Trend Report of Virtual Worlds (Metaverse)

Virtual Worlds & the EC Communication on Virtual Worlds and Web 4.0 (July 2023)

In this age of rapid technological progress and connectivity, the concept of Virtual Worlds has emerged as a captivating and transformative force. Often referred to as Metaverses, these Virtual Worlds are multi-dimensional spaces where users can engage in a wide array of activities—from socialising and working to playing games, shopping, and more. They go beyond traditional online interactions, offering fully immersive, and persistent digital environments. Metaverse is predicted to grow into an EUR 800 billion market by 2024[1].

Although there is no universally accepted or agreed definition of the terms Metaverse, Web 4.0, and Virtual Worlds[2], from a technology standpoint, Web 4.0 is commonly considered to be the next generation of the Internet evolving[3] from Web 1.0, a static, one-way communication channel, Web 2.0, a centralised web where social media channels connect people and Web 3.0[4], a decentralised, and Artificial Intelligence (AI)-based web where end-users can create, share and connect content through search and analysis based on the capability to comprehend the meaning of words[5]. Web 4.0 is an autonomous, interconnected, interoperable, immersive network, incorporating ground-breaking technologies like Extended Reality (XR)[6], AI, cloud/edge computing, Internet of Things (IoT), 5G, and Distributed Ledger Technology (DLT), including blockchain[7]. Virtual Worlds are part of the transition to a more generalised use of 3D environments accessed through enhanced user interfaces like Virtual Reality (VR) headsets and require multiple technical blocks for smooth and real-time integration of digital and real objects such as Augmented Reality (AR), blockchain, Non-Fungible Tokens (NFTs), and computing, enabling more personalised and engaging user experiences[8]. Virtual Worlds are theorised as foundational elements of the Metaverse, which in turn denotes an "interoperable network" of interconnected Virtual Worlds[9]. Key characteristics are massive scale, real-time rendering, and continuity of

[1] https://www.bloomberg.com/professional/insights/markets/metaverse-may-be-800-billion-market-next-tech-platform/. The article puts together the market value of gaming (software, services, and ads), hardware, social media ads and live entertainment.
[2] For a broad overview of the debate, see: K. Giang Barrera and D. Shah, "Marketing in the Metaverse: Conceptual understanding, framework, and research agenda", *J. Bus. Res.*, vol. 155, p. 113420, Jan. 2023, doi: 10.1016/j.jbusres.2022.113420; K. Dwivedi *et al.*, "Metaverse beyond the hype: Multidisciplinary perspectives on emerging challenges, opportunities, and agenda for research, practice and policy", *Int. J. Inf. Manag.*, vol. 66, p. 102542, Oct. 2022, doi: 10.1016/j.ijinfomgt.2022.102542; S. M. Park and Y. -G. Kim, "A Metaverse: Taxonomy, Components, Applications, and Open Challenges", IEEE Access, vol. 10, pp. 4209–4251, 2022, doi: 10.1109/ACCESS.2021.3140175; I. Hupont Torres, V. Charisi, G. De Prato, et al., "Next generation virtual worlds – Societal, technological, economic and policy challenges for the EU," European Commission, Joint Research Centre, Publications Office of the European Union, 2023, pp.11-18. Available: https://data.europa.eu/doi/10.2760/51579; M. Ball, *The Metaverse: And How It Will Revolutionize Everything*. Liveright Publishing, 2022; F. Di Porto and D. Foà, "Defining Virtual Worlds: Main Features and Regulatory Challenges," Issue Paper, July 2023. Available: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4507397;
[3] I. Hupont Torres, V. Charisi, G. De Prato, et al., "Next generation virtual worlds – Societal, technological, economic and policy challenges for the EU," European Commission, Joint Research Centre, Publications Office of the European Union, 2023, pp. 11-18. Available: https://data.europa.eu/doi/10.2760/51579
[4] V. Barassi and E. Treré, "Does Web 3.0 come after Web 2.0? Deconstructing theoretical assumptions through practice", *New Media Soc.*, vol. 14, no. 8, pp. 1269–1285, Dec. 2012, doi: 10.1177/1461444812445878.
[5] European Commission (2023), Staff Working Document accompanying the Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions on "An EU initiative on Web 4.0 and virtual worlds: a head start in the next technological transition", SWD(2023) 250 final, Strasbourg, 11 July 2023, part 1, p. 32
[6] Extended reality (XR) offers an umbrella term that covers all forms of virtual, augmented and mixed reality Technologies. See N. Xi, J. Chen, F. Gama, M. Riar, and J. Hamari, "The challenges of entering the metaverse: An experiment on the effect of extended reality on workload", *Inf. Syst. Front.*, vol. 25, no. 2, pp. 659–680, Apr. 2023, doi: 10.1007/s10796-022-10244-x.
[7] I. Hupont Torres, V. Charisi, G. De Prato, et al., "Next generation virtual worlds – Societal, technological, economic and policy challenges for the EU," European Commission, Joint Research Centre, Publications Office of the European Union, 2023. Available: https://data.europa.eu/doi/10.2760/51579
[8] European Commission (2023), Staff Working Document accompanying the Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions on "An EU initiative on Web 4.0 and virtual worlds: a head start in the next technological transition", SWD(2023) 250 final, Strasbourg, 11 July 2023, part 1, p. 32
[9] L. Floridi, "Metaverse: A Matter of eXperience," *Philosophy & Technology*, September 2022. Available: http://dx.doi.org/10.2139/ssrn.4121411 (noting that "just as there is the Web and there are websites, there is the Metaverse and the 'metaverse sites'").

