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Metaverse as the New Eleusis 2.0: Are We in the Midst of the Next Renaissance?

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Abstract: For all the fascination with the Metaverse, the term has currently no consensus definition or consistent description. Most industry leaders define it in the manner that fits their own worldviews and/or the capabilities of their companies. Some argue that it is perhaps from the original vision and origins of the Metaverse where we find the best insight into what the eventual Metaverse might look like. Towards this end, this paper reviews the original vision and origins of the Metaverse, including its wide ranging and somewhat surprising elements. To set the stage, we first review the 6G vision and then introduce Society 5.0 as the meta narrative for naturally embedding the Metaverse, given that the Metaverse and Society 5.0 bear striking similarities. We expand on the central role of cyber-physical-social systems (CPSS) in the emerging Metaverse for integrating human, artificial, natural, and organizational intelligence with the help of digital twins and Web3 blockchain technologies. Specifically, we propose a future stigmergy enhanced Society 5.0 based on a blockchain-enabled CPSS, explore the benefits of blockchainizing gamified experiences, and point to awe-inspiring VR/AR/XR experiences that are at once brand new and very ancient, just like the original Metaverse vision itself.

Keywords: 6G, Blockchain, Collective intelligence, Cyber-physical-social systems (CPSS), Metaverse, Next G, Society 5.0, Stigmergy, Tokenomics, Web3.

1. Introduction

To rethink society, Al Gore advocates in "The Future: Six Drivers of Global Change" to exploit digital tools for growing access to what he calls the Global Mind. We shape our tools and then our tools shape us – we become what we behold, as famously stated by Marshall McLuhan, the eminent media theorist credited with predicting the rise of the Internet. In our opening keynote [1] of the inaugural Blockchain & Cryptocurrency Congress (B2C'), we focused on the wireless evolution of "connected things" to "collective intelligence" (CI), which plays a central role in the 6G vision of rendering future mobile networks more human-centered than 5G. Towards this end, we adopted the unifying concept of stigmergy, a common mechanism used to produce cognition in the human brain as well as natural societies, to advance CI in future self-organizing techno-social systems known as cyber-physical-social systems (CPSS). Specifically, we proposed a techno-social environment using advanced blockchain technologies for CPSS members, which extends human capabilities and enables activities toward human co-becoming by facilitating indirect communication via tokenized digital twins that steer the collective behavior toward higher levels of CI in a stigmergy-enhanced Society 5.0 and emerging Web3 token economy, including the transition from today's robonomics to tomorrow's tokenomics.

In this paper, we first review the main contributions of our keynote briefly touched on above. Given that the emerging *Metaverse* is anticipated to be the successor to today's mobile Internet, we will expand the scope of our keynote by including additional content on the nexus between the

aforementioned Society 5.0 and the emerging Metaverse. With the rise of the Metaverse, the Internet will no longer be at arm's length. The Metaverse will be about being inside the Internet rather than simply looking at it from a phone or computer screen. Instead, it will surround us visually and socially and will radically reshape society. The Metaverse has been heralded as a logical successor to today's Web2 user-generated content platforms (e.g., Facebook, YouTube, Twitter, Reddit), 2D interfaces (e.g., smartphone, tablet), and centralized virtual worlds (e.g., Fortnite, Roblox). Virtual reality (VR), augmented reality (AR), artificial intelligence (AI), beyond 5G (B5G), blockchain technology, non-fungible tokens (NFTs), decentralized autonomous organizations (DAOs), and online social activities accelerated by a global pandemic together with other technologies and trends are converging to construct a virtual universe in the form of the Metaverse. With the mass digital adoption driven by Covid-19, we finally find ourselves on the verge of something big and potentially paradigm shifting: The Metaverse.

The remainder of the paper is structured as follows. In Section 2, we first review the 6G vision and Next G research activities. Section 3 elaborates on the emerging Web3 token economy. For illustration of future tokenized ecosystems, Section 4 studies the use case of a stigmergy-enhanced Society 5.0 and points to its evolution towards extended stigmergy and new dynamic media. In Section 5, we describe the Metaverse and its potential benefits in technically greater detail and how the original Metaverse vision may be naturally embedded in our meta narrative Society 5.0. Finally, Section 6 concludes the paper.

2. 6G and Next G

2.1. 6G Vision and Next G Alliance's 6G Roadmap

The vision of 6G is to render society more human-friendly, sustainable, and efficient. By combining 6G wireless technologies with advanced AI and IoT, new experiences can be created that bridge the physical, biological, and digital worlds. This will lead to a fully integrated system where industry and technology can work together with physical and living systems at all scales, while acting as a global mind that controls and manages all events to meet social and economic human needs [2].

Several tools exist to combine the physical and digital worlds, such as VR, AR, and mixed reality (MR). VR completely replaces a user's view with a computer-generated virtual environment, while AR creates an overlay of virtual content for the physical environment. MR combines VR with the real world to create virtual objects that can interact with the physical environment. According to Qualcomm, a new convergence of VR/AR/MR technologies is emerging under the umbrella term of extended reality (XR). Qualcomm views XR as the next-generation of mobile computing platform, which encompasses AR, VR, and MR to realize the entire reality-virtuality continuum for realizing advanced human experiences, e.g., human-machine interaction.

The advent of B5G and 6G have introduced new possibilities in areas such as collective intelligence, smart cities and industries, and remote healthcare. To support these advancements, novel services and applications such as digital twins have been introduced. Digital twins represent a powerful platform for future digital services that facilitate the fusion of physical and digital worlds. Digital representations of objects may be used in digital twin worlds to augment human intelligence and enable superhuman capabilities. Four main technological drivers are emerging in the 6G era: (*i*) trustworthiness of wireless systems, (*ii*) sustainability and energy-efficiency of mobile technology, (*iii*) accelerated automation, and (*iv*) digitalization to simplify and improve people's lives [3]. Although the specifics of 6G networks still remain unclear, there has been a significant push from both I academia and industry to develop standards and enabling technologies by the year 2030 [4].

The Next G Alliance (www.nextgalliance.org) was introduced by the Alliance for Telecommunications Industry Solutions (ATIS) in October 2020 to advance North American wireless technology leadership over the next decade through private-sector-led efforts. The initiative places a strong emphasis on technology commercialization and encompasses the entire lifecycle of research, development, manufacturing, standardization, and market readiness. Recently, in [5], Alex Sprintson provided an overview of the National Science Foundation (NSF)'s support for Next G research and clarified the difference between 6G and the NSF's understanding of Next G, as shown in Fig. 1. The Next G Alliance has identified the following four foundational realms of 6G applications and use cases: Living, experience, critical, and societal goals. Improving daily quality of life, enabling new experiences, and supporting social and economic needs are key outcomes that 6G systems should aim to achieve. It is important to recognize that technology and society have a symbiotic relationship. By shaping human behavior and lifestyles through technology, technological evolution in turn marches forward. Furthermore, it will be crucial to integrate both social and economic considerations throughout the entire lifecycle of 6G research and development. The Next G Alliance's 6G roadmap highlights the importance of addressing these issues and identifies them as key targets for 6G systems.

The Next G Alliance aims to achieve widescale adoption of 6G technologies both domestically and globally. Towards this end, it is crucial to create a roadmap, which outlines several goals that ATIS is working on. These include:

- Trust, security, and resilience: The Next G Alliance aims to create a secure and resilient network that can be trusted by all users. This includes

developing advanced security measures to protect against cyber threats and other vulnerabilities.

- Enhanced digital world: It seeks to create an enhanced digital world that offers multisensory experiences to users. This will be achieved by leveraging emerging technologies such as VR, AR, and haptic feedback.
- AI-native future network: It aims to develop a network that is optimized for AI applications. This will involve developing new AI algorithms and architectures that can be integrated into the network.
- Energy efficiency and environmental sustainability: The Next G Alliance recognizes the importance of energy efficiency and environmental sustainability in the development of next-generation networks. As such, energy efficiency and environmental considerations will be at the forefront of all decisions throughout the network's life cycle.

