

Musings on the Metaverse and on how the Internet of Digital Reality Encompasses Future Developments of the Internet

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Abstract—Internet of Digital Reality (IoD) is a concept that encompasses various aspects of the next level of communication between digital cognitive entities. Extending the concept of IoT and IoE, IoD includes all kinds of entities interacting in virtual reality, focusing not only on the technology, physical and logical networks, but also on cognitive aspects and human factors. The Metaverse – as a key element of IoD – was introduced and has lately been re-vitalized as a kind of vision for the future of the Internet, especially focusing on social media, where users interact via their avatars in a fully immersive VR scenario. In this paper, I nevertheless argue that IoD is more than a “VR Facebook”, and that although the Metaverse can offer a new kind of experience, it isn’t free from drawbacks and valid criticisms.

Index Terms—Internet of Digital Reality, Future Internet, Facebook, Metaverse, Virtual Reality

I. INTRODUCTION

A. What is the Metaverse

The Metaverse can be seen as the next level of the Internet with decentralized, persistent online 3D virtual environments [1]. Virtual spaces in the Metaverse will be mostly accessible not only through VR and AR headsets, but also via mobile devices and desktop computers as well. The Metaverse can be expected to have many use cases, however, currently it is more a vision and a future perspective than an existing platform due to technological limitations regarding access devices, sensors, actuators and computational capacity needed to interact with and “live” in such real-time virtual environments.

In 2008, Sivan tracked the term Metaverse back in history to as early as 1992 [2]. Its first use cases were collected in that work, such as Second Life, where human characters spent their time, played, worked and lived in a 3D environment focusing on social structures and business as well. There is still no consensus about the definition of the Metaverse. Song suggested that the components of virtual reality, mirror worlds, augmented reality, and life-logging would serve as the pillars of the Metaverse, and proposed a definition that included human behavior and user experience [3]. Mystakidis defined it as a post-reality universe, a persistent multiuser environment merging the physical world and digital virtuality solutions, mainly via AR and VR technology [4].

This paper reviews previous literature on the Metaverse and attempts to provide a refined definition and a structural

gathering for this social and technological phenomenon. Furthermore, the main goal is to find its place among the various emerging fields beyond IoT, especially, where not only the technical development but human factors and cognitive aspects play a significant role. Finally, critical aspects and current technical and non-technical problems will be collected and highlighted to suggest directions of development. From the social aspect, the Metaverse can be seen as a “social good”. The technology promises to weaken differences in gender, race, as well as mental and physical disabilities in the near future. On the other hand, masking real life properties of human users and hiding behind idealized avatars can result in problems and deepen existing real life problems. Therefore, science, research and development of such systems should strongly focus on human factors [5].

B. Facebook and Meta

In 2020 NVIDIA presented a 3D real-time simulation and collaboration platform called “Omniverse” as a next-generation alternative for the Internet. At Connect 2021 conference, Mark Zuckerberg introduced Facebook’s vision of the Metaverse as the successor to the mobile Internet, and announced that his company would be renamed to Meta [6]. In Zuckerberg’s vision, the interconnected digital spaces of a Metaverse would allow one to do things that would otherwise be impossible in the physical world (however this could be also true for various other things). Zuckerberg’s Metaverse is also characterized by social presence, the feeling of being there with another person or other people, and can be expected to eventually encompass work, entertainment, and everything in between.

However, the main focus within Zuckerberg’s Metaverse is nevertheless on social media, thus, it is a technology envisaged primarily for the enhancement of interaction among human users. Applications such as Horizon Home for the Oculus Quest platform, will be extended by Horizon Worlds and Workrooms for social interaction in the VR world. Horizon World has already gained 300,000 users by February 2022, having increased the number of users tenfold in 3 months (Figure 1). The platform is meant to be the successor of Facebook, a cartoon-like virtual environment inside which avatars can interact. In a way similar to Minecraft, users can build their own environment, and many “sub worlds” already exist.

