards development status in standards development organizations (SDOs);
- standardization gap analysis.

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of these Technical Specifications. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of these Technical Specifications are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within these Technical Specifications does not give it, as a stand-alone document, the status of a Recommendation.

TBD

[ITU-T X.yyy] Recommendation ITU-T X.yyy (date), *Title*.

3 Terms and definitions

3.1 Terms defined elsewhere

This Technical Report uses the following terms defined elsewhere:

3.1.2 term [reference]: definition

3.1.3 term [reference]: definition

3.2 Terms defined here

This Technical Report defines the following terms:

3.2.1 term [reference]: definition

3.2.2 term [reference]: definition

4 Abbreviations

ABC spell it out

5 Conventions

None

6 Metaverse-related technologies

This clause provides the overview of metaverse-related technologies from the perspective of standards development. Table 1 shows the technologies that power the metaverse.

Table 1: Technologies that power the metaverse

Technical areas	Technologies
General	• Metaverse itself
Digital identity	• Identity Management • Avatar
Human argumentation	• Digital human • VR/AR/MR • Immersive media • User Interaction • Brain–computer interface (BCI)
Infrastructure	• Network (5G/6G, etc.) • Cloud/Edge Computing
Technology enabler	• AI • IoT • Big Data • Digital Twin • Blockchain • Crypto Currency • NFT
Ethics	• Ethics
Security and privacy	• CyberSecurity • Privacy • PII • Safety • Child online protection • Trust
Regulation	• Economic • Regulatory • Competition
Accessibility and sustainability	• Accessibility • Sustainability

	• Inclusion

6.1 General

[TBD]

6.2 Digital identity

[TBD]

6.3 Human argumentation

[TBD]

6.4 Infrastructure

[TBD]

6.5 Technology enabler

[TBD]

6.6 Ethics

[TBD]

6.7 Security and privacy

[TBD]

6.8 Regulation

[TBD]

6.9 Accessibility and sustainability

[TBD]

7 Metaverse-related standards development status in SDOs

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

7.1 Common

[TBD]

7.2 Identity Management

Table X: ITU-T deliverables and work items

Study group	Reference	Title	Status
	ITU-T X.1403	Security guidelines for using distributed ledger technology for decentralized identity management	Published (09/2020)
To be added…			

- **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.

7.3 Avatar

[TBD]

7.4 Digital human

Table X: ITU-T deliverables and work items

Study group	Reference	Title	Status

SG16	ITU-T F.748.15	Framework and metrics for digital human application systems	Published (03/2022)
SG16	ITU-T F.748.14	Requirements and evaluation methods of non-interactive 2D real-person digital human application systems	Published (03/2022)
To be added…			

- **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 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, 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.

Table X: ISO/IEC deliverables and work items

Study group	Reference	Title	Status
	ISO/IEC 19794 (series)	Information technology - Biometric data interchange formats	Published
	ISO/IEC 29794 (series)	Information technology - Biometric sample quality	Published
	ISO/IEC 39794 (series)	Information technology - Extensible biometric data interchange formats	Published
To be added…			

- **ISO/IEC 19794** is one of a family of International Standards being developed by ISO/IEC JTC 1/SC 37 that support interoperability and data interchange among biometric applications and systems. This family of standards specifies requirements that solve the complexities of applying biometrics to a wide variety of person-recognition applications, whether such applications operate in an open systems environment or consist of a single, closed system. ISO/IEC 19794 series contains following parts:
  - ISO/IEC 19794-1:2006 Information technology -- Biometric data interchange formats -- Part 1: Framework
  - ISO/IEC 19794-1:2011 Information technology -- Biometric data interchange formats -- Part 1: Framework
  - ISO/IEC 19794-2:2005 Information technology -- Biometric data interchange formats -- Part 2: Finger minutiae data
  - ISO/IEC 19794-2:2011 Information technology -- Biometric data interchange formats -- Part 2: Finger minutiae data
  - ISO/IEC 19794-3:2006 Information technology -- Biometric data interchange formats -- Part 3: Finger pattern spectral data
  - ISO/IEC 19794-4:2005 Information technology -- Biometric data interchange formats -- Part 4: Finger image data
  - ISO/IEC 19794-4:2011 Information technology -- Biometric data interchange formats -- Part 4: Finger image data

