Visioning for a Future-Proof Global 6G from Business, Regulation and Technology Perspectives

Petri Ahokangas, Marja Matinmikko-Blue, and Seppo Yrjölä

***Abstract*—Future 6G has been envisioned to connect human, digital, and physical worlds as a novel general-purpose connectivity platform infrastructure that converges different enabling technologies for various purposes across domains. Competing 6G vision documents have been published to influence the global IMT towards 2030 and beyond (i.e. 6G) vision work at the ITU-R in terms of enabling technologies, usage scenarios and capabilities, following the technology-dominated tradition stemming from prior mobile communication generations. The current visions comprise a complex mix of competing and partially overlapping elements, lacking a coherent and holistic framework and terminology to reconcile a global 6G vision that would help in its successful development and commercialization. Although the published visions increasingly address sustainability and human-centricity as key drivers, they lack an integrated multi-disciplinary and multi-stakeholder approach to integrating the drivers. To help the global 6G vision building process, this paper offers a human-centric and sustainability-driven framework and actions for defining and developing 6G. The framework defines inter-related questions needed to define and develop 6G, such as: why we are doing 6G, who we are doing it for, who are doing it, what purposes users will use it for, how users will use it, how we will make 6G work, and how we will measure it. The framework is used for presenting selected future examples for 6G usage scenarios. The presented framework builds on the analysis of the existing 6G vision works and forms a foundation for joint global future-proof 6G visioning.**

***Index Terms*—6G, vision, human-centric, sustainability**

I. INTRODUCTION

THE global vision work on IMT towards 2030 and beyond, commonly referred to as 6G, is expected to be completed in 2023 by the International Telecommunication Union Radiocommunication sector (ITU-R). The approaching deadline of the ITU-R vision makes it a timely topic to ensure competitiveness in the 6G era. The current 6G visions prepared and published by leading research institutions, and industry stakeholders in different countries offer complementary and partially competing views on how 6G should be defined and what its key contents should be in terms of enabling technologies, usage scenarios, and capabilities. White papers as listed in [1] continue the technology-dominated tradition created for the IMT-2020 (i.e. 5G) vision [2].

Commercializing 6G as a new kind of general-purpose technology [3] will fundamentally be a business model problem, in addition to a complex technology problem. Up to 4G, the connectivity business models have remained surprisingly unchanged allowing the mobile network operators (MNOs) to dominate the market, although they have been seriously challenged by the content-owning, cloud-based over-the-top (OTT) Internet giants. The IMT-2020 vision for 5G [2] identified three technical usage scenarios: enhanced mobile broadband (eMBB), ultra-reliable and low latency communications (URLLC), and massive machine-type communications (mMTC), adopting a service-centric approach for 5G. These three usage scenarios opened the opportunity to disrupt the industry business models from connectivity-centric models toward integrated content (data-based) or context (location-based or service-specific) models up to offering the whole network as a service (NaaS). 5G also led to stakeholders deploying the network on one’s own, as exemplified by the appearance of local and often private networks deployed by different of non-MNO stakeholders.

For 6G the business model disruption will potentially be even more profound. The first 6G white paper defined it as *ubiquitous wireless intelligence* [4], indicating the convergence of connectivity and artificial intelligence (AI) to offer novel services to humans and machines alike, and assuming the emergence of a new 6G ecosystem. A similar view was offered by the European Hexa-X project [5] that envisions 6G as an *intelligent fabric of technology enablers connecting human, physical, and digital worlds*, extending the definition toward user experience and societal outcomes. The envisioned holographic communications and transhumanism via novel human-machine interaction, e.g. extended by haptic or empathic communications to access the Metaverse, has widened the vision discussion to all areas of human and machine life. Considering the above, it appears evident that a technology-dominated approach falls short in creating a globally adopted, sustainable, long-lasting, and adaptable—i.e. future-proof—6G. These new expectations placed on 6G technologies will have direct impact on the way 6G should be defined, designed, deployed, further developed, and especially

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commercialized with novel business models.

