

"A Survey on Metaverse: Fundamental, Security, and Privacy" "Section II: An Overview of Metaverse"

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Source: https://giphy.com/gifs/facebook-meta-metaverse-Ch7bEcIsZJHWxTCIU

1. Metaverse Definition

- Metaverse is highly immersive virtual world-enabled technology where people can gather to socialize, play, work, and feel physically available in the real environment.
- It is synthesized world which is composed of
 - ✓ User-controlled Avatars + Digital Things + Virtual Environments + Computer-generated Elements.
 - ✓ Humans (Avatars) can use their virtual identity via smart device for communication, collaboration, and socialization to each other.



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Source: https://www.usatoday.com/story/tech/2021/11/10/metaverse-what-is-it-explained-facebook-microsoft-meta-vr/6337635001

Fig. : Metaverse Environment

2. Existing Metaverse-related Standards

Two standards are used in existing research for Metaverse.

ISO/ IEC 23005 (MPEG-V) \checkmark

a. ISO/ IEC 23005

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IEEE 2888 \checkmark

- Main objective of this standard that provide the basic interface between real world and the virtual world to realize seamless information exchange, simultaneous reactions, and interoperability.
- It is applicable for metaverse-related business services, where the association of audiovisual information, rendered sensory effects, and virtual objects (e.g., avatars and virtual items) can benefit the interactions between virtual and real worlds. Virtual world



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2. Existing Metaverse-related Standards continue....

b. IEEE 2888

- Main objective of this standard that define standardized interfaces for synchronization of cyber and physical worlds.
- It offers foundation for building metaverse systems, where both virtual and real worlds can affect each other with specifying information formats and application program interfaces (APIs) to control actuators and obtain sensory information.



3. Metaverse Architecture

• The construction of metaverse blends physical, human, and digital worlds.

1. Human Society (Human World)

- Human users along with their inner psychologies and social interactions constitute the human world.
- Equipped with smart wearable devices (e.g., VR/AR helmets), humans can interact and control their digital avatars to play, work, socialize, and interact with other avatars.
- Use a human-computer interaction (HCI) and extended reality (XR) technologies.



2. Physical Infrastructure (Physical World)

- It offers supporting infrastructures such as sensing/ control, communication, computation, storage for Metaverse.
- These supports multi-sensory data perception, transmission, processing, and caching, as well as physical control.
- Networking is provided via the communication infrastructure consisting of various heterogeneous wireless or wired networks (e.g., cellular communications, unmanned aerial vehicle (UAV) communications, and satellite communications).
- Powerful computation and storage capacities are provisioned via the computation and storage infrastructure assisted by cloud-edge-end computing.



3. Interconnected Virtual Worlds

- According to the Metaverse Standards, Digital World is combination of Digital Avatars, Virtual Environments, and Virtual Goods and Services.
- **Digital Avatar:** Avatars refer to the digital representation of human users in the metaverse. It can be any shape such as human, animal, imaginary creature, and others.
- Virtual Environments: It refer to the simulated real or imaginary environments in the metaverse such as Virtual Meeting Place, Playgrounds, and others.
- Virtual Goods/ Services: It refer to the tradeable commodities (e.g., skins, digital arts, and land parcels) produced by virtual service providers (VSPs) or the users in the metaverse.
- Virtual Services means digital currency, digital regulation, social service, etc.



4. Metaverse Engine

- It uses the big data from the real world as inputs to generate, maintain, and update the virtual world via the interactivity, AI, digital twin, and blockchain technologies.
- XR and HCI technology is used for interconnection between various digital avatar for specific functions.
- AI algorithms perform personalized avatar/content creation, large scale metaverse rending, and intelligent service offering to enrich the metaverse ecology.
- With Digital Twin technology provide virtual environments according to user experience or real world (Mirroring of Real World)
- Secure infrastructure and trust free trading and service offering by Blockchain technology.



5. Information Flow

- Humans can interact with physical objects via HCI technology and experience virtually augmented reality (e.g., holographic telepresence) via XR technology.
- The human world and the digital world are connected through the Internet, i.e., the largest computer network in the world.
- Users can interact with the digital world via smart devices such as smartphones, wearable sensors, and VR helmets, for the creation, sharing, and acquisition of knowledge.
- The IoT infrastructure bridges the physical world and the digital world by using inter-connected smart devices for digitalization, and thereby information can flow freely between the two worlds.