  - ISO/IEC 19794-5:2011 Information technology -- Biometric data interchange formats -- Part 5: Face image data
  - ISO/IEC 19794-6:2005 Information technology -- Biometric data interchange formats -- Part 6: Iris image data
  - ISO/IEC 19794-6:2011 Information technology -- Biometric data interchange formats -- Part 6: Iris image data
  - ISO/IEC 19794-7:2014 Information technology -- Biometric data interchange formats -- Part 7: Signature/sign time series data
  - ISO/IEC 19794-7:2021 Information technology - Biometric data interchange formats - Part 7: Signature/sign time series data
  - ISO/IEC 19794-8:2006 Information technology -- Biometric data interchange formats -- Part 8: Finger pattern skeletal data
  - ISO/IEC 19794-8:2011 Information technology -- Biometric data interchange formats -- Part 8: Finger pattern skeletal data
  - ISO/IEC 19794-9:2007 Information technology -- Biometric data interchange formats -- Part 9: Vascular image data
  - ISO/IEC 19794-9:2011 Information technology -- Biometric data interchange formats -- Part 9: Vascular image data
  - ISO/IEC 19794-10:2007 Information technology -- Biometric data interchange formats -- Part 10: Hand geometry silhouette data
  - ISO/IEC 19794-11:2013 Information technology -- Biometric data interchange formats -- Part 11: Signature/sign processed dynamic data
  - ISO/IEC 19794-13:2018 Information technology - Biometric data interchange formats - Part 13: Voice data
  - ISO/IEC 19794-14:2022 Information technology - Biometric data interchange formats - Part 14: DNA data
  - ISO/IEC 19794-15:2017 Information technology - Biometric data interchange format - Part 15: Palm crease image data
- **ISO/IEC 29794** defines and specifies methodologies for objective, quantitative quality score expression, interpretation, and interchange. ISO/IEC 29794 series contains following parts:
  - ISO/IEC 29794-1:2016 Information technology - Biometric sample quality - Part 1: Framework
  - ISO/IEC 29794-4:2017 Information technology - Biometric sample quality - Part 4: Finger image data
  - ISO/IEC 29794-6:2015 Information technology - Biometric sample quality - Part 6: Iris image data
  - ISO/IEC TR 29794-5:2010 Information technology -- Biometric sample quality -- Part 5: Face image data
- **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

7.5 VR/AR/MR

[TBD]

Table X: ITU-T deliverables and work items

Study group	Reference	Title	Status
SG16	ITU-T H.430.3	Service scenario of immersive live experience (ILE)	Published (08/2018)
SG12	ITU-T P.919	Subjective test methodologies for 360° video on head-mounted displays	Published (10/2020)
	ITU-T F.746.14	Requirements and reference framework for cloud virtual reality systems	Published (12/2022)
	ITU-T G.1035	Influencing factors on quality of experience for virtual reality services	Published (11/2021)
	ITU-T P.1320	Quality of experience assessment of extended reality meetings	Published (07/2022)
	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)
	ITU-T J.301	Requirements for augmented reality smart	Published (10/2014)
	ITU-T J.302	System specifications of augmented reality smart television service	Published (10/2016)
	ITU-T F.740.2	Requirements and reference framework for digital representation of cultural relics and artworks using augmented reality	Published (06/2021)
	ITU-T Q.4066	Testing procedures of augmented reality applications	Published (09/2020)
	ITU-T G.1036	Quality of experience influencing factors for augmented reality services	Published (07/2022)
To be added…			

- **ITU-T H.430.3**: 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.
- **ITU-T P.919**: 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 F.746.14**: 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 G.1035**: 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 P.1320**: 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 Y.3109**: 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 J.301**: This specifies requirements that should be considered for augmented reality (AR) smart television system (AR-STV).
- **ITU-T J.302**: This specifies the related technologies that should be implemented for augmented reality smart television system.
- **ITU-T F.740.2**: 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 Q.4066**: This defines approaches for testing for various applications of AR.
- **ITU-T G.1036**: 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.

Table X: ISO/IEC deliverables and work items

Study group	Reference	Title	Status
	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 14772-2:2004	Information technology - Computer graphics and image processing - The Virtual Reality Modeling Language	Published

		(VRML) - Part 2: External authoring interface (EAI)	
	ISO/IEC 18038:2020	Information technology - Computer graphics, image processing and environmental representation - Sensor representation in mixed and augmented reality	Published
	ISO/IEC TR 23842 (series)	Information technology for learning, education and training - Human factor guidelines for virtual reality content	Published
	ISO/IEC TR 23843:2020	Information technology for learning, education and training - Catalogue model for virtual, augmented and mixed reality content	Published
To be added…			

- **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 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 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 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 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.

