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Standardization roadmap for metaverse

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Standardization roadmap for metaverse

Summary

Recently, metaverse has become one disruptive area of innovation with great potential to enhance our economy, and change the way of living. In this nascent phase of the metaverse, the industry is not yet clear about the direction and steps of technical development. This Technical Report is intended to outline a concise roadmap of metaverse standardization. In clause six, a framework of metaverse standards is provided. It is structured in four categories (i.e., General standards, Application and service standards, Enabling technology standards, Interoperability and ICT related infrastructure standards). In clause seven, the report presents the motivation of standardization and lists each metaverse-related standardization tasks, as well as relevant study groups of SDOs, consortium and forums that are working on the topic.

This technical report will be beneficial to the standardization activities of ITU-T study groups, other SDOs, consortium and forums.

Keywords

Blockchain; CitiVerse; digital twin; metaverse; roadmap; standardization

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 "*Standardization roadmap for metaverse*" approved at the 7th meeting of the ITU Focus Group on metaverse (FG-MV) held on 12-13 June 2024.

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Additional information and materials relating to this report can be found at: https://www.itu.int/go/fgmv. If you would like to provide any additional information, please contact Cristina Bueti at tsbfgmv@itu.int.

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1 Scope

This technical report provides a roadmap of standards for metaverse. It outlines the standardization pathways while considering the ongoing work being carried out by various standards development organizations (SDOs) and forums.

2 References

[ITU-T Y.4600] Recommendation ITU-T Y.4600 (2022), *Requirements and capabilities of a digital twin system for smart cities*.

[ITU-T FG-MV-20] ITU-T Focus Group Technical Specification FGMV-20 (2023), *Definition of metaverse*.

3 Definitions

3.1 Terms defined elsewhere

This Technical Report uses the following terms defined elsewhere:

3.1.1 metaverse [ITU-T FG-MV-20]: An integrative ecosystem of virtual worlds offering immersive experiences to users, that modify pre-existing and create new value from economic, environmental, social and cultural perspectives.

NOTE – A metaverse can be virtual, augmented, representative of, or associated with the physical world.

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

NOTE – A digital twin may require different capabilities (e.g., synchronization, real-time support) according to the specific domain of application.

3.2 Terms defined in this Technical Report

None.

4 Abbreviations and acronyms

3GPP	3rd Generation Partnership Project
AI	Artificial Intelligence
AR	Augmented Reality
CNCF	Cloud Native Computing Foundation
DMTF	Distributed Management Task Force
ETSI	European Telecommunications Standards Institute
ICT	Information and Communications Technology
IDC	Internet Data Center
IDEA	Immersive Digital Experiences Alliance
ISO	International Organization for Standardization
IEC	International Electrotechnical Commission

IEEE	Institute of Electrical and Electronics Engineers
IETF	Internet Engineering Task Force
IoT	Internet of Things
HL7	Healthcare Level 7
GHG	Green House Gas
JTC	Joint Technical Committee
OCP	Open Compute Project
QoE	Quality of Experience
SDOs	Standards Development Organizations
SLAM	Simultaneous Localization and Mapping
SNIA	Storage Networking Industry Association
UI	User Interface
VR	Virtual Reality
W3C	World Wide Web Consortium

5 Conventions

None.

6 Framework and timeline of metaverse standards

6.1 Framework of metaverse standards

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

- General standards,
- Application and service standards,
- Enabling technology standards, and
- Interoperability and ICT related infrastructure standards.

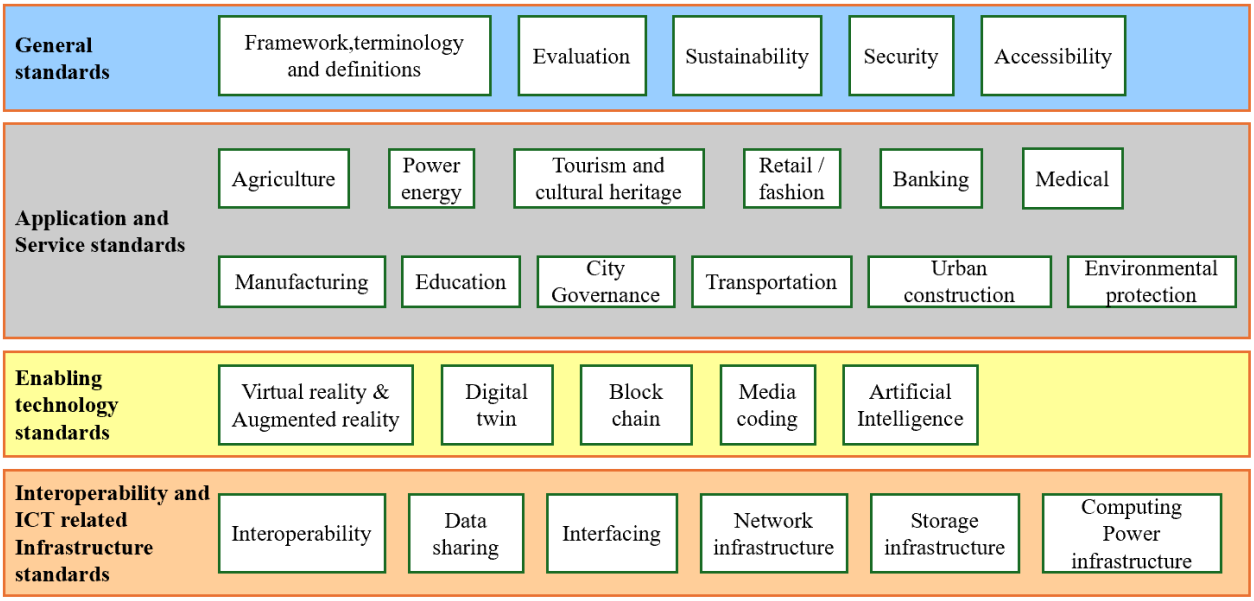

Figure 1 - Example of metaverse standard categories

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

Framework, terminology and definitions (see subclause 7.1.1),

Evaluation (see subclause 7.1.2),

Sustainability (see subclause 7.1.3),

Security (see subclause 7.1.4), and

Accessibility (see subclause 7.1.5).

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 (see subclause 7.2.1),

Power energy (see subclause 7.2.2),

Tourism and cultural heritage (see subclause 7.2.3),

Retail and fashion (see subclause 7.2.4),

Banking (see subclause 7.2.5),

Medical (see subclause 7.2.6),

Manufacturing (see subclause 7.2.7),

Education (see subclause 7.2.8),

City Governance (see subclause 7.2.9),

Transportation (see subclause 7.2.10),

Urban Construction (see subclause 7.2.11), and

Environmental protection (see subclause 7.2.12).

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 description of desired standards are provided as follows:

Virtual reality and augmented reality (see subclause 7.3.1),

Digital twin (see subclause 7.3.2),

Blockchain (see subclause 7.3.3),

Media coding (see subclause 7.3.4), and

Artificial Intelligence (see subclause 7.3.5).

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

Interoperability (see subclause 7.4.1),

Data sharing (see subclause 7.4.2),

Interfacing (see subclause 7.4.3),

Network infrastructure (see subclause 7.4.4),

Storage infrastructure (see subclause 7.4.5), and

Computing power infrastructure (see subclause 7.4.6).

