CHAPTER 1
Introduction

"Computers are useless. They can only give you answers."

Pablo Picasso
(1881–1973)

1.1. Toward 6G: A New Era of Convergence

This book is a sequel to our last Wiley-IEEE Press book titled "Toward 6G: A New Era of Convergence," which was authored together with Amin Ebrahimzadeh and was the first published book on future 6G mobile networks [1].

In our prequel book, we argued that 6G should not only explore more spectrum at high-frequency bands but, more importantly, *converge driving technological trends*. Our applied approach was in line with the bold, forward-looking research agenda put forth by Saad et al. [2], which intends to serve as a basis for stimulating more out-of-the-box research that will drive the 6G revolution. Specifically, Saad et al. [2] claim that there will be the following four driving applications behind 6G: (i) multisensory extended reality (XR) applications, (ii) connected robotics and autonomous systems, (iii) wireless brain–computer interaction (a subclass of human–machine interaction), and (iv) blockchain and distributed ledger technologies. Among other 6G driving trends, they emphasize the importance of edge intelligence and the emergence of smart environments and new human-centric service classes, as well as the end of the smartphone era, given that smart wearables are increasingly replacing the functionalities of smartphones. They argue that smartphones were central to 4G and 5G. However, in recent years there has been an increase in wearable devices whose functionalities are gradually replacing those of smartphones, ranging from integrated headsets to smart body implants that can take direct sensory inputs from human senses.

6G and Onward to Next G: The Road to the Multiverse, First Edition. Martin Maier.

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These emerging smart wearables may bring an end to smartphones and potentially drive a majority of 6G use cases.

One of the most intriguing 6G visions out there at the time of writing our prequel book was outlined by Harish Viswanathan and Preben E. Mogensen, two Nokia Bell Labs Fellows, in an open access article titled "Communications in the 6G Era" [3]. In this article, the authors focus not only on the technologies but they also expect the human transformation in the 6G era through *unifying experiences across the physical, biological, and digital worlds* in what they refer to as the network with the sixth sense. Combining the multi-modal sensing capabilities with the cognitive technologies enabled by the 6G platform will allow for analyzing behavioral patterns and people's preferences and even emotions, hence creating a sixth sense that anticipates user needs and allowing for interactions with the physical world in a much more intuitive way.

Furthermore, Viswanathan and Mogensen [3] claim that new themes are likely to emerge. Specifically, the future of connectivity is in the creation of *digital twin worlds* that are a true representation of the physical and biological worlds at every spatial and time instant, unifying our experience across these physical, biological, and digital worlds. Digital twins of various objects created in edge clouds will form the essential foundation of the future digital world. Digital twin worlds of both physical and biological entities will be an essential platform for the new digital services of the future. Digitalization will also pave the way for the creation of new virtual worlds with digital representations of imaginary objects that can be blended with the digital twin world to various degrees to create a mixed-reality, super-physical world, enabling new *superhuman* capabilities. Augmented reality (AR) user interfaces will enable efficient and intuitive human control of all these worlds, whether physical, virtual, or biological, thus creating a unified experience for humans and the human transformation resulting from it. Dynamic digital twins in the digital world with increasingly accurate, synchronous updates of the physical world will be an essential platform for augmenting human intelligence.

Importantly, Viswanathan and Mogensen [3] outlined a *vision of the future life and digital society* on the other side of the 2030s. While the smartphone and the tablet will still be around, we are likely to see new man–machine interfaces that will make it substantially more convenient for us to consume and control information. The authors expect that wearable devices, such as earbuds and devices embedded in our clothing, will become common. We will have multiple wearables that we carry with us and they will work seamlessly with each other, providing natural, intuitive interfaces. Touch-screen typing will likely become outdated. Gesturing and talking to whatever devices we use to get things done will become the norm. The devices we use will be fully context-aware, and the network will become increasingly sophisticated at predicting our needs. This context awareness combined with new man–machine

interfaces will make our interaction with the physical and digital world much more intuitive and efficient. The computing needed for these devices will likely not all reside in the devices themselves because of form factor and battery power considerations. Rather, they may have to rely on locally available computing resources to complete tasks beyond the edge cloud. As consumers, we can expect that the self-driving concept cars of today will be available to the masses by the 2030s. They will be self-driving most of the time and thus will substantially increase the time available for us to consume data from the Internet in the form of more entertainment, rich communications, or education. Further, numerous domestic service robots will complement the vacuum cleaners and lawn mowers we know today. These may take the form of a swarm of smaller robots that work together to accomplish tasks.

In fact, according to [4], nothing has happened yet in terms of the Internet. The Internet linked humans together into one very large thing. From this embryonic net will be born a collaborative interface, a sensing, cognitive apparatus with power that exceeds any previous invention. The hard version of it is a future brought about by the triumph of a superintelligence. According to Kelly, however, a soft singularity is more likely, where artificial intelligence (AI) and robots converge – humans plus machines – and together we move to a complex interdependence. This phase has already begun. We are connecting all humans and all machines into a global matrix, which some call the *global mind* or *world brain*. It is a new regime wherein our creations will make us better humans. This new platform will include the collective intelligence (CI) of all humans combined with the collective behavior of all machines, plus the intelligence of nature, plus whatever behavior emerges from this whole. Kelly estimates that by the year 2025 every person will have access to this platform via some almost-free device.

Our prequel book described the latest developments and recent progress on the key technologies enabling 6G mobile networks, paying particular attention to their seamless convergence. Among other potential research directions, 6G will take cloud services to the next level by moving many of the computational and storage functions from the smartphone to the cloud. As a result, most of the computational power of the smartphone can focus on presentation rendering, making virtual reality (VR), AR, or XR more impressive and affordable. Furthermore, 6G will transform a transmission network into a computing network. One of the possible trademarks of 6G could be the seamless convergence and harmonious operations of transmission, computing, AI, machine learning, and big data analytics such that 6G is expected to detect the users' transmission intent autonomously and automatically provide personalized services based on a user's intent and desire.

In the final chapter of our prequel book, we took an outlook on how future profound 6G technologies will weave themselves into the fabric of

everyday life until they are indistinguishable from it. As a result, the boundary between virtual (i.e. online) and physical (i.e. offline) worlds is to become increasingly imperceptible, while both digital and physical capabilities of humans are to be extended via edge computing variants with embedded AI capabilities. More specifically, we elaborated on the implications of the transition from the current gadgets-based Internet to a future Internet that is evolving from bearables (e.g. smartphone), moves toward wearables (e.g. Google and Levi's smart jacket or Amazon's announced voice-controlled Echo Loop ring, glasses, and earbuds), and then finally progresses to nearables (e.g. intelligent mobile robots). Nearables denote nearby surroundings or environments with embedded computing/storage technologies and service provisioning mechanisms that are intelligent enough to learn and react according to user context and history in order to provide user-intended services. While 5G was supposed to be about the Internet of Everything (IoE), to be transformative 6G might be just about the opposite of Everything, i.e. Nothing or, more technically, No Things. Toward this end, we introduced the *Internet of No Things* as an extension of immersive VR from virtual to real environments, where human-intended Internet services – either digital or physical – appear when needed and disappear when not needed. In doing so, the Internet of No Things helps tie both online and offline worlds closer together for the extension of human capabilities and experiences, ranging from conventional VR and AR to advanced XR and even more sophisticated cross-reality environments that involve various types of physical and digital realities.

Figure 1.1 depicts our proposed architecture of the Internet of No Things, which integrates the following three evolutionary stages of mobile computing: (i) ubiquitous, (ii) pervasive, and (iii) persuasive computing. Ubiquitous computing is embedded in the things surrounding us (i.e. nearables), while pervasive computing involves bearables and wearables. Persuasive computing aims at changing or even transforming the behavior of human users through social influence. As explained in technically greater detail in Chapter 5, the Internet of No Things will be instrumental in not only establishing XR as the next-generation mobile computing platform for the extension of human capabilities and experiences but also enabling future communication technologies that are anticipated to fold into our surroundings, thereby helping us get our noses off the smartphone screens and back into our physical and biological environments. The Internet of No Things represents an important stepping stone toward ushering in the 6G post-smartphone era and its underlying fusion of digital and real worlds created and delivered by non-traditional converged service platforms.

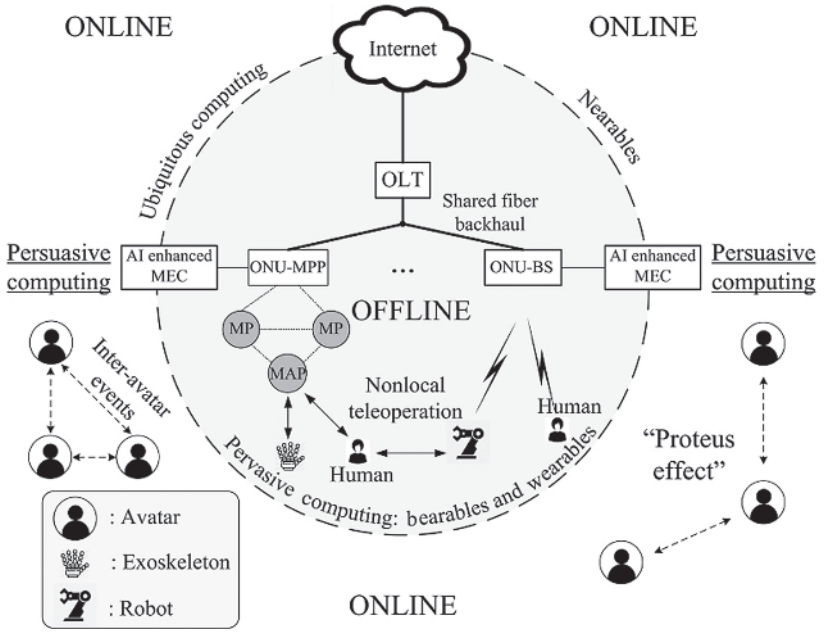

Figure 1.1 Internet of No Things: Integrating ubiquitous, pervasive, and persuasive computing for the extension of human capabilities and experiences.
Source: Maier et al. (2020). © 2020 IEEE.