Table X: IEC deliverables and work items

Study group	Reference	Title	Status

	IEC 63145-20-20:2019	Eyewear display - Part 20-20: Fundamental measurement methods - Image quality	Published
	IEC TR 63308:2021	Virtual reality equipment and systems - Market, technology and standards requirements	Published
To be added…			

- **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.
- **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.

Table X: IEEE deliverables and work items

Study group	Reference	Title	Status
	IEEE 3079-2020	IEEE Standard for Head-Mounted Display (HMD)-Based Virtual Reality(VR) Sickness Reduction Technology	Published
	IEEE 1589-2020	IEEE Standard for Augmented Reality Learning Experience Model	Published
To be added…			

- **IEEE 3079-2020**: Head-mounted display-based virtual reality sickness-reducing technology is defined.
- **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

7.6 Immersive media

[TBD]

7.7 User Interaction

Table X: ISO/IEC deliverables and work items

Study group	Reference	Title	Status
	ISO/IEC TR 15440:2016	Information technology - Future keyboards and other input devices and entry methods	Published
To be added…			

- **ISO/IEC TR 15440:2016** supported by the history of information technology keyboards during the last three 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.

7.8 Brain–computer interface (BCI)

[TBD]

7.9 Network (5G/6G, etc.)

Table X: ITU-T deliverables and work items

Study group	Reference	Title	Status
	ITU-T Y.3090	Digital twin network - Requirements and architecture	Published (02/2022)
	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 F.746.15	Requirements for smart broadband network gateway in multimedia content transmission	Published (12/2022)
	ITU-T F.743.15	Requirements for multi-operator core network enabled multimedia services	Published (03/2022)
	ITU-T Y.3120	Functional architecture for latency guarantee in large scale networks including IMT-2020 and beyond	Published (01/2023)

	ITU-T Y.3138	Unified multiaccess edge computing for supporting fixed mobile convergence in IMT-2020 networks	Published (09/2022)
To be added…			

- **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 J.1631** describes 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 over integrated broadband cable networks. Cloud VR is a new cloud computing technology for VR services. With fast and stable transport networks, VR contents are stored and rendered in the cloud. Audiovisual contents are encoded, compressed and transmitted to user terminals. This Recommendation specifies the network requirements of Cloud VR services.
- **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 F.743.15** specifies the requirements for multi-operator core network (MOCN) enabled multimedia services (MOCN-MS). This Recommendation not only defines a high-level functional framework of MOCN enabled multimedia services, but also specifies the sharing capability information unit (SCIU) function requirements and MOCN-MS system requirements according to this framework. In addition, several scenarios for MOCN enabled multimedia services are provided in this Recommendation.
- **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 Y.3138** specifies the requirements, architecture and functions of unified multiaccess edge computing for supporting FMC in networks.

7.10 Cloud/Edge Computing

Table X: ITU-T deliverables and work items

Study group	Reference	Title	Status
	ITU-T Y.3510	Cloud computing infrastructure requirements	Published (02/2016)
	ITU-T Y.3514	Cloud computing - Trusted inter-cloud computing framework and requirements	Published (05/2017)
	ITU-T Y.3516	Cloud computing - Functional architecture of inter-cloud computing	Published (09/2017)
	ITU-T Y.3535	Cloud computing - Functional requirements for a container	Published (02/2022)

	ITU-T Y.3536	Cloud computing - Functional architecture for cloud service brokerage	Published (02/2022)
	ITU-T Y.3538	Cloud computing - Global management framework of distributed cloud	Published (09/2022)
	ITU-T Y.3539	Cloud computing - Framework of risk management	Published (01/2023)
	ITU-T X.1601	Security framework for cloud computing	Published (10/2015)
	ITU-T X.1603	Data security requirements for the monitoring service of cloud computing	Published (03/2018)
To be added…			

- **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 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 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 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 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 Y.3538** introduces the framework and functional requirements for the global management of distributed cloud.
- **ITU-T Y.3539** provides framework of risk management in 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 X.1601** describes the security framework for cloud computing.
- **ITU-T X.1603** analyses data security requirements for the monitoring service of cloud computing which includes monitoring data scope requirements, monitoring data lifecycle, security requirements of monitoring data acquisition and security requirements of monitoring data storage.