6.2 Timeline for standardization of metaverse

Considering that the levels of preparation and maturity for standardization tasks differ, the priority of development tasks such as general, enabling technology, Interoperability and ICT-related infrastructure standards also varies.

Figure 2 provides an overview of the estimated timeline in the scheme. This is not exhaustive list but is meant to give some ideas of the range of tasks. As indicated in the timeline, some activities are already ongoing in the year of 2023. General standards such as Framework, terminology and definitions are being developed by ITU focus group on metaverse (FG-MV). Some pre-standardization works, such as technical specifications and technical reports, have already been completed on different topics. Formal standardization work could begin based on the existing deliverables from FG-MV.

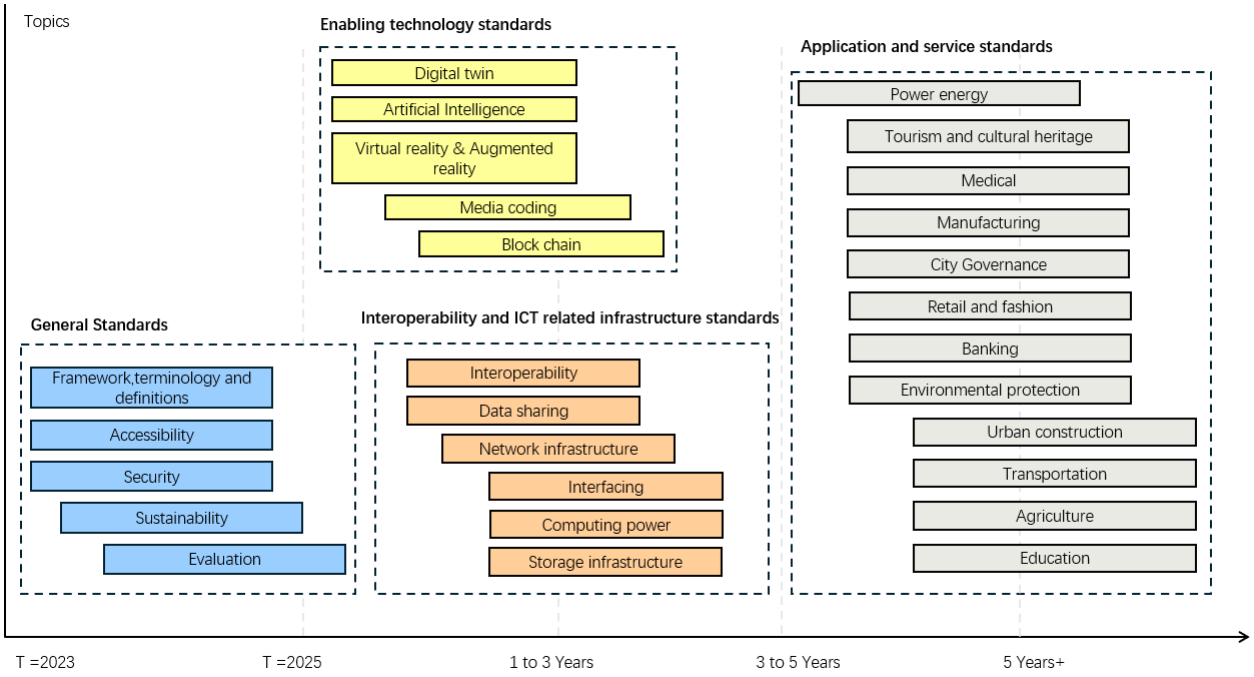

Figure 2 Possible timeline for standardization of metaverse

The suggested priority of launching the work items of standardization is as follows:

in General standards,

- High priority: Framework, terminology and definitions, Accessibility, Security
- Medium priority: Sustainability
- Low priority: Evaluation

in Enabling technology standards,

- High priority: Digital twin, Artificial Intelligence, Virtual reality & Augmented reality
- Medium priority: Media coding,
- Low priority: Blockchain

in Interoperability and ICT related infrastructure standards,

- High priority: Interoperability, Data sharing
- Medium priority: Network infrastructure
- Low priority: Interfacing, Computing power, Storage infrastructure

in Application and service standards,

NOTE - The priorities of metaverse application and service standards depends on different industries and regulatory bodies. Hence, it is essential to involve relevant stakeholders to determine prioritization based on industry and public sector considerations.

- High priority: Power energy
- Medium priority: Tourism and cultural heritage, Medical, Manufacturing, City Governance, Retail and fashion, Banking, Environmental protection
- Low priority: Urban construction, Transportation, Agriculture, Education

6.3 Standardization roadmap and gap analysis

This technical report aims to enable ITU-T to formulate a strategy for the standardization of the metaverse and to promote collaboration in standardization. This report provides an estimated schedule for specific "Tasks" of standardization, and "Relationship" section connects with the "gap analysis", while the detailed gap analyses will be addressed in another FG-MV deliverable called "Metaverse standardization landscape for gap analyses" [b-ITU-T FG-MV-52].

The "standardization roadmap" and "gap analysis" develop a cross-domain strategy for standards, concerning the metaverse and identifying relevant study groups, as well as coordinating with them to develop ITU-T Recommendations.

7 Motivation, Tasks and relationships of metaverse standards

This standardization roadmap offers the strategic guidelines for the metaverse by outlining motivation, tasks and relationships. It discusses pre-standardization contents to mark the starting point of a strategy intended for further development.

The motivation section helps ITU-T members identify standardization needs and clarifies why standardization efforts in a particular area are necessary. Additionally, tasks break down broader objectives into actionable steps, allowing members to focus their efforts effectively during the standardization process. The Relationships section lists relevant stakeholders, such as SDOs and industry consortia. ITU-T can collaborate with these SDOs to accelerate the standard development work and enhance the quality of outcomes.

In other words, each part provides a comprehensive overview of the motivation behind standardization efforts, specific tasks to be undertaken, and the collaborative relationships involved in addressing various aspects of the metaverse.

7.1 General standards

7.1.1 Framework, terminology and definitions

Motivation
Metaverse is a new field, its concepts and application scenarios are extensively diverse and multifaceted. Establishing a standardized framework and commonly agreed terminology can help all parties in the industry and academia to better understand and communicate the concepts and practices of the metaverse and avoid confusion or misunderstanding. Enterprises may have different technologies and business models when building the metaverse. This will make it difficult for them to achieve cross-industry collaboration and development. Developing standards will promote the growth of all industries.
Tasks
Tasks include but are not limited to:

Developing recommendations, supplements, reports, guidelines, and so on, as appropriate on common frameworks of metaverse across different verticals. Developing common frameworks to identify the basic architectural compositions and views on metaverse. These will be based on the requirements derived from the industry needs. Developing, maintaining, and enhancing the Recommendations on terminology related to metaverse, and the definitions of the terms. Developing common terminology-ontology for metaverse for minimal semantic interoperability of metaverse. Providing the necessary collaboration for joint activities in this field within ITU and between ITU-T and other relevant SDOs, consortia and forums.
Relationship
ITU-T SCV (Standardization committee for vocabulary) IEC TC1 (Terminology) IEEE MWG (Metaverse Working Group) W3C Immersive Web Working Group 3GPP SA (3rd Generation Partnership Project)

