Metaverse Services: The Way of Services Towards the Future

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***Abstract*—With the emergence of new generation of digital technologies, e.g., artificial intelligence, blockchain, cloud computing, big data, edge computing, 5G/6G, VR/AR/MR, and the Internet of Things, an exciting era of metaverse is coming. Interacted and linked with the physical world, metaverse offers a platform of a new social ecosystem, dealing with digital twins and empowering virtual-reality symbiosis. In metaverse, social activities and business processes are performed based on the sequences of workflow or service processes. Bridging both the virtual space and the real world, such metaverse services are more complicated and present many new challenges and research topics. In this paper, the concept and characteristics of metaverse services are presented, the key technologies and typical use cases are reviewed, and the future challenges and opportunities of metaverse services are also discussed.**

***Index Terms*—Metaverse services, Metaverse service space, service computing, Internet of Things, metaverse service ecosystem, Web 3.0, Big Service 2.0**

I. Metaverse and Its Influences on Services

Recent years have witnessed the strong waves of new generation digital technologies that have brought profound impact on businesses and the society. In particular, the emergence of *metaverse* promises to change the way society and digital economy services are accessed and enacted [1]–[5]. The term metaverse has its origins as a portmanteau of *meta* and *universe*. Initially coined by Neal Stephenson in his 1992 science fiction novel "Snow Crash" [6], Metaverse represents a virtual world, where humans, as programmable avatars, interact with each other and software agents, in a three-dimensional virtual space that uses the metaphor of the reality world. People may connect to the metaverse by wearing portable terminals, goggles and other equipment. Over the recent few years, metaverse has come into the social-technical fields worldwide. With the push of the major tech giants, e.g., Meta, Microsoft, Apple, Google, NVIDIA, Tencent, Tiktok, Baidu, Roblox, NetEase, more and more Internet and game software companies have engaged in the metaverse related fields, to explore the opportunities and to work on the challenges [7], [8].

So what is metaverse, exactly? Many people or organizations have given their viewpoints about metaverse and its characteristics. Matthew Ball explains that the metaverse is: "a massively scaled and interoperable network of real-time rendered 3D virtual worlds that can be experienced synchronously and persistently by an effectively unlimited number of users with an individual sense of presence, and with continuity of data, such as identity, history, entitlements, objects, communications and payments" [9]. David Baszucki, the Roblox CEO, describes, "in our vision, metaverse platforms will connect people from different life experiences with new and interesting ideas. We believe these connections will help build empathy by safely immersing people in different perspectives, where they will hear diverse viewpoints". Mark Zuckerberg, Facebook CEO, announced the new Meta name for Facebook at its Connect 2021 conference on October 28, 2021. He says, "In the Metaverse, you'll be able to do almost anything you can imagine—get together with friends and family, work, learn, play, shop, create—as well as completely new experiences that don't really fit how we think about computers or phones today". Gartner states that "Technically, a metaverse is a collective virtual shared space, created by the convergence of virtually enhanced physical and digital reality. For simplicity's sake, think of a metaverse as the next iteration of the Internet, which started as individual bulletin boards and independent online destinations". In China, the Committee on Scientific Terminology defines metaverse as "a virtual world interacted with reality world, being constituted through digital technologies, what is a realistic mapping or transcend reality".

As a summary, the metaverse can be seen as an IT-enabled digital virtual ecosystem of human life, work, creation and entertainment, etc., in the forms of digital twins, digital natives, virtual-real symbiosis and virtual-real interactions. It is a virtual social universe that interacts with the physical reality world.

For the characteristics of metaverse, Matthew Ball summarizes eight essential elements, including virtual world, 3D, real-time rendering, interoperability, massive extension, sustainability, synchronism, unlimited users and individual existence [9]. David Baszucki identifies eight characteristics as well, including identity, friends, immersive, low friction,

variety, anywhere, economy, and civility. More characteristics of metaverse are discussed in the literature. Among them, the key characteristics of metaverse include immersive experience, virtual-real symbiosis of human/matters/things/scenes, and digital virtual economy and society [7], [10].

Metaverse is realized and supported by a set of new information technologies, e.g., artificial intelligence, human-machine interaction and extended reality (XR) devices, digital game and entertainment [11], networked cloud computing and edge computing, 5G/6G communication, Internet of Things (IoT), blockchain and NFT (non-fungible tokens), virtual-reality fusion, decentralized community governance, and Internet of Services [12]–[15].