Table X: ISO/IEC deliverables and work items

Study group	Reference	Title	Status
	ISO/IEC 22123 (series)	Information technology - Cloud computing	Published
	ISO/IEC 19944 (series)	Cloud computing and distributed platforms - Data flow, data categories and data use	Published
	ISO/IEC 19086 (series)	Information technology - Cloud computing - Service level agreement (SLA) framework	Published
	ISO/IEC 22624:2020	Information technology - Cloud computing - Taxonomy based data handling for cloud services	Published
	ISO/IEC 17788:2014	Information technology -- Cloud computing -- Overview and vocabulary	Published
	ISO/IEC 17789:2014	Information technology - Cloud computing - Reference architecture	Published
	ISO/IEC 19941:2017	Information technology - Cloud computing - Interoperability and portability	Published
	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 23951:2020	Information technology - Cloud computing - Guidance for using the cloud SLA metric model	Published
	ISO/IEC TR 23188:2020	Information technology - Cloud computing - Edge computing landscape	Published
	ISO/IEC TR 23187:2020	Information technology - Cloud computing - Interacting with cloud service partners (CSNs)	Published
	ISO/IEC TR 23613:2020	Information technology - Cloud computing - Cloud service metering elements and billing modes	Published
	ISO/IEC TR 23186:2018	Information technology - Cloud computing - Framework of trust for processing of multi-sourced data	Published
	ISO/IEC TS 23167:2020	Information technology - Cloud computing - Common technologies and techniques	Published

	ISO/IEC TR 22678:2019	Information technology - Cloud computing - Guidance for policy development	Published
To be added…			

- **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 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 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 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 17788:2014** provides an overview of cloud computing along with a set of terms and definitions.
- **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 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 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 TR 23951:2020** describes guidance for using the ISO/IEC 19086-2 metric model, illustrated with examples.
- **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.

- **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 TR 23613:2020** describes a sample set of cloud service metering elements and billing modes
- **ISO/IEC TR 23186:2018** describes a framework of trust for the processing of multi-sourced 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 TS 23167:2020** provides a description of a set of common technologies and techniques used in conjunction with cloud computing.
- **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.

7.11 AI

[TBD]

7.12 IoT

Table X: ITU-T deliverables and work items

Study group	Reference	Title	Status
	ITU-T J.482	Requirements of a radio frequency (RF)/Internet protocol (IP) video switching system	Published (03/2021)
	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.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.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 X.1352	Security requirements for Internet of things devices and gateways	Published (09/2022)

	ITU-T Y.4000/Y.2060	Overview of the Internet of things	Published (06/2012)
	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.4217	Service requirements and capability framework for Internet of things-related crowdsourced systems	Published (08/2022)
	ITU-T Y.4481	Framework for data middle platform in Internet of things and smart sustainable cities	Published (08/2022)
	ITU-T Y.4809	Unified Internet of things identifiers for intelligent transport systems	Published (10/2021)
	ITU-T Y.4810	Requirements for data security of heterogeneous Internet of things devices	Published (11/2021)
	ITU-T Q.3055	Signalling protocol for heterogeneous Internet of things gateways	Published (12/2019)
To be added…			

- **ITU-T J.482** studies 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 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 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 quickly deployed by cable television operators. This Recommendation is part 2 of a multi-part deliverable.
- **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 programmes originating from the Internet to users.
- **ITU-T X.1352** establishes detailed requirements for five security dimensions applicable to Internet of things (IoT) device and gateway.
- **ITU-T Y.2060** 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 Y.2074** provides requirements for Internet of things (IoT) devices used for operation of IoT applications in the context of disaster in addition to the common requirements of IoT in

ITU-T Y.2066. It also provides requirements for the operation of IoT applications during disaster.

- **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 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 Y.4809** defines field formats for identifying road signs and signals, and identifies specific values for identifiers of such signs and signals.
- **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.
- **ITU-T Q.3055** describes the signalling protocol for heterogeneous IoT gateways.

Table X: IEC deliverables and work items

Study group	Reference	Title	Status
	IEC 60050-741:2020	International Electrotechnical Vocabulary (IEV) - Part 741: Internet of Things (IoT)	Published
To be added…			

- **IEC 60050-741:2020** provides a definition of Internet of Things along with related terms and definitions.