1.2. Fusion of Digital and Real Worlds: Multiverse vs. Metaverse

In May 2019, the ITU-T Focus Group Network 2030 (FG-NET-2030), an initiative focusing on the fixed networks domain, published the first white paper on their Network 2030 vision [5]. Network 2030 is an abstraction of network technologies required to deliver advanced applications in 2030 and the decade after. It aims at coexisting with deployed infrastructures, incrementally inserting new capabilities in both public and private fixed (wireline) networks. According to [5], the next frontier in multimedia after VR and AR will include holographic media and multi-sense network services, e.g. haptic communication services. Soon our experiences with VR/AR will determine that they are not real enough, calling for new media, unencumbered by today's head-mounted displays (HMDs). The fusion of digital and real worlds across all dimensions is the driving theme for Network 2030, created and

delivered by non-traditional converged service platforms, where developers do not hesitate to use technologies from as many disciplines as possible. They do not discriminate whether services and applications will be used by human beings, or by physical, digital, or virtual objects.

The European Telecommunications Standards Institute (ETSI) launched its Industry Specification Group (ISG) fifth generation fixed network (F5G) initiative, which aims at promoting the expansion of fixed networks to as many sectors as possible via fiber-to-the-everywhere-and-everything (FTTE) [6]. F5G also considers complementary wireless technologies, most notably WiFi 6, for the last meters to enable use cases such as cloud VR, online gaming, smart factory, and the support for the evolution of 5G networks. According to [6], F5G is the foundation of the new digital age and is a prerequisite for the digital transformation of the whole society. F5G is just the beginning and a first step for more generations to come. The evolution of F5G, together with that of mobile 5G and 6G, is expected to support new application scenarios involving digital avatar life, full sensory (including tactile and haptic) Internet, and a ubiquitous intelligent society in this new era of convergence.

In the final chapter of our prequel book, we also introduced the concept of the so-called *Multiverse* as an interesting attempt to help realize the fusion of digital and real worlds. The Multiverse offers eight different types of reality, including but not limited to VR and AR, as explained shortly. A term closely related to the Multiverse is the recently emerging *Metaverse*. According to [7], the Metaverse will be the precursor of the Multiverse. Specifically, the Metaverse might be viewed as the next step after the Internet, similar to how the mobile Internet expanded and enhanced the early Internet in the 1990s and 2000s. The various adventures that this place has to offer will surround us both socially and visually. The Metaverse is unique in that it spans a wide range of interconnected platforms as well as the digital and physical worlds underpinned by decentralized *Web3* technology.

As shown in Figure 1.2, while the Web1 (read-only web) and Web2 (read-and-write web) enabled the knowledge economy and today's platform economy, respectively, the Web3 will enable the *token economy* where anyone's contribution is compensated with a token. The token economy enables completely new use cases, business models, and types of assets and access rights in a digital way that were economically not feasible before, thus enabling completely new use cases and value creation models. Note that the term token economy is far from novel. In cognitive psychology, it has been widely studied as a medium of exchange, and arguably more importantly, as a positive reinforcement method for establishing desirable human behavior, which in itself may be viewed as one kind of value creation. Unlike coins, however, which have been typically used only as a payment medium, tokens may serve a

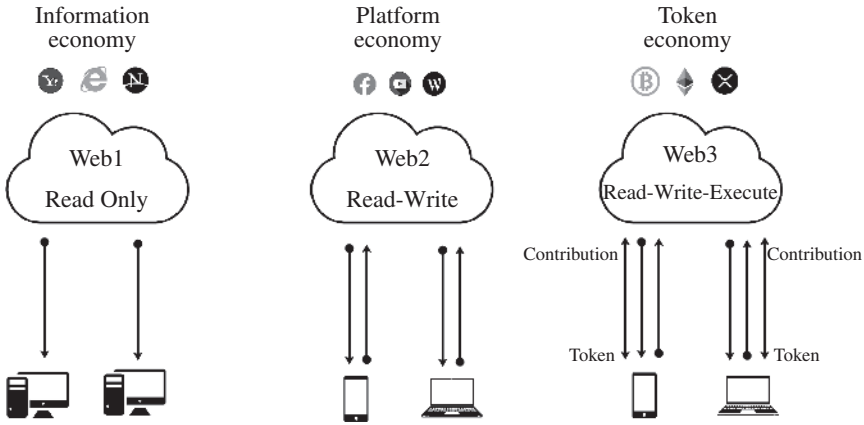

Figure 1.2 Evolution of Internet economy: From read-only Web1 information economy and read-write Web2 platform economy to read-write-execute Web3 token economy based on decentralized blockchain technologies.

wide range of different non-monetary purposes. Such purpose-driven tokens are instrumental in incentivizing an autonomous group of individuals to collaborate and contribute to a common goal. The exploration of tokens, in particular different types and roles, is still in the very early stages [8].

According to [7], the Metaverse will put the user first, allowing every member of our species to delve into new realms of possibilities. A modern, digital renaissance is taking place on the grandest state we have ever seen, involving billions of connected brains. In the coming decades, a new era of virtual life will bring in our next big milestone as a networked species.

In the following, we briefly elaborate on the salient features and main characteristics of the Multiverse and Metaverse.

1.2.1. The Multiverse: An Architecture of Advanced XR Experiences

In this section, we briefly highlight how the Multiverse can be used to tie both online and offline worlds closer together in the Internet of No Things. According to [9], the Multiverse offers a powerful experience design canvas to uncover hidden XR opportunities by fusing the real and the virtual, thereby creating *cross-reality environments* or so-called *third spaces*. Third spaces are created whenever one transverses the boundary between different XR realms within any given experience, as explained in more detail shortly. It is worthwhile to mention that, in "The Computer for the 21st Century,"

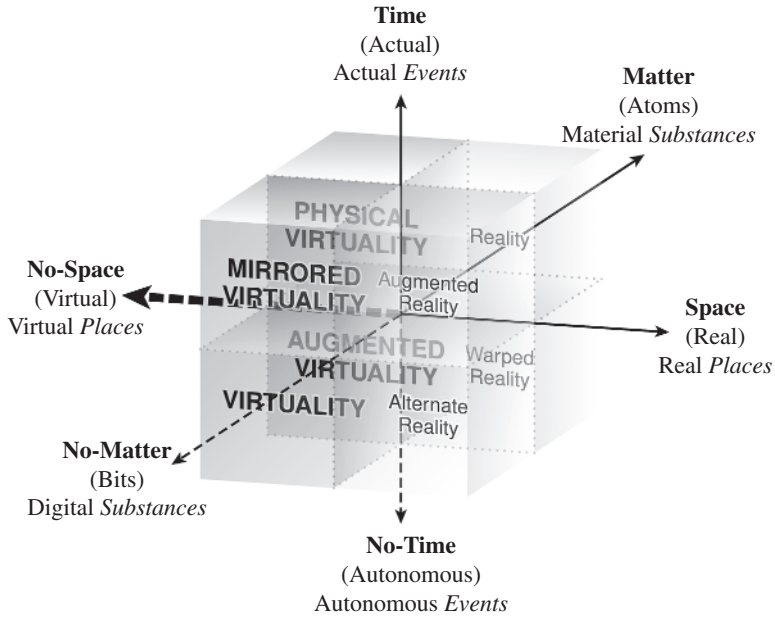

Figure 1.3 The Multiverse as an architecture of advanced XR experiences: Three dimensions, six variables, and eight realms.
Source: (Pine and Korn, 2011) © Berrett-Koehler Publishers.

Mark Weiser seems to had something similar in mind when describing what he initially called *embodied virtuality*, which is now more widely referred to as ubiquitous computing [10].

Apart from conventional VR and AR, future XR technologies may realize novel, unprecedented types of reality. Thus, X may be rather viewed as a placeholder for future yet unforeseen developments on the digital frontier. An interesting attempt to charter the unknown territory is the Multiverse, which may serve as an architecture of advanced XR experiences. As shown in Figure 1.3, the Multiverse consists of the following architectural components:

- **Dimensions:** There are the three well-known physical dimensions – Space, Time, and Matter – that constitute our physical reality.
- **Variables:** In addition, there are three non-physical dimensions – referred to as *No-Space*, *No-Time*, and *No-Matter* – that make up the virtual world. Unlike their physical counterparts, these three digital dimensions are not subject to the constraints imposed by physical space, time, and matter. Thus, in total there are six variables that can be exploited for the design of advanced XR experiences.