In metaverse, everything including human, things, scenes, digital twins, digital natives, activities and behaviors, is performed by means of various digital technical elements or digital building blocks. These building blocks of metaverse can be called "Metaverse-Ware" [10]. A metaverse-ware is the basic constitution element to build the metaverse world, which can be a complex component, element, agent, service or object. Every metaverse-ware can be implemented by digital hardware, software or software-hardware complex entities, and can also be encapsulated as a service using service computing technologies [16].

Interactions between people and things in the metaverse, as well as social activities and business processes under various virtual-real fused scenarios are all structured. These structures can be enhanced from those identified in other information systems, including choreographies and protocols [17], group behavior and capabilities [18], and contractual commitments [19] and other norms in organizations [20]. The fusion of the metaverse and services will ensure the orderly, efficient and reliable operation of the metaverse social ecosystem. Services play an important role in enabling the variety of functions of the metaverse. The metaverse ecosystem and metaverse-ware, people/matters/things/fields and their business processes, metaverse application scenarios, can all be defined as service forms, so as to improve the operation of metaverse ecosystems in an orderly and efficient way. Meanwhile, the metaverse will also cause significant changes of services and bring new problems and opportunities in the development of service computing, service science and engineering. The characteristics of metaverse will greatly extend the scope of the services, thereby giving the birth to "Metaverse Services" [10].

In this paper, the concept and specific key characteristics of metaverse services are presented in Section II, and a generic architecture of metaverse service system and the key technologies are proposed in Section III. Section IV introduces several use cases of Metaverse services. In Section V, the future challenges and opportunities of metaverse services are pointed out. Finally, Section VI provides some concluding remarks.

II. Metaverse Services: Concept and Characteristics

Exploring the intersection of the metaverse [9] and services computing [21], [22], a metaverse service can be defined as a complex service form organized by the massive heterogeneous digital services appearing in the metaverse virtual space and virtual-real fusion space, which is used to solve the service problems of digital avatars, digital twins, and digital natives in metaverse, through cross-network, cross-domain, cross-region, and cross-world aggregations and collaborations [10], [23].

Compared with the traditional services, the characteristics of the metaverse mentioned in Section I, together with the cross-aggregation characteristics of business processes with cross time-space, cross-world, cross-region, and cross-domain features, make metaverse services more diverse and complex. In addition to the basic characteristics of services, metaverse services also have new features such as the complexity of virtual-real fusion services, immersive experience, cross-scenario scalability across time and space, multi-dimensional and multi-modal service mode diversity, cross-network, cross-region, and cross-world service aggregation, intelligence enhancement based on AI generated content (AIGC) and user generated content (UGC), accuracy of personalized services for large-scale customers, and immersive entertainment experiences based on virtual service scenarios.

Metaverse services have brought new problems and challenges to Services Computing, Service Science, and Service Engineering. As early as 2012, the lead author, Prof Xiaofei Xu, proposed the concept of "Big Services" [24], with the definition: "A Big Service is a complex service form (or complex service network) formed by the aggregation and collaboration of massive heterogeneous services across worlds (real and digital), domains, regions, and networks". Big services are used to solve the problem of big data correlation business processing and business applications in digital enterprises or society, creating service value. Compared with Big Service, a metaverse service is also a complex service that aggregates across worlds, domains, regions, and networks. Its existence form is more diverse and its business content is more complex. Metaverse service can be seen as an upgraded version of Big Service, i.e., "Big Service 2.0".

Table I offers some further comparisons of traditional services and metaverse services, according to a number of aspects, including service entities, service agents, service platforms, service sources, service networks, service experience, and service governance.

III. Architecture and Driving Technologies of Metaverse Services

A. Architecture of Metaverse Services

The metaverse service ecosystem includes virtual and real service participants in the metaverse world, immersive experiential interfaces for real or virtual customer interactions, metaverse service solutions and their scenarios for virtual or real users, metaverse application-related service communities

TABLE I
COMPARISON OF TRADITIONAL INTERNET SERVICES AND METAVERSE SERVICES ALONG KEY ASPECTS

Aspect	Internet Services	Metaverse Services
Entities	Software Services, service app, and service models	Digital Twins, virtual native Services, Metaverse-ware services
Agents	Human users, software service agents	Human users, digital twins
Platforms	Software as a Service (SaaS), cloud-based platforms	Environment as a Service (EaaS), Metaverse service platforms
Sources	Software services, Web service sources, data services	Metaverse services, virtual society sources, NFT sources, data services
Networks	Web, Internet of Things, Internet of Services, Network terminals	Metaverse-Space Networks, VR/AR/MR terminals
Experience	Service provision on demand, reality service experience, terminal-based service provision	Virtual-reality service experience, immersive service experience, mixed reality service experience
Governance	Focused on the technology and its support of business	Focused on humans and their interactions through the metaverse

or domains and their service clusters, decentralized metaverse service platform clusters and their service networks, service resources and data from various service organizations or metaverse scenes, and independent metaverse service organizations and their local networks. Figure 1 depicts a hierarchical architecture of the metaverse service system, including the infrastructure layer, the local service layer, the service community layer, the convergence solution layer, and the virtual-reality interface layer.