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Fig. 1. Promoting Tweet of Horizon World

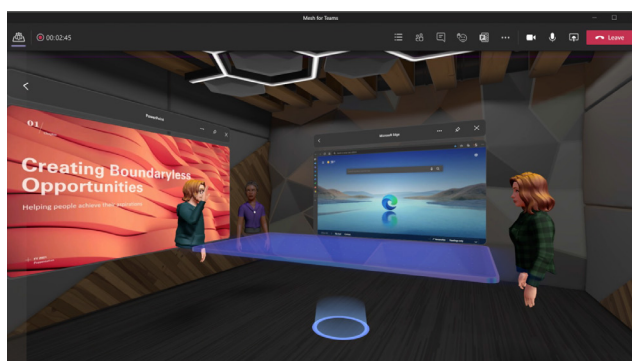


Fig. 2. Virtual meeting places in Teams 2022

Meta's AI Research Supercluster (RSC) computer system will serve to handle communication among tens of thousands of users, including sophisticated content filtering and moderation. Currently, the cluster uses 6800 graphic processors, and can complete machine vision tasks 20-times faster than the competitors. When completed, it will have 16,000 GPUs, one exabyte of memory, and will perform AI learning at 16 TByte/sec speed. VR support for Messenger has been launched already, and voice calls will be included with the system in the near future.

C. Beyond Meta

Gaming in virtual reality not only includes action games, but AR/VR Chess, Formula racing and other sport activities will be available. The idea is getting new traction through online gaming using virtual reality [7], i.e. the Oculus Quest 2 VR headsets are going to be extended by further sets of accessories, while Quest for Business is being developed for work scenarios [8]. Microsoft also announced new devel-

opments after Facebook's press release, raising attention to Minecraft as a Metaverse game. The company's other popular games called Halo and Flight Simulator can be seen as a "2D Metaverse game" already that would be enhanced by 3D technology. Furthermore, Microsoft announced that users are able to portray themselves as a cartoon avatar in Teams with Microsoft Mesh (Figure 2).

Another development from Facebook, called Project Cambria (unofficially called Oculus Quest Pro) will be a high-end device at a higher price, packed with all the latest advanced technologies, including improved social presence, eye and face tracking, pancake optics, and more. Photo-realistic avatars and real-time, 3D reconstructions of real-world locations will be offered for VR (Figure 3) [9].

In the case of the Metaverse, it is important to stress that even if the spaces (including navigation, exploration techniques, graphics etc.) look like 3D games, the content is not necessarily (and in general will not be) determined and modified by a game developer company, but by the users. For example, both human users and legal entities like companies can buy land, properties, VR commodities, which can then be modified dynamically within the spaces. Pioneers of this vertical market include fashion companies (Gucci sold a digital replica purse for more money than the original real-world item), gambling, cryptocurrency exchange (CFD), and auction houses. In a recent interview, Zuckerberg himself has expressed his vision that users will spend as much money on their VR clothing as on their physical clothing ¹.

D. Progress in the Metaverse

Moving from independent virtual worlds to an integrated network of 3D virtual worlds rests on progress in four areas: immersive realism, ubiquity of access and identity, interoperability, and scalability – areas that were defined and described already in 2013 [10]. Institutional and popular interest and ongoing improvements in hardware performance were mentioned as key factors for a functioning Metaverse, and they still have not been solved in the last decade.

A three-layer future architecture for the Metaverse has been suggested from a macro perspective, containing infrastructure, interaction, and ecosystem. The authors also presented a historical overview and discussed novelties of the Metaverse with a detailed timeline and table of specific attributes [5].

A related concept called the "Immersive Internet" has also been proposed as a gigantic, unified, persistent, and shared realm. It has since been recognized that emerging technologies such as mixed and augmented realities, 5G, Artificial Intelligence, HCI, Edge and Cloud computing, as well as IoT are a part of this concept [11].

At the same time, Seidel focuses more on the connection aspects of the Metaverse, calling it a "meta design space". In this context, spaces are interconnected, created by "designers" and transitions between physical and virtual experiences are

¹Zuckerberg on the Lex Fridman podcast, February 26, 2022: <https://youtu.be/5zOHSysMmH0>



Fig. 3. In Meta's Metaverse, people create avatars of themselves with specific facial expressions or skin colors. The Cambria headset is specifically designed and it will includes sensors that enable a user's avatar to make natural eye contact in real time.

especially important [12]. Designers are still human actors, although artificial entities can also evolve to designers in the future.