- **Realms:** Given that there are three (3) pairs of variables, each with two (2) opposite physical/digital dimensions, we have a total of $2^3 = 8$ possible realms. Each realm creates a different type of reality, ranging from conventional VR and AR to more sophisticated types of reality, e.g. mirrored virtuality, warped reality, and alternate reality. Mirrored virtuality absorbs the real world into the virtual and creates a virtual expression of reality that unfolds as it actually happens, providing a particular bird's eye view. Warped reality plays with time in any way possible by taking an experience firmly grounded in reality and shifting it from actual to autonomous time. Alternate reality, on the other hand, creates an alternative view of the real world by constructing a digital experience and superimposing it onto a real place. Unlike AR, however, alternate reality manipulates time and allows looking to the future freed from the bonds of actual time.

In Chapter 3, we will describe the Multiverse's eight different realms in technically greater detail and its great potential for the design of advanced XR experiences in a more comprehensive manner.

1.2.2. Metaverse: The Next Big Thing?

Recall from above that the Metaverse is anticipated to be the next Internet. The Metaverse is a new realm that will combine the actual and virtual worlds. It is all about virtual experiences and digital assets. Among others, the Metaverse ought to have the following main characteristics: (i) It must be a *shared experience*; just as it is in the real world, we get to witness events as they unfold; (ii) it must be possible to purchase and sell things to each other in a *virtual economy*; (iii) it has to be possible for people to participate in *activities that combine the real and virtual worlds*. Accordingly, the Metaverse has been described as a set of virtual experiences, locales, and products that increased in popularity as the Covid-19 pandemic's online-everything transformation took place. The Metaverse has the potential to alter practically every area of our life drastically. For instance, in the Metaverse, we can travel, study, work, consume entertainment, shop, and communicate with others. More importantly, the Metaverse will open up new avenues for earning a living and compensating for a broad and diversified spectrum of previously unrewarded creative activity (see also Web3 token economy above) [7].

Several companies have already embraced the Metaverse. Apple, Google, Samsung, The Walt Disney Company, Nintendo, Nvidia, Facebook, Amazon, Microsoft, Epic Games, and others are involved. For instance, recently, on 18 January 2022, Microsoft has announced the acquisition of game developer and interactive entertainment content publisher Activision Blizzard in

an all-cash deal worth almost USD$69 billion. The deal is Microsoft's largest acquisition in its 46-year history. The acquisition is being widely seen as a big bet to keep Microsoft competitive in the burgeoning Metaverse space. Their key point is that the Metaverse has the potential for social interaction, experimentation, entertainment, and, most importantly, profit. A rising number of organizations are searching for ways to use it. While other businesses are still figuring out what the term means, the Metaverse is already gaining traction in the gaming industry, with Epic Games and Roblox leading the charge. The two video gaming titans present a vision of what the Metaverse may be in terms of content and audience. For instance, Epic Games' *Fortnite* gave a virtual concert that drew over 12 million people.[1] At the same time, Roblox and Gucci collaborated to build a virtual Gucci Garden environment where limited-edition virtual bags were sold. One of the digital bags was sold for the equivalent of USD$4115, USD$800 more expensive than the physical counterpart. Epic Games is also providing far more than simply a practical on-ramp to its Metaverse-building efforts. Thousands of games use its *Unreal Engine*, the second largest independent gaming engine, which makes it simple to interchange assets, integrate experiences, and share user profiles [7].

On the other hand, there have been some critical voices recently surfacing about the lack of compelling use cases and potential pitfalls of the Metaverse. Perhaps most famously, Elon Musk, CEO of SpaceX and Tesla, poked fun at the Metaverse. On 21 December 2021, in an interview with *The Babylon Bee*,[2] he noted that he grew up being told not to sit too close to a television screen, as it was bad for his eyesight, quoting him: "I don't know if I necessarily buy into this Metaverse stuff. Sure, you can put a TV on your nose," mocking the suggestion that people would willingly wear VR/AR headsets for big chunks of their day and the idea that this would actually transport a person into a different world, "although people talk to me a lot about it – Web3." He added: "I think we're far from disappearing into the Metaverse. This sounds just kind of buzzword-y," though he acknowledged that he might be seen as rejecting the Metaverse in the same way many dismissed the Internet in its early days of 1990s: "There's some danger that that's the case. But I currently am unable to see a compelling Metaverse situation. I don't get it. Maybe I will, but I don't get it yet."

[1]It is worthwhile to mention that, according to [7], Fortnite was allegedly only a side project. The game was published quietly in 2017, and by May 2020, 350 million individuals had signed up for an account – up 100 million from March 2019 – with over 57 million active players. Fortnite made more than USD$1.2 billion in its first 10 months, making it the first free-to-play game to do so. When it first launched in 2018, its mobile app made USD$2 million each day.

[2]For the full interview, please visit: https://babylonbee.com/podcast/basic/276.

Even more critical about the Metaverse is Ethan Zuckerman, former director of the Center for Civic Media at MIT. In an article in *The Atlantic*,[3] Zuckerman argues that Facebook's recently presented Metaverse imagines futures that have been imagined a thousand times before. He claims that Facebook's Metaverse looks pretty much like they imagined one would like in 1994, when he together with his collaborator Daniel Beck were hoping to recreate the vision that Neal Stephenson had outlined in his 1992 book *Snow Crash*. He admits that they were both self-conscious enough to understand that Snow Crash took place in a dystopia, and that Stephenson was positing a beautiful virtual world because the outside world had become so bad that no one wanted to live in it. Zuckerman concludes that today's Metaverse creators are missing the point. The Metaverse isn't about building perfect virtual escape hatches – it's about holding a mirror to our own broken, shared world.

In Chapter 2, we will delve deeper into the original vision of the Metaverse, outlined by Neal Stephenson in his seminal book *Snow Crash*, and contrast it to the more familiar concept of cyberspace. Unlike cyberspace that resides entirely in virtuality, the Metaverse aims at connecting virtuality with reality, making it possible for people and other sentient beings, intelligent mobile robots, as well as software AI agents to communicate and interact in shared environments. Further, Chapter 2 will introduce and explain in technically greater detail the main attributes and key enabling technologies of the Metaverse, including so-called *non-fungible tokens (NFTs)*.

1.3. The Big Picture: Narratives for 2030 and Beyond

1.3.1. From IoT-Based Industry 4.0 to Human-Centric Cyber–Physical–Social Systems

The current fourth industrial revolution has been enabled through the Internet of Things (IoT) in association with other emerging technologies, most notably cyber-physical systems (CPS). CPS help bridge the gap between manufacturing and information technologies (IT) and give birth to the *smart factory*. This technological evolution enables *Industry 4.0* as a prime agenda of the High-Tech Strategy 2020 Action Plan taken by the government of Germany, the Industrial Internet from General Electric in the USA, and the Internet+ from China. Smart factories under Industry 4.0 have several benefits such as optimal resource handling, but also imply minimum human intervention in manufacturing [11].

[3] Ethan Zuckerman, "Hey, Facebook, I Made a Metaverse 27 Years Ago," The Atlantic, 29 October 2021.

When human beings are functionally integrated into a CPS at the social, cognitive, and physical levels, it becomes a so-called *cyber-physical–social system (CPSS)*, whose members may engage in cyber-physical–social behaviors that eventually enable *metahuman* beings with types of superhuman capabilities. CPSS belong to the family of future techno-social systems that by design still require heavy involvement from humans at the network edge instead of automating them away. A promising example of such human-centric CPSS is the aforementioned Internet of No Things, which we briefly introduced above in Section 1.1 and which we will describe in technically greater detail below in Chapter 5. In addition, we will elaborate on how human-centric blockchain technologies, most notably the emerging *decentralized autonomous organization (DAO)*, which has become a hot topic spawned by the rapid development of blockchain technologies in recent years [12], may be exploited to enable the heavy involvement of humans interacting with autonomous AI agents and robots.

For further information and a comprehensive up-to-date survey of the state of the art, challenges, and opportunities of CPSS, we refer the interested reader to [13].

1.3.2. Human-Centric Industry 5.0

In this section, we touch on the anticipated transition from today's technology-driven Industry 4.0 to tomorrow's *human-centric Industry 5.0* and its two visions of human-robot co-working and a more holistic bioeconomy based on the two mutually beneficial principles of digitalization and, more interestingly, *biologization*.

Recently, in January 2021, the European Commission released the first edition of their policy brief on Industry 5.0 [14]. Industry 5.0 will be defined by a re-found and widened purposefulness, going beyond producing goods and services for profit. A purely profit-driven approach has become increasingly untenable. In a globalized world, a narrow focus on profit fails to account correctly for environmental and societal costs and benefits. Further, crises such as the Covid-19 pandemic highlighted the fragility of our current approach to globalized production, especially where value chains serve basic human needs, e.g. healthcare. This wider purpose constitutes three core elements: (i) human-centricity, (ii) sustainability, and (iii) resilience.

One of the most important paradigmatic transitions characterizing Industry 5.0 is the shift of focus from technology-driven progress to a thoroughly human-centric approach. An important prerequisite for Industry 5.0 is that technology serves people, rather than the other way around, by expanding the capabilities of workers (up-skilling and re-skilling) with innovative technological means such as VR/AR tools, mobile robots, and exoskeletons.