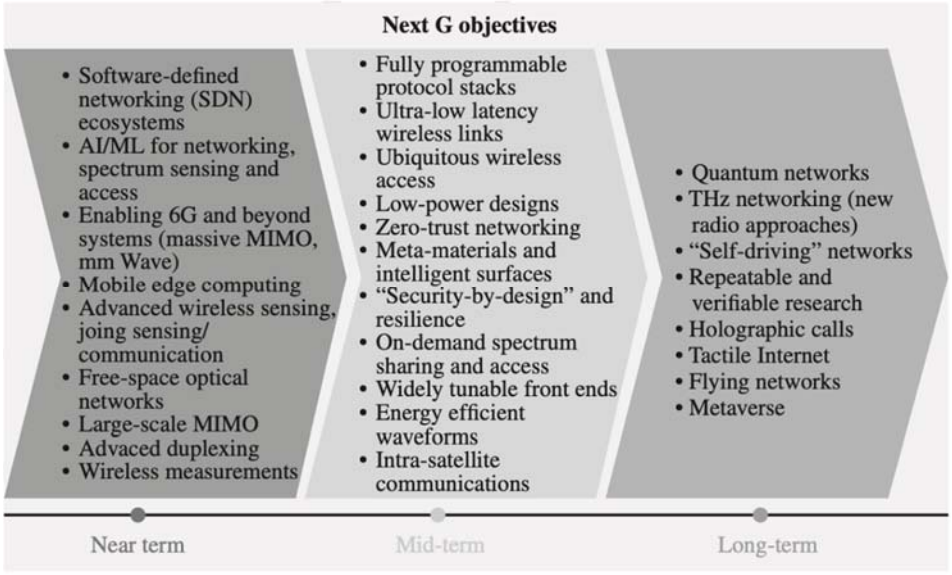

Fig. 1. NSF's view on Next G research: Near-, mid-, and long-term objectives [5].

According to the Next G Alliance, there are numerous opportunities for developing social and economic solutions through the advancement of 6G technologies. The five backbone groups of the Next G Alliance are currently working to achieve interdependencies between human and technological evolution, while prioritizing North America's interests and aligning them with the United Nations' Sustainable Development Goals (SDGs). These SDGs include digital equity, trust, sustainability, economic growth, and quality of life. This alignment involves the collaboration between stakeholders in both the public and private sectors, including academic researchers, industry leaders, policymakers, and members of the general public. In doing so, the development of 6G technologies will be inclusive, sustainable, and aligned with the needs and goals of society as a whole.

2.2. Cyber-Physical Continuum

By blurring of the lines between the physical and digital worlds, digital twins will create a "cyber-physical continuum." Essentially, digital twins are dynamic virtual replicas of real-world physical objects, processes, and systems. The resultant cyber-physical continuum serves as a bridge between the digital and physical realms, leading to limitless connectivity, intelligence, and a fully synchronized network. The ultimate result is the creation of a *Virtual Society*, where events in the virtual or real worlds influence one another and AI plays a central role in managing and adapting human interactions [6].

Predictions indicate that by 2030, today's society will rely on advanced technologies such as AI, adaptive robotics, VR/AR, additive manufacturing, and IoT, all synchronized to work together via 6G. Fig. 2 presents Ericsson's vision of the cyber-physical continuum in the 6G era, which will allow for immersive experiences and the full merging of realities. The cyber-physical continuum provides a close link to reality, enabling users to experience digital objects and environments in a way that is deeply integrated with the physical world. More specifically, the cyber-physical continuum will enable movements between the physical world and its programmable digital representation by providing intelligence, connectivity, and synchronization of the two worlds. The physical world will be equipped with a vast number of sensors that will send real-time data to update the digital representation. Similarly, actuators in the real world will carry out commands from intelligent agents in the digital world. As a result, it will be possible to trace, analyze, observe, and act in real time, as well as simulate, predict, and program

future actions. As we shall see in Section 5, the concept of the cyber-physical continuum is similar to the emerging Metaverse, where digital objects are projected onto physical objects that are represented digitally, allowing them to seamlessly coexist as merged reality and enhance the real world [7].

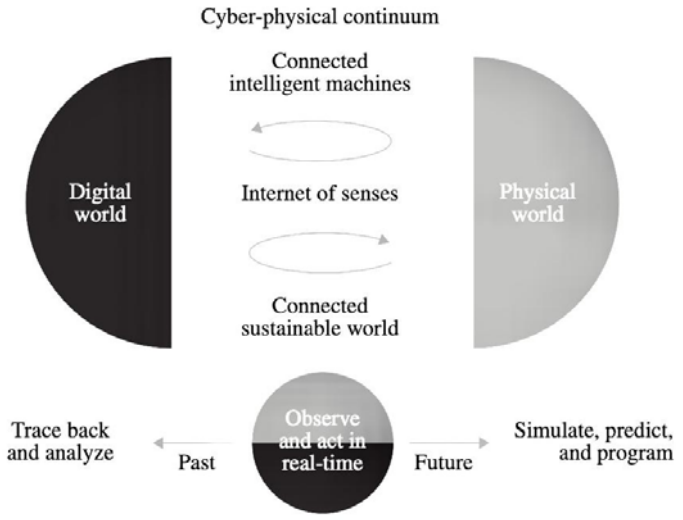

Fig. 2. Ericsson's envisioned cyber-physical continuum for the 6G era [7].

2.3. Overview of 6G Research Activities

As new 6G services and applications such as holographic communications and digital twins emerge, there is a growing need for traditional key performance indicators (KPIs) like delay, data rate, and reliability, to ensure that 6G networks can serve as a general-purpose technology (GPT). In addition to technological and economic considerations, researchers are currently examining other factors such as geopolitical tensions, when analyzing the benefits and requirements of 6G. To fully understand and develop future networks, it is important to consider various aspects of 6G, including the use of AI, machine learning (ML), THz communications, energy management, security, mobility management, green 6G, as well as optical wireless communication (OWC). In addition, the attributes of applications, use cases, and architecture of 6G networks need to be considered.

Table 1 summarizes some of the most important ongoing research efforts on 6G communication systems [8]. The Technology for Network 2030 group within the International Telecommunications Union Telecommunication (ITU-T) standardization sector was established in July 2018 to focus on the capability of future networks, including International Mobile Telecommunications (IMT). ITU-T studies novel forward-looking scenarios, such as holographic-type communications (HTC), ubiquitous intelligence, Tactile Internet, multi-sense experience, and digital twins [9].

In the era of 6G, we have the potential to bring about a transformative effect on society at large scale. This can be achieved by leveraging on the convergence of technologies to drive the digital economy. Towards this end, we need to shift our attention from individual technologies or products to platforms and ecosystems. While the current focus of 6G research efforts lies largely on visions, use cases, and requirements, it will become increasingly important to approach 6G from a multidisciplinary perspective by taking into account not only technologies but also business and societal aspects in order to meet the demands of the future digital economy [10].

3. Emerging Web3 Token Economy

Fig. 3 illustrates the evolution of the Internet from Web1 to Web3. The Internet has progressed from Web1, which was a read-only information economy, to the current Web2 and its read-write platform economy. Blockchain technology has been given rise to Web3, which enables a read-write-execute *token economy* that compensates contributors of data with tokens. Note that this contrasts with Web2, which exploits user data for targeted advertising. The closely related term of *token engineering* denotes an emerging field that addresses the design and verification of tokenized ecosystems. Web3 retains the read-write frontend of Web2, but with changes to the data structures in the backend [11].

Table 1. Summary of ongoing research efforts on 6G communication systems [8].