7.1.2 Evaluation

Motivation
To develop comprehensive standards that address the evaluation and assessment aspects of the metaverse, it is necessary to outline the framework and evaluation methodology of metaverse objects, ensuring that they align with principles of environmental sustainability, ethical practices, and long-term societal benefit.
Tasks
Tasks include but are not limited to: Developing Recommendations for conducting sustainability impact assessments in the metaverse, evaluating the environmental, social, and economic implications of virtual environments and technologies. Developing guidelines for conducting life cycle assessment of digital assets within the metaverse. Identifying methods for collecting and calculating reliable data to feed into the assessment model.
Relationship
ITU-T SG16 ITU-T SG20 (IoT, smart cities and communities) ITU-T SG5 (Environment, EMF and circular economy) ISO/IEC JTC1/SC 24 (Computer graphics, image processing and environmental data representation) Khronos Group

7.1.3 Sustainability

Motivation

Sustainability of metaverse addresses environmental, economic, and social and cultural sustainable aspects. This includes green and low carbon development of metaverse, methodology on assessment of GHG (Green House Gas) emissions of metaverse, impacts on sustainable metaverse applications, and social safety to mitigate harassment in the metaverse.
Tasks
Tasks include but are not limited to: Developing recommendations for addressing sustainability impacts on the environmental, social, and economic implications of virtual environments and technologies. Developing guidelines for the use of digital goods and services in place of physical ones within the metaverse. Identifying methods for collecting and calculating reliable data related to environmental, economic, and social and cultural sustainable aspects.
Relationship
ITU-T SG5 IEEE Sustainable ICT Initiative ISO/IEC JTC1/SC39 (Sustainability, IT and data centres) ISO/TC 207 (Environmental management) ISO/TC 301 (Energy management and energy savings) Khronos Group GeSI (Global Enabling Sustainability Initiative) DESI (Digital Environment Sustainability Initiative)

7.1.4 Security

Motivation
The Security in the metaverse encompasses several key aspects: cybersecurity, children online protection, trust, and digital identity. And these aspects form the foundation of a secure and trustworthy metaverse environment. The motivation for establishing security standards lies in ensuring the safety, PII protection, and trustworthiness of digital interactions within virtual environments.
Tasks
The standardization of security should be based on the related standards, supporting the security requirements of metaverse platforms. Tasks include but are not limited to: Developing comprehensive guidelines specifically tailored to metaverse security, addressing the intricacies of virtual spaces, user interactions and data handling. Developing encryption standards for protecting digital assets within the metaverse, including digital currencies, virtual goods, and sensitive user data. Developing guidelines for incident response plans specific to metaverse security, outlining steps to be taken in the event of a cybersecurity incident. Developing guidelines to govern the creation, distribution, and accessibility of age-appropriate content within the metaverse.

Developing recommendations for age verification and user authentication within metaverse platforms to prevent the creation of fake or misleading virtual identities. Developing recommendations for privacy protection tailored to adults' and children's needs, ensuring their data is handled responsibly and legally within the metaverse. Developing guidelines to formulate comprehensive trust frameworks specific to the metaverse, outlining the principles, recommendations, and protocols that underpin trustworthy virtual interactions. Developing guidelines for embedding trust-enhancing features such as end-to-end encryption, secure authentication, and privacy-preserving technologies into metaverse ecosystems. Developing recommendations for securing virtual transactions, including currency exchanges, digital asset transfers, and other financial interactions within the metaverse. Developing guidelines for standardized protocols for digital identity management within the metaverse, ensuring secure and verifiable identification of users and entities. Developing recommendations to mitigate identity spoofing and impersonation risks within the metaverse, including the development of anti-fraud measures and identity validation protocols. Developing guidelines for privacy-preserving digital identity practices within the metaverse, addressing data minimization, user consent, and secure handling of personal information. Developing recommendations for secure and reliable digital identity verification mechanisms, encompassing multifactor authentication, knowledge-based authentication, and emerging technologies like decentralized verification process to enhance overall decentralized identifiers. Providing the necessary collaboration for joint activities in the field between ITU and other SDOs conducting related work on metaverse.
Relationship
ITU-T SG17 (Security) ITU-T SG16（Multimedia & digital technologies) ISO/IEC JTC1/SC27 (Information security, cybersecurity and privacy protection) COP (Child Online Protection Initiative) DIF (Decentralized Identity Foundation) W3C Web Security Interest Group Kantara Initiative IETF (Internet Engineering Task Force) IEEE CYBSI (Cybersecurity Initiative) OASIS (Organization for the Advancement of Structured Information Standards) OpenID Foundation

7.1.5 Accessibility

Motivation
To ensure inclusivity for different individuals is not only a moral imperative but also a foundational element of accessibility in metaverse platforms. International standardization plays a critical role in promoting accessibility and guaranteeing that security measures cater to the need of all users, regardless of their physical or cognitive abilities.
Tasks

The standardization of accessibility should support the accessibility requirements of different users in metaverse platforms. Tasks include but are not limited to: Developing guidelines for inclusive privacy and consent mechanism within the metaverse, addressing the diverse communication needs of users with various abilities. Developing assistive technology compatibility guidelines to ensure compatibility with assistive technologies such as screen readers, voice recognition software, and adaptive input devices, within metaverse platforms. Developing recommendations to allow multimodal and multilingual communication. Providing the necessary collaboration for joint activities in the field between ITU and other SDOs conducting related work on metaverse.
Relationship
ITU-T SG16 W3C WAI (Web Accessibility Initiative) ISO/IEC JTC1/SC35 (User interfaces) CEN/TC 122 (ERGONOMICS)

7.2 Application and service standards

7.2.1 Agriculture

Motivation
Establishing standards for agriculture metaverse could create a global framework for more efficient, sustainable and collaborative agricultural practices. This could enhance agricultural productivity, address global challenges, and contribute to food security and environmental sustainability.
Tasks
The standardization of agriculture in metaverse should fulfil the service requirements related to agricultural production. NOTE 1 - The service of agricultural production includes: virtual planting, parallel agricultural simulation and optimization of processing and manufacturing. Tasks include, but are not limited to: Developing guidelines for integrated services regarding agriculture production in metaverse, including crop simulation, solid and weather simulation, and parallel computing, and so on. Developing Recommendations for guidelines and best practices related to the implementation of agriculture production services to optimize agriculture practices such as processing and manufacturing. Providing the necessary collaboration for joint activities in this field between ITU-T and SDOs, consortia and forums, conducting related work on Agriculture metaverse.
Relationship
ITU-T SG16 ITU-T SG20 ISO/IEC JTC1 /SC 31 (Automatic identification and data capture techniques)

ISO/IEC JTC1/SC41 (Internet of Things and digital twin) UN FAO (United Nations Food and Agriculture Organization)