data. Major technology companies including Apple, Google, Meta Platforms (Facebook), Microsoft, Nvidia, Niantic, Roblox, Unity, and Valve are developing the technologies that will shape the future of the Metaverse[10].

Recently, the European Commission (EC) published a Communication on Web 4.0 and virtual worlds in July 2023. This initiative establishes explicit definitions of key terms like "Virtual Worlds"[11] and "Web 4.0"[12] and outlines the EU's vision and strategy for the technological transition. It is based on four key pillars derived from the Digital Decade policy programme[13]:

- **Empowering people and reinforcing skills**: The EU aims to build a European talent pool of Virtual World specialists via its funding programmes. It also wishes to increase public awareness and understanding of these technologies through the creation of a Virtual Worlds Toolbox.
- **Business**: The EU plans to foster a Web 4.0 industrial ecosystem bringing together different players of the Virtual Worlds value chain to ensure technological continuity in the region. It proposes a New European Partnership on Virtual Worlds and regulatory sandboxes among Member States for testing Virtual World technology and services.
- **Government**: The Commission envisages local and national governments paving the way to Web 4.0 by using digitalisation to enhance public service delivery and tackle societal challenges. It pledges to support flagship projects and initiatives on smart communities, city planning, public policy, health, and science.
- **Shaping Global Standards**: The Commission highlights the need for close cooperation with Member States to navigate the societal shifts brought about by Web 4.0 and Virtual Worlds. It plans to form an expert group composed of Member State representatives to promote the exchange best practices across the EU and internationally. It also aims to support the creation of a technical multi-stakeholder governance process to address fundamental aspects of Virtual Worlds and Web 4.0.

While the governance of this new digital frontier remains in the early stages, the EU, through its new strategy on Web 4.0 and Virtual Worlds, aims to lay the groundwork for the next generation of the internet and harness the potential of Virtual Worlds. It wishes to gain a first-mover advantage and establish itself as a leader in Web 4.0 and Virtual Worlds, and ensure that the emerging digital landscape is open, secure, trustworthy, fair, and inclusive for European citizens, businesses, and public administrations, in line with the EU values, principles, and fundamental rights. The EU is setting the stage for a digital future that is intrinsically European.

The role of blockchain in Virtual Worlds as a base/infrastructure technology

Virtual Worlds are becoming the new trend in the digital ecosystem. The EC's Communication on Virtual Worlds and Web 4.0 of July 2023[14] underlines the importance of secure and decentralised technologies that enable these complicated environments. Blockchain technology is highly recognised as a core technology for such virtual environments and enables a wide range of activities, e.g. from gaming to virtual commerce.

[10] Council of the European Union, "Metaverse – Virtual world, Real Challenges," ART Research Paper, p.8, 9 March 2022. Available: https://www.consilium.europa.eu/media/54987/metaverse-paper-9-march-2022.pdf; McKinsey & Company, "Value creation in the metaverse: The real business of the virtual world," p. 21, June 2022. Available: https://www.mckinsey.com/capabilities/growth-marketing-and-sales/our-insights/value-creation-in-the-metaverse

[11] Virtual Worlds are persistent, immersive environments based on technologies including 3D and extended reality (XR), which make it possible to blend physical and digital worlds in real time for a variety of purposes such as designing, making simulations, collaborating, learning, socialising, carrying out transactions or providing entertainment. See European Commission, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee, and the Committee of the Regions: An EU initiative on Web 4.0 and virtual worlds: a head start in the next technological transition, COM(2023) 442 final, 11 July 2023

[12] Web 4.0 is the expected fourth generation of the World Wide Web. Using advanced artificial and ambient intelligence, the internet of things, trusted blockchain transactions, Virtual Worlds and XR capabilities, digital and real objects and environments are fully integrated and communicate with each other, enabling truly intuitive, immersive experiences, seamlessly blending the physical and digital worlds. See European Commission, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee, and the Committee of the Regions: An EU initiative on Web 4.0 and virtual worlds: a head start in the next technological transition, COM(2023) 442 final, 11 July 2023.