Public. Time	Topics	Major Contributions
June 2020	ML	Possible challenges and potential research directions of advancing ML technologies into the future 6G network in terms of communication, networking, and computing perspective.
April 2019	ML	Reviews the state-of-the-art advances in ML and quantum computing and proposes a quantum computing-assisted ML framework for 6G networks.
Dec. 2020	AVML	Summarizes some intelligent approaches of applying Al and ML tools to optimize 6G networks, including THz communications, energy management, security, mobility management, and resource allocation.
Nov. 2020	THz	Analyzes link budget of THz links with justified estimates of calculus terms, such as the achievable or required noise figure, transmit power, and antenna gain.
Nov. 2020	THz	Discusses full protocol stack for the realization of end-to-end terahertz 6G mobile networks, from medium access control, network to transport layer.
June 2019	THz	Describes the technical challenges and potentials for wireless communications and sensing above 100GHz. and present discoveries, approaches, and recent results that will aid in the development and implementation of 6G networks.
Sept. 2019	Technologies	Five technology enablers for 6G, including pervasive Al at network edge, 3D coverage consisting of ten-estriol networks, aerial platforms, and satellite constellation, a new physical layer incorporating sub-THz and VLC, distributed security mechanisms, and a new architecture.
Dec. 2019	Green 6G	A Survey on new architectural changes associated with 6G networks and potential technologies such as ubiquitous 3D coverage, pervasive Al, THz, VLC, and blockchain.
Dec. 2020	AI	Outlines the concept of trustworthy autonomy for 6G and clarifies how explainable Al can generate the qualitative and quantitative modalities of trust.
June 2020	Al	The core concepts of explainable Al for 6G, including public and legal motivations, definitions, the trade-off between explainabilily and performance, explainable methods, and an explainable Al framework for future wireless systems.
Mar. 2020	Al	Argues that 1 000 times price reduction from the customer's viewpoint is the key to success and uses Al-assisted intelligent communications to illustrate the drive-force behind.
Aug. 2019	Al	Discusses potential technologies for 6G to enable ubiquitous Al applications and Al-enabled approaches for the design and optimization of 6G.
Dec. 2019	Al	A special issue provides a comprehensive treatment on all the technology aspects related to ML for wireless communications, covering fading channel, channel coding, physical-layer design, network slicing, resource management, mobile edge, fog computing, and autonomous network management.
Oct. 2020	MIMO	An overview of holographic MIMO surface (HMIMOS) communications including the available hardware architectures for re-configuring such surfaces, highlighting the opportunities and key challenges in designing HMlMOS-enabled wireless communications for 6G.
Mar. 2020	Use cases	Foresees several possible use cases and key technologies that are considered as the enablers for these 6G use cases.

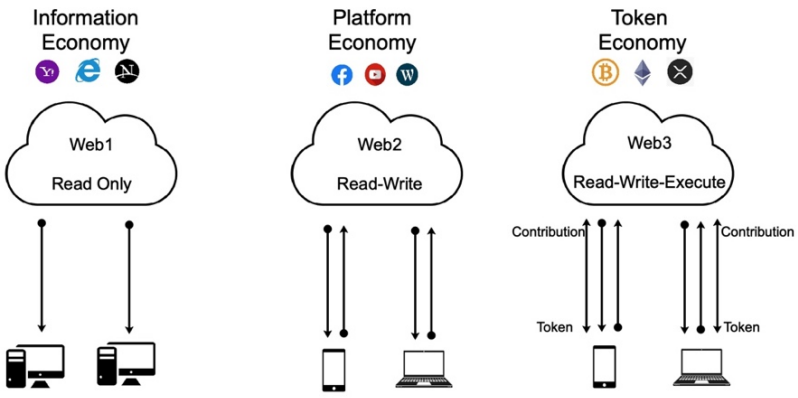

Fig. 3. The evolution of the Internet from Web1 to Web3 [11].

Blockchain is a disruptive technology due to its decentralization, traceability, and tamperproof features. It is expected to integrate with 6G networks in order to build safer and more reliable mobile network infrastructures. However, the current blockchain landscape is fragmented, and interoperability is critical to facilitate broad adoption. The National Institute of Standards and Technology (NIST) defines interoperability in blockchain architectures as a composition of distinguishable blockchain systems that can execute transactions across multiple systems, where data recorded in one blockchain can be accessed by another in a semantically compatible manner [12]. Web3 is a new technology that uses blockchain, cryptocurrencies, and decentralized autonomous organizations to create a democratic and decentralized system for exchanging digital assets, managing e-commerce, social media, and gaming. It has become widely deployed in three primary areas: DeFi (Decentralized Finance), NFTs, and decentralized gaming. DeFi is a peer-to-peer ecosystem for financial services without intermediaries, NFTs are blockchain-verified digital assets, and decentralized gaming uses token-based economies and virtual worlds [13, 14]. Smart contracts are used to automate processes via self-executing software, whereby Ethereum is the most widely used platform for developing smart contracts. Ethereum operates as a transaction-based state machine that uses accounts, including externally owned accounts (EOAs) and contract accounts. EOAs are controlled by private keys and do not have any associated code, while contract accounts are controlled by their associated contract code. Smart contracts provide greater contractual security at lower costs than traditional legal systems [15].

Blockchain technology provides users with the opportunity to experiment with secure, decentralized systems that may enable new social models beyond today's economy. Web3 creates complex technology-enabled social organisms that require an iterative social governance process of finding consensus about policy upgrades. Governance is the term used to describe the social consensus process over protocol evolution, which can be conducted either off-chain or on-chain. However, current proposals for on-chain governance are plutocratic, giving more voting power to token holders with more tokens, which is contradictory to decentralization. Off-chain governance, on the other hand, excludes many small token holders. It is still unclear what the right balance between on-chain vs. off-chain governance will look like in the future [16].

3.1. Tokens

The term cryptocurrency doesn't accurately describe the new assets that were not initially intended to represent money. Instead, the term token is more suitable as it encompasses all types of tokens, including non-monetary assets. Tokens are used in blockchain systems as non-sensitive surrogate values that replace sensitive information through a process known as *tokenization* [17]. Blockchain technology may be used for launching new tokens or wrapping existing ones, but suitability for tokenization requires the support for transaction systems, systematic features for token interaction, and uncapped scalability. Access to tokens requires a dedicated wallet software, which manages the public-private key pair related to the blockchain address. The private key owner is the token's owner or custodian, who can initiate token transfers, access rights, or voting rights by signing with the associated private key. A token contract is a type of smart contract that assigns conditional rights to the token holder, allowing her to manage digital or physical assets and access rights to those assets. Tokens may represent a variety of things and facilitate collaboration across markets and jurisdictions, leading to more transparent, efficient, and fair interactions. Tokens can also incentivize individuals to contribute to a collective goal, created upon proof of a certain behavior. There are two main types of tokens: fungible tokens and non-fungible tokens (NFTs). Fungible tokens are designed to be interchangeable with other units of the same asset, while NFTs are unique and cannot be replaced with anything else. Further, tokens may be programmed with an expiration date to discourage hoarding, causing them to either change state or expire altogether.

3.2. Purpose-Driven Tokens

Purpose-driven tokens are used to incentivize individuals to work towards a collective goal, e.g., creating a public good or reducing negative externalities. In economics, externalities refer to the costs (negative externalities) or benefits (positive externalities) that affect a third party that did not choose to participate in the economic transaction. Purpose-driven tokens offer a new way of creating collective value and provide an alternative to our current economic system that mainly incentivizes individual profit. They aim to motivate individuals towards a greater purpose beyond personal profit, thereby creating an operating system for a new economy. Ethereum and other blockchain networks provide a public infrastructure for creating purpose-driven tokens with just a few lines of code. They may have limited transferability such that they can be exchanged only for local products and services within a community, thus creating a community currency [11].

In addition to economics, the study of public choice theory, theory of public goods, and behavioral sciences is essential for understanding and designing purpose-driven tokens. The term public goods is central for designing purpose-driven tokens. Public goods are goods that anyone can use without paying for them and reducing availability to others. Note that digital goods can be easily copied and distributed, making them non-rivalrous. Providing public goods can be difficult due to the well-known free-rider

problems where some people will not contribute even if they benefit. Token governance mechanisms need to anticipate and address these issues. If public goods become restricted, they become club goods, which are artificially scarce. Purpose-driven tokens can use nudging as a mechanism to encourage individuals to contribute to public goods and reduce negative externalities of a common good. Nudging builds on the assumption of bounded rationality and accounts for psychological, emotional, cultural, cognitive, and social factors that impact the decision-making process. Behavioral economics investigates why market actors behave economically irrational and how others can benefit from this irrationality. The field of purpose-driven tokens can learn from behavioral game theory.