A description and prescription of the value chain of this market was also provided – a vision for the future powered by creators and built upon decentralization and grouped into seven layers as seen in Figure 4 [13]. The potential and risks of globally accessible 3D virtual spaces as part of the digital transformation of society and business was also recognized [14]–[16]. MetaSociety will emerge in MetaCities, where MetaEnterprises create a MetaEconomy – mapping of real world entities and business into the virtual space [17].

E. Metabusineses

Goldman Sachs has recently listed the most important companies relevant to the Metaverse, such as Meta (Facebook), Snap, Nvidia, Google and Roblox. Some of these companies are already present on the stock exchange [18]. They see Metaverse as the next generation Internet, also known as Web3.0. Web2.0 moved communication from the desktop to mobile devices and cloud services, Web3.0 will be the VR-based Internet using avatars. The basic technology should be Non-fungible Tokens (NFT) and blockchain. The goal is twofold: enhancing the physical world with values using AR and having open interfaces, standards and roles with an expected roll-out in ten years. At the beginning of the Internet era, users were in “read-only” mode, exploring static, rarely updated 2D webpages. Around 2005, a new paradigm arose, as websites went into “write” mode from the user's

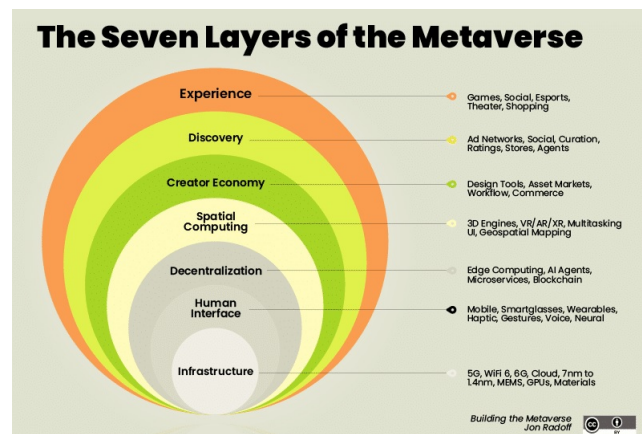


Fig. 4. Seven layers of the Metaverse [13]

perspective: blogs, social media, videosharing sites created a platform for self-expression that we call Web2.0. Web3.0 will be extended by ownership and digital property rights, where digital documents and art can be valuable products, with the ability to differentiate between original and copies (see e.g., the Bored Ape Yachting Club cartoon monkeys, CryptoPunks NFT collections, see Figure 7). NFTs have introduced new possibilities and together with blockchain technologies they can serve as a basis for future business models in the Metaverse and various digital reality applications [19], [20].

In February, 2022 JP Morgan's Onyx blockchain division



Fig. 5. JP Morgan's virtual property in Decentraland

published a short report on the Metaverse and revealed that the company acquired a piece of virtual property in Decentraland (Figure 5).

Currently, business in Decentraland is based on cryptocurrency. The NFT market correlates with the cryptocurrency market, and pricing of the latter can help in understanding NFT pricing patterns [21]. However, there are many risks in cryptotrading with crime control being absent [22]. The easiest way for companies to enter the Metaverse is based on already existing customers, fans, or “followers” in the real-world, independent of whether the product is physical or virtual (e.g., a service). Influencers, who have become key players in the pop culture of the previous decade (the 2020s) and have a great influence on business models can attract people to these ecosystems and by reaching a critical mass of users, they can contribute to the mass acceptance new technologies. There is still no original application specifically developed for IoD (and for the Metaverse). Existing solutions are simply placed in a 3D environment without exploiting the possibilities of immersion. Furthermore, there are no metrics or measurement methods to certify the outcomes.

Whether these new technologies will be hyped-up playgrounds for the elite or will be used to create serious applications for the Web3.0 that are secure and decentralized will be revealed in the future.