4. Key Characteristics of Metaverse



Fig. 5 : Key Characteristics of Metaverse

1. Immersiveness (Immersive Realism)

- Computer-generated virtual space is sufficiently realistic to allow users to feel psychologically and emotionally immersed.
- The immersive realism can be approached through the structure of sensory perception and expression.

4. Key Characteristics of Metaverse continue....

2. Hyper Spatiotemporality

- The real world is restricted by the finiteness of space and the irreversibility of time.
- Hyper spatiotemporality refers to the break of limitations of time and space in the Metaverse.

3. Sustainability

- The sustainability indicates that the metaverse maintains a closed economic loop and a consistent value system with a high level of independence.
- It should be built on a decentralized architecture with open innovations.



4. Key Characteristics of Metaverse continue....

4. Interoperability

- Users can seamlessly move across virtual worlds (i.e., sub-metaverses) without interruption of the immersive experience.
- Digital assets for rendering or reconstruction of virtual worlds are interchangeable across distinct platforms.
- 5. Scalability
- The scalability refers to the capacity of metaverse to remain efficient with the number of concurrent users/avatars, the level of scene complexity, and the mode of user/avatar interactions.
- 6. Heterogeneity
- The heterogeneity of metaverse includes heterogeneous virtual spaces, heterogeneous physical devices, heterogeneous data types, heterogeneous communication modes, as well as the diversity of human psychology innovations.

5. Enabling Technologies of Metaverse

1. Interactivity

- XR devices such as Helmet Mounted Displays (HMDs) are the main component in the Metaverse.
- Multi-sensory immersiveness, Augmented Experience, real-time user/avatar/environment interaction is provided by VR/ AR/ MR via Holographic Displays, HCI, and 3D Modeling.
- VR provides immersive experiences in a virtual world, AR delivers true presence experiences of virtual holograms, graphics, and videos in the real world, and MR offers a transition experience between

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Fig. 6 : Technologies in Metaverse

5. Enabling Technologies of Metaverse continue....

2. Digital Twin

- Digital twin represents the digital clone of objects and systems in the real world with high fidelity and consciousness.
- It enables the mirroring of physical entities, as well as prediction and optimization of their virtual bodies, by analyzing real-time streams of sensory data, physical models, and historical information.
- Digital twins can provide precise digital models of the expected objects with intended attributes in the metaverse with high accuracy.

3. Blockchain

- Blockchain technologies offer an open and decentralized solution for building the sustainable virtual economy, as well as constructing the value system in the metaverse.
- Blockchain is a distributed ledger, in which data is structured into hash-chained blocks and featured with decentralization, immutability, transparency, and auditability.
- De-Fi stands for decentralized finance, which aims to deliver secure, transparent, and complex financial
 SeoulTech UCS Lab services.

5. Enabling Technologies of Metaverse continue....

4. Networking

- In the Metaverse, 6G, SDN (Software Defined Network), IoT empower ubiquitous network is used for networking or communication.
- In 6G, space-air-ground integrated network (SAGIN) is a promising trend for seamless and ubiquitous network access to metaverse services.
- SDN enables the flexible and scalable management of large-scale metaverse networks via the separation of the control plane and data plane.
- In SDN-based metaverse, the physical devices and resources are managed by a logically centralized controller using a standardized interface such as OpenFlow.
- IoT is a network of numerous physical objects that are embedded with sensors, softwares, communication components, and other technologies with the aim to connect, exchange, and process data between things, systems, clouds, and users over the Internet.

5. Enabling Technologies of Metaverse continue....

5. Ubiquitous Computing

- Create an environment where computing appears anytime and everywhere for users.
- Ubiquitous computing enables smooth adaptation to the interactions between human users and the physical space.
- For improved users' quality-of-experience (QoE) in ubicomp, the cloud-edge-end computing orchestrates the highly scalable cloud infrastructures and heterogeneous edge computing infrastructures via complex inner/inter-layer cooperation paradigms.