3.3. Mechanism Design and Token Engineering

Mechanism design is a subfield of economics that deals with designing games to incentivize everyone to contribute to a collective goal. Token mechanism design, or token engineering, is an emerging field that requires a more nuanced approach to adequately address issues like the aforementioned free-rider problem and resultant tragedy of the commons. Token engineering focuses on developing token-based economies through modelling and documentation that are implemented in the blockchain system. Token engineering uses simulation models such as agent-based modelling to handle complexity and produce multi-stakeholder models. For instance, activity based management (ABM) was used to analyze the dynamics of the Bitcoin network and simulate the trading market, while generalized frameworks and simulation environments were created for other cryptocurrency and blockchain designs [18]. Token engineering comprises the theory, practice, and tools to analyze, design, and verify tokenized ecosystems. Up to date, however, there has been little overlap between the academic community and developers of purpose-driven tokens. Open research challenges in token mechanism design include the design of a bottom-up token engineering framework to enable the design of future tokenized ecosystems.

4. Use Case of Future Tokenized Ecosystems: Stigmergy-Enhanced Society 5.0

Stigmergy is a ubiquitous concept that can be used to study cognition across various scales, from individual mental states to inter-individual emergence of culture in societies. It is a common mechanism used by both natural societies (e.g., ant colonies) and artificial systems (e.g., swarm intelligence in AI). Stigmergy involves self-organized systems, where local decisions lead to the emergence of colony-level decision-making. Insect societies use pheromone-based interactions to achieve spatiotemporal coherence and migrate to a selected location through a winner-take-all process. Stigmergy is also found in the human neural system, where neuronal firing leads to the release of neurotransmitters and neuromodulators that modulate activity in the brain's neural network [19]. Neuromodulators are characterized by their ability to act at short distances, affecting neurons and synapses that are located close to their release sites, typically just a few cells apart. This allows for stigmergic interactions between multiple synapses to occur [20].

The concept of stigmergy is a class of self-organization mechanisms that can be exploited as a means to achieve internal communication integrity in society by borrowing from biological superorganisms with brain-like cognitive abilities, e.g., colonies of social insects. Stigmergy allows for indirect, mediated coordination between actions, with the traces left on the environment serving as a form of collective memory. In stigmergy, traces left by individuals in their environment feedback on them and incite subsequent actions, resulting in indirect communication and maintaining social cohesion. To apply the concept of stigmergy to the Internet, we expanded our previously reported XR architecture of the so-called *Internet of No Things* [21]. The Internet of No Things offers human-intended services without the need for wearing any personal computing or storage devices. This transition from today's gadget-based Internet to the gadget-free Internet of No Things is divided into the following three phases: (*i*) bearables (e.g., smartphones), (*ii*) wearables (e.g., smart jackets, voice-controlled rings, glasses, and earbuds), and finally, (*iii*) nearables, which are nearby environments with embedded computing/storage technologies that can learn and react according to user context and history in order to provide user-intended services. For illustration, the left-hand side of Fig. 4 depicts the Internet of No Things architecture, which represents an example of future *cyber-physical-social systems (CPSS)* that integrate human beings into a cyber-physical system at the social, cognitive, and physical level. CPSS members can engage in cyber-physical-social behaviors, leading to the emergence of metahuman beings with superhuman capabilities. For more information on CPSS, the interested reader is referred to [22].

Fig. 4 illustrates how the Internet of No Things can be transformed into a stigmergy-enhanced *Society 5.0* (to be described in more detail shortly) through the use of an online environment based on advanced Ethereum blockchain technologies and different types of offline agents such as social robots, embodied AI, and humans. An Ethereum blockchain based DAO is used for self-operation, self-governance, and self-evolution via operational rules recorded on the blockchain in the form of smart contracts. Importantly, purpose-driven tokens are applied to incentivize individual behavior toward contributing to a user-defined purpose or collective goal [23].

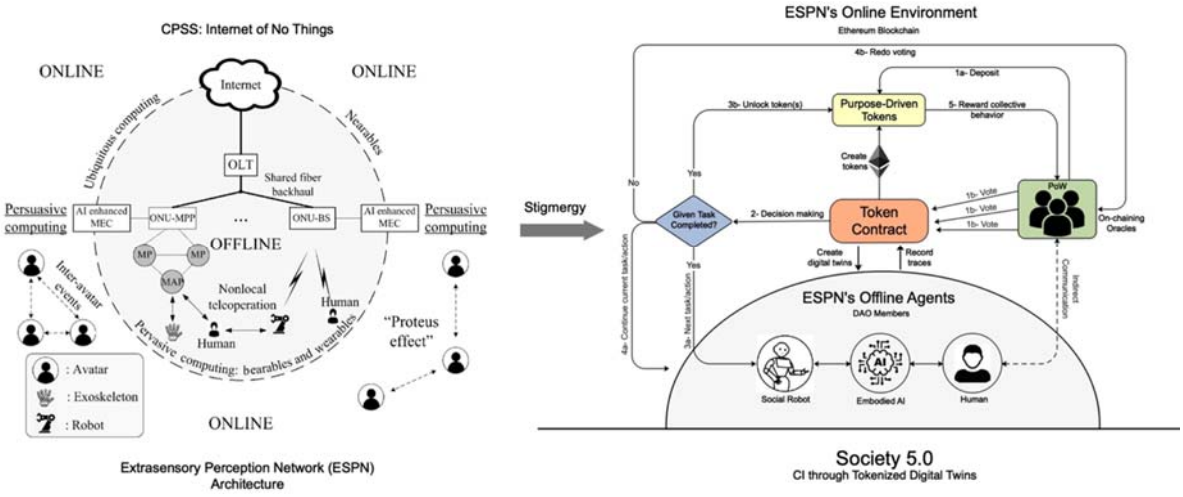

Fig. 4. Stigmergy enhanced Society 5.0 using tokenized digital twins for advancing collective intelligence (CI) in CPSS.

4.1. From Industry 4.0 to Society 5.0

Industry 4.0 deals with the integration of information and communication technologies (ICTs) into industrial processes, leading to the digitalization of manufacturing. More specifically, Industry 4.0 integrates advanced technologies such as cyber-physical systems (CPS), IoT, cloud computing, and big data analytics into the manufacturing process. The goal is to create a more flexible, intelligent, and connected manufacturing system that can quickly respond to changing market demands. CPS represent key components that enable networked systems to communicate and interact in real time. Big data analytics involves collecting and analyzing data to optimize processes, reduce downtime, and improve quality control. Cloud computing enables manufacturers to store and process data in a centralized location, allowing for easier access and collaboration with partners and suppliers. Among others, the benefits of Industry 4.0 include increased efficiency, productivity, and flexibility [24].

In January 2021, the European Commission published their first policy brief on Industry 5.0. One of the major changes in Industry 5.0 is the shift from technology-focused advancement to an approach centered around humans. This means that technology serves people, rather than the other way around. Industry 5.0 aims to expand the capabilities of workers through the use of innovative technological means such as VR/AR tools, mobile robots, and exoskeletons. The goal is to up-skill and re-skill workers and provide them with the tools they need to do their jobs more efficiently. An important difference between Industry 4.0 and 5.0 is the focus on sustainability. Industry 5.0 seeks to create a more sustainable manufacturing system that is environmentally friendly and socially responsible. This involves reducing waste, energy consumption, and emissions, as well as promoting ethical practices and social responsibility [25].

While there is a relationship between Industry 5.0 and Society 5.0 as they both aim to transition to a new paradigm, Society 5.0 goes beyond manufacturing and addresses wider societal issues. Society 5.0 refers to a broader societal transformation in which advanced technologies are integrated into all aspects of human life to address social challenges and create a sustainable and inclusive society. This transformation involves the integration of technologies such as AI, IoT, as well as blockchain into various sectors, including healthcare, education, and transportation. Society 5.0 aims to create a human-centric society that balances economic growth with social and environmental well-being. Fig. 5 shows the main differences between the different types of society and their co-evolution with industry from Society 1.0 to Society 5.0 [26].