7.2.2 Power energy

Motivation
Standardizing power energy metaverse allows for more efficient management of virtual resources. By following established standards and best practices, metaverse operators can better allocate virtual power plants, reducing waste and ensuring a more equitable distribution of resources. This does not only enhance the overall user experience but also serves as a valuable model for real-world energy management, demonstrating the importance of efficient allocation and consumption.
Tasks
The standardization of power energy in metaverse should fulfill the services related to power generation, distribution, and utilization. Tasks include, but are not limited to: Developing guidelines for power in metaverse such as virtual or digital environments related to power generation, distribution, or utilization, operation planning, equipment maintenance, and personnel training. NOTE – [b-ITU-T FGMV-09] Discusses various core power grid businesses such as operation planning, equipment maintenance and personnel training. Developing recommendations for integrated power energy management in metaverse based on the existing power energy related standards, safety codes, and industry-specific regulations. Developing guidelines for power energy in virtual or digital environments that specifically address renewable energy sources such as solar and wind to promote eco-friendly power generation, distribution, and utilization in the metaverse. Developing guidelines for carbon emissions within power energy in metaverse, covering aspects like energy source, grid transmission, end-use consumption, and energy storage aimed at allocating carbon emission responsibility in the metaverse. Developing guidelines for on-site operations of power systems in the metaverse such as virtual scenarios related to detailed modelling of electrical equipment components, maintenance and repair of power systems, emergency power failures, and virtual scenarios for grid rehearsal and recovery in disaster situations. Providing the necessary collaboration for joint activities in this field between ITU-T and SDOs conducting related work on power energy metaverse.
Relationship
ITU-T SG20 ITU-T SG5 IEC TC57 (Power systems management and associated information exchange)

7.2.3 Tourism and cultural heritage

Motivation
The motivation to develop tourism metaverse is driven by the desire to provide accessible, diverse, and personalized travel experiences, while addressing environmental concerns and offering economic opportunities. It will redefine the way for people to explore and engage with the world.

Tasks
The standardization of tourism in metaverse should fulfill the integrated services related to stationary tourism. NOTE 1 - Stationary tourism refers to tourist experiences that people can enjoy through technology, without physically moving, as described in [b-Monaco]. Tasks include, but are not limited to: Developing guidelines for tourism in metaverse such as exploiting the simulated environments. Developing Recommendations for integrated tourism services in metaverse based on VR,AR,MR,XR, telepresence, and immersive storytelling. Developing Recommendations for integrated tourism services within heritage parks and galleries in the metaverse. Developing recommendations for integrated accessible tourism services for all in the metaverse. Providing the necessary collaboration for joint activities in this field between ITU-T and SDOs, consortia and forums, conducting related work on tourism metaverse.
Relationship
ITU-T SG16 UNWTO (The United Nations World Tourism Organization) ISO/IEC JTC1/SC24(Computer graphics, image processing and environmental data representation) ISO/IEC JTC1/SC41 ISO/IEC JTC1/SC38 (Cloud computing and distributed platforms)

7.2.4 Retail and fashion

Motivation
The transformative power of the metaverse has the potential to redefine consumer' experiences, greatly impacting retail and fashion. The retail and fashion metaverse will enhance accessibility, and revolutionize commerce. The motivation for establishing standardization is to seamlessly integrate retail and fashion applications to ensure a harmonized, immersive, and secure metaverse environment for global users.
Tasks
The standardization of the retail/fashion industry in the metaverse should fulfill the service requirements related to customers and retailers. Tasks include, but are not limited to: Developing guidelines for the services relating to the creation of virtual retail spaces within the metaverse, encompassing design principles, user interfaces, and interactive features. Developing guidelines relating to seamless integration across different metaverse platforms, allowing retailers to reach a broad and diverse audience and ensuring a consistent user experience. Developing guidelines for real-time integration of virtual retail inventories with real-world supply chains, ensuring accurate representation of available products and efficient order fulfilment. Developing guidelines for real-time integration of virtual retail inventories with real-world representation of human diversity, ensuring accurate representation of diverse needs to avoid exclusion by size, shape, ability or ethnicity.

Providing the necessary collaboration for joint activities in this field between ITU-T and SDOs, consortia and forums, conducting related work on metaverse.
Relationship
ITU-T SG16 ISO/TC133 (Clothing sizing systems-Size designation, size measurement methods and digital fittings) W3C WICG (Web Platform Incubator Community Group) Khronos Group OMG (Object Management Group) VR/AR Association RILA (Retail Industry Leaders Association)

7.2.5 Banking

Motivation
The motivation to develop the bank metaverse is driven by the desire to create a secure, interoperable, accessible, and user-friendly virtual banking environment that aligns with regulatory requirements and fosters trust and confidence among users. It is necessary to address the unique challenges and opportunities presented by the intersection of banking and the metaverse. The standardization of bank metaverse should fulfil services such as payment integration, blockchain and cryptocurrency, and digital asset management, ensuring a secure, efficient, and interoperable virtual financial environment.
Tasks
Tasks include, but are not limited to: Developing guidelines for the integration of blockchain technology and the use of cryptocurrencies in virtual banking, ensuring security and regulatory compliance. Developing guidelines for seamless integration of Fin Tech solution within the virtual banking environment. Developing guidelines for seamless and easy to understand interaction of diverse user needs with the virtual banking environment. NOTE – This involves exploring technologies such as artificial intelligence, machine learning, and data analytics to enhance customer experiences, automate processes, and optimize financial decision-making. Collaborating with financial regulatory authorities to ensure that virtual banking standards align with existing and emerging regulatory frameworks. Collaborating with vulnerable group representatives, especially the elderly and people with disability organisations to ensure that virtual banking standards align with vulnerable group needs and requirements. Providing the necessary collaboration for joint activities in this field between ITU-T and SDOs, consortia and forums, conducting related work on banking metaverse.
Relationship
ITU-T SG17 ITU-T SG16

ITU-T SG20 ISO/TC68/SC8 (Reference data for financial services) ISO/TC307 (Blockchain and distributed ledger technologies) W3C Web Payments WG

7.2.6 Medical

Motivation
The development of the medical metaverse is motivated by the potential for realistic training, global access to healthcare through telemedicine, remote surgery assistance, collaborative research, enhancing patient engagement, especially for vulnerable groups, pandemic preparedness, and adaptability to emerging technologies.
Tasks
The standardization of medical metaverse should fulfil the service requirements of doctors, nurses, patients, hospitals and health centres. NOTE 1 - Medical metaverse services include, but are not limited to, medical training simulations, patient education and engagement, telemedicine, remote surgery assistance, Research and development spaces, and pharmaceutical drug development. Tasks include, but are not limited to: Developing guidelines for medical services in the metaverse based on existing health care- related standards, including electronic health records, electronic medical equipment resources, telemedicine. Developing guidelines for 3D hospital simulation with existing medical-related standards. Developing guidelines relating to developing realistic virtual scenarios for surgical procedures, medical emergencies, and patient interactions. Developing guidelines of public health metaverse through which to discover and respond to regional and/or global crises of epidemics and pandemics. Developing guidelines relating to implementing gamified elements to enhance engagement and motivation for patients to participate in their own health care. Developing standards for the integration of digital twin technology with existing e-health standards, enabling virtual representations of biological systems, drug molecules, and patient profiles to enhance simulation and modelling in drug development. Developing standards for immersive training programs for medical college students in the metaverse, enabling pharmaceutical researchers and clinicians to enhance their skills in a virtual environment. Developing guidelines for communication between patients and medical experts and vice versa towards accessible interaction by all, ensuring also that information and communication are easy to understand. Providing the necessary collaboration for joint activities in this field between ITU-T and SDOs, consortia and forums, conducting related work on metaverse.
Relationship
ITU-T SG16 ITU-T SG20 UN WHO