II. EVOLUTION FROM IoT TO IoD

Internet of Things (IoT) describes the network of physical objects, things, that are embedded with sensors, software, and other technologies for the purpose of connecting and exchanging data with other devices and systems over the Internet [23], [24]. Things can be physical machines, or sensors that have a virtual counterpart (a virtual or digital twin). We associate IoT with a large number of machines that are connected, creating something “smart”, usually being able to make some kind of simple decisions. It is also a collection of non-human users communicating on the Internet with some degree of freedom. With the introduction of higher-

level decision making, machine learning, artificial intelligence etc., the concept of IoT can be extended in many ways [25], [26].

As a case in point, the **Internet of Everything (IoE)** includes people, data and processes within IoT based on smart, intelligent networked connections. Network intelligence is a key factor here, but human factors and non-technological issues are still neglected.

The concept of **Internet of Digital Reality (IoD)** was introduced for a better understanding of new possibilities behind the sharing of digital realities in networked settings [27], [28]. The term Digital Reality is not new, it has been used for different reasons and from different aspects [29], [30]. Technological developments in communication, management and human-computer interactions have led to quantitative and qualitative evolution in many ways. First of all, modalities for accessing and displaying information are being extended beyond 2D audio and video. 3D spaces, fully immersive environments using all modalities require not only new equipment, but the understanding of cognitive factors and users' behaviour. A virtual environment shared by human users, machines, AIs, digital twins etc. poses an enormous cognitive load, danger and possibilities (Figure 6). IoD deals with these problems from a principled scientific perspective. To highlight the importance of the cognitive aspects, the 1st international conference organized on IoD concluded to complement the term of IoD to be the Internet of Digital and Cognitive Realities.

The most relevant aspect of IoD is that it creates a higher-level functional integration (network) of digital entities, 3D virtual environments, different technologies and information (data). Real-world counterparts of these entities may or may not exist. A digital (cognitive) entity can be seen as a 3D representation of a “homepage”. Today, information can be accessed using text input/output, two-dimensional stills and/or motion picture visual information and sometimes using sounds.

Pillars of IoD have been listed as follows [27]:

- Cognitive entities interacting in the digital reality
- Information and data
- Underlying communication networks
- Artificial Intelligence
- Accessing hardware interfaces
- Cognitive infocommunications and human factors
- Safety
- Digital business and legal issues
- Digital Society

In a 3D VR scenario, information can be accessed in a more natural, intuitive way by moving and navigating in a 3D immersive space, replacing traditional I/O methods with gestures, haptics, 3D audio/video and speech communication. The role of the Metaverse here is to serve as an organized collection of 3D spaces which on the one hand serve as a foundation for decentralized digital economies, but which on the other hand can also contribute to the creation of new digital realities (provided that they participate in a high-level integration of capabilities towards a specific goal) [27], [28].