[13] https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/europe-fit-digital-age/europes-digital-decade-digital-targets-2030_en

[14] European Commission, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee, and the Committee of the Regions: An EU initiative on Web 4.0 and virtual worlds: a head start in the next technological transition, COM(2023) 442 final, 11 July 2023.

At its core, blockchain acts as a decentralised ledger that records all transactions across a network of computers. Applied to Virtual Words, this means that all relevant transactions, be it the sale of virtual land or the exchange of digital costumes, are recorded in a blockchain. This ensures transparency and immutability. The above-mentioned infrastructure serves as a protective mechanism against fraud and helps provide a trustworthy environment that increases user confidence and security.

Blockchain architecture[15]: In recent years, decentralised architecture has gained widespread recognition for its benefits in various areas. It addresses critical issues on the Internet of Things (IoT), such as security. The concept of blockchain was first introduced with the cryptocurrency Bitcoin. This technology enables a peer-to-peer network that is openly accessible and does not require users to disclose personal information to participate. With blockchain, anyone can participate in transactions, with security and trust guaranteed by consensus mechanisms and a public ledger, and transactions are verified by specific nodes. Specifically, blockchain can be defined as an "append-only data structure where information is grouped in sets, called "blocks" with each block cryptographically referencing, through a hash function, forming a "chain". This data set is distributed in a network of peers who can independently verify its validity while its updating is subject to special rules"[16] and each transaction is performed with a unique public/private key pair. Along with scalability, blockchain research concentrates on consensus solutions[17] that are efficient, secure, and scalable. While public blockchain algorithms offer scalability[18], permissioned versions are more secure and efficient, but not scalable. Blockchain offers a way to mitigate the risks associated with third-party privacy breaches without jeopardising privacy. Its consensus mechanisms ensure that transaction details are verifiable at every stage. This makes blockchain a central element of the modern digital infrastructure, where most business and trading activities are conducted online.

Decentralisation in Virtual Worlds: One of the most significant advantages of blockchain is the decentralisation of authority. Traditional Virtual Worlds operated under the control of central entities, which maintained absolute control over the world's data and economics[19]. Blockchain disrupts this model by distributing the control to the users themselves. This paradigm shift not only enhances transparency but also empowers users, who can participate in governance models, vote on changes, or even influence the direction of the Virtual World's development[20].

Smart contracts and automation[21]: Smart contracts automate agreements and transactions in a blockchain network, executing predetermined actions when certain conditions are met. In Virtual Worlds, this means automating processes such as payments, asset transfers, or even complex game mechanics. For instance, a smart contract could automatically transfer ownership of a virtual asset once payment is confirmed, without any human intervention, thereby reducing the potential for disputes and enhancing user experience.

Challenges and limitations: Despite its potential, blockchain technology in Virtual Worlds is not without challenges. Scalability remains a significant issue; as the number of transactions increases, the underlying blockchain must manage these without compromising speed or increasing costs. Moreover, the environmental

[15] T. Ali Syed, A. Alzahrani, S. Jan, M. S. Siddiqui, A. Nadeem, and T. Alghamdi, 'A Comparative Analysis of Blockchain Architecture and its Applications: Problems and Recommendations', IEEE Access, vol. 7, pp. 176838–176869, 2019, doi: 10.1109/ACCESS.2019.2957660.

[16] Dionysopoulos, L., Marra, M., Urquhart, A., 2024. Central bank digital currencies: A critical review. International Review of Financial Analysis 91, 103031. https://doi.org/10.1016/j.irfa.2023.103031

[17] Z. Zheng, S. Xie, H. Dai, X. Chen and H. Wang, "An Overview of Blockchain Technology: Architecture, Consensus, and Future Trends," 2017 IEEE International Congress on Big Data (BigData Congress), Honolulu, HI, USA, 2017, pp. 557-564, doi: 10.1109/BigDataCongress.2017.85.

[18] Ismail and Materwala, 'Article A Review of Blockchain Architecture and Consensus Protocols: Use Cases, Challenges, and Solutions', Symmetry, vol. 11, no. 10, p. 1198, Sep. 2019, doi: 10.3390/sym11101198.

[19] I. G. I. Sudipa, P. W. Aditama, and C. P. Yanti, 'Building the Virtual World: A Literature Review on the Integration of Metaverse and Blockchain Technology'.

[20] T. Ali Syed, A. Alzahrani, S. Jan, M. S. Siddiqui, A. Nadeem, and T. Alghamdi, 'A Comparative Analysis of Blockchain Architecture and its Applications: Problems and Recommendations', IEEE Access, vol. 7, pp. 176838–176869, 2019, doi: 10.1109/ACCESS.2019.2957660.

[21] Kõlvart, M., Poola, M., Rull, A. (2016). Smart Contracts. In: Kerikmäe, T., Rull, A. (eds) The Future of Law and eTechnologies. Springer, Cham. https://doi.org/10.1007/978-3-319-26896-5_7

impact of some blockchain systems, particularly those based on proof-of-work algorithms, poses sustainability concerns. Innovations in blockchain, such as proof-of-stake algorithms, are being explored to address these issues by reducing the energy required for transactions.