W3C WoT WG (Web of Things working group) IEEE computer society VGTC (Visualization and Graphics Technical Community) HL7 (Healthcare Level Seven) ISO/TC69 (Applications of statistical methods)

7.2.7 Manufacturing

Motivation
The Motivation to develop manufacturing metaverse is to improve production efficiency, promote innovation, ensure safety, and enable the synergistic development of virtual and physical production environments. The standardization of the manufacturing metaverse should fulfill the requirements to provide a framework for integrating of advanced technologies such as digital twins, augmented reality, and artificial intelligence, facilitating innovation in the manufacturing process.
Tasks
Tasks include but are not limited to: Developing guidelines for the integration of digital twin technologies to enable virtual and real production environments to work together. Developing guidelines for optimizing collaborative operations in virtual supply chains. Providing the necessary collaboration for joint activities in this field between ITU-T and SDOs, consortia and forums conducting related work on metaverse.
Relationship
ITU-T SG20 IEC TC 66 (Industrial-process measurement, control and automation) ISO/TC 184/SC4 (Industrial data) OMP (Open Manufacturing Platform)

7.2.8 Education

Motivation
The development of the education metaverse is instrumental in achieving consistency, quality, and interoperability across diverse virtual learning environments.
Tasks
The standardization of the education metaverse should fulfill the service requirements of students, teachers and educational organizations. NOTE - The services of the education metaverse include but are not limited to supporting personalized communication and learning experiences tailored to individual students needs and preferences and enabling seamless interoperability between different educational platforms and tools within the metaverse. Tasks include but are not limited to: Developing guidelines for accessible, inclusive and adaptive learning pathways, personalized content delivery, and student progress tracking in order to enhance the customization of educational experiences.

Developing standards for data exchange, communication protocols, and integration interfaces to ensure compatibility and accessibility across various educational applications. Providing the necessary collaboration for joint activities in this field between ITU-T and SDOs, consortia and forums conducting related work on metaverse
Relationship
ITU-T SG16 ITU-T SG20 ISO/IEC JTC1/SC36 (Information technology for learning, education and training) IEEE Education Society EDUCAUSE W3C EOWG (Education and Outreach Working Group) UNESCO (United Nations Educational, Scientific and Cultural Organization)

7.2.9 City Governance

Motivation
The development of city governance in the metaverse encompasses integrating advanced technologies to fulfil specific requirements, including urban infrastructure mapping, urban planning, environmental monitoring, emergency response and crisis management, citizen engagement and sustainability.This application of metaverse, referred to as CitiVerse, aims to create a comprehensive and interconnected virtual environment for urban management. The standardization of city governance within the metaverse includes establishing a foundation for seamless integration, providing a robust framework for urban management ensuring urban management efforts in the metaverse are inclusive, diverse, and accessible to all citizens.
Tasks
Tasks include but are not limited to: Developing guidelines and best practices for requirements analysis for inclusive city development within the CitiVerse. Developing guidelines for promoting cultural and linguistic inclusivity within the CitiVerse, recognizing and accommodating diverse cultural expressions and language modalities in virtual environments to foster a sense of belonging and cultural diversity. Developing guidelines for mapping and synchronizing virtual models with the physical city infrastructure, allowing for accurate simulation and monitoring. Developing guidelines for virtual sensors, environmental data representation, and sustainability metrics to support decision-making on eco-friendly urban policies. Developing protocols recommendation for virtual simulations of emergency scenarios, coordination platforms, and information dissemination to enhance city resilience. Developing protocols recommendation for accessible virtual communication in all scenarios, coordination platforms, and information dissemination to enhance citizen inclusion. Providing the necessary collaboration for joint activities in this field between ITU-T and SDOs, consortia, and forums to conduct related work on metaverse.
Relationship
ITU-T SG3 ITU-T SG5

ITU-T SG13(Future networks)
ITU-T SG16
ITU-T SG20
OGC (Open Geospatial Consortium)
IEC TC 57 (Power systems management and associated information exchange)
ISO/TC268 (Sustainable cities and communities)

7.2.10 Transportation

Motivation
As the metaverse transforms from a virtual space into an immersive and interconnected digital reality, transportation within this virtual realm becomes a crucial element for user experience and collaboration. To ensure seamlessness interoperability across metaverse platforms, international standardization plays a pivotal role in establishing guidelines and recommendations for transportation applications and services. The standardization of transport issues in metaverse should fulfill the dynamic requirements of drivers, vehicles, traffic infrastructures, and other stakeholders.
Tasks
Tasks include, but are not limited to: Developing comprehensive guidelines for constructing accessible and safe transportation metaverse to ensure consistency and compatibility across platforms. Developing guidelines for designing and integrating virtual vehicles within metaverse environments, considering factors such as user interface, accessibility, controls and safety features. Developing recommendations and best practices relating to implementing sustainable transportation metaverse to increase operational efficiency and safety. Developing guidelines for virtual logistics and supply chain management, enhancing efficiency, ensuring sustainability and reducing operational complexities. Providing the necessary collaboration for joint activities in the field between ITU and other SDOs conducting related work on transportation metaverse.
Relationship
ITU-T SG5 ITU-T SG16 ITU-T SG20 ISO/TC 204 (Intelligent Transport Systems) ISO/TC 268 (Sustainable cities and communities) CEN/TC 278 (European Committee for Standardization) W3C Automotive and Transportation Group SAE J3016 (Society of Automotive Engineers) OGC (Open Geospatial Consortium) Khronos Group

7.2.11 Urban construction

Motivation
Urban construction in metaverse can enhance the efficiency and safety of project planning, design, construction and maintenance. The virtual environment created based on the metaverse allows engineers, decision-makers and other participants to simulate projects, assess risks, and conduct training with unprecedented accuracy and interactivity. In this way, urban construction in the metaverse aims to optimize resource allocation, reduce on-site errors and improve the level of intelligent safety management on site. The standardization of urban construction in metaverse should fulfill the service requirements of planners, designers, engineers, and construction teams.
Tasks
Tasks include, but are not limited to: Developing guidelines for urban construction in metaverse, such as virtual scenarios for on-site operations, routine maintenance, tool inspections, and emergency breakdowns. Developing recommendations for virtual on-site operations in the metaverse, based on existing standards, safety codes, and specific industry regulations related to urban construction, also ensuring that information and communication are easy to understand. Proposing recommendations for integrated urban construction in metaverse for post-natural disaster scenarios (such as blizzards and earthquakes), including site simulation and emergency operations.
Relationship
ITU-T SG20