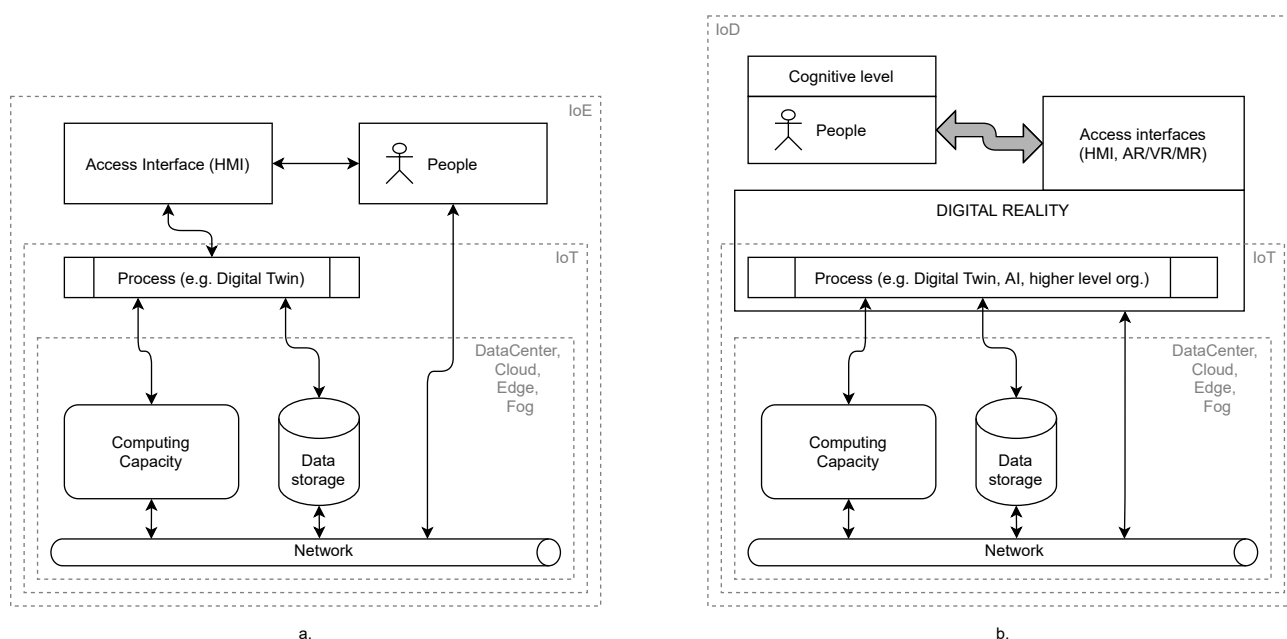


Fig. 6. Overview of the different philosophies of IoT, IoE and IoD

The Internet of Digital Reality in turn enables such realities to be shared and managed in networked scenarios.

A. IoD in the Popular Culture

In 1984, William Gibson's multiple award-winning science-fiction novel of the cyberpunk genre called *Neuromancer* hit the shelves. It introduced the global computer network in cyberspace, a virtual reality dataspace called the "matrix". In this future with the help of brain-VR/AR interfaces users can enter the grid-like 3D virtual environment inhabited by representations of real world entities. It can be explored and communication and information transfer is maintained under the supervision of various artificial intelligences. Later, the book was extended to a trilogy, followed by computer games with the same name on the C64 and Amiga platforms.

The concept of the Metaverse – and the name itself – first appeared in Neal Stephenson's *Snow Crash* story (1992) years later, where a pizza delivery boy acted as an undercover agent in the Metaverse. It is Stephenson's vision of how a virtual reality-based Internet might evolve in the near future, populated by user-controlled avatars, as well as system daemons. It appears to its users as an urban environment, developed along a single road that runs the entire circumference of a spherical planet. In 2021 HBO Max announced that they are developing a TV series from the novel.

Later, movies such as the *Matrix* Trilogy, *Blade Runner*, *Johnny Mnemonic*, Japanese Manga series (*Akira*) and RPG games (*Final Fantasy*, *Cyberpunk 2020* and *Cyberpunk 2077*) made the genre even more popular. Post-industrial dystopian future settings, high-tech, cybernetics, advanced robotics, multinational corporations and virtual reality have

been essential parts of the stories and artwork. Even the music industry gave rise to formations in the 80s (Kraftwerk, Psydoll, Sigue Sigue Sputnik) that combined electronic music, heavy riffs and retrofuturistic outfits. Digital fine arts and even architectural design were touched by the genre.

III. METACRITICS

Along with renewed interest in the Metaverse, critics have also emerged, claiming that the Internet and related technologies are already a Metaverse in their own right, and that adding VR to this mixture is just another way to increase marketing efforts – an attempt by Facebook to catch up with Google, Amazon and Microsoft, while at the same time to counteract its decline in popularity among young people compared top platforms like TikTok, Minecraft and Roblox [31].

In parallel, more principled concerns have also been made public, including whether each player in big tech will create its own Metaverse, while trying to lock in users with specific hardware and software solutions. The question of whether decentralization can retain its original meaning in such an environment seems to be a valid one.

There are equally concerns about how the Metaverse can be regulated, e.g., how control over accessible content is to be managed. A correspondent of BBC News entered the Metaverse with a fake profile of a 13-year old girl using the Meta Quest VR helmet and had unrestricted access to adult content. Of course, this problem may be somewhat independent of the Metaverse, as access to any kind of web-based content raises similar challenges, although the fact that the Metaverse is expected to rely on decentralized solutions more than any networked technology before may be an indicator of

renewed challenges in this area. Decentralized systems have the problem of responsibility that has to be addressed in order to gain trust.