Future virtual environments offer numerous opportunities in various areas, but they also bring with them several challenges that encompass technical, social, economic, and legal dimensions[22]. In these virtual spaces, important issues such as privacy, security, and ethical dilemmas as well as social inequalities need to be addressed. There is a risk of excessive collection of personal and sensitive data and widespread surveillance in both virtual and physical spaces. This could lead to severe forms of surveillance capitalism by private companies or repressive surveillance by authoritarian regimes. In addition, issues such as data manipulation, attacks that inject false data, challenges in tracing data ownership and provenance, and intellectual property violations are pressing concerns.

In addition, combating discrimination, social inequality, digital divide, hate speech, harassment, cyberbullying, and misinformation is crucial for the protection of human rights both online and offline. It is crucial to promote inclusion and represent the diversity of people by ensuring that everyone has access to resources and services, regardless of economic, physical, or geographical limitations. These digital rights require that accessibility and inclusion are not only a priority but also influence design decisions, particularly for vulnerable groups such as minors.

The role of blockchain in Virtual Worlds as a technology enabling useful applications such as NFTs and crypto assets

Virtual Worlds have gained significant attention over the last few years as the next “big thing” of digital evolution, and blockchain is one of its fundamental pillars due to its decentralised nature. However, studies related to the use and adoption of blockchain in the Metaverse context have not been fully explored[23].

Blockchain was first introduced, along with the creation of the first cryptocurrency, Bitcoin, in 2008, bringing along the concepts of asset tokenisation and Decentralized Finance (DeFi)[24]. These concepts have gained attention and evolved since their introduction, e.g., with the development of several standards, such as the NFTs based on the ERC-721 standard[25], and the Fungible Tokens based on the ERC-20. Given its origin, using blockchain to create a decentralised financial system for the Metaverse might be the most evident use case to apply it. Such a monetary system removes any third party or intermediaries in transactions, allowing for peer-to-peer transactions and ensuring security and transparency.

NFTs can play a crucial role in Virtual Worlds, where everything is digital, and even real-life objects can be represented as digital twins. Defined under the ERC-721 and originally run on Ethereum, NFTs are unique, immutable, indivisible, and non-interchangeable representations of anything, ranging from real-life objects (e.g., tickets and paintings) to virtual assets (e.g., virtual identities). In their essence, NFTs are cryptographic assets representing proof of ownership and are directly connected to the blockchain[26,27]; hence, they cannot exist without it. NFTs can be used for many different assets, either having a connection between the real and

[22] T. Ali Syed, A. Alzahrani, S. Jan, M. S. Siddiqui, A. Nadeem, and T. Alghamdi, ‘A Comparative Analysis of Blockchain Architecture and its Applications: Problems and Recommendations’, IEEE Access, vol. 7, pp. 176838–176869, 2019, doi: 10.1109/ACCESS.2019.2957660; T. Huynh-The et al., ‘Blockchain for the metaverse: A Review’, Future Gener. Comput. Syst., vol. 143, pp. 401–419, Jun. 2023, doi: 10.1016/j.future.2023.02.008.
[23] Thien Huynh-The, Thippa Reddy Gadekallu, Weizheng Wang, Gokul Yenduri, Pasika Ranaweera, Quoc-Viet Pham, Daniel Benevides da Costa, Madhusanka Liyanage, Blockchain for the metaverse: A Review, Future Generation Computer Systems, Volume 143, 2023, Pages 401-419, ISSN 0167-739X, https://doi.org/10.1016/j.future.2023.02.008
[24] Saeed Banaeian Far, Seyed Mojtaba Hosseini Bamakan, Qiang Qu, Qingshan Jiang, A Review of Non-fungible Tokens Applications in the Real-world and Metaverse, Procedia Computer Science, Volume 214, 2022, Pages 755-762, ISSN 1877-0509, https://doi.org/10.1016/j.procs.2022.11.238
[25] https://ethereum.org/en/developers/docs/standards/tokens/erc-721/, Accessed: 12/4/2024
[26] https://edition.cnn.com/2021/03/17/business/what-is-nft-meaning-fe-series/index.html, Accessed: 12/4/2024
[27] POLONA, C., André, M. & Maria, N., 2022. Metaverse: Opportunities, risks and policy implications, EPRS: European Parliamentary Research Service. Belgium. Retrieved from https://policycommons.net/artifacts/2476871/metaverse/3498933/ on 17 Apr 2024. CID: 20.500.12592/gjscr8.

the digital world or being completely digital[24]. Digital identities, an analogy of actual identities in the real world, can be represented in the Metaverse by NFTs, enabling identity management and access control.