The infrastructure layer mainly includes basic services offered by service providers, including software services, metaverse virtual services, IoT services, cloud services, data services, communication services, platform services, etc. The local service layer includes integrated services, which are service collections provided by service providers for the existing or potential metaverse business applications. The services in the service community layer include cross-world service aggregation communities that integrate virtual and real aspects at the domain level. These services are mostly the collections of composed services provided in the local service layer.

The convergence solution layer consists of complex services that integrate virtual and real aspects across networks and domains to meet various customer needs. These complex services, which are interconnected through hyperlinks, are mostly aggregated collections of service communities that meet the customer needs [25]. Finally, the virtual-reality interface layer focuses on the personalized perception of virtual and real customers' needs, and is typically aggregated from the cross-network, cross-domain, and cross-world fusion of virtual and real service elements, forming a meta-universe solution for large-scale services. These services are customized for specific customer needs, with a focus on user requirements and experience.

B. Driving Technologies of Metaverse Services

The theoretical and methodological aspects in developing metaverse services can be organized around the service mechanisms and representations, requirements engineering, engineering methodology, service system operation and optimization methods, quality assurance, and metaverse applications.

The new change and new challenges of meataverse services will become the driving force for the development and advancement of service computing, especially:

- New Forms of Services in Meatverse. Through fusing new technology, new contents and new ecosystems over the real-virtual worlds, metaverse will bring new forms and new models of services.
- New Types of Customers. Diverse user avatars, virtual agents or events in metaverse will become the new customers or initiators to drive the service requirements and to trigger service processes.
- New Requirements. As increasing growth of digital twins and natives interconnected over multi-worlds, and better immersive user experiences, end users will require more customized and integrated service solutions.
- New Approaches. The activities and behaviors of metaverse services will change the ways of people's life and work. The approaches to build services in virtual space or real-virtual worlds need to be changed accordingly.
- New Convergence. It would be a challenge to converge heterogeneous services and resources from multi-domains, multi-network and multi-worlds in metaverse into an optimized service solution on demands.
- New Governance. It would be difficult to govern the decentralized virtual society, service communities and their business operations in the new metaverse ecosystems.
- New Quality. It would be challenging to ensure the service quality in the quickly flowing business operations and processes in complicated metaverse environment.

Some of the key enabling technologies and research topics of metaverse services include the architecture of metaverse service system, the model of service aggregation across time and space, the virtual-real fusion characteristics of metaverse service space, the multidimensional division of service space and its relationship, the service perception and cognition of metaverse digital identity, digital twins/natives hybrid community, immersive and experiential service interaction technology based on VR/AR/MR, service design and process optimization methods under the virtual-real fusion scenario, service methodology on metaverse service fusion and supply-demand matchmaking, service value theory based on NFT and metaverse service engineering method of value perception, decentralized and trustworthy operation and dynamic evolution of metaverse service system, metaverse service credit model and security based on blockchain and NFT, and metaverse service quality evaluation and assurance.