A. The Pyramid Scheme

At the beginning of 2022, Zuckerberg presented the numbers of Meta about the 4th quarter and the total year of 2021. Number of users, profit and stock exchange rates were falling. The historical decline of stock value by 26 percent in one day resulted in a multi-billion dollar loss. Especially young people do not seem to be really inspired about Zuckerberg's Metaverse, and falling business expectations for the future are more important for stock exchange rates than visionary thinking. Other tech companies such as Spotify or Netflix also suffered losses.

On the other hand, the real estate business in other Metaverses (Sandbox, Decentraland, Somnium, Cryptovoxels) seem to be very popular. In 2021 more than 500 million dollars were spent on virtual real estate. Basically, there is no upper limit to the amount of money exchanged for digital landscapes, which prompted many business insiders to point to pyramid schemes. Even using NFTs for property rights is an idea that brings with itself more questions than answers, as there is no real value or central executive body behind them.

There is a connection between NFT and cryptocurrency sales, and both markets promise perspectives and risks [32], [33]. A systematic study about the opportunities and challenges of NFTs was given in [34]. Similarly, an overview covering 146 research papers on aspects of cryptocurrency trading was presented [35]. These considerations are more financial than technical ones, and they can be driving factors behind the developments for the Metaverse.

A pyramid scheme is an unsustainable business model, where top-level members recruit new members, who pay costs up the chain [36]. It is illegal in many countries and it is seen as fraud. Multi-Level Marketing (MLM) is almost the same, but usually involves some kind of goods and services to be sold, often virtual or no-value products. However, these are legal business practices [37]. The so called Ponzi schemes do not necessarily have a pyramid structure, but promise high returns by taking investment money from recruited newcomers who end up losing their money [38]. Virtual real estate investments following these schemes foreshadow a bubble waiting to burst. Even if there would be unlimited number of spaces and financial assets backing NFTs, the number of possible customers willing to pay are limited.

B. Technology behind Metaverse and IoD

Another issue behind the Metaverse and also perhaps behind IoD is that virtual and augmented reality technologies including audio, video and haptics modalities are not yet fully developed.

Decades ago, VR spaces and the underlying technologies were science fiction, and simply reflected how authors imagined the future. In the meantime, a parallel but synergic evolution of various technologies offer a new, combined reality

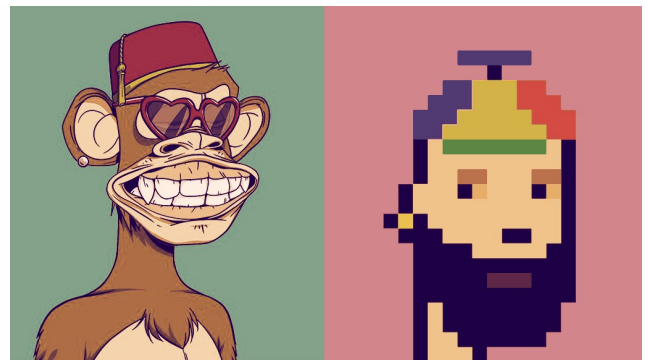


Fig. 7. A Bored Ape and a CryptoPunk: the most popular and largest Ethereum profile picture projects based on NFT.

or realities [39]–[42]. The question is whether concurrent solutions of metaverses will be compatible, massively scaled real-time in 3D and interoperable, i.e. whether the end result will be a single Metaverse, or locally managed independent solutions.

VR faces problems that are similar to those faced by 3D television some years ago: complicated equipment was needed for something that could be done in 2D easily and effectively (e.g., Minecraft's VR playing mode is the least played version). Use cases and applications have to deliver real improvements in user experience, safety, user friendliness etc. in order to put Metaverse and IoD applications on the shelves. Social impact, human factors became a significant role and IoD deals with these questions as well.

Research within IoD (and thus within Metaverses as well) is also focused at network and communication solutions. 5G and the upcoming 6G technologies (the Chinese company Oppo has already presented the first white book) will offer high bandwidth and low latency at relatively short spatial distances (some tens of meters).