6. Artificial Intelligence (AI)

- AI technology acts as the "brain" of metaverse which empowers personalized metaverse services, massive metaverse scene creation and rendering, multilingual support in the metaverse by learning from massive multimodal input via big data inference.
- AI enables smart interactions (e.g., smart shopping guide and user movement prediction) between user and avatar/NPC (non-player character) via intelligent decision-making.

1. Game

- Game is the current hottest metaverse application.
- The sandbox game Second Life1 offers a modifiable 3D virtual world where players can join in as avatars and create their virtual architectures and sell them, as well as participate in social activities such as art shows and even political gatherings and visiting embassy.
- Roblox is a global user-created game platform, in which players can create games and design items such as skins and clothes. It proposes eight key features of the metaverse: identity, friends, immersion, anywhere, diversity, low latency, economy, and civilization.
- Fortnite is a massive multi-player online (MMO) shooter game designed by Epic Games, where players can build buildings and bunkers as well as construct islands.





Fig. 7: Metaverse Game: ROBLOX

2. Social Experience

- Metaverse can revolutionize our society and enable a series of immersive social applications such as virtual lives, virtual shopping, virtual dating, virtual chatting, global travel, and even space/time travel.
- Tencent developed a Digital Palace Museum4 in 2018 which allows tourists to freely visit the palace museum and its exhibitions with a panoramic and immersive view by wearing VR helmets in their homes.

3. Online Collaboration

- Horizon Workroom5 is an office collaboration software (run in Oculus Quest 2 helmet) released by Meta (parent company of Facebook), which allows people in any physical location to work and meet together in the same virtual room.
- Microsoft Mesh6 is an MR platform supported by Azure, which enables users working from multiple sites to cooperate virtually via holographic presence and shared experience.

4. Simulation & Design

- 3D simulation, modeling, and architectural design is another application of Metaverse.
- NVIDIA has built its open platform named Omniverse7 to support multi-user real-time 3D simulation and visualization of physical objects and attributes in a shared virtual space for Industrial Applications.

5. Creator Economy

The metaverse mainly includes four modes of content creation: professional-generated content (PGC), professional- and user-generated content (PUGC), user-generated content (UGC), and AI-generated content (AIGC).
 TABLE III
 A SUMMARY OF CONTENT CREATION MODES IN THE METAVERSE

Mode	Description	Feature	Instance
PGC	Contents are produced by professionals	Centralization, low diversification, high quality & cost	GTA, Unity
PUGC	Contents are produced by professionals and users	Semi-centralization, medium diversification, medium cost	Second Life, Minecraft, Fortnite
UGC	Contents are produced and traded among users	Decentralization, high diversification, uneven quality & low cost	Roblox, Decentraland, Cryptovoxels
AIGC	Contents are produced or partially produced by AI	High efficiency, low cost & fast	MetaHuman

Prototype	Application	Immersive	Hyper Spatiotemporal	Sustainable		Interoperable	Scalable	Heterogeneous
Thototype				Open	Decentralized	inter oper able	Scalable	Heterogeneous
Second Life	MMO Game	Partly	\checkmark	Partly	×	×	\checkmark	N/A
Roblox	MMO Game	\checkmark	\checkmark	\checkmark	×	Partly	\checkmark	N/A
Fortnite	MMO Game	\checkmark	\checkmark	Partly	×	Partly	\checkmark	N/A
Digital Palace Museum	Travelling	\checkmark	×	×	×	×	Partly	N/A
Horizon Workroom	Working	\checkmark	×	×	×	×	Partly	N/A
Omniverse	Simulation	\checkmark	\checkmark	\checkmark	×	Partly	\checkmark	\checkmark
Decentraland	Game	\checkmark	\checkmark	\checkmark	\checkmark	×	\checkmark	Partly
Cryptovoxels	Game	\checkmark	\checkmark	\checkmark	\checkmark	×	\checkmark	Partly

TABLE IV SUMMARY OF EXISTING METAVERSE PROTOTYPES IN DIFFERENT APPLICATIONS



Source: https://tenor.com/view/meta-metaverse-zuck-zuckerberg-gaming-in-the-metaverse-gif-23714672

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Thank you for your attention