Currently, two visions emerge for Industry 5.0. The first one is human–robot co-working, where humans will focus on tasks requiring creativity and robots will do the rest. The second vision for Industry 5.0 is bioeconomy, i.e. a holistic approach toward the smart use of biological resources for industrial processes [15]. The bioeconomy has established itself worldwide as a mainstay for achieving a sustainable economy. Its success is based on our understanding of biological processes and principles that help revolutionize our economy dominated by fossil resources and create a suitable framework so that economy, ecology, and society are perceived as necessary single entity and not as rivals. More specifically, biologization will be the guiding principle of the bioeconomy. Biologization takes advantage of nature's efficiency for economic purposes – whether they be plants, animals, residues or natural organisms. Almost every discipline shares promising interfaces with biology. In the long term, biologization will be just as significant as a cross-cutting approach as digitalization already is today. Biologization will pave the way for Industry 5.0 in the same way as digitalization triggered Industry 4.0. It is also obvious that the two trends – biologization and digitalization – will be mutually beneficial [16].

It is interesting to note that in [14], the authors also elaborate on the relation between the concepts of Industry 5.0 and *Society 5.0*. While both concepts are related in the sense that they refer to a fundamental shift of our society and economy toward a new paradigm, Society 5.0 is not restricted to the manufacturing sector but addresses larger social challenges based on the integration of physical and virtual spaces, which we have discussed above in Section 1.2. In the following, we further elaborate on the Society 5.0 vision.

1.3.3. Society 5.0

Society 5.0 is an initiative of the Fifth Science and Technology Basic Plan taken by the government of Japan to facilitate a human-centered approach that puts humans in the loop of today's CPS [17]. The human-centeredness of Society 5.0 was recently investigated in technically greater detail by Gladden [18], who describes the goal of Society 5.0 as the ability to create equal opportunities for all and to provide the environment that helps unleash the full potential of each individual. To do so, Society 5.0 will leverage on emerging information and communications technologies (ICT) to its fullest such that physical, administrative, and social barriers to each individual's self-realization are removed. Gladden [18] concludes that from an anthropological perspective, Society 5.0's inclusion of diverse non-human entities – most notably social robots and AI agents – as participants is nothing new, but instead something quite ancient, a return to the unpredictability, wildness, and continual encounters with the other that characterized

Societies 1.0 and 2.0, thanks to the prevalence of diverse non-human agency resulting from a heavy reliance on animals as key participants in society and the societies' religious and spiritual dimension. For illustration, Figure 1.4 depicts the transition from past to future societies and their co-evolution with industry [18–20].

The Industrial Revolution reduced the agricultural population from more than 90% to less than 5%. Similarly, the IT revolution reduced the manufacturing population from more than 70% to approximately 15%. The Intelligence Revolution of the 6G era will reduce the entire services population to less than 10%. Upon the question where will people go and what will they do then, Wang [21] gives the following answer: Gaming! Not leisure, but scientific gaming in cyberspace. Artificial societies, Computational experiments, and Parallel execution – the so-called ACP approach – may form the scientific foundation while CPSS platforms may be the enabling infrastructure for the emergence of intelligent industries. Everything will have its parallel avatar or digital twin in the cyberspace such that we can conduct numerous scientific games before any major decision or operation. This new, yet unknown CPSS-enabled connected lifestyle and working environments will eventually lead to high satisfaction as well as enhanced capacity and efficiency. Further, Wang [21] foresees that the Multiverse or parallel universes based on Hugh Everett's many-worlds interpretation (MWI) of quantum physics will become a reality in the age of complex spaces with intelligent industries. However, he warns that the capability of CPSS to collect tremendous energy from the masses through crowdsourcing in the cyberspace and then release it into the physical space can bring us both favorable and unfavorable consequences. Therefore, one of the critical research challenges is the human-centric construction of complex spaces based on CPSS.

Similar to Industry 4.0/5.0, Society 5.0 merges the physical space and cyberspace by applying not only social robots and embodied AI but also emerging technologies such as ambient intelligence, VR/AR, and advanced human–computer interfaces (HCI), in addition to our aforementioned CPSS example of the Internet of No Things. As shown in Figure 1.4, Society 5.0 will also exploit *bionics* and *robonomics*. Robonomics studies the sociotechnical impact of social human–robot interaction (sHRI) as well as blockchain technologies such as the DAO as well as cryptocurrencies – not only coins but also tokens – for the social integration of robots into human society [22].

It is important to note that Society 5.0 counterbalances the commercial emphasis of Industry 4.0. If the Industry 4.0 paradigm is understood as focusing on the creation of the smart factory, the Society 5.0 is geared toward creating the world's first *super smart society*. More interestingly, according to [23], Society 5.0 also envisions a paradigm shift from conventional monetary to future nonmonetary economies based on technologies that can

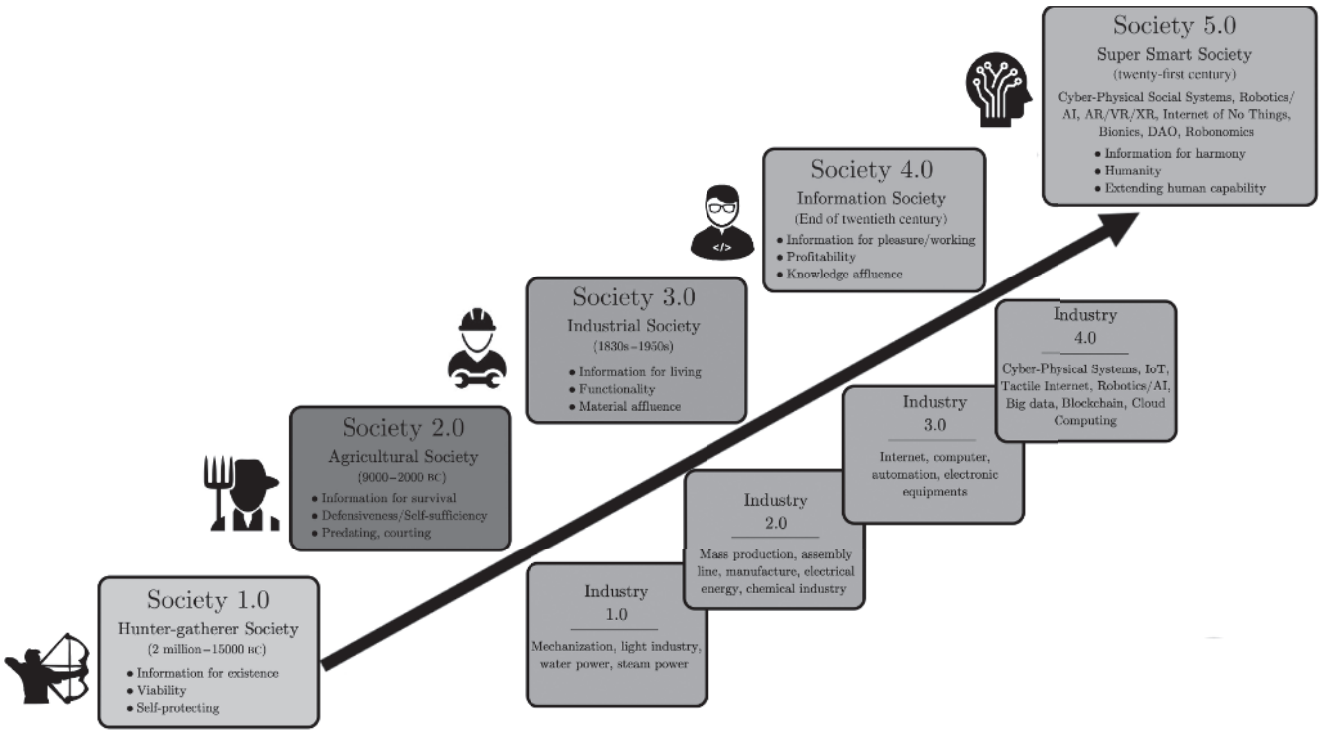

Figure 1.4 Co-evolution of society and industry toward Society 5.0.
Adapted from [18–20]. Beniiche et al. (2022). © 2022 IEEE.

measure activities toward *human co-becoming* that have no monetary value. As opposed to the Western traditional idea of the human as being or having, the idea that humans will be transformed equates to the idea of the human as becoming. We cannot become human by ourselves. It is only when others come to engage us that we become human. We become human with others. In other words, we are human co-becomings. Further, [23] elaborates that there are two paths in Buddhist practices toward enlightenment. One path changes one's mind, while the other path changes one's bodily experience. The two paths are sine qua non to complement Buddhist practices. To Kūkai, a Japanese Buddhist monk, "detached knowing" was not enough. Instead, he advocated "engaged knowing." According to him, this is what Buddhism is all about. In Society 5.0, the focus will be on the enhancement of human capabilities and the transformation of our way of living along with body and mind. Once capabilities in a society are enriched, social mobility will increase accordingly and social disparity becomes relatively weak. Toward this end, the future Society 5.0 should have indexes for social mobility as well as enrichment of capabilities.

Hitachi-UTokyo Laboratory (H-UTokyo Lab) [23] concludes by stating that in order to ensure that Society 5.0 does not become a dystopian society, we have to redefine the modern concept of humanity and find a path toward human co-becoming with others. Nonetheless, this path is not so easy, because humans are open to possibilities to transform themselves into any directions, including undesirable ones. In other words, we do not have a fixed *telos* (from the Greek *télos*, purpose, end, or goal) for co-becoming.[4] It would be wonderful indeed if our ancient knowledge like that of Kūkai turns up again in the future society in a new form (to be further discussed below in Section 1.4).