Technology foresight and futures research have provided insights into how 6G could emerge, what it could become, and what its impacts could be on users, businesses and organizations, sustainability, and societies, also at the geopolitical level [6]. Alas, the ongoing 6G vision work has resulted in a complex mix of partially overlapping and competing elements, parallel use case scenarios for different contexts, purposes, and stakeholders. As an example, service robots or collaborative robots can be used in almost any context as indicated by the Next G Alliance [7] and Hexa-X vision work [5]. It can be concluded that the published key 6G vision documents do not share a common, systematic framework nor terminology that would support developing a future-proof 6G.

Until now, 6G vision work has focused on future-oriented techno-economic analysis utilizing and combining methods flavored with various contextual elements. There is no common holistic—i.e. comprehensive, multi-perspective, multi-level, and multi-stakeholder—frame nor a shared approach for the inclusion of business and regulatory aspects, including sustainability or human centricity, to the technology-based visions presented on future 6G. To cover this gap, this paper aims at answering the following research questions:

- What perspectives should be considered in visioning a future-proof 6G?
- How could a future-proof 6G vision be defined and developed?

Applying a qualitative thematic analysis and technology foresight methodologies, this research integrates and extends the results of currently available 6G vision and white papers, expert insights derived from over 10 6G white paper workshops with over 70 contributing external experts organized by the authors as a part of the Finnish 6G Flagship program, and the authors' experiences in the global 6G vision work. The research contributes by:

- Integrating business, technology and regulation perspectives and multiple stakeholders to envision a future 6G with a sound conceptual/theoretical approach stemming from business model theory [8].
- Synthesizing and proposing a novel holistic and systematic *6G visioning framework* with key elements and terminology for defining and communicating a future-proof 6G.
- Laying out an agenda for developing future-proof 6G.

To achieve our aims, the research continues as follows. After the introduction in Chapter I, we discuss the perspective needed for defining future-proof 6G in Chapter II. In Chapter III, we discuss the levels of analysis and fundamental principles for defining 6G. Chapter IV presents the visioning framework as a flow with examples on how to use the framework. The discussion is concluded in Chapter V.

II. Perspectives Needed for Defining 6G

The defining of a joint global 6G vision calls for considering different perspectives including business/market, technology, and regulation/policy perspectives, which are inter-related. Commercializing a future-proof general-purpose 6G calls for a systematic approach and vision that considers the emerging, enabling, and embedded trajectories of new technologies [9]. Whether one examines the business/market, technology, or regulation/policy perspective, global strategies and policies are difficult to develop without a common framework and unified terminology—and shared visions even more so. Thus, to complement the existing technology-dominant perspective to defining 6G, this research proposes to extend the definition of 6G to cover the business/market and regulatory/policy perspectives (Fig. 1) for defining the vision of a sustainable, human-centric, and future-proof 6G. In Fig. 1, these perspectives are linked to 6G system goals [10],[5],[11].

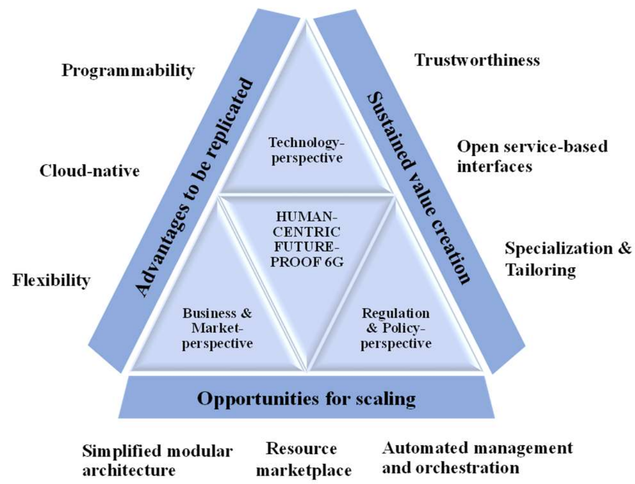

Fig. 1. Perspectives for defining a future-proof 6G.

Network infrastructure hardware and cloud agnostic programmability must meet the demands of numerous and diverse applications in addition to the needs of developers. Flexibility and a high degree of specialization are necessary for it to be deployed on large-scale wide area networks as well as on extremely local community, on-premises and personal-area networks. Extreme tailoring and agile service deployment is required to make each zone, sub-network, and network unique and tailored to its intended use case and business needs. Fully cloud-native network functions and services of the future 6G must be flexibly and dynamically placed anywhere on heterogenous and distributed public and private cloud platforms to achieve a wide variety of key performance indicator (KPI) and key value indicator (KVI) objectives.