The concept of lights-out manufacturing and production, where factories operate without human presence on-site, is at the core of the philosophy behind today's IoT-based Industry 4.0. The Japanese government's Society 5.0 initiative, on the other hand, takes a more human-centered approach and involves integrating humans into the loop of CPS through the use of social robots, embodied AI, ambient intelligence, VR/AR, and advanced human-computer interfaces (HCI). Both Industry 4.0 and Society 5.0 merge the physical and cyberspace by leveraging ICT to the fullest. However, Society 5.0 aims to create the world's first super-smart society and counterbalances the commercial focus of Industry 4.0 [27].

Furthermore, Society 5.0 aims to bring about a paradigm shift from conventional monetary to non-monetary economies based on technologies that measure activities toward human co-becoming that have no monetary value. The ultimate goal of Society 5.0 is to create equal opportunities for all individuals and provide an environment for realizing each person's potential. To this end, emerging technologies will be employed to eliminate physical, administrative, and social barriers to self-realization.

Society 5.0's inclusion of diverse non-human entities, such as social robots and AI agents, is not a new concept but a return to the unpredictability, wildness, and continual encounters with the other that characterized Societies 1.0 and 2.0. This was due 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 dimensions [28].

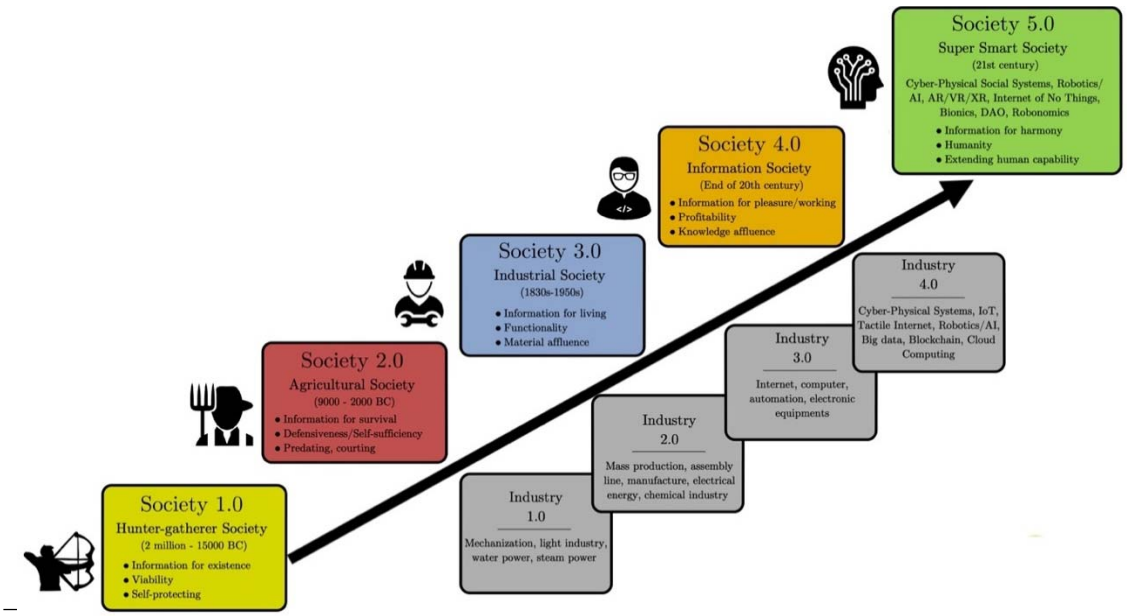

Fig. 5. Co-evolution of society and industry.

4.2. Stigmergy-Enhanced Society 5.0

Fig. 6 depicts our considered multilayer token engineering DAO framework for Society 5.0 based on the aforementioned Internet of No Things as CPSS of choice. The multilayer token engineering DAO framework for Society 5.0 consists of the following five layers: (*i*) basic technology, (*ii*) governance operation, (*iii*) incentive mechanism, (*iv*) organization form, and (*v*) manifestation.

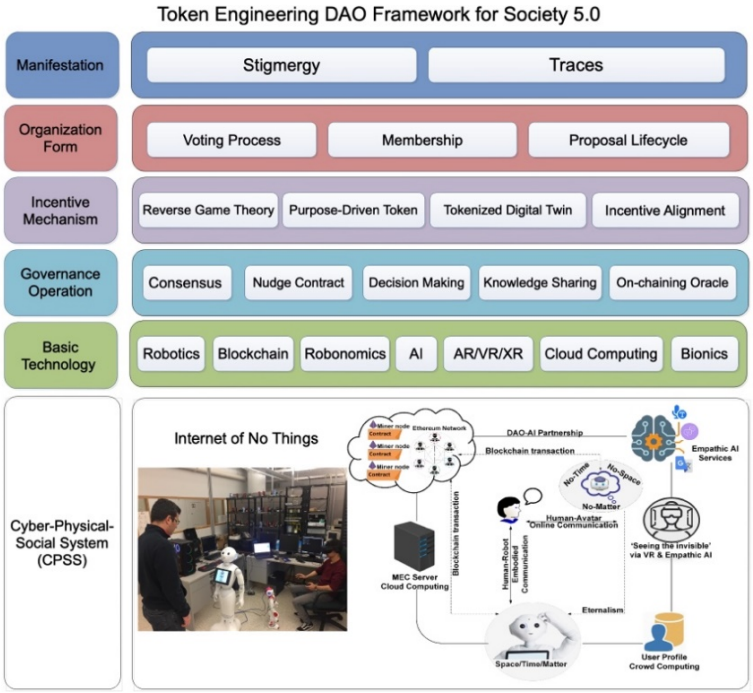

Fig. 6. CPSS-based bottom-up token engineering DAO framework for Society 5.0.

State-of-the-art CPSS can be converted into a stigmergy-enhanced Society 5.0 by performing the following five steps:

1. Start by specifying the purpose of the tokenized ecosystem, which should extend human capabilities and measure activities toward human co-becoming through the use of AI to CI.
2. Select the Internet of No Things as the CPSS of choice to help create intelligent environments for providing human-centred services.
3. Define Proof-of-Work (PoW) as a mechanism to regulate access to club goods, using on-chaining oracles to enable the trustworthy on-chaining of blockchain-external off-chain information stemming from human users.
4. Design tokens with proper incentive alignment and use token contracts to create tokenized digital twins that represent physical or digital assets and assign access rights/permissions to the blockchain address of the token holder.
5. Facilitate indirect communication among DAO members via stigmergy and traces by recording purpose-driven token-incentivized activities in the blockchain-enabled online environment and using these blockchain transactions as traces to steer collective behavior toward higher levels of CI in Society 5.0.

For measuring CI, we leverage the crowd intelligence of Amazon Mechanical Turk (MTurk) workers and a blockchain oracle that discover a hidden reward map consisting of purpose-driven tokens by means of image tagging. Specifically, CI is defined as the ratio of discovered/rewarded number and total number of purpose-driven tokens. Fig. 7 depicts the setup and experimental steps of our implementation in more detail. We developed a JavaScript-based human intelligence task (HIT) platform that lets human end-users select from 20 ImageNet images and add relevant image tagging information. The answers provided by MTurk workers are evaluated by an on-chaining oracle using ERC-20-compliant access right tokens that regulate the voting process and release the purpose-driven tokens. The human end-users leave the discovered/rewarded tokens as stigmergic traces on the blockchain to help participating DAO members update their knowledge about the discovered reward map and continue its exploration.

Fig. 8 illustrates that a DAO with stigmergy is able to discover a greater number of hidden tokens in the reward map compared to a DAO without stigmergy. We have also found that the internal reward of the DAO with stigmergy is higher, indicating that the members are able to better coordinate and cooperate in their exploration of the reward map. Overall, the results show that stigmergy has a positive impact on both CI and internal reward in terms of earned tokens. For further technical details, we refer the interested reader to [23].