Table X: IETF deliverables and work items

Study group	Reference	Title	Status
	IETF RFC 7554	Using IEEE 802.15.4e Time-Slotted Channel Hopping (TSCH) in the Internet of Things (IoT): Problem Statement	Published
	IETF RFC 8240	Report from the Internet of Things Software Update (IoTSU) Workshop 2016	Published
	IETF RFC 8477	Report from the Internet of Things (IoT) Semantic Interoperability (IOTSI) Workshop 2016	Published
	IETF RFC 8576	Internet of Things (IoT) Security: State of the Art and Challenges	Published
	IETF RFC 9006	TCP Usage Guidance in the Internet of Things (IoT)	Published
	IETF RFC 9124	A Manifest Information Model for Firmware Updates in Internet of Things (IoT) Devices	Published

To be added…			

- **IETF 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 RFC 8240** provides a summary of the Internet of Things Software Update (IoTSU) Workshop that took place at Trinity College Dublin, Ireland on the 13th and 14th of June, 2016.
- **IETF RFC 8477** provides a summary of the "Workshop on Internet of Things (IoT) Semantic Interoperability (IOTSI)", which took place in Santa Clara, California March 17-18, 2016.
- **IETF RFC 8576** discusses the various stages in the lifecycle of a thing, documents the security threats to a thing and the challenges that one might face to protect against these threats, and discusses the next steps needed to facilitate the deployment of secure IoT systems.
- **IETF 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.
- **IETF 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.

Table X: IEEE deliverables and work items

Study group	Reference	Title	Status
	IEEE 2413-2019	IEEE Standard for an Architectural Framework for the Internet of Things (IoT)	Published
	IEEE 2144.1-2020	IEEE Standard for Framework of Blockchain-based Internet of Things (IoT) Data Management	Published
	IEEE 1528.7-2020	IEEE Guide for EMF Exposure Assessment of Internet of Things (IoT) Technologies and Devices	Published
To be added…			

- **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, healthcare, 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
- **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.

- **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.

7.13 Big Data

Table X: ITU-T deliverables and work items

Study group	Reference	Title	Status
	ITU-T Y.3600	Big data - Cloud computing based requirements and capabilities	Published (11/2015)
	ITU-T Y.3601	Big data - Framework and requirements for data exchange	Published (05/2018)
	ITU-T Y.3602	Big data - Functional requirements for data provenance	Published (09/2022)
	ITU-T Y.3603	Big data - Requirements and conceptual model of metadata for data catalogue	Published (12/2019)
	ITU-T Y.3604	Big data - Overview and requirements for data preservation	Published (02/2020)
	ITU-T Y.3605	Big data - Reference architecture	Published (09/2020)
	ITU-T Y.3606	Big data - Deep packet inspection mechanism for big data in network	Published (12/2021)
	ITU-T Y.3607	Big data - Functional architecture for data provenance	Published (01/2023)
To be added…			

- **ITU-T Y.3600** provides an approach to use cloud computing to meet existing challenges in the use of big data.
- **ITU-T Y.3601** specifies the framework and requirements for data exchange in a big data ecosystem, identifies general concepts, patterns, activities, and functional requirements based on the big data ecosystem and capabilities defined in ITU-T Y.3600.
- **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 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 Y.3604** provides overview and requirements of big data preservation. It addresses the overview of big data preservation, functional requirements of big data preservation, use cases of big data preservation.
- **ITU-T Y.3605** specifies the big data reference architecture (BDRA). The Recommendation provides a description of reference architecture concepts, user view, functional view and cross cutting aspects.
- **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.
- **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.

Table X: ISO/IEC deliverables and work items

Study group	Reference	Title	Status
	ISO/IEC 20546:2019	Information technology - Big data - Overview and vocabulary	Published
	ISO/IEC 20547 (series)	Information technology - Big data reference architecture	Published
To be added…			

- **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.
- **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

Table X: IEEE deliverables and work items

Study group	Reference	Title	Status
	IEEE 2813-2020	IEEE Standard for Big Data Business Security Risk Assessment	Published
To be added…			

- **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.

7.14 Digital Twin

Table X: ITU-T deliverables and work items

Study group	Reference	Title	Status
	ITU-T Y.4600	Requirements and capabilities of a digital twin system for smart cities	Published (08/2022)
To be added…			

- **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).

7.15 Blockchain

Table X: ITU-T deliverables and work items

Study group	Reference	Title	Status
	ITU-T L.1317	Guidelines on energy efficient blockchain systems	Published (11/2021)
	ITU-T Y.2247	Framework and requirements of network- oriented data integrity verification service based on blockchain in future networks	Published (01/2023)
To be added…			

- **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.

- **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.