As we shall see in Chapter 8, in virtual worlds, people don't have trouble forming ad hoc groups constantly, because people are often thrown together by various quests. It is completely normal to walk up to strangers with no introduction whatever and ask them to join you in pursuit of a task. Virtual worlds unite collectivism and individualism in a complementary manner. In doing so, they create an *ideal community–individual relationship* in which we could always be independent if we wanted to be, but there would also be a community available at all times if we wanted to be part of a group. Toward this end, in Chapter 8, we borrow ideas from the *biological superorganism* with brain-like cognitive abilities observed in colonies of social insects. Specifically, the concept of stigmergy (from the Greek words *stigma* "sign" and *ergon* "work"), originally introduced in 1959 by French zoologist Pierre-Paul Grassé, is a class of self-organization mechanisms that made it possible to provide an elegant explanation to his paradoxical observations

[4]Télos is a term used by philosopher Aristotle to refer to the full potential or inherent purpose or objective of a person or thing, similar to the notion of an end goal or *raison d'être*. According to Wikipedia, it can be understood as the "supreme end of man's endeavour."

that in a social insect colony individuals work as if they were alone while their collective activities appear to be coordinated. In stigmergy, traces are left by individuals in their environment that may feed back on them and thus incite their subsequent actions. The colony records its activity in the environment using various forms of storage and uses this record to organize and constrain collective behavior through a feedback loop, thereby giving rise to the concept of *indirect communication*. As a result, stigmergy maintains social cohesion by the coupling of environmental and social organization. Note that with respect to the evolution of social life, the route from solitary to social life might not be as complex as one may think.

1.4. Purpose and Outline of Book

In our introductory discussion of 6G in Section 1.1, we have seen that next-generation mobile networks should not only explore more spectrum at high-frequency bands but, more importantly, converge 6G driving trends, most notably emerging smart wearables, smart environments, and new human-centric service classes. We have also seen that intriguing 6G visions foresee the emergence of the following new themes:

- **Theme 1:** Touch-screen typing will likely become outdated, while *wearable devices* will become common place, enabling future communication technologies that are anticipated to *fold into our surroundings*, thereby helping us get our noses off the smartphone screens and back into our physical and biological environments.
- **Theme 2:** *Human transformation through unifying experiences* across the physical, biological, and digital worlds in what is referred to as the network with the sixth sense.
- **Theme 3:** Seamless convergence and harmonious operations of communication and computation to detect users' transmission intent autonomously and provide *user-intended services* by means of integrated ubiquitous, pervasive, and persuasive computing, aiming at changing or even transforming the behavior of humans through *social influence*.
- **Theme 4:** Creation of new *virtual worlds* that can be blended with the digital twin world to various degrees to create a mixed-reality, super-physical world that enables new *superhuman capabilities*.
- **Theme 5:** Rise of a new regime that connects all humans and machines into a global matrix, which some call the global mind or world brain, leveraging on the *CI* of all humans combined with the collective behavior of all machines, plus the *intelligence of nature*, plus whatever behavior emerges from this whole.

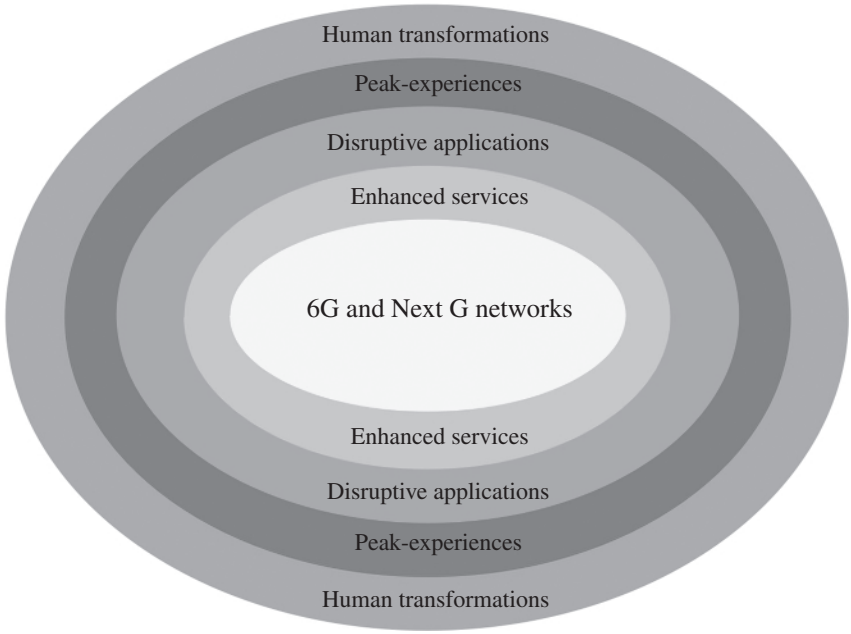

Figure 1.5 6G and Next G networks offering enhanced services to disruptive applications in order to enable peak-experiences and human transformations.

This book aims at weaving the aforementioned themes carefully together in future 6G and Next G networks and the enhanced services they offer to disruptive applications in order to enable peak-experiences and human transformations, as illustrated in Figure 1.5. Throughout the book, we pay particular attention to the fusion of digital and real worlds across all dimensions in the recently emerging Metaverse and the closely related Multiverse and its different types of reality, created and delivered by non-traditional converged service platforms, where developers do not hesitate to use technologies from as many disciplines as possible, including but not limited to technological disciplines. Recall from Section 1.2 that the Metaverse with its shared experience, virtual economy, and activities that combine the real and virtual worlds will be the precursor of the Multiverse. The Metaverse might be viewed as the next step after the Internet, which will surround us both socially and visually, underpinned by decentralized Web3 technology. The Web3 will enable the token economy where anyone's contribution is compensated with a token that may serve a wide range of different non-monetary purposes. We will elaborate on the token economy, a term widely studied in cognitive psychology for establishing desirable human behavior, in the context of 6G

and Next G networks. Of particular interest will be purpose-driven tokens, which are instrumental in incentivizing an autonomous group of individuals to collaborate and contribute to a common goal and whose different types and roles are still in the very early stages of research.

We have seen that, despite the current lack of compelling use cases and potential pitfalls of the Metaverse, a rising number of organizations are searching for ways to use it. While other businesses are still figuring out what the term means, the Metaverse is already gaining traction in the gaming industry, with Epic Games' Fortnite and Roblox leading the charge. Due to this lack of compelling use cases, it is of critical importance to put the Metaverse in a bigger context in order to illustrate and thus help better understand its potential benefits. In Section 1.3, we have pointed to three spheres of contexts, in which we outlined different narratives for the year 2030 and beyond. In this book, we select Society 5.0 as the frame story or, if you will, *meta narrative*, in which the Metaverse as well as Multiverse can be embedded naturally. Using Society 5.0 as the meta narrative gives sense to the Multiverse and its precursor Metaverse, given that the Multiverse, Metaverse, and Society 5.0 bear striking similarities, as explained next.

1.4.1. Embedding the Multiverse and Metaverse in Meta Narrative Society 5.0

Recall from Section 1.3.3 that Society 5.0 has the following characteristics:

- **Goals:** Create world's first super smart society; create equal opportunities for all and provide the environment to unleash full potential of each individual; envision paradigm shift from conventional monetary to future non-monetary economies based on technologies that can measure activities toward human co-becoming; facilitate human transformation.
- **Approach:** Human-centered approach that puts humans in the loop of today's CPS; ACP approach forms scientific foundation for emergence of intelligent industries; scientific gaming with avatars or digital twins in cyberspace; Multiverse or parallel universes based on Hugh Everett's MWI of quantum physics will become reality in the age of complex spaces.
- **Enabling Technologies:** Leverage on emerging ICT to its fullest; CPSS platforms may be the enabling infrastructure for emergence of intelligent industries; apply emerging technologies such as social robots, embodied AI, ambient intelligence, VR/AR, advanced HCI, bionics, robonomics, DAO, and tokens.

- **Anthropological Perspective:** Inclusion of diverse non-human entities – most notably social robots, AI agents, avatars, and digital twins – as participants is nothing new, but instead something quite ancient
- **Religious and Spiritual Dimensions:** Apply Buddhist practices toward enlightenment such as "engaged knowing" advocated by Japanese Buddhist Kūkai; focus on enhancement of human capabilities.
- **Ancient Knowledge:** Télos is a term used by philosopher Aristotle to refer to the full potential or inherent purpose or objective of a person or thing, it can be understood as the supreme end of man's endeavor; humans do not have a fixed télos for co-becoming; it would be wonderful indeed if ancient knowledge like that of Buddhist Kūkai turns up again in future society in new form.
- **Metrics:** More complex metrics required to take social issues into account; develop indexes for enrichment of human capabilities as well as social mobility; once capabilities in society are enriched, social mobility increases and social disparity becomes relatively weak.
- **Risks:** Collecting tremendous energy from the masses through crowdsourcing in cyberspace and then release it into physical space can bring both favorable and unfavorable consequences; therefore, enable human-centric construction of complex spaces based on CPSS; redefine modern concept of humanity and find path toward human co-becoming with others to ensure that Society 5.0 does not become a dystopian society.

For illustration, Table 1.1 summarizes the above characteristics of Society 5.0, which we use as our meta narrative in which both Metaverse and Multiverse can be embedded naturally given their striking similarities and subtle differences. Recall from above that we'll describe the Metaverse and Multiverse in more depth in Chapters 2 and 3, respectively. Hence, some of the technical details shown in Table 1.1 will become clearer in these subsequent chapters. Notwithstanding, the table provides a useful overview that helps make the following insightful observations.