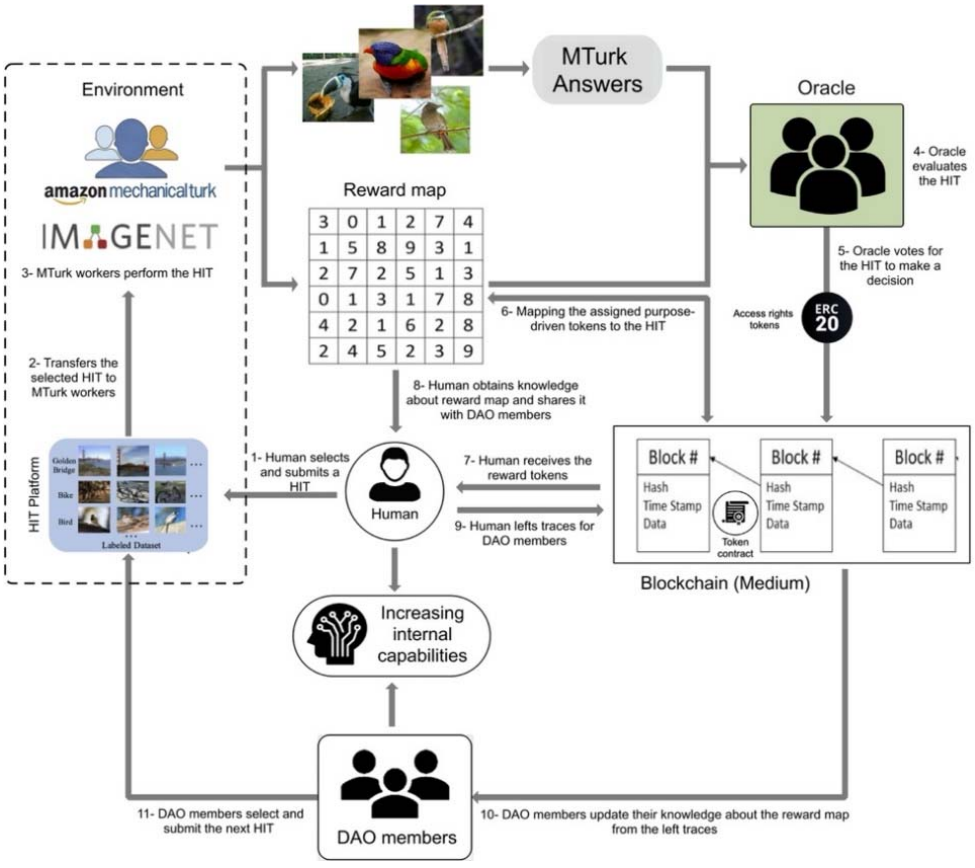

Fig. 7. Discovery of hidden token reward map through individual or collective ImageNet tagging via Amazon MTurk and on-chaining oracle.

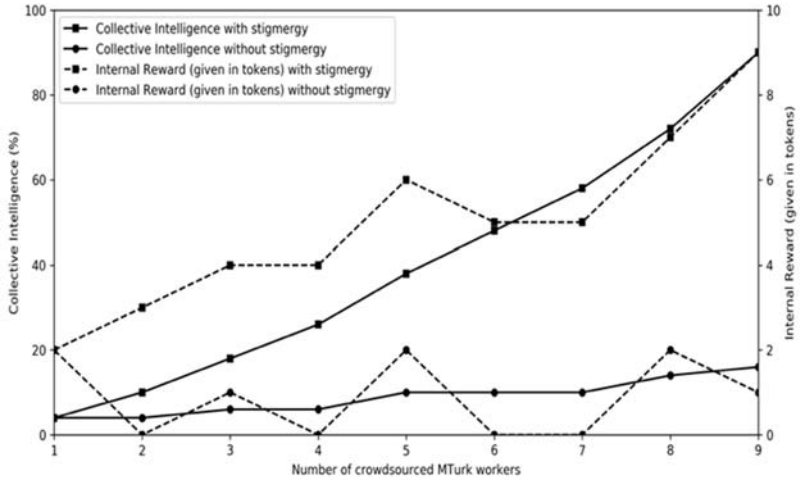

Fig. 8. Collective intelligence (given in percent) and internal reward (given in tokens) with and without stigmergy vs. number of crowdsourced Amazon MTurk workers.

4.3. Toward Extended Stigmergy and Dynamic Media

In his critically acclaimed book "Social Physics" [29], a term originally coined by Auguste Comte, the founder of modern sociology, Alex Pentland argues that social interactions (e.g., social learning and social pressure) are the primary forces driving the evolution of CI. According to Pentland, CI emerges through shared learning of surrounding peers and harnessing the power of exposure to cause desirable behavior change and build communities. Further, he observes that most digital media are better at spreading information than spreading new habits due to the fact that they don't convey social signals, i.e., they are socially blind. However, electronic reminders are quite effective in reinforcing social norms learned through face-to-face interactions. He concludes that humans have more in common with bees than we like to admit and that future techno-social systems (like the emerging Metaverse, discussed shortly) should scale up ancient decision-making processes we see in bees.

This conclusion is echoed by Max Borders through his concept of the social singularity that defines the point beyond which humanity will operate much like a *hive mind* (i.e., collective consciousness) [30]. Currently, two separate processes are racing forward in time: (i) the technological singularity: Machines are getting smarter (e.g., machine learning and AI), and (ii) the social singularity: Humans are getting smarter. In fact, he argues that these two separate processes are two aspects of the same underlying process waiting to be woven together towards creating new human-centric industries, where human labor will migrate into more deeply human spheres using the surpluses of the material abundance economy and the assistance from CI. More and more, we'll act like bees to get big things done, whereby humans act as neurons in a human hive mind with blockchain technology acting as connective tissue to create *virtual pheromone trails*, i.e., programmable incentives. The traces left in the medium may be interpreted as a form of collective memory. According to [31], the usual assumption is that the medium is passive, meaning that it does not modify the traces. However, in *dynamic media*, which may be constituted by a population of other types of agents, the medium has some effect over the traces, giving rise to the term *extended stigmergy*. Once the medium has some effect over the traces the door is open for new types of dynamic virtual environments, such as the emerging *Metaverse*.

5. The Metaverse: Original Vision Embedded in Meta Narrative Society 5.0

With the mass digital adoption of remote work and online social activities accelerated by a global pandemic, we may finally find ourselves on the verge of something big and potentially paradigm-shifting: The Metaverse. It will surround us both socially and visually and 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 Metaverse ought to have the following main characteristics: (*i*) It must be a shared experience; (*ii*) it must be possible to purchase and sell things to each other in a virtual economy; and (*iii*) it has to be possible for people to participate in activities that combine the real and virtual worlds [32].

Several companies have already embraced the Metaverse. Apple, Google, Samsung, The Walt Disney Company, Nintendo, Nvidia, Facebook (renamed Meta), Amazon, Microsoft, Epic Games, and others are involved. For instance, recently, on January 18, 2022, Microsoft has announced the acquisition of game developer and interactive entertainment content publisher Activision Blizzard in an all-cash deal worth almost $69 billion. 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. In fact, *gamified experiences* based on emerging Web3 technologies will be instrumental in providing a system of incentives, which enables players to earn tokens in the Metaverse and purchase digital items such as player equipment, avatar clothing, and NFTs. These *play-to-earn* and *play-to-own activities to earn tokens* in the Metaverse create not only its own Metaverse economy but also community [33].

In his recently published book "The Metaverse: And How It Will Revolutionize Everything," Canadian writer Matthew Ball argues that one of the most exciting aspects of the Metaverse is how poorly understood it is today [34]. Ball observes that for all the fascination with the Metaverse, the term has no consensus definition or consistent description. Most industry leaders define it in the manner that fits their own worldviews and/or capabilities of their companies. Notwithstanding, it is fair to assume that there can be only one Metaverse – just as there is "the Internet," not "an Internet" or "the Internets." Ball opines that it is perhaps from Neal Stephenson's original vision and origins of the Metaverse described in his seminal novel *Snow Crash*, where we find the best insight into what the eventual Metaverse might look like [35].

5.1. Metaverse: Origins and Original Vision

Snow Crash is set in Los Angeles in the 21st century after a worldwide economic collapse. People have begun to increasingly use electronic currency. To compensate for the loss of tax revenue, the government has created hyperinflation. Moreover, the CIA has merged with Library of Congress, giving rise to the Central Intelligence Corporation (CIC). People may sell intel that they have gathered to the CIC. Contributions are paid by the CIC if their clients use them.