Moreover, real inanimate objects can be easily translated into digital ones using NFTs, such as unique pieces of clothing, signed contracts, and proof of ownership. The same can be applied to digital assets such as parts of digital land and a virtual certificate, which can also be represented using NFTs. Some of the most prominent examples of Metaverse projects, such as Decentraland and Sandbox[23], combine cryptocurrencies based on the ERC-20 standard[28] with NFTs, creating unique financial environments. In such systems, users can use cryptocurrency to acquire digital assets represented by NFTs.

What are the merits of using blockchain in Virtual Worlds?

As the previous sections show, integrating blockchain technology in Virtual Worlds is more than a fundamental pillar. It's a game-changer that brings undeniable benefits and possibilities to the Metaverse. Decentralisation is one of the most essential characteristics of the blockchain (and Virtual Worlds).

- **Decentralisation**: The Virtual Worlds, designed to be open to everyone, must not adhere to and be controlled by a single entity or organisation**Error! Bookmark not defined.**. The blockchain's decentralised nature amplifies this notion, offering multiple services that utilise decentralisation as their foundation. The most illustrious example is the decentralised finance system that can be offered. All economic transactions in such decentralised monetary systems use cryptocurrencies as their financial token. This eliminates a central authority that oversees the transactions and actions of users and any other intermediary between these transactions. Furthermore, some blockchain implementations, such as permissioned blockchain networks[29], support decentralised governance, where every participant can vote and participate in important decision-making procedures. A prominent example is the setup of Decentralized Autonomous Organizations (DAOs)**Error! Bookmark not defined.**, democratic systems where users are required to vote for any changes affecting the DAO and its operation.
- **Data redundancy**: Data redundancy is one key characteristic associated with the blockchain technology[23]. Since blockchain leverages the concept of decentralisation and operates relying on multiple computing nodes dispersed across the network(s), it ensures high data redundancy and availability at all times by default. Even if a network node is taken down for any reason (e.g., maintenance, network failure), data is not lost and can still be accessed by any point of the Metaverse, even from different Virtual Worlds. As a result, the users will have access to their digital identities, represented by NFTs, and/or to their crypto assets (whether cryptocurrencies or other digital assets represented by NFTs) at all times.
- **Immutability**: One of its most notable features is the immutability of transactions on a blockchain. In blockchain, the data contained in the transactions are formulated into blocks that are encrypted and then chained with the previous blocks[23]. Hence, altering this data would require massive computational power and time since that would require altering the data of every other block that precedes the targeted data (or a block). The massive amount of data that is circulated in the Metaverse needs to be verified and kept consistent throughout its lifecycle. These characteristics are fundamental when it comes to the creation of accurate digital twins, training and using AI services, and gathering and using data from IoT sensors and other devices connected to the Metaverse.
- **User control**: Users need to have complete control of their identity[23] and any other sensitive data, both in the real-life world and in the Virtual World. Metaverse collects this information to formulate the identities of its users and offer them tailored services (e.g., personalised treatment plans). Blockchain provides these capabilities with access control policies, encryption methods (e.g., hashing functions), and the enforcement of smart contracts executed only by authorised users and when certain conditions are met.

[28] https://ethereum.org/en/developers/docs/standards/tokens/erc-20/, Last accessed at: 12/04/2024
[29] https://www.investopedia.com/news/public-private-permissioned-blockchains-compared/#toc-permissioned-blockchain, Last accessed at: 12/04/2024

- **Traceability and transparency**: These characteristics are key features of the blockchain and can be leveraged in various ways in Metaverse's premises[30]. In a vast world like Metaverse, information flow, and origin might take much work to track. Blockchain technology tackles this issue directly by providing traceability mechanisms since every transaction is recorded on the blockchain ledger and can be sought out at any time. A complete catalogue of the transactions is available to users, so they can cross-check any piece of information that has been recorded on-chain, such as the history of their crypto assets' transactions, and validate their point of origin and how they came across it, aiding in the detection of any false or manipulated information.
- **Interoperability**: By incorporating blockchain technology in the Virtual Worlds, data interoperability and cross-platform communication can be realised. It is possible that each virtual realm in the Virtual Worlds can use a different blockchain and different applications. Thus, stakeholders might have different assets in different worlds that they may want to access from another world, including their NFT-based identities or other crypto assets such as their cryptocurrencies[23]. The development of a cross-chain protocol for communication between different blockchains, while ensuring the interoperability of data, is feasible using cross-blockchain technologies.

What are the merits of Web 3.0 to Web 4.0 Virtual Worlds?

Web 3.0 represents the current generation of the web, which is decentralised, autonomous, increasingly intelligent, immersive, and interconnected. It is considered to mark the beginning of a significant shift towards a new Web 4.0 paradigm, where physical and digital worlds will seamlessly blend. Within this rapidly evolving Web 3.0 to 4.0 context, next-generation Virtual Worlds are likely to provide highly interconnected, intelligent, immersive, social, and personalised user experiences, as well as develop a strong connection with the real-world economy, eventually becoming an extension of it.