As shown in Table 1.1, super smartness and intelligence lie at the heart of both Society 5.0 and the Metaverse. Their common goal nicely aligns with the roadmap to 6G, outlined by Letaief et al. [24], which envisions that 6G will be transformative and will revolutionize the wireless evolution from "connected things" to "connected intelligence." As we will see in Chapter 4, 6G is anticipated to offer an ICT infrastructure that enables end users to perceive themselves as surrounded by a huge artificial brain providing humans with immense cognitive capabilities [25]. The resultant human transformations are

Table 1.1 Meta narrative Society 5.0 vs. embedded Metaverse and Multiverse: striking similarities and subtle differences.

	Meta narrative Society 5.0	**Metaverse**	**Multiverse**
Goals	Super smart society for twenty-first century	Central intelligence corporation in twenty-first century	The coming age of digital experiences
Approach	Humans put in loop of today's CPS	Humans paid for gathering intel	Human transformation via peak-experiences
Enabling Technologies	VR/AR, avatars, digital twins, social robots, embodied AI, CPSS, bionics, DAO, tokens	VR, avatars, daemons, hypercard, biological virus, metavirus, non-fungible tokens (NFTs)	VR/AR, XR, cross-reality environments, coins of time, eudaimonic technology
Anthro-pological Perspective	Nothing new, but instead something quite ancient: Inclusion of diverse non-human entities	At once brand new and very ancient: no difference between modern culture and Sumerian	First culture in history to use high technology to manufacture human experience, advent of postmaterialist culture
Religious and Spiritual Dimensions	Buddhist practices toward enlightenment, Japanese Buddhist Kūkai's "engaged knowing" for human co-becoming	Christian pentecostalism ("speaking in tongues"), Greek theomania, Shamanic "sacred" language of nature, "kinaturu" (African tongue of the ancestors of all magicians)	The Eternal: Realm of the truly Infinite, Eternity
Ancient Knowledge	Aristotle's concept of télos (367–347 BC)	Sumerian creation myth (5000 BC)	Limitless mind, emer-gence of consciousness
Metrics	More complex metrics required for advancement of human capabilities, social mobility, and equity	N/A	N/A
Risks	Dystopian society, crowdsourcing with un-favorable consequences	Dystopian future, neurolinguisitic hacking, brain damage	Transversal experiences never before engendered or encountered

best achieved via peak-experiences, as illustrated above in Figure 1.5, which, unlike machines, humans thrive on and which are central not only to the coming age of digital experiences in the Multiverse, but also to the human-centric approach of Society 5.0 and the Metaverse. In Chapter 9, we will further elaborate on how the infinite potential of humans may be unleashed for our next evolutionary leap toward becoming metahuman. Given their underlying theme of fusion of digital and real worlds, it comes as no surprise that the Multiverse and Metaverse, embedded in the meta narrative Society 5.0, have many enabling technologies in common, ranging from VR/AR, avatars, social robots to DAO, (non-fungible) tokens, and *eudaimonic* technology in support of delivering the aforementioned peak-experiences.[5]

It is also interesting to note the overlap of religious and spiritual dimensions, rooted in ancient knowledge, whereby Society 5.0 and the Metaverse are nothing new, but instead something quite ancient. Or, put differently, they are *at once brand new and very ancient*, possibly ushering in the advent of a new culture in human history. Another important observation from Table 1.1 is the fact that neither the Metaverse nor the Multiverse define any specific metrics. This is where the choice of using Society 5.0 as meta narrative will be instrumental in defining more complex metrics required for measuring the advancement of human capabilities as well as social mobility and equity.

Finally, despite all the exciting opportunities on the road ahead to the Multiverse, it is of critical importance to address the risks of creating a dystopian society and a future with unintended negative consequences. Chapter 10 is therefore dedicated to the discussion of the opportunities and risks arising from the Metaverse.

1.4.2. The Art of 6G and Next G: How To Wire Society 5.0

Recently, in [26], we elaborated on how future 6G and Next G mobile networks should be applied to wire Society 5.0. Clearly, as described in our prequel book, open research challenges include millimeter-wave and terahertz (THz) communications, reconfigurable intelligent surfaces (RIS), the transition from network softwarization to network intelligentization, and the integration of underwater networks into four-tier space–air-ground–underwater network architectures. It is also worthwhile to briefly mention that many of the 5G key performance indicators (KPIs) will still be valid, though scaled by a factor of 10, 100, or even 1000, thus making 6G, in part, an incremental linear upgrade of 5G.

More importantly, we expanded on Alibaba Group's Yiqun Cai's recent OFC plenary talk on how technologies and applications drive the

[5]The term eudaimonia is etymologically based in the Greek words *eu* (good) and *daimon* (spirit). It is commonly translated as "happiness" or "welfare."

evolution of networking, where he concluded by presenting the equation *Networking = Art + Science + Engineering*. In the follow-up Q&A, he further elaborated on the first part of this equation, Art, by stating that modern networking requires not only scientific rigor and engineering know-how, but also creativity and originality. More specifically, he added that today's complex networks are more than computer science – they grow; they are life. Clearly, this implies that modern networks may be better viewed as techno-social systems that exhibit complex adaptive system (CAS) behavior and resemble biological superorganisms.

In the following, we briefly review the major conclusions drawn by Maier et al. [26], making the case that 6G and Next G should go beyond the incremental mindset of previous generations of mobile networks. Further, we highlight the unique potential benefits of the virtual world for society in that it provides a useful extension of the real-world economy by compensating for well-known market failures, e.g. rising income inequality.

1.4.2.1. Next G: Beyond Incremental 6G = 5G + 1G Mindset

There exists a wide consensus among the different stakeholders in the optical communications and networking community that there will be no 6G without fiber. To meet the very wide range of extreme requirements of beyond-5G (B5G) and 6G users, the latest progress on simplified digital coherent technologies for ultimate-capacity passive optical networks (PONs) carrying more than 100 Gbps per wavelength holds great promise for offering low-complexity optical access systems as well as key optical transport platforms heading toward 400 Gbps-based Ethernet transceivers for the 80 km range and over 800 Gbps short-reach applications [27].

The mobile radio spectrum, on the other hand, is not sufficient for the 100 Gbps data transmission rates envisaged for future 6G networks. According to [28], 6G requires a fundamental redesign of the physical layer extending beyond the theory of Shannon, giving rise to the so-called post-Shannon information theory with higher capacity potential. Furthermore, Fettweis and Boche [28] elaborate on possible true 6G innovations. Beside the symbiosis of radio communication and radio sensor technology as a key 6G technology, the authors argue that every odd-numbered generation of cellular networks first "practices" a new leap innovation with business users before the following even-numbered generation makes it a mass application for consumers. Specifically, while the promise of 5G is to start the Tactile Internet in order to control real and virtual objects in real time, 6G must provide an infrastructure to enable remotely controlled mobile robotic solutions for everyone – the Personal Tactile Internet.[6] Interestingly, the authors raise the important issue

[6]Note that this democratization of the Tactile Internet is identical to Bill Gates' original vision from the year 2007 of having a personal robot in every home [29].

of *trustworthiness* and postulate that the entire network architecture for 6G must be newly developed, which will require new procedures and paradigms. In fact, they claim that today's biggest challenge is the loss of trustworthiness and restoring trust must be understood as a basic societal challenge. For illustration, they draw a historical comparison between today and the renaissance, where Johannes Gutenberg's invention of the printing press in 1450 revolutionized society and heralded 300 years of renaissance. While some used the printing press to invent fake news and populism, Martin Luther used it to spread his ideas and overthrow the monopoly of knowledge of the monks.

Given the above challenges, one might argue that 6G should be more than only another cellular technology upgrade. Instead, 6G should go beyond continuing the linear incremental thinking 6G = 5G + 1G of past generations of mobile networks. The recently launched Next G Alliance is a bold new initiative to advance North American mobile technology leadership in 6G and beyond. Among its members are not only the major mobile network operators and manufacturers of North America but also, and arguably more interestingly, many of the key over-the-top (OTT) Internet players, including Apple, Google, Facebook, and Microsoft. One of the goals of the Next G Alliance is to create a roadmap that addresses the development and manufacturing across new markets and business sectors and promote widescale adoption of Next G technologies, both domestically and globally. To help get there, the current Next G roadmap sets audacious goals, most notably, (i) trust, security, and resilience, (ii) an enhanced digital world consisting of multi-sensory experiences, (iii) an AI native future network, while (iv) energy efficiency and environment must be at the forefront of decisions throughout the life cycle.

In our view, apart from meeting the traditional capacity and reliability requirements, one of the key 6G challenges of optical access systems and optical transport platforms is the support for precision of time in data delivery referred to as timeliness. Providing timeliness as a fundamental communication service will be central to the success of disruptive 6G applications. In particular, time-engineered communication services with coordinated guarantees over multiple traffic flows, which must be synchronized with respect to rendering of near real experiences, are anticipated to play a critical role in helping realize truly immersive *holographic-type communication (HTC)* for future hologram-based applications with skyrocketing volumetric bandwidth demands into the terabits-per-second range, an increase by several orders of magnitude over HD or even 3D VR video [30].