Table X: IEEE deliverables and work items

Study group	Reference	Title	Status
	IEEE 2418.2-2020	IEEE Standard for Data Format for Blockchain Systems	Published
	IEEE 2418.10-2022	IEEE Standard for Blockchain based Digital Asset Management	Published
	IEEE 3801-2022	IEEE Standard for Blockchain-based Electronic Contracts	Published
	IEEE 2142.1-2021	IEEE Recommended Practice for E-Invoice Business Using Blockchain Technology	Published
	IEEE 2418.7-2021	IEEE Standard for the Use of Blockchain in Supply Chain Finance	Published
	IEEE P3217	IEEE Standard for Application Interface Specification for Blockchain Systems	Published
	IEEE P3205	IEEE Standard for Blockchain Interoperability - Data Authentication and Communication Protocol	Published
	IEEE P3218	IEEE Standard for Using Blockchain for Carbon Trading Applications	Published
	IEEE P3207	IEEE Standard for Blockchain-based Digital Asset Identification	Published
	IEEE 2146.1-2022	IEEE Standard for Entity-Based Risk Mutual Assistance Model through Blockchain Technology	Published
	IEEE 3802-2022	IEEE Standard for Application Technical Specification of Blockchain-based E-Commerce Transaction Evidence Collecting	Published
To be added…			

- **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 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 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 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 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 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 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 blockchains 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 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 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 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 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.

7.16 Crypto Currency

[TBD]

7.17 NFT

[TBD]

7.18 Ethics

[TBD]

7.19 Cyber Security

[TBD]

7.20 Privacy

[TBD]

7.21 PII

[TBD]

7.22 Safety

[TBD]

7.23 Child online protection

[TBD]

7.24 Trust

[TBD]

7.25 Economic

[TBD]

7.26 Regulatory

[TBD]

7.27 Competition

[TBD]

7.28 Accessibility

[TBD]

7.29 Sustainability

[TBD]

7.30 Inclusion

[TBD]

8 Gap analysis for metaverse standardization

8.1 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 composed of two axes. The horizontal axis describes document categories that cover the subject of applications as follows:

- **General, definition**: the standard which provides general descriptions or terms and definitions of the technology;
- **Use cases, requirements**: the standard which provides use cases and derived general/functional requirements;
- **Framework, architecture**: the standard which provides reference architecture and framework;
- **Data model, format, protocol, API**: the standard which provides data model, format, protocol, API;
- **Others** (e.g., guidelines, profile, etc.).

The vertical axis describes the related technologies that powers the metaverse as follows:

- **common;**
- **Identity Management;**
- **Avatar;**
- **Digital human;**
- **VR/AR/MR;**
- **Immersive media;**
- **User Interaction;**
- **Brain–computer interface (BCI);**
- **Network (5G/6G, etc.);**
- **Cloud/Edge Computing;**
- **AI;**
- **IoT;**
- **Big Data;**
- **Digital Twin;**
- **Blockchain;**
- **Crypto Currency;**
- **NFT;**
- **Ethics;**
- **Cyber Security;**
- **Privacy;**
- **PII**
- **Safety**
- **Child online protection**
- **Trust**
- **Economic**
- **Regulatory**
- **Competition**
- **Accessibility**
- **Sustainability**
- **Inclusion**

Table X shows the standardization matrix related to metaverse.

Table X: Standardization matrix of the metaverse

	General/ Definition	Use case/ Requirement	Framework/ Architecture	Data model, Format, Protocol, API	Others (e.g., Guideline, profile, etc.)
Common					
Identity Management					
Avatar					
Digital human					
VR/AR/MR		ITU-T H.430.3			ITU-T P.919
Immersive media					
User Interaction					
Brain–computer interface (BCI);					
Network (5G/6G, etc.)					
Cloud/Edge Computing					
AI					
IoT					
Big Data					
Digital Twin					
Blockchain					

	General/ Definition	Use case/ Requirement	Framework/ Architecture	Data model, Format, Protocol, API	Others (e.g., Guideline, profile, etc.)
Common					
Crypto Currency					
NFT					
Ethics					
CyberSecurity					
Privacy					
PII					
Safty					
Child online protection					
Trust					
Economic					
Regulatory					
Competitions					
Accessibility					
Sustainability					
Inclusion					

8.2 Analysis on standardization matrix of the metaverse

This subclause provides the analysis on standardization matrix of the metaverse including the follows:

- metaverse-related technology-specific standards development status in SDOs;
- standard stages for metaverse-related technology-specific development;
- SDO-specific key technologies;
- further considerations
- [TBD].