Web 4.0 offers a fundamentally transformative model of engagement, promising to change the way people interact with each other and the world around them. Important drivers of this revolutionary digital transition are the high technology readiness level of key enabling technologies (e.g. AI, blockchain, IoT and 5G amongst others), novel and more immersive human-machine interfaces such as VR/AR headsets with high-resolution displays, availability of large and highly performant computing and data storage infrastructures, an unprecedentedly vast community of highly engaged adopters/users, increasing interest from the public sector and governments and strong investments from the private sector, including major tech companies, venture capital, and global brands[31].

Although they are far from their potential end state, Web 4.0 and next generation Virtual Worlds are expected to embody the following characteristics[32].

- **Immersivity:** It refers to a deep, "in-web" presence, where users experience environments not just "in front of" but "within" the web, enhancing sensory engagement. These environments can be customised to meet user needs, offering varying levels of immersion depending on the technologies employed, providing more personalised services and user experiences.
- **Synchronicity:** Virtual environments support real-time communication and interaction between users, in ways that make them feel as if they were in a common environment. Different devices and technologies allow for diversified degrees of synchronicity.

[30] V. T. Truong, L. Le and D. Niyato, "Blockchain Meets Metaverse and Digital Asset Management: A Comprehensive Survey," in IEEE Access, vol. 11, pp. 26258-26288, 2023, doi: 10.1109/ACCESS.2023.3257029
[31] For more information see I. Hupont Torres, V. Charisi, G. De Prato, et al., "Next generation virtual worlds – Societal, technological, economic and policy challenges for the EU," European Commission, Joint Research Centre, Publications Office of the European Union, pp. 14-16, 2023. Available: https://data.europa.eu/doi/10.2760/51579
[32] See F. Di Porto, D. Foà, S. Ennis, "Emerging virtual worlds: Implications for Policy and Regulation," CERRE Tech Media and Telecom Report, pp. 16-17, February 2024. Available: https://cerre.eu/wp-content/uploads/2024/02/CERRE_Virtual_Worlds_Report.pdf

- **Persistence:** Virtual Worlds continue to evolve even when users are not connected to them, and the consequences of such evolution are perceived by/affect the user when connected again.
- **Unity:** It refers to a plurality of Virtual Worlds that are interconnected and interoperable, a condition that does not exist in the present phase but will materialise at a more mature stage of development. Once Virtual Worlds are unified (that is, interconnected and interoperable), users will be able to move their identities, data, currencies, and items seamlessly across different environments.
- **Mass content creation**: Users will be able to create content (for instance, through generative AI, or NFTs minting programmes) or apps to add new features to Virtual Worlds, modifying the environment in which they enjoy the services. Virtual worlds will more and more feature a content economy created at mass scale that will help populate it[33].
- **Three-dimensionality:** User experience occurs within computer-simulated electronic 3D virtual environments (in the case of VR) or through interaction with computer-simulated electronic 3D virtual elements (in AR and MR). This characteristic is strictly connected to the "in-web presence" feature.

Trends/conclusions for the future

When considering the future applications of blockchain technology in Virtual Worlds, it is important to consider the future trends of the Virtual World itself[34]. Web 4.0 and Virtual Worlds will be built on technologies and capabilities that will increasingly blend the physical and Virtual Worlds. This seamless integration will provide new, meaningful, and profound ways of connecting people not only to each other but to everything from brands, places, and services. New-generation Virtual Worlds are also emerging as the biggest growth opportunity for several industries in the coming decade, given the sheer breadth of potential applications and uses.

Identity representation: A major trend that has already started but remains at the forefront of the cooperation between Metaverse and the blockchain is identity[35] and avatar representation through NFTs[24] Avatars are expected to play a significant role in the evolution of Virtual Worlds[36] with the development of blockchain-based reputation systems that are tied to the avatars and participation in processes of decentralised governance of Virtual Worlds (e.g., DAOs). Thus, utilising blockchain and NFTs for identity and avatar management will continue to be a point of attention and research in the coming years.

Training & Education: Metaverse will transform education and training, making them essentially location-agnostic. Teacher-to-student or peer-to-peer learning can take place in virtual spaces and specially designed learning environments, thus serving as innovative educational tools that allow for personalised learning, enhancing student motivation and creativity[37]. Moreover, employers will be able to deliver ongoing training and upskilling programs in simulated real-life-like environments without risking their employees' safety[38]. Blockchain can play an essential role in this sector, mainly using NFTs that can be leveraged for a variety of applications[39]. NFTs can be used to represent the students' identities, preventing fraud in case of exams or to create digital content, such as textbooks or other training material by teachers, and distribute it among students, avoiding copyright issues and illegal possession of such material.