Unlike today's VR/AR HMDs, holograms will facilitate more natural experiences for human users and represent the ideal type of nearables to be inserted in the surrounding environment of our proposed Internet of No Things for the 6G post-smartphone era. Many hologram-based applications are highly interactive in nature and involve ultra-fast feedback loops, giving

rise to the so-called "user interactivity challenge." Contrary to other types of multimedia services, the user interactivity challenge of immersive HTC will require ultra-low latency even if dealing with prerecorded content that does not involve real-time interaction with a remote party, as the user still interacts with the content simply by virtue of changing viewing angle and position. One specific challenge of minimizing network latency for HTC concerns the latency for the first packet in a flow. This generally incurs greater delay than later packets, as flow rules and entries may not yet have been installed. Clemm et al. [30] showed that *decentralization* of networks has a significant impact on reducing flow setup latency.

Clearly, advanced human-centered blockchain technologies such as validating on-chaining oracle and DAO hold great promise to resolve the aforementioned issues of trustworthiness and decentralization. Today's Internet is ushering in a new era. While the first generation of digital revolution brought us the Internet of information, the second generation – powered by decentralized blockchain technology – is bringing us the Internet of value, a true peer-to-peer platform that has the potential to go far beyond digital currencies and record virtually everything of value to humankind in a distributed fashion without powerful intermediaries. Arguably more importantly, though, the blockchain technology enables trusted collaboration that can start to change the way wealth is distributed as people can share more fully in the wealth they create. As a result, decentralized blockchain technology helps create platforms for distributed capitalism and a more inclusive economy [31].

While Gutenberg's invention gave birth to printing, the Internet's full potential still remains to be unleashed in the years to come. It is well known that Gutenberg's printing press played a pivotal role in Luther's reformation of society. According to [32], we don't yet know what the Internet truly is. Measured in Gutenberg time, we stand today at about the year 1481 with the progression of disruption in society. Note that Luther was born in the year 1483. Hence, the Internet's Martin Luther is yet to come.

1.4.2.2. Society 5.0: Exodus to the Virtual World?

In [33], Edward Castronova argues that people move their time and attention in response to their experiences in the separate realms of the real and virtual. He argues that the real and virtual worlds will become more similar. That is, the real world will become more like the virtual world, and vice versa.

Arguably more interesting, he states that it is indeed a singular power of the virtual world that it can create anything for free, except labor. It is considered absolutely intolerable that a player have nothing to do. Thus, the virtual world must ensure that there is always another quest to do and that every player, at all times, has some way of turning her own action into some

reward. As a result, unlike the real world, the virtual world has the potential to provide full employment by design. What's more, the virtual world can start all players at zero wealth and anyone who needs money can get it, since work is always available. Hence, all players start on an equal basis, giving rise to *equality of opportunity*.

It has often been proposed that equality of opportunity ought to be the guiding principle of social policy. Policies that make the economic game obviously fairer are likely to become popular as virtual worlds broaden their influence. And what is striking is that even though online games exhibit economic inequality so vast that it dwarfs real-world inequality, nobody seems to care about inequality of outcomes. Indeed, Castronova observes that it is more fun if the outcomes actually do differ wildly, because players expect that if one acquires some new power she should also be offered greater rewards. Otherwise, the virtual world would be no fun at all. In other words, people don't complain about a lack of *vertical equity*, but they howl about failed *horizontal equity* – not only in the virtual world but also in the real world. Clearly, given its unique potential benefits, the virtual world provides a useful extension of the real-world economy by compensating for its well-known market failures, e.g. rising income inequality.

1.4.3. Finding Your 6G/Next G Blind Spot

We often use the term "blind spot" as a metaphor for the area of knowledge or understanding that we do not have or pay no attention to. For giving you the experience of the blind spot we humans have, Harris [34] used Figure 1.6 along with these instructions:

1. Hold this figure in front of you at arm's length.
2. Close your left eye and stare at the cross with your right.
3. Gradually move the page closer to your face while keeping your gaze fixed on the cross.
4. Notice when the dot on the right disappears.
5. Once you find your blind spot, continue to experiment with this figure by moving the page back and forth until any possibility of doubt about the existence of the blind spot has disappeared.

Figure 1.6 Visual experience of the existence of the blind spot: Follow the above instructions and see dot on the right disappearing and reappearing.

Punctuating ordinary experience in this way makes all the difference. Given this exemplary change in human perception of the world literally (not metaphorically) disappearing and reappearing in front of one's own eyes, this book aims at providing the reader with new complementary material that covers the latest Internet developments and that has not been covered in our prequel book. More specifically, this book puts a particular focus on 6G and Next G networks in the context of the emerging Metaverse as the successor of today's mobile Internet that has defined the last two decades. We hope that this book will be instrumental in helping readers inquire into new areas of knowledge or understanding that they didn't have or didn't pay attention to previously and thereby finding your 6G/Next G blind spot. Ideally, this book gives readers not only answers, but also confronts them with novel questions not asked let alone answered before.

1.4.4. Outline

The remainder of the book comprises the following 10 chapters:

In the first part of Chapter 2, we set the stage by providing a comprehensive description of the original Metaverse vision outlined by Neal Stephenson in his novel *Snow Crash*, which plays in Los Angeles in the twenty-first century, an unspecified number of years after a worldwide economic collapse and hyperinflation created by the government due to the loss of tax revenue as people increasingly began to use electronic currency. As we will see, snow crash is a hypercard which looks much like a business card and contains a *neurolinguistic virus* that uses the human brain as a host, jumping from one person to the next, kind of in the same way that a virus moves from one computer to another. Similar to machine language as the elemental language of computers, this neurological phenomenon comes from structures buried deep within the brain, common to all people, which can be found in many ancient cultures, sometimes referred to as the *language of nature*. The neurolinguistic virus is developed as a new powerful technology that is able to reprogram people's minds and alter their behaviors with the goal of advancing the human race by delivering it from the grip of the old civilization and its old rules people are stuck in. In the Metaverse, the key realization is that there's no difference between modern culture and ancient Sumerian. It is at once brand new and very ancient, getting us to observe the birth of a *new religion*. In the second part of Chapter 2, we highlight the different Metaverse components, applications, and open research challenges, followed by a couple of recent illustrative examples of early Metaverse deployments from both industry and academia. Among other open challenges, *cross-disciplinary research* will be necessary, involving cognitive science, social sciences, psychology, and economics, to better understand humans and thus build a deeper Metaverse.

Chapter 3 explores the infinite possibility of the Multiverse. Apart from describing each of its eight distinct realms of experience in technically greater detail, we elaborate on the importance of *experience innovation at the digital frontier* in business today, where people desire experiences – memorable events that engage people in inherently personal ways, emotionally, physically, intellectually, and even spiritually, more than the other economic offerings. More than in any of the other sectors of the economy (commodities, goods, and services), the currency that supports the emerging experience and transformation economies is the *coin of time*, where value will be determined more by how time is spent and less by how money is spent. We briefly introduce the *experience design canvas* as a valuable tool to take full advantage of the Multiverse and also discuss how its eight realms may be expanded outward in order to create *transversal experiences* never before envisioned, engendered, or encountered, which enable humans to do things they otherwise are not able to do. As a result, experiences are created that eventually help enable the transformation of humans. Finally, we touch on how the Multiverse goes beyond the Metaverse origins in that it creates third spaces that involve realms other than reality and virtuality, followed by some concluding remarks on the *limitless mind* and realms beyond time, space, and matter.

Next, in Chapter 4, we put the Metaverse and Multiverse in perspective of 6G and Next G networks. More specifically, we review the recent progress toward realizing the 6G vision as well as the current state of the art of 6G research activities. Among others, we discuss Ericsson's recent 6G research outlook and their anticipated *6G paradigm shifts*, e.g. from physical and digital worlds to a cyber-physical continuum, from data links to services beyond communication, and new capabilities, some of which may be more qualitative in nature. Moreover, we explain how future dual-functional wireless networks supported by integrated sensing and communications technologies act as the bond to bridge the physical and cyber worlds, giving rise to so-called *perceptive mobile networks (PMNs)*. We also touch on *quantum-enabled* 6G wireless networks, *blockchainized* mobile networks, and *AI-native* 6G networks. In our discussion, we pay particular attention to edge AI and *mimicking nature* to further imbue native intelligence by means of brain-inspired *stigmergy*, thereby enabling intelligent and seamless interactions among the human world, physical world, and digital world.

After presenting the 6G standardization roadmap, we further elaborate on the *difference between 6G and Next G* research. As we shall see, Next G research includes, but is not limited to, the specific KPI requirements and topics of interest addressed by 6G standard development organizations. Importantly, Next G research includes the Metaverse as one of their long-term objectives. Finally, we take a closer look at the recently published *Next G Alliance Roadmap* to 6G. Specifically, we outline Next G Alliance's audacious goals

and priorities to address both the societal and economic needs, most notably the *acceleration of digital transformation* across society, *transformation of human interactions* across physical/digital/biological worlds, as well as human and machine 6G *Digital World Experiences (DWEs)* unthinkable with previous generations. Arguably more importantly, we also elaborate on the *symbiotic relationship* between technology and a population's societal and economic needs, whereby technology shapes human behavior and human needs shape technological evolution. Moreover, we explain the four foundational areas for 6G applications and use cases. According to Next G Alliance's Roadmap, humans are expected to be the ultimate beneficiaries of 6G, opening up new doors for development of *human-centric technologies* that positively influence human behaviors and technology-mediated human-to-human interactions, in turn advancing the societies they create. At the same time, *sustainability* must be at the forefront of decisions throughout the life cycle, given that climate challenges are expected to seriously disrupt business as usual and change the way citizens worldwide live their lives.