7.2.12 Environmental protection

Motivation
Taking into consideration the ongoing efforts within the United Nations Framework Convention on Climate Change to combat climate change, it is important to develop standards related to the sustainable development of the metaverse which can be considered at all stages from design, to use to final disposal of technologies.
Tasks
Tasks include but not limited to: Developing guidelines for conducting ecosystem simulation assessments within the metaverse, aimed at measuring accuracy, dynamic changes, and stability of virtual ecosystems. Developing guidelines and best practices for carbon emission-related simulations in the environmental metaverse, such as carbon sources, carbon sinks, carbon capture and carbon monitoring. Developing guidelines for comprehensive assessments of energy-saving and emission-reduction effects in the metaverse, evaluating the environmental benefits, economic feasibility, and social impacts of technologies like renewable energy utilization, energy-saving appliances, intelligent building systems, and sustainable transportation solutions. Establishing guidelines for conducting product life cycle assessments in the metaverse for various products, such as vehicles and medical equipment, to evaluate their environmental impact and sustainability.
Relationship
ITU-T SG20

ITU-T SG5 IEC TC57

7.3 Enabling technology standards

7.3.1 Virtual reality and Augmented reality

Motivation
VR (Virtual reality) and AR(Augmented reality) technologies offer immersive, interactive and seamless experiences that enrich user's perception of the world and enhance communication, collaboration, and engagement. The motivation for establishing standards on VR and AR is driven by the desire to enhance interoperability, inclusive accessibility, optimized performance, and security.
Tasks
The standardization of VR and AR should support the development of the metaverse. Tasks include but are not limited to: Developing standardized protocols for VR interactions, encompassing gestures, gaze tracking, and voice commands, ensuring consistency across metaverse platforms. Developing recommendations for visual and audio fidelity in VR experiences, addressing resolution, frame rates, spatial audio, and other factors crucial for an immersive environment. Developing guidelines for essential hardware components in VR devices. NOTE 1 – Establishing specifications for display technologies, optics, and tracking sensors to ensure compatibility and optimal performance across different HMD (Head-Mounted Display) models. Developing guidelines for creating AR content, ensuring consistency and quality across various metaverse platforms. Developing guidelines for accurate spatial mapping to enable precise placement of AR content within the physical environment. Developing guidelines for AR hardware components to ensure compatibility, performance optimization and energy efficiency. Developing guidelines for seamless integration between AR and the IoT (Internet of Things) within metaverse environments. Developing guidelines for accurate spatial mapping to enable precise placement of AR content within the physical environment. NOTE 2 – Related mapping technologies include SLAM (Simultaneous Localization and Mapping), which ensures a seamless integration of virtual and physical elements. Providing the necessary collaboration for joint activities in the field between ITU and other SDOs conducting related work on Virtual reality and Augmented Reality in the metaverse.
Relationship
ITU-T SG9 ITU-T SG16 ITU-T SG17 ITU-T SG20 W3C (World Wide Web Consortium) Immersive Web Working Group

Khronos Group
IEEE 2048 VRARWG (VR/AR Working Group)
ISO/IEC JTC1/SC24
IDEA (The Immersive Digital Experiences Alliance)
IETF (Internet Engineering Task Force)
OGC (Open Geospatial Consortium)

7.3.2 Digital twin

Motivation
Digital twin technology, integrating physical and virtual worlds, plays a pivotal role in shaping the metaverse landscape. Establishing standards on digital twins in the metaverse will be motivated by the requirements of enhanced simulation and modelling and real-time synchronization.
Tasks
The standardization of digital twins should support the development of the metaverse. Tasks include but are not limited to: Developing guidelines that evaluate the quality of digital twin simulations and models, ensuring an accurate representation of physical entities and environments within the metaverse for realistic simulations. Developing guidelines for real-time synchronization between physical entities and their digital twins, ensuring dynamic and responsive interactions within the metaverse ecosystem. Developing guidelines for virtual sensors within digital twins, ensuring accurate environmental data collection and representation, and supporting decision-making processes within the metaverse. Providing the necessary collaboration for joint activities in the field between ITU and other SDOs conducting related work on digital twins in the metaverse.
Relationship
ITU-T SG13 ITU-T SG16 ITU-T SG17 ITU-T SG20 ISO/IEC JTC1/SC41 OMG (Object Management Group) IEC TC 65 (Industrial-process measurement, control and automation) OGC Geo for Metaverse DWG (Domain Working Group)

7.3.3 Block chain

Motivation
The integration of blockchain technology within the metaverse is poised to revolutionize the digital landscape. It offers unparalleled security, transparency, and interoperability. Blockchain's decentralized and tamper-resistant nature aligns perfectly with the diverse and dynamic nature of the metaverse, laying the foundation for secure transactions, verifiable digital assets, and collaborative virtual environments.

Tasks
The standardization of the block chain should support the development of the metaverse. Tasks include but are not limited to: Developing recommendations for guidelines and best practices for ensuring data integrity, security, and privacy within blockchain-based metaverse ecosystems. Developing guidelines for token creation, management, and exchange within metaverse environments, ensuring compatibility and consistency. NOTE – Addressing issues related to the representation and interoperability of diverse digital assets in blockchain-based metaverse scenarios. Providing the necessary collaboration for joint activities in the field between ITU and other SDOs conducting related work on blockchain in the metaverse.
Relationship
ITU-T SG16 ITU-T SG17 ISO/TC 307 (Blockchain and distributed ledger technologies) IEEE Block chain Initiative W3C Blockchain Community Group OGC-Blockchain and Distributed Ledger Technologies Domain Working Group BSC (Blockchain Standards Coordination) OpenID Foundation

7.3.4 Media coding

Motivation
In the context of the metaverse, where immersive and dynamic multimedia experiences are paramount,the motivation to establish robust and adaptive standards for media coding arises from the need to facilitate seamless content creation, distribution and consumption, ensuring a consistent and high-quality user experience across diverse metaverse platforms. The standardization of media coding aims to set the stage for innovation, interoperability, and the creation of compelling virtual environments.
Tasks
The standardization of media coding should support the development of the metaverse. Tasks include, but are not limited to: Developing comprehensive guidelines for immersive audio-visual encoding, encompassing spatial audio, realistic rendering, and high-resolution visuals. Developing guidelines for assessing and enhancing QoE (Quality of Experience) in metaverse media coding. Developing guidelines that optimize network resource utilization for media transmission within the metaverse. Providing the necessary collaboration for joint activities in the field between ITU and other SDOs conducting related work on media coding in the metaverse.
Relationship

ITU-T SG16
ITU-T SG12 (Performance,QoS & QoE)
ITU-T SG11 (Protocols,testing & combating)
ISO/IEC JTC1/SC29 (Coding of audio, picture, multimedia and hypermedia information)
IETF (Internet Engineering Task Force)
W3C WebRTC (Web Real-Time Communications)

7.3.5 Artificial Intelligence

Motivation
Artificial Intelligence (AI) introduces a new dimension of intelligent and adaptive interactions, enhancing user experiences. The incorporation of large language models further amplifies the capabilities of AI within the metaverse. The motivation for establishing standards on AI promotes interoperability and optimizes performance within this dynamic digital space.
Tasks
The standardization of AI within the metaverse should support its development. Tasks include, but are not limited to: Developing standardized protocols for AI-driven interactions within the metaverse, encompassing natural language processing, contextual understanding, and adaptive behaviour, ensuring a consistent and user-friendly experience across diverse platforms. Developing guidelines for the responsible and inclusive integration of AI, including large language models, in metaverse applications, considering accessibility features, user diversity, and avoiding biases in AI-driven interactions on a large scale. Providing the necessary collaboration for joint activities in the field between ITU and other SDOs conducting related work on AI applications in the metaverse.
Relationship
ITU-T SG16 ITU-T SG17 ITU-T SG20 W3C AI KR (Artificial Intelligence Knowledge Representation Community Group) IEEE Computer Society ISO/IEC JTC1/SC42 (Artificial Intelligence) IDEA (The Immersive Digital Experiences Alliance)

7.4 Interoperability and ICT related infrastructure standards

7.4.1 Interoperability

Motivation
Interoperability stands as the key factor for this interconnected metaverse, ensuring that users can traverse, communicate and engage effortlessly across virtual environments. The motivation for developing standards to support interoperability aims for breaking down silos, promote innovation, and create a unified metaverse experience that transcends individual platforms and boundaries. Lack of interoperability among metaverse platforms can lead to a fragmented user experience and

inconvenience, as users cannot interact or share their experiences across different metaverse platform environments. This restriction may limit user engagement and increase development costs, as service providers need to duplicate efforts for multiple platforms.