[33] McKinsey & Company, "Value creation in the metaverse: The real business of the virtual world," p. 21, June 2022. Available: https://www.mckinsey.com/capabilities/growth-marketing-and-sales/our-insights/value-creation-in-the-metaverse
[34] https://blockchainmagazine.net/top-10-metaverse-trends-in-2024/, Last accessed at: 16/04/2024
[35] Banaeian Far, S., Hosseini Bamakan, S. NFT-based identity management in metaverses: challenges and opportunities. *SN Appl. Sci.* **5**, 260 (2023). https://doi.org/10.1007/s42452-023-05487-5
[36] Duggal, A., Gupta, M., & Gupta, D. (2023). SIGNIFICANCE OF NFT AVTAARS IN METAVERSE AND THEIR PROMOTION: CASE STUDY. Scientific Journal of Metaverse and Blockchain Technologies, 1(1), 28–36. https://doi.org/10.36676/sjmbt.v1i1.04
[37] For example, the University of California at San Diego's Rady School of Management uses a virtual campus for real-time lectures, breakout spaces, and outdoor areas. See Virbela, "UCSD Launches Its International Micro-MBA Program," 2022.
[38] Bank of America, "Bank of America is First in Industry to Launch Virtual Reality Training Program in Nearly 4,300 Financial Centers," October 7, 2021
[39] Wu, C.-H.; Liu, C.-Y. Educational Applications of Non-Fungible Token (NFT). Sustainability 2023, 15, 7. https://doi.org/10.3390/su15010007

Healthcare: Web 4.0 and Virtual Worlds will offer limitless possibilities to deliver healthcare—efficiently, cheaply, and more widely—through telehealth, remote therapy, or remote treatments on the Metaverse. The use of XR and 3D technologies and digital twins will enhance pre-operative planning, reduce human errors during operations and improve medical analysis, diagnosis, and treatment[40]. It will also enable users to visualise their health and wellness journey, making healthcare more tangible and personalised. Another noteworthy example is the use of blockchain, gamification techniques[41], and Virtual Worlds to create innovative solutions that can significantly enhance the quality of life for citizens[42]. Incentive schemes can be created to encourage users to engage in daily walks or other activities. Such schemes can reward users with NFTs that can be exchanged[43] in virtual marketplaces, including virtual trips within the Metaverse.

Tourism: New tourism and travel experiences will emerge with increased adoption of Web 4.0. Those who cannot travel will be able to experience their favourite destinations and visit religious and cultural sites, all through fully engaging and interactive experiences[44], while reducing their carbon footprint[45].

Fashion & retail: The fashion industry is an interesting example of how Virtual Worlds and blockchain already have and continue to affect the industry sector[46]. With the advent of Virtual Worlds and avatars, many fashion companies and luxury brands[47] will likely adopt blockchain technology to either turn existing fashion items into NFTs and make them available to the Virtual Worlds or create exclusive virtual items. Selling virtual fashion, essentially NFTs has yielded massive incomes[48] for the companies that ventured into it, and even though not all big luxury brands have exploited this opportunity, they are expected to take the plunge. Additionally, fashion brands use NFTs for practical applications like loyalty tokens or digital twins. The latter stores vital information about a product's history, authenticity, and ownership, benefiting luxury retailers in combating counterfeiting[49]. Finally, next-generation Virtual Worlds present an opportunity for retailers to reimagine and personalise the store environment for individuals and groups of customers. Brands can leverage VR/AR to offer 3D, navigable, and branded spaces allowing customers to experience and buy virtual or physical goods as well as try out products not available in-store[50].

Manufacturing: The integration of Virtual Worlds within Industry 4.0 can significantly enhance industrial processes. The use of digital twins can improve product design, manufacturing, and simulation processes as well as increase operational efficiencies (e.g., predictive maintenance, quality control, and supply chain