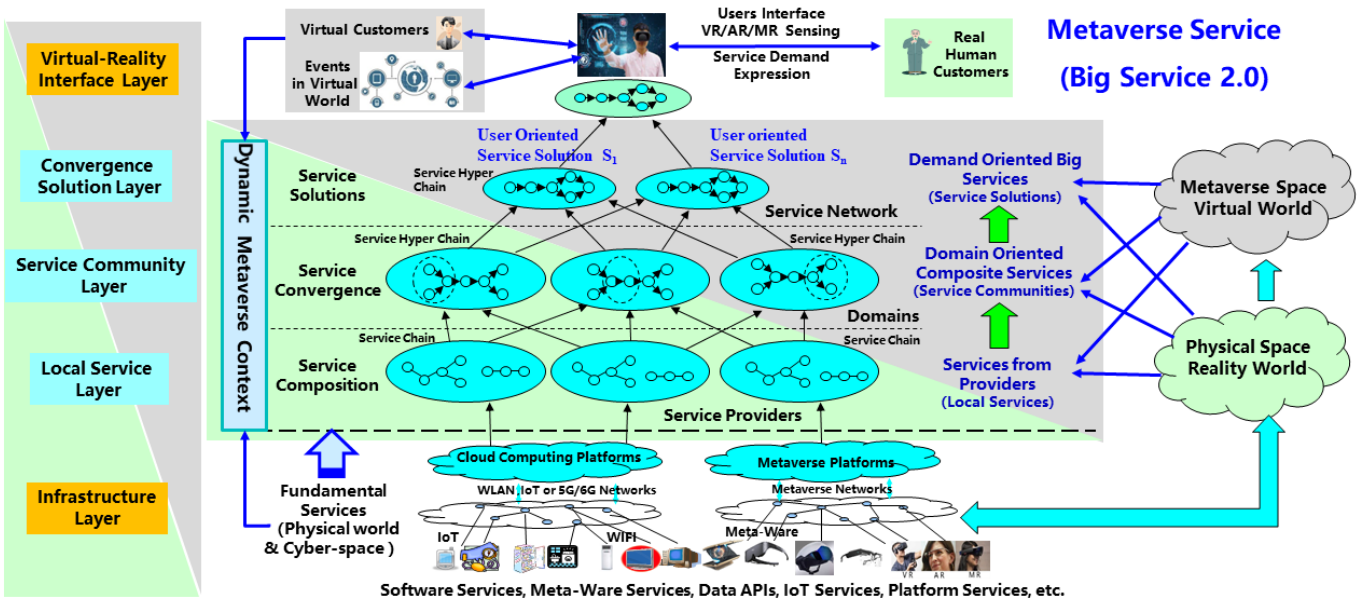

Fig. 1. The Generic Architecture of Metaverse Service Systems

IV. Use Cases of Metaverse Services

The future metaverse world will be composed of different interconnected and linked metaverse scenes. Such application scenes are the important elements of the metaverse world and the concentrated expression of its features. The core components of metaverse application scenarios mainly include: multi-dimensional scenes that feature virtual-real fusion across time and space, virtual avatars, immersive experiences based on XR technology, open content creation based on AIGC (AI generated content), and virtual economy based on NFT (non-fungible tokens). Some typical metaverse service application use cases include:

- **Healthcare Metaverse**. Metaverse services will break through the time and space barriers in the current medical systems, improve the coordination between patients, medical equipment, and treatment plans, innovate healthcare provisioning models, provide personalized diagnosis and treatment plans for patients, and provide precise medical services. Typical scenarios include remote medical collaborative diagnosis and consultation, intelligent clinical surgery, smart virtual doctor services, medical experience services, smart healthcare and medical management, and education and training services. For aged care, metaverse services can utilize virtual reality, holographic interactive technology, various interactive methods, and intelligent tools to support the full process operation of elderly care services such as intelligent home life services, smart elderly companionship services, virtual nursing homes, virtual elderly social services, and assisted rehabilitation services [26], [27].
- **Education Metaverse**. Metaverse services will provide student-centered, immersive, experiential, interactive, and collaborative teaching and learning through the integration of virtual and physical spaces and technologies such as artificial intelligence, to enhance student perception and to improve educational efficiency and effectiveness [28]. Some typical scenarios include realistic interactive scene-based teaching services, smart learning companion-assisted learning services, virtual teacher and teaching assistant collaborative education services, customized learning services based on digital avatars and digital twins, especially to counter other harmful effects of the technology such as misinformation [29], smart online teaching services, and technology training services based on reality scene simulation.
- **Industrial Metaverse**. Industrial metaverse refers to the use of digital twinning, virtual-real coexistence, and virtual-real collaboration to create a new industrial Internet of Things (IoT) system. It involves digital product collaborative research, development and design, intelligent manufacturing based on digital twinning, equipment operation and maintenance services, product testing in simulation environments, panoramic enterprise management and decision making, and employee training services [30].
- **Gaming Metaverse**. Metaverse provides a great gaming environment and presents players with a more free, open, and realistic world, with scenes involving user virtual identities, games content creation, immersive game playing experiences, game player social services, digital currencies and transactions, and virtual game community governance [31].
- **Tourism Metaverse**. Metaverse services will break through the time and spatial limitations, and construct

tourism and culture virtual spaces with multi-dimensional timelines, and immersive and interactive experiences, to enhance tourists' satisfaction and to increase the value of the tourism industry chain [32]. The typical scenarios include metaverse scenic tours, real-life immersive tourism projects, escape rooms, theme parks, metaverse digital museums, and virtual cultural performance.