To realize the interoperable metaverse, it is essential to provide standards for cross-platform interoperability, including standardized protocols and interfaces over different technologies and platforms.

Tasks

The development of standards should ensure the interoperability, which enables different metaverse platforms/systems to achieve cross-platform transaction.

Tasks include, but are not limited to:

Developing guidelines and recommendations related to metaverse interoperability.

Developing guidelines for creating open and seamless metaverse interoperable environments between metaverse platforms.

Utilizing existing enabling technologies and their evolution for metaverse cross-platform interoperability.

Developing use-cases and service scenarios, requirements, and functional architecture for metaverse cross-platform interoperability.

Developing protocols and interfaces for metaverse cross-platform interoperability.

Utilizing emerging technologies for metaverse cross-platform interoperability.

Keeping the up-to-date gap analysis for standardization on metaverse cross-platform interoperability.

Providing the necessary collaboration for joint activities in the field between ITU and other SDOs conducting related work on Interoperability in the metaverse.

NOTE – The tasks include, but are not limited to, developing common standards and protocols for avatar creation, customization, and transfer, which are essential in ensuring avatar interoperability between platforms specified in [b-FGMV-19].

Relationship

All ITU-T SGs

W3C Web of Things Interest Group

Khronos Group

IEEE SCC21 (Standards Coordinating Committee 21)

OGC (Open Geospatial Consortium)

ISO/IEC JTC1/SC32(Data management and interchange)

VRM Consortium

ISO TC 133, TC 172 on metaverse

IEC TC 100, TC 110, TC 159 on metaverse devices and systems

ISO & IEC JSEG 15 (metaverse)

ISO/IEC JTC 1 SC 6, SC 24, SC 29, SC 35, SC 36 on metaverse related aspects

IEEE SA MWG (Metaverse WG), ARMDWG (Augmented Reality on Mobile Devices WG), 2888 WG (Interfacing Cyber and Physical World WG)

IETF ICNRG on metaverse contents distributions

3GPP SA2 on mobile metaverse
Khronos 3D Formats Working Group on metaverse content format
OpenUSD on metaverse content and environment format
W3C Metaverse Interoperability CG, DID (Distributed ID) WG
MSF (Metaverse Standards Forum)
OMF (Open Metaverse Foundation)
OMI (Open Metaverse Interoperability)
OMA3 (Open Metaverse Alliance)
MPAI (Moving pictures, audio and data coding by artificial intelligence)

7.4.2 Data sharing

Motivation
As the metaverse rapidly evolves and gains prominence across various industries, the need for seamless interoperability has become paramount. Central to this interoperability is the effective sharing and exchange of data among diverse metaverse platforms. To address this critical aspect, the motivation is to develop comprehensive guidelines for standardizing data sharing within metaverse interoperability.
Tasks
Tasks include, but are not limited to: Developing protocols for data encryption and authentication. NOTE – Establishing robust protocols for encrypting shared data and implementing secure authentication mechanisms to safeguard user information. Developing the guidelines or recommendations of types of data critical for interoperability and establish standardized formats for efficient exchange. Developing standards for data exchange between metaverse platforms, addressing data formats, structures, and security protocols to enable smooth interoperability. Developing guidelines for efficient and secure data storage, retrieval, and exchange within IDCs (Internet Data Centres). Developing guidelines for data sharing considering accessible interaction by all, ensuring also that information and communication is easy to understand. Providing the necessary collaboration for joint activities in the field between ITU and other SDOs conducting related work on data sharing in the metaverse.
Relationship
ITU-T SG20 ITU-T SG13 ITU-T SG16 W3C/Community Groups/ Credible Web Community Group Khronos Group ISO/IEC JTC1/SC32 (Data management and interchange) IETF (Internet Engineering Task Force)

XR Association (XRA)
J-SCTF (IEC-ISO-ITU Joint Smart Cities Task Force)

7.4.3 Interfacing

Motivation
The standardization of interfacing is rooted in interconnected ecosystems, it aims to optimize resource utilization and consistent user interfaces.
Tasks
Tasks include, but are not limited to: Developing the guidelines on interfacing in metaverse interoperability such as define interfacing protocols. Developing UI (user interface) guidelines to ensure a consistent and intuitive user experience, focusing on common design elements, navigation principles, and accessibility standards. Providing the necessary collaboration for joint activities in the field between ITU and other SDOs conducting related work on interfacing in the metaverse.
Relationship
ITU-T SG20 ITU-T SG16 ISO/IEC JTC1/SC35 DIF (Decentralized Identity Foundation) IETF (Internet Engineering Task Force)

7.4.4 Network infrastructure

Motivation
Network infrastructure plays a pivotal role as the cornerstone of ICT-related infrastructure. The motivation for establishing standardization is to ensure scalable, resilient, and low-latency network architectures, fostering a globally interconnected metaverse.
Tasks
Tasks include, but are not limited to: Developing guidelines for the scalability challenges of network architectures in the metaverse, accommodating the growing demand for data-intensive applications and services. Developing recommendations for guide seamless integration of IMT-2020 and future-generation technologies, ensuring metaverse networks are equipped to handle evolving connectivity requirements. Developing guidelines for dynamic bandwidth allocation, allowing metaverse network to adapt to varying user demands and ensure optimal performance during peak usage. Developing guidelines for effective and efficient network management practices within the metaverse. Providing the necessary collaboration for joint activities in the field between ITU and other SDOs conducting related work on network infrastructure in the metaverse.
Relationship

ITU-T SG9
ITU-T SG13
ITU-T SG15
IETF (Internet Engineering Task Force)
ONF (Open Networking Foundation)
3GPP SA
ETSI (European Telecommunications Standards Institute)

7.4.5 Storage infrastructure

Motivation
In the evolving landscape of the metaverse, where data is the lifeblood of immersive experiences, the storage infrastructure acts as a foundational element. Standardization is needed to ensure resilient, secure, and sustainable storage architecture within the metaverse.
Tasks
Tasks include, but not limited to: Developing metadata guidelines for enhance data retrieval efficiency within the metaverse, enabling swift and accurate access to stored content, and supporting a variety of applications and use cases. Developing guidelines for storage infrastructure resilience and disaster recovery within the metaverse, minimizing data loss and downtime in the face of unexpected events. Providing the necessary collaboration for joint activities in the field between ITU and other SDOs conducting related work on storage infrastructure in the metaverse.
Relationship
ITU-T SG16 SNIA (Storage Networking Industry Association)

7.4.6 Computing power infrastructure

Motivation
In the dynamic landscape of the metaverse, computational demands are diverse and intense. The motivation for establishing standardization is to ensure scalable, efficient, and sustainable computing architectures, developing a metaverse that seamlessly accommodates complex applications, hardware and services.
Tasks
Tasks include, but not limited to: Developing guidelines for addressing the scalability challenges of computing architectures in the metaverse, accommodating diverse workloads, and fluctuating computational demands. Developing guidelines for energy-efficient computing in the metaverse, promoting sustainable practices and minimizing the environmental impact of intensive computational activities. Developing recommendations for seamless integration of quantum computing technologies within metaverse computing infrastructures, exploring potential advantages for complex simulations and cryptographic operations.