[40] C. Riley-Missouri, "Virtual reality could soon let your doctor 'step inside' your blood sample," World Economic Forum, 2019. Available: https://www.weforum.org/agenda/2019/06/doctor-to-step-inside-biopsy-samples-with-vr/; L. M. Wellens *et al.*, 'Comparison of 3-Dimensional and Augmented Reality Kidney Models With Conventional Imaging Data in the Preoperative Assessment of Children With Wilms Tumors', *JAMA Netw. Open*, vol. 2, no. 4, pp. e192633–e192633, Apr. 2019, doi: 10.1001/jamanetworkopen.2019.2633; A. Elmi-Terander *et al.*, 'Feasibility and Accuracy of Thoracolumbar Minimally Invasive Pedicle Screw Placement With Augmented Reality Navigation Technology', *Spine*, vol. 43, no. 14, 2018. Available: https://journals.lww.com/spinejournal/fulltext/2018/07150/feasibility_and_accuracy_of_thoracolumbar.19.aspx;
[41] Thomason, Jane. "Metahealth-how will the metaverse change health care?." Journal of Metaverse 1.1 (2021): 13-16.
[42] R. Chengoden et al., "Metaverse for Healthcare: A Survey on Potential Applications, Challenges and Future Directions," in IEEE Access, vol. 11, pp. 12765-12795, 2023, doi: 10.1109/ACCESS.2023.3241628.
[43] A. Musamih *et al*., "Metaverse in Healthcare: Applications, Challenges, and Future Directions," in *IEEE Consumer Electronics Magazine*, vol. 12, no. 4, pp. 33-46, 1 July 2023, doi: 10.1109/MCE.2022.3223522. keywords: {Metaverse;Medical services;Artificial intelligence;Consumer electronics;X reality;Cloud computing;Three-dimensional displays},
[44] For instance Ariva Digital's Wonderland platform is working to allow users to travel to imagined or recreated destinations. See Ariva Digital, "A new dawn in tourism history," 2022. See also D. Gursoy, S. Malodia, and A. Dhir, 'The metaverse in the hospitality and tourism industry: An overview of current trends and future research directions', *J. Hosp. Mark. Manag.*, vol. 31, no. 5, pp. 527–534, Jul. 2022, doi: 10.1080/19368623.2022.2072504.
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[46] https://medium.com/@Spaceseven/top-nft-trends-for-2024-the-next-step-into-the-future-4be2c76fbe7a, Last accessed at: 16/04/2024
[47] Joy, A., Zhu, Y., Peña, C., & Brouard, M. (2022). Digital future of luxury brands: Metaverse, digital fashion, and non-fungible tokens. Strategic Change, 31(3), 337–343. https://doi.org/10.1002/jsc.2502
[48] Hyejune Park, Rachel Esther Lim, Fashion and the metaverse: Clarifying the domain and establishing a research agenda, Journal of Retailing and Consumer Services, Volume 74, 2023, 103413, ISSN 0969-6989, https://doi.org/10.1016/j.jretconser.2023.103413.(https://www.sciencedirect.com/science/article/pii/S0969698923001601)
[49] For more information on specific use cases in the apparel and fashion industry see McKinsey & Company, "Value creation in the metaverse: The real business of the virtual world," p. 41-44, June 2022. Available: https://www.mckinsey.com/capabilities/growth-marketing-and-sales/our-insights/value-creation-in-the-metaverse
[50] For more information on specific use cases in the retail industry see McKinsey & Company, "Value creation in the metaverse: The real business of the virtual world," p. 46-48, June 2022. Available: https://www.mckinsey.com/capabilities/growth-marketing-and-sales/our-insights/value-creation-in-the-metaverse; See also K. Jadhav, S. V.P., A. Ambikapathy, S. M.A., K. Gulati, and N. Kumar, 'The rise of 3D E-Commerce: the online shopping gets real with virtual reality and augmented reality during COVID-19', *World J. Eng.*, vol. ahead-of-print, Sep. 2021, doi: 10.1108/WJE-06-2021-0338.

management). This integration promotes sustainable industry practices through resource and process optimisation and innovative business models[51].

Web 4.0 and Virtual Worlds have the potential to revolutionise aspects such as employee engagement, customer experience, omnichannel sales and marketing, product innovation, and community building. It is estimated that by 2026, 25 % of people will spend at least an hour daily in the Metaverse for work, shopping, education, social activities and/or entertainment[52]. With its potential to generate up to USD 5 trillion in value by 2030[53], the Metaverse is simply too big to be ignored. Businesses, policymakers, consumers, and citizens need to embark on their educational Metaverse journeys and translate knowledge into economically and socially viable actions that unlock the potential of this digital transformation.

[51] For instance, BMW is experimenting with creating digital twins of entire factories, and designing products using Nvidia's Omniverse technology. Brian Caulfield, "NVIDIA, BMW blend reality, virtual worlds to demonstrate factory of the future," NVIDIA, April 13, 2021. See also J. Leng, D. Wang, W. Shen, X. Li, Q. Liu, and X. Chen, 'Digital twins-based smart manufacturing system design in Industry 4.0: A review', *J. Manuf. Syst.*, vol. 60, pp. 119–137, Jul. 2021, doi: 10.1016/j.jmsy.2021.05.011; X. Yao, N. Ma, J. Zhang, K. Wang, E. Yang, and M. Faccio, 'Enhancing wisdom manufacturing as industrial metaverse for industry and society 5.0', *J. Intell. Manuf.*, vol. 35, no. 1, pp. 235–255, Jan. 2024, doi: 10.1007/s10845-022-02027-7.

[52] https://www.gartner.com/en/newsroom/press-releases/2022-02-07-gartner-predicts-25-percent-of-people-will-spend-at-least-one-hour-per-day-in-the-metaverse-by-2026

[53] McKinsey & Company, "Value creation in the metaverse: The real business of the virtual world," p. 36, June 2022. Available: https://www.mckinsey.com/capabilities/growth-marketing-and-sales/our-insights/value-creation-in-the-metaverse