IV. RESEARCH AREAS AND FUTURE AGENDA FOR DEVELOPMENTS

The Metaverse - as part of IoD - has gained much research attention in recent times. A research agenda was also proposed about the Metaverse. In this, various computer-mediated virtual environments were created including social networks, video conferencing, virtual 3D worlds, AR and NFT games [11]. The authors defined the Metaverse as "*a virtual environment blending physical and digital, facilitated by the convergence between the Internet and Web technologies, and Extended Reality*", a duality between the real physical and the digital virtual world. However, the main focus is on the users' avatars and the way they can live a different (second) life in the digital reality. This might be a different approach than used by digital twins, where the similarity between the real thing and its digital twin should be great and model its functionality as good as possible.

A blockchain-driven Metaverse prototype of a university campus was designed, tested and discussed in [5]. The main

focus here was on applications for social goods. The Metaverse's architecture was decomposed into three layers, namely infrastructure, interaction, and ecosystem, and a timeline of evolution was envisaged for future developments.

A. Internets of Whatever

The introduction of the Metaverse into the spotlight brings along with it associations with existing and new terms of "Internet of X" solutions. There is an endless possibility of creating such phrases. This highlights the need to extend the well-known terms of IoT and maybe IoE as well. Different areas beyond IoT are emerging, focusing on different aspects, fields of interests and trying to evolve to a stand-alone field of research. The Internet of Nano Things (IoNT), the Internet of Mission-Critical Things (IoMCT) and the Internet of Mobile Things (IoMT) show the need for further differentiation within IoT [43]. Medical experts have also proposed a definition of the Metaverse in Medicine as the Medical Internet of Things (MIoT) using AR and/or VR glasses [44].

The Internet of Skills defines a network based on connections between skills, actions and activities [45]. Especially the case of haptics as a modality using 5G networks and its capabilities (such as network slicing, QoS measurements) for healthcare applications is in focus. Here, not only "things" and "users" are connected, but capabilities, competences, information and know-how, with strong focus on usability, manipulations and interactions.

Unfortunately, the abbreviation IoS can be used for different things. Regarding audio applications, the term Internet of Audio Things (IoAT) and Internet of Musical Things (IoMusT) forming together the umbrella term Internet of Sounds (IoS), showing the need for extension of the IoT term in the world of sounds [46], [47]. The Internet of Musical Things is a research area consisting of the extension of IoT to the music domain. Interoperability represents a central issue within this domain, where heterogeneous objects dedicated to the production and/or reception of musical content are envisioned to communicate between each other [48]. The Internet of Sounds is a research area that is progressing at a steady pace, with several endeavors aimed at the academic, industrial, and artistic level. It stems from the intersection of the field of Sound and Music Computing with that of IoT [49].

To make things more complicated, IoS also denotes Internet of Senses, referring to connected sensors in order to interact with digital entities from the distance, using modalities different from auditory and visual [50]. All these suggest that the term IoT is exceeded, and there is a need for a higher level concept covering new areas that we call IoD (Figure 6).

V. CONCLUSIONS

The concept of the Metaverse was recently re-defined and introduced to the wider public by Zuckerberg. However, the term, and more importantly, the content and meaning of this term is not new. The Metaverse seems to represent an evolutionary step towards the future of the Internet, where

users are immersed in a 3D virtual environment within work, entertainment, gaming, social media and other use case scenarios, and can trade commodities within these use cases in a decentralized way. Though it is the source of widespread excitement, the Metaverse has also drawn critics, who claim that it is just another way to generate profits and does not represent substantial novelties. Who is correct remains to be seen, but research agendas, fields of interests were already introduced showing the need to extend the Internet of Things concept. In this context, it is important to note that cognitive digital entities will be the future actors of the Internet, including human users, things, skills, AIs, using new hardware and software developments, networks, I/O devices and modalities. Given that the Internet of Digital Reality (IoD) covers all these with a strong focus on cognitive infocommunications, human factors and related sciences, it seems to be a valid argument that IoD is a more general concept in which Metaverses can play a key role.

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