Providing the necessary collaboration for joint activities in the field between ITU and other SDOs conducting related work on computing power in the metaverse.
Relationship
ITU-T SG13 OCP (Open Compute Project) DMTF (Distributed Management Task Force) CNCF (Cloud Native Computing Foundation)

Appendix I
Related SDOs

The appendix outlines various working groups in standardization bodies such as ITU, ISO/IEC, and others in research related to the metaverse. It particularly emphasizes the ITU's potential future advancements in metaverse standards through its study groups and also elaborates detailed introduction of other SDOs in their current standardization efforts.

I.1 ITU:

ITU-T SCV (Standardization Committee for Vocabulary)

ITU-T SCV is tasked with developing and maintaining standardized terminology and vocabulary related to the metaverse. This includes defining and clarifying key terms, concepts and definitions used across various ITU-T study groups and related standards efforts to ensure consistency and interoperability in the development and implementation of metaverse technologies. ITU-T SCV collaborates with other relevant standardization bodies to align vocabulary and terminology efforts globally.

ITU-T SG3 (Economic and Policy Issues)

ITU-T SG3 examines the economic and policy implications, including regulatory frameworks, taxation, and economic models, which are connected with virtual economies within metaverse platforms.

ITU-T SG5 (Environment and Climate Change)

ITU-T SG5 could address the energy efficiency and environmental impact of metaverse technologies, developing standards for sustainable infrastructure and green practices to minimize the carbon footprint of virtual worlds and digital interactions.

ITU-T SG9 (Broadband cable and TV)
ITU-T SG9 explores the integration of virtual reality (VR) and augmented reality (AR) technologies into integrated broadband and cable networks to support the requirements of the metaverse.

ITUT SG11 (Protocols, Testing & Combating Counterfeiting)

ITU-T SG11 could standardize protocols and testing methods for the metaverse, also combating counterfeiting within virtual environments. This includes initiating work on classical protocols and interfaces for metaverse-related technologies.

ITU-T SG12 (Quality of Service and Experience)

ITU-T SG12 could works on standards ensuring optimal performance, quality of service (QoS), and quality of experience (QoE), which could applied in metaverse applications and services, focusing on metrics, monitoring techniques and optimization strategies tailored to virtual environments.

ITU-T SG13 (Future Networks)

The ITU Study Group 13 “Future Networks”could works on general functional requirements for metaverse networks. This includes the study of a functional framework, the description of a generic functional architecture, and a specific focus on key management functions.

ITU-T SG15 (Optical Transport Networks and Access Network Infrastructures)

ITU-T SG15 explores the integration of virtual reality (VR) and augmented reality (AR) technologies into optical transport networks and access network infrastructures to support the requirements of the metaverse.

ITU-T SG16 (Multimedia and Digital Technologies)

ITU-T SG16 could investigate standards for multimedia coding, systems and applications that enable immersive experiences within the metaverse, including virtual worlds, social interaction platforms and immersive storytelling.

ITU-T SG17 (Security)

ITU-T SG17 focuses on cybersecurity standards specifically tailored for the metaverse environment, addressing authentication, encryption, and threat detection mechanisms to ensure the security of virtual interactions and digital assets within metaverse platforms. Key areas include certification for market uptake, integration of metaverse networks with other networks, specifying metaverse-specific components, and embedding and use of applications.

ITU-T SG20 (Internet of Things and Smart Cities and Communities)

ITU-T SG20 could works on standards for integrating IoT devices and smart city infrastructure with the metaverse, enabling seamless interaction between virtual environments and the physical world, enhancing the overall functionality and intelligence of connected communities within the metaverse context.

I.2 ISO/IEC JTC1

ISO/IEC JTC1/SC 7 (Software and Systems Engineering)

SC 7 is responsible for standardizing processes, supporting tools, and documentation systems that assist in the engineering of software products and systems. This includes methodologies, tools and technologies designed to manage the lifecycle of software.

ISO/IEC JTC1/SC 24 (Computer Graphics, Image Processing, and Environmental Data Representation):

This subcommittee focuses on standardization in the fields of computer graphics, image processing, and environmental data representation, facilitating interoperability and advancements in these technologies.

ISO/IEC JTC1/SC 27 (Information Security, Cybersecurity and Privacy Protection):

SC 27 is dedicated to standardizing methods for enhancing IT security and privacy, covering everything from cryptography to security management and personal identity verification.

ISO/IEC JTC1/SC 31 (Automatic Identification and Data Capture Techniques)

SC 31 develops and facilitates standards related to the design and implementation of auto-identification and data capture technologies like bar codes, RFID, card technologies, biometrics, and item numbering.

ISO/IEC JTC1/SC 35 (User Interfaces)

SC 35 is tasked with standardization in the field of user interfaces, encompassing user interface design for software, hardware, and services to enhance accessibility, usability and performance of systems.

ISO/IEC JTC1/SC 38 (Cloud Computing and Distributed Platforms)

SC 38 provides standardization in the areas of cloud computing and distributed computing platforms. It focuses on frameworks, models, and technologies that facilitate services and applications based on cloud resources.

ISO/IEC JTC1/SC 41 (Internet of Things and Digital Twin)

SC 41 is dedicated to the standardization of Internet of Things (IoT) and Digital Twin technologies. It works on developing foundational standards that ensure interoperability, security, and effective deployment of IoT and digital twin ecosystems.

ISO/IEC JTC1/SC 42 (Artificial Intelligence)

SC 42 leads the ISO/IEC efforts on standardization in the field of artificial intelligence. It works on standards for AI concepts, frameworks, systems, and assurance to facilitate reliable, secure and trustworthy AI technologies.

I.3 W3C

W3C Immersive Web Working Group:

This group aims to bring high-performance virtual and augmented reality to the open web. Its work includes the development of APIs to integrate VR and AR into web applications.

W3C WAI (Web Accessibility Initiative):

WAI develops strategies, guidelines, and resources to help make the web accessible to people with disabilities. This includes developing standards for web content, user agents, and authoring tools.

I.4 IEEE

IEEE Virtual Reality and Augmented Reality Working Group:

This group works on the development of standards and best practices for virtual and augmented reality technologies, focusing on enhancing user experience through interoperability and innovation.

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