Users appear in the Metaverse as user-controlled avatars to build and develop virtual things. In addition, system daemons may appear to maintain the Metaverse. Interestingly, the biological body of human users may be actually affected in that they suffer brain damage in the real world by merely looking at a bitmap image in a certain datafile named Snow Crash. More specifically, Snow Crash is a hypercard that looks much like a business card, which is able to store a virtually infinite amount of information, including computer viruses. In fact, Snow Crash is not only a virus but also a drug and, somewhat surprisingly, even a religion. Religion is like a virus, whereby a piece of information is replicated inside the human mind and jumps from person to person. This is also known under the technical term "glossolalia," a neurological phenomenon exploited in a variety of religious rituals, e.g., Pentecostal Christians speaking in tongues, Pagan Greeks' theomania, as well as many other ancient and aboriginal cultures speaking a shamanic "sacred" language of nature. Glossolalia is caused by structures that are buried deep within the human brain and is thus common to all people.

In modern times, people do not believe in such kinds of things, except in the Metaverse where magic becomes real. The key realization of the Metaverse is the fact that there's no difference between modern culture and Sumerian, which created an advanced civilization in Mesopotamia, now modern-day Iraq, around 4500 BC. It is at once brand new and very ancient, making us experience the birth of a new religion. Neurolinguistic hacking was developed as a new powerful technology by the monopoly owner of the Metaverse's underlying communications network. Further, he has perfected glossolalia and turned it into science. As a result, he is able to control people by planting radio receivers into their brains and broadcasting instruction directly into their brains. Subsequently, people act out the received instructions, acting as if they have been programmed. In addition, he devised a digital metavirus in binary code, which may infect not only computers but also hackers by destroying their mind. This binary virus cannot be stopped. Fortunately, however, there exists also an antidote to it, which dates back to the Sumerian creation myth. It would jam the people's mother-tongue neurons, thereby preventing them from being programmed.

Ever since its publication in 1992, Neal Stephenson's original vision of the Metaverse, which we summarized above, had a strong influence in high-tech circles, especially Silicon Valley. He coined the word "Metaverse," because he thought that existing words, e.g., virtual reality, were awkward to use.

5.2. Meta Narrative: Society 5.0

Recall from Section 4.1 that Society 5.0 aims at creating the world's first super smart society by applying a human-centered approach. Furthermore, from an anthropological point of view, Society 5.0's goal of including diverse non-human entities, e.g., AI software agents and social robots, as participants is nothing new. Instead, it is something quite ancient. In addition, the authors of [28] elaborate on Buddhist practices toward human co-becoming and enlightenment. To Kukai, a Japanese Buddhist monk, detached knowing was not sufficient. Instead, Kukai recommended "engaged knowing." In Society 5.0, the focus will be on the enhancement of human capabilities. By enriching human capabilities in a society, social mobility increases and social disparity decreases. Towards this end, the future Society 5.0 should have more complex metrics required for measuring the advancement of human capabilities, social mobility, and equity. The authors of [28] conclude that the modern concept of humanity has to be redefined to avoid that Society 5.0 becomes a dystopian society. This is far from easy since humans may transform themselves into different directions,

including undesirable ones. We do not have a fixed télos for co-becoming, a philosophical term used by Aristotle to denote the full potential or purpose of a person [28].

For illustration, Table 2 summarizes the above characteristics of Society 5.0, which we use as our meta narrative for embedding the Metaverse, given their striking similarities and subtle differences. As shown in Table 2, 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 in [36], which envisions that 6G will transform the wireless evolution from "connected things" to "connected intelligence." It is also interesting to note their 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 2 is the fact that the Metaverse does not 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.

5.3. Blockchainizing Offline and Online Games: The Trust, Origami, and Wordle Game Use Cases

In this section, we further explore the benefits of blockchainization for the use cases of three well-known offline and online games. Recall from above that gamified experiences together with play-to-earn/own activities to earn tokens will be instrumental in creating not only its own Metaverse economy but also its own Metaverse community.

Let's start with the *trust game*, a landmark experiment of behavioral economics and game theory. Our implemented blockchain-enabled trust game involved pairs of human players, who were both endowed with X Ether and paired anonymously across the Internet. The two players sequentially exchanged a fraction $0 \le p \le 1$ and $0 \le q \le 1$ of their endowment, respectively. Thus, p and q represent a measure of the first player's generosity and the second player's reciprocity, respectively. Fig. 9 shows the measured average normalized reciprocity q/p vs. players' deposit of D Ether, an effective yet simple blockchain mechanism for increasing user engagement. We observe that a deposit of only $D = 2$ Ether suffices to quadruple the average normalized reciprocity from roughly 20% to 80%. Fig. 9 also depicts the measured average social efficiency, which defines the optimal resource distribution of a society. We observe that social efficiency reaches 100% if the players deposit their full endowment, i.e., $D = X$ Ether. Note that both reciprocity and social efficiency represent useful metrics for measuring the advancement of human capabilities and equity in Society 5.0, as advocated for in Section 5.2.

Table 2. Meta Narrative Society 5.0 vs. Embedded Metaverse: Striking Similarities and Subtle Differences.

	Meta Narrative Society 5.0	Metaverse
Goals	Super Smart Society for 21st Century	Central Intelligence Corporation in 21st Century
Approach	Humans put in loop of today's CPS	Humans paid for gathering intel
Enabling Technologies	VR/AR, avatars, digital twins, social robots, embodied AI, CPSS, bionics, DAO, tokens	VR, avatars, daemons, hypercard, biological virus, metavirus
Anthropological 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
Religious & 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, e.g., "kinaturu" (African tongue of the ancestors of all magicians)
Ancient Knowledge	Aristotle's concept of télos (367-347 BC)	Sumerian creation myth (5000 BC)
Metrics	More complex metrics required for advancement of human capabilities, social mobility, and equity	N/A
Risks	Dystopian society, crowdsourcing with unfavorable consequences	Dystopian future, neurolinguisitic hacking, brain damage

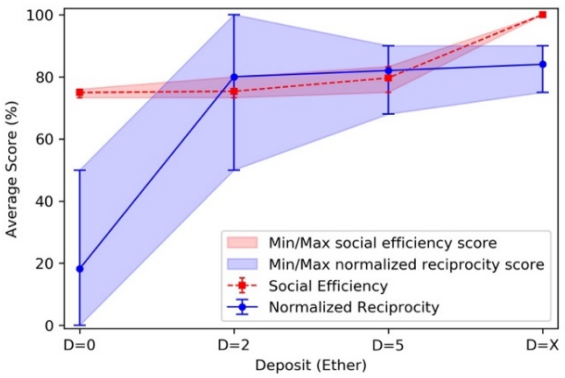

Fig. 9. Normalized reciprocity and social efficiency as a function of blockchain mechanism deposit (depicted with minimum-to-maximum measured score intervals).

Next, let us shed some light on the pros and cons of different types of VR/AR/XR for an improved Metaverse interaction. Towards this end, we study the well-known *origami game*, where a human player has to fold a cube with the support of state-of-the-art head-mounted VR/AR devices Oculus Quest 2 and Microsoft HoloLens 2 in all eight realms of the so-called *Multiverse*, which, according to [32], will be the successor of the Metaverse. Due to space constraints, we refer the interested reader to [21] for a technically more detailed description of the Multiverse and its eight distinct realms of experiences spanning the entire reality-virtuality continuum. We distinguish two scenarios: (i) *online*: players build the origami cube with the online help of crowdsourced Amazon MTurk workers, and (ii) *offline*: players build the origami cube on their own locally. Fig. 10 compares the experimental average task completion time (TCT) of playing the cube origami game with five online (MTurk workers) and five offline (local human) players in each Multiverse realm. Among others, we observe that the realm Mirrored Virtuality is the most suitable realm for online players because they can see a synchronized holographic cube rendered in real time, resulting in the lowest TCT among all online scenarios.