V. Future Trends and Challenges of Metaverse Services

Currently, although the research and development of metaverse services is still in its early stages, it has already shown a positive trend towards networked, intelligent, ubiquitous, and virtual services. In the realm of metaverse service design, Liu et al. [33] proposed an intelligent integration framework called Slicing4Meta that customizes metaverse services by incorporating multi-dimensional resources and various physical-virtual components. Du et al. [34] developed an attention-aware network resource allocation scheme that assists metaverse service providers in offering competitive and economical service designs to consumers while achieving profit maximization. For metaverse resource allocation, Jiang et al. [35] introduced a hierarchical game-theoretic approach for Coded Distributed Computing (CDC), providing a framework for efficiently using idle resources for intensive computation tasks in the metaverse. Du et al. [36] explored an attention-aware network resource allocation scheme and employed eye-tracking and remote rendering techniques to optimize resource allocation based on users' interests and maximize quality of experience (QoE).

Regarding metaverse governance, Rosenberg [37], [38] emphasized the importance of identifying potential dangers within the metaverse and implementing meaningful regulations to mitigate these risks. The metaverse provides expanded opportunities not only for good but also for bad. Users can harm each other in terms of their metaverse identities or through those identities into their identities in the conventional physical world. In addition, metaverse platforms would have far greater powers of manipulation than imagined in current social media or news media, where the problems of misinformation and manipulation are rampant. We need new ways of thinking about such concerns. Centrally imposed regulations would be useful but far from adequate, especially in countering the risks inherent in user-user interactions. We need to computationally model sociotechnical systems [20] and the associated challenges of ethics in system terms [39], not merely in individual decision making [40]. We need models of trust that build on those for human-human interactions [41] but focus on how the ability, benevolence, and integrity of technologies embedded in societies can be understood [42].

As a relatively new research and development area, we can view the future directions of metaverse services from the perspectives of new forms, new requirements, new driving factors, new approaches and governance, and new convergence:

- *New formalities and applications*: The metaverse ecosystems across real-virtual worlds will bring new models and fusion features of services. With metaverse services, many application fields will be changed and the new application areas will appear.
- *New requirements*: As the increase of digital twins and digital natives interconnected over multi-worlds for better immersive user experiences, it is critical to conduct metaverse service demands and requirement prediction. It is also a challenge to ensure the service quality in the quick flowing of business operation and processes in the complicated metaverse environment.
- *New driving factors*: In metaverse, diverse user avatars, virtual agents or events happening will become new "customers" or initiators to drive the service requirements and to trigger service processes.
- *New approaches and governance*: New approaches are needed in metaverse to build or provide services in virtual space or real-virtual worlds. In addition, it is challenging to govern a decentralized society [20], [43], which is how we ought to understand service communities in the metaverse ecosystems.
- *New convergence*: It would be a challenge to converge heterogeneous services and resources from multi-domains, multi-network and multi-worlds in metaverse into an optimized service solution on demands.

Regarding the research on metaverse services, there are many important issues that are worth exploring. Some of them are the ecological cognition of people/things/scenes in the metaverse and the spatial mechanism of metaverse services; the cross-network, cross-domain, and cross-world aggregation ecology theory of metaverse services and their evolutionary mechanism; virtual humans/digital avatars and their feature representation and modeling; the decentralized multi-platform system architecture and interoperability of metaverse services; the development of new paradigms and design methods for metaverse service systems based on accurate supply-demand matchmaking; metaverse service auto-generation and aggregation based on AIGC; AI and big data analysis for metaverse scenes; metaverse service value system based on NFT; metaverse service credit and security based on blockchain; and typical application fields and their characteristics of metaverse services. Other challenges brought by the metaverse are also worth investigation, including metaverse service ecological governance, virtual user identity authentication, virtual service authentication and protection, protection of virtual assets and service rights, and user privacy information protection.

VI. Conclusion

By seamlessly integrating the physical and the virtual worlds, metaverse has been widely regarded as one of the key enablers of our future society with profound social and economic impacts. Empowered by the new generation of digital technologies such as Internet of Things, digital twins, virtual and augmented reality (AR/VR), 5G/6G, blockchain, service computing, and edge computing, metaverse applications and services hold the potential to revolutionize the way we live,

work, learn, and interact. However, converged metaverse services are more complicated with unique characteristics, presenting many challenges to service design, development, and governance. In this paper, we discuss the concept and specific features of metaverse services, present a generic architecture for metaverse services, and review the key technologies. We also introduce several use cases of metaverse services and briefly discuss the challenges and open opportunities in this area.

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