In Chapter 5, we elaborate on how the Internet of No Things with its underlying human-intended services may serve as a useful stepping stone toward realizing the far-reaching vision of future 6G networks, ushering in the 6G post-smartphone era, given that smart wearables are increasingly replacing the functionalities of smartphones. We then elaborate on the recently emerging *invisible-to-visible* technology concept, which we use together with other key enabling network technologies to tie both online and offline worlds closer together in an Internet of No Things and make it "see the invisible" through the awareness of nonlocal events in space and time. As an illustrative example of advanced XR experiences that transverse the boundary between the Multiverse realms, we study the delivery of *extrasensory human perceptions*, i.e. senses other than the five human senses. As we will see, with the advent of advanced XR technologies it might be easier to mimic the quantum realm instead of actually tapping into it. In addition, we present a *DAO use case study* where we explore how blockchain technologies, in particular the DAO, may be leveraged to decentralize the Tactile Internet as a promising example of future techno-social systems, which are anticipated to play an important role in 6G. In particular, we shed light on the importance of crowdsourcing of human expertise to solve problems that machines alone cannot solve well. Finally, we explore how the CI of unskilled crowd members of the DAO can be enhanced by means of nudging via a smart contract, giving rise to the concept of *hybrid-augmented intelligence* for addressing problems and requirements that may not be easily trained or classified by machine learning, especially due to fact that many problems that humans face tend to be of high uncertainty, complexity, and open-ended, and the Internet provides an immense innovation space for hybrid-augmented intelligence.

Chapter 6 explains Web3 and the important problem of *token engineering*, which is defined as the theory, practice, and tools to analyze, design, and verify tokenized ecosystems, in technically greater detail. Token engineering, also referred to as *token mechanism design*, is an emerging field. One may think of mechanism design as the engineering part of economic theory. It deals with the question of how to design a game, but starts at the end of the game (i.e. its desirable outcome) and then goes backward when designing the mechanism. Therefore, it is also referred to as "reverse game theory." As the field of tokens matures, it is likely that related disciplines like behavioral game theory will find its way into the modeling of tokens. Furthermore, this chapter describes the important process of *tokenization*, i.e. the process of creating tokenized digital twins via tokens. Tokens might be the killer application of Web3 networks. Specifically, we elaborate on the differences between fungible and NFTs, also known as NFTs, with regard to their interchangeability and divisibility. Of particular interest is the design of tokens, which may be programmed to have an expiration date with an inbuilt deflation (i.e. negative interest rate) to prevent hoarding and inflation, as exemplified by our discussion of "free money" (or Freigold) and Edison-Ford community money. Throughout Chapter 6, we pay close attention to the question of how so-called *purpose-driven tokens* may be used to create technology-enabled social organisms that enable the collective production of *tech-driven public goods* or *club goods*, which come with certain exclusion mechanisms in place, including associated *externalities* – both negative ones (costs) and positive ones (benefits). Overall, this chapter tries to help better understand how purpose-driven tokens are instrumental in restoring common goods and resolving many tragedy-of-the-commons problems society faces today by providing an *operating system for a new type of economy*.

In Chapter 7, we follow up on the previous chapter and introduce two examples of a new type of economy: *robonomics* and *tokenomics*. Robonomics is an emerging field, which studies the sociotechnical impact of blockchain technologies on behavioral economics and cryptocurrencies (both coins and tokens) for the social integration of robots into human society, including persuasive robotics as enforcer or supervisor of human behavior modification. Many studies have shown that the physical presence of robots benefits a variety of social interaction elements such as persuasion, likeability, and trustworthiness. Importantly, these robots are less like tools and more like partners, whose persuasive role in a social environment is mainly human-centric. We investigate the widely studied *trust game* of behavioral economics, an example of so-called public good games, in a blockchain context, which captures any generic economic exchange between two parties, while paying close attention to the importance of developing efficient cooperation and coordination technologies. We demonstrate experimentally that a social efficiency – a term closely related to *social capital* and *equity* – of up to 100% can be achieved

by using the blockchain mechanism of deposit to enhance both *trust* and *trustworthiness*. We then present an *on-chaining oracle* blockchain architecture for a networked *N*-player trust game that involves a third type of human agents called observers, who track the players' investment and reciprocity. Of particular interest to us is the design of appropriate reward and penalty mechanisms. We experimentally demonstrate that the presence of third-party reward and penalty decisions helps raise the average normalized reciprocity above 80%, even without requiring any deposit. Further, we experimentally demonstrate that mixed logical-affective *persuasive strategies* for social robots improve the trustees' trustworthiness and reciprocity significantly. Finally, the chapter explains the anticipated paradigm shift from conventional monetary to future *nonmonetary economies* based on technologies that can measure activities toward human co-becoming that have no monetary value. Specifically, the chapter elaborates on the shift from conventional monetary economics to nonmonetary tokenomics enabled by tokenization in different value-based scenarios.

Chapter 8 delves into the *human-centeredness* of Society 5.0. While the primary focus of 5G has been on industry verticals, future 6G mobile networks are anticipated to become more human-centered. Toward this end, it is important to take a number of different factors into account in order to develop a more realistic understanding of *human nature* that challenges that of rational individuals driven by self-interest, as traditionally assumed in mainstream economics. Emerging CPSS aim at functionally integrating human beings into today's CPSs at the social, cognitive, and physical levels. CPSS are instrumental in realizing the human-centered Society 5.0 vision. Society 5.0 envisions human beings to increasingly interact with social robots and embodied AI in their daily lives. In this chapter, we expand on our work on robonomics and tokenomics in the previous chapter. After introducing our *CPSS based bottom-up multilayer token engineering framework for Society 5.0*, we experimentally demonstrate how the collective human intelligence of a blockchain-enabled DAO can be enhanced via purpose-driven tokens. More specifically, we aim at driving the *bionic convergence* of robonomics, DAO, and the Internet of No Things as our CPSS of choice to advance the CI of Society 5.0 in the next-generation Internet known as Web3. Importantly, we experimentally demonstrate the potential of the *biological stigmergy mechanism* for advancing CI in a CPSS-based DAO via tokenized digital twins, ushering in the future *stigmergic society* that will leverage on time-tested self-organization mechanisms borrowed from nature. Note that, in doing so, the future stigmergic society follows the guiding principle of *biologization*.

In Chapter 9, we double down on the potential of biologization as well as the mutually beneficial symbiosis between biologization and digitalization for the purpose of human development and our possible evolution into future *metahumans* with infinite capabilities. To better understand the natural

potential of humans, we start by reviewing a recently proposed theory of biological human uniqueness and the qualities that make us humans and become such a distinctive species in comparison to our closest primate relatives with regard to (i) social cognition, (ii) coordinated decision-making, and (iii) uniquely human sociality. In particular, we show that evolution works only in response to a specific adaptive ecological problem that presents itself and how evolution makes those individuals best equipped to solve it have an adaptive advantage, thereby making us *smarter* and creating a *fundamentally new form of sociality* via a new form of cooperation and a concomitant new form of communication to support this cooperation, two attributes that are front and center in the super smart Society 5.0 vision. Leveraging on those insights into biological human uniqueness in a future human-centered Society 5.0, we then elaborate on their implications for the future Metaverse by introducing the concept of *symbiomimicry* as a promising means to help exit the Anthropocene and enter the Symbiocene in the coming 6G and Next G era. Further, given that the creation of novel shared physical and/or digital worlds in the Metaverse create the possibility of new kinds of concepts based on humans' unique capability of bifurcated experiences, we present a variety of different *concepts of the true nature of reality* that bring us one or more steps closer to the original Metaverse vision in Snow Crash, ranging from *MetaHuman Creator* for building a bespoke photorealistic digital human and *infinite reality* for realizing virtual immortality to *metareality* for harvesting transformative peak-experiences that hint at enormously expanded human potential.

Chapter 10 is dedicated to the discussion of the specific opportunities as well as risks of the Metaverse. Our comprehensive discussion of the Metaverse ranges from *cyberutopianism* to *digital cosmopolitanism*, while taking a close look at the recent end of globalization and the critical importance of technology, e.g. cryptocurrencies and decentralized network structures with *small-world* scale-free properties, for invoking the future of progress in a deglobalized world. We will elaborate on the crucial role decentralized small-world network structures play for designing methods to create robust networked systems, ranging from the social to the economic and the political, in order to avoid the collapse of whole systems.

Among other opportunities, we explain how the Metaverse may provide the digital tools for growing access to the *Global Mind*, whereby humans act as neurons in a *human hive mind* with blockchain technology acting as connective tissue to create virtual pheromone trails via programmable incentives and *extended stigmergy in dynamic media*. Furthermore, we explain how 6G, Next G, and the Metaverse may eventually pave the way to the *peak-experience machine* by democratizing access to the upper range of human experiences and making

them available for the masses in order to foster mass flourishment and unleash the infinite potential of humans. On the flip side, we describe the risk that the Metaverse may turn humans into *cybernetic organisms (cyborgs)*, enhanced with internal neural implants to artificially create intellectual, emotional, and even spiritual experiences. The Metaverse may also become an advanced *behavior modification machine* that exploits a vulnerability in human psychology of uberworked and underpaid worker bees in an exacerbated platform capitalism. After weighing both opportunities and risks and outlining possible solutions, we wrap up Chapter 10 by envisioning a humanistic setting for the emerging Metaverse in support of *team human* in a future human-centric Society 5.0.

Finally, in Chapter 11, we draw our conclusions and provide an outlook on the future of 6G, Next G, and the road ahead to the Multiverse.

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