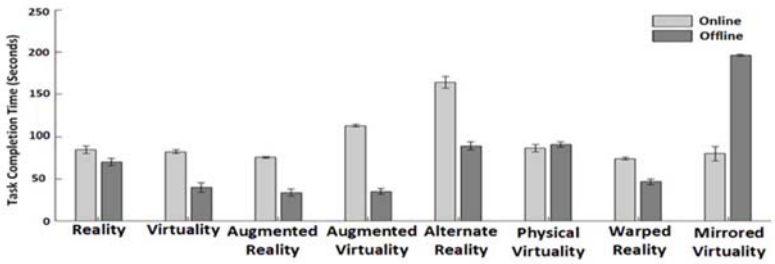

Fig. 10. Experimental average task completion time (TCT) of cube origami game with and without using crowdsourced Amazon MTurk workers in different realms of the Multiverse (depicted with minimum-to-maximum TCT intervals).

Finally, let us consider the *Wordle* game, which was developed during Covid-19 lockdowns and became a worldwide Internet phenomenon. The goal of the game is to find a daily changing secret word, which consists of exactly five letters, within six tries by using cognitive cues in form of differently colored keys on a smartphone screen. We developed a blockchainized multiplayer version of the Wordle game that allows remote expert players to play-to-earn tokens and cooperate with local novice players by providing them with cognitive assistance via smart contracts. Fig. 11 illustrates the beneficial impact of blockchainization on TCT and number of tries for ten different secret words selected randomly from Wordle's database.

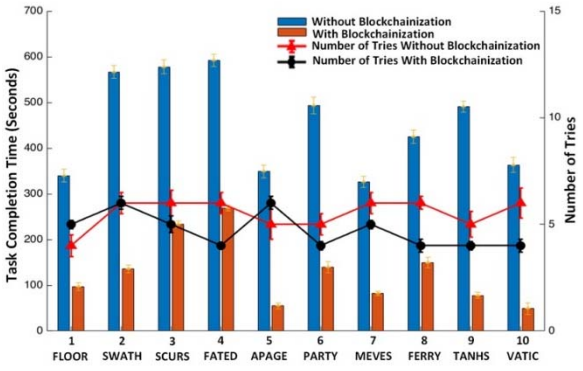

Fig. 11. Experimental results for multiplayer version of Wordle game with and without blockchainization with ten secret words selected randomly from Wordle's database (depicted with minimum-to-maximum intervals).

5.4. Eleusis 2.0: Toward Virtual Immortality, Eternal Life, and the Peak-Experience Machine

In [37], the authors often refer to Neal Stephenson's novel *Snow Crash*, discussed in Section 5.1, and provide an account how VR is changing societies, cultures, and human nature as we know them. They observe that VR has accelerated at an astounding pace during the last couple of decades. They argue that avatars can be "more human than human" with regard to their *virtual immortality*. In the physical world, many people do their best to extend longevity with multivitamins, proper diet, and regular trips to the doctor's office. However, if immortality is the goal, then we're currently out of luck biologically. On the other hand, ten minutes inside a typical VR setup allows digital-tracking equipment to capture literally millions of bytes of data about a person's movements, appearance, and behavior. With virtual tracking data collected over a long period of time, one can preserve much or even most of people's idiosyncracies. Having a version of oneself around forever allows a person to affect future events and shape the experiences of others. After one passes on, her grandchildren and their children can experience her avatar tell a story, give a hug, and provide advice, among many other things. It is, in short, a ticket to *eternal life*. Recently, the Metaverse company Somnium Space has revealed intentions to provide its users with virtual immortality with the addition of a new "Live Forever" mode using AI-based eternal avatars.

Recently, in [38], we highlighted a couple of other peak-experience examples, namely out-of-body near-death and afterlife experiences, which have been realized using a VR headset together with a hydraulic motion platform, haptic gloves, and real-time rendering technology. More importantly, we argued that future 6G and Next G networks should promote the development of a *peak-experience machine* that prioritizes activities over passivities. This would encourage people to actually plug into Robert Nozick's notorious experience machine, which gives users the choice between everyday reality and a presumably preferrable simulated reality. Nozick famously claimed that people want to do the actions, and not just have the experience of doing them, and have contact with a deeper, non-man-made reality (see [38] for further details).

In ancient Greece, Athens' best and brightest flocked to Eleusis for two thousand years. As shown in Fig. 12, Eleusis was located on the outskirts of ancient Athens. Mysteries, from the Greek verb *muo* (μυω) meaning "to shut one's eyes," were said to hold the entire human race together. Plato was permanently transformed by whatever he observed in Eleusis. Aristotle is known for saying that "initiates came to Eleusis not to learn something, but to experience something." Wouldn't it be nice if the Metaverse became the new *Eleusis 2.0* – a parallel plane on the brink of the Internet for human leisure, labor, and life more broadly – where we "shut" our eyes using advanced XR head-mounted devices, which give way to awe-inspiring experiences that are at once brand new and very ancient?

Fig. 12. The "Mysteries of Eleusis" on the outskirts of ancient Athens (Source: www.starmythworld.com).

We don't yet know what the Internet truly is. Eventually, however, its impact is expected to be similar to Gutenberg's printing press, which revolutionized society and ushered in the Renaissance. Preeminent digital theorist Douglas Rushkoff argues that our cultural institutions, markets, and technologies were once forces for human connection and expression, but now repress and isolate us. In his recently published manifesto "Team Human," Rushkoff advocates that it's time to remake society together, as the team we actually are rather than as individual players. In lieu of creating new relationships between people, today's digital technologies replaced them with something else. Our most advanced technologies are thwarting our connectivity instead of enhancing it. Unfortunately, his has been by design. On the flip side, that's also why it can be reversed. Rushkoff concludes that we are in the midst of a Renaissance. The current dismay and calamity around us are less symptoms of a society on the brink of collapse than those of one about to give birth. However, Rushkoff emphasizes that a Renaissance without retrieval of lost, essential values is just another revolution. He adds that the beauty of living in a Renaissance moment is that we can retrieve what we lost the last time around.

6. Conclusions

Improving daily quality of life, enabling new experiences, and supporting social and economic needs are key outcomes that 6G systems should aim to achieve. The Next G Alliance's 6G roadmap highlights the importance of addressing these issues and identifies them as key targets for 6G systems. By blurring the lines between the physical and digital worlds, the 6G era envisions to create a cyber-physical continuum, whose ultimate result is the creation of a Virtual Society that is deeply integrated with the physical world through the portal of the emerging Metaverse. While the current focus of 6G research efforts lies largely on visions, use cases, requirements, and technologies, it will become increasingly important to meet the demands of the future digital economy, which is currently evolving from today's Web2 platform economy into the emerging Web3 token economy based on decentralized blockchain technologies.

In this paper, we have focused on Society 5.0 and its aim to create the world's first super-smart society and counterbalance the commercial focus of Industry 4.0/5.0. We have presented our proposed multilayer token engineering DAO framework for Society 5.0 based on state-of-the-art CPSS, which can be converted into a stigmergy-enhanced Society 5.0 using tokenized digital twins to record purpose-driven token-incentivized activities in the blockchain-enabled online environment and use these stigmergic traces on the blockchain to steer collective behavior toward higher levels of collective intelligence. Future techno-social systems should scale up ancient decision-making processing we see in stigmergic societies of social insects (e.g., bees or ants), whereby humans act as neurons in a human hive mind with blockchain technology acting as connective tissue to virtual pheromone trails (i.e., programmable incentives) left in dynamic media and novel virtual environments such as the emerging Metaverse, which have some effect over the stigmergic traces exploiting a concept known as extended stigmergy. Given their striking similarities and subtle differences, we argued

that the original vision of the Metaverse can be naturally embedded in our meta narrative Society 5.0. To explore the main characteristics of the Metaverse, namely gamified shared experiences offering play-to-earn/own activities to earn tokens in a virtual economy and community, we have reported on our experimental results that demonstrate the beneficial impact of blockchainizing offline and online games. We concluded by providing an outlook on future developments with regard to advanced VR/AR/XR experiences, ranging from virtual immortality and eternal life, and a peak-experience machine that enables the Metaverse to become the new Eleusis 2.0 and usher in a new Renaissance.

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