The marketplace orchestration of resources, capabilities, and services such as network functions, storage, computing, AI/ML, extended reality (XR) and the metaverse are required to enable scaling. The adoption of digital twins (virtual replicas of the network) are a prerequisite to improving efficiency and productivity while enabling dynamic application aware networks that will close the gap between an application's objective and network requirements. Open and service-based interfaces for users and developers are required to make resources discoverable and accessible and allow functions and services from multiple sources to be assembled and integrated based on specific use cases, business needs and conditions. Advanced orchestration and automation across multiple network and administrative domains, stakeholders, and distributed multilayered platforms and resources are urged for scalability. Trustworthy 6G with fully inclusive coverage, resilient multi-connections, and trust zones will be among the key value drivers in 6G. To meet the envisioned novel 6G service requirements, both the radio access and core network should significantly improve in terms of flexibility, scalability, and programmability. This requires a new level of simplification of the system architecture with a minimum number of functionalities and protocols.

A) Business and Market Perspective

From the business, market, and techno-economic perspective, and to benefit from 6G innovation, the 6G vision needs to systematically address business and societal opportunities, value creation and capture mechanisms, and competitive advantages of 6G as antecedents for economic feasibility and successful commercialization in the digitalizing business ecosystem [3]. For commercialization, the framework should also address the expected outcomes of 6G, the scalability of the developed solutions, replicability of the solutions across different use cases, domains, verticals, and markets globally, and sustainability and resilience—also in terms of continuity, complementarity, and extendibility of the lifecycle of the solutions [12]. The triple bottom line sustainability principle of ensuring that today's actions do not limit the range of economic, social, and environmental options open to future generations—should direct and guide 6G R&D attention. Solving major sustainability challenges with ICT-based solutions and services presents a major business opportunity for 6G R&D. At the same time 6G needs to be developed to fulfill upcoming sustainability requirements. An ecosystem-level approach that also includes users of 6G will be important so that the dominance of specific stakeholders does not prevent the whole ecosystem from succeeding.

B) Technology Perspective

The emerging trajectory of 6G—based on breakthrough inventions introduced by a multiplicity of actors across its life cycle and representing different technologies such as AI or converged communications, localization, imaging, and sensing—may produce significant variations and competing solutions in 6G commercialization. 6G has been envisioned as a novel, general-purpose connectivity platform infrastructure that connects the human, physical and digital worlds [5], converging data and other platforms in numerous application domains and verticals. This enabling trajectory of 6G brings the need for complementary assets that may become costly due to their domain-specificity. The business models used for commercializing 6G will comprise various firm-level and ecosystem-level activities to create an embedding trajectory for value creation and capture from 6G innovation [13]. The emerging, enabling, and embedding trajectories of 6G as a new technology to be commercialized are good reasons to argue for a holistic framework that would guide the 6G definition, development, and policies related to its deployment [9].

C) Regulation and Policy Perspective

Regulation and policy are critical in shaping the mobile communications market [14]. Considering the environmental, societal, and economic sustainability, there are regulations that address different perspectives defining clear requirements, for example for environmental sustainability. From the regulation and policy perspective, 6G needs to be developed for differing regulatory frameworks related to aspects such as spectrum regulation, market power, data access, ownership and use, and requirements set for platforms, digital markets, services and AI. A paradigm change already seen in 5G is the emergence of an increasing number of local mobile communication networks deployed by different (non-MNO) stakeholders, which fully depends on regulatory decisions on spectrum availability and other aspects. Additional regulatory pressures may emerge from environmental requirements, CO2 compensation schemes, and industry-vertical-specific regulations related to the need for national sovereignty. Recent discussions on regulation reflect the need to renew the currently static practices, consider sustainable development, address the timely and flexible utilization of emerging technologies with novel, innovative business models and preventing harm to the public.

The business/market, technology, and regulation/policy perspectives complement the picture for 6G. Practically, 6G will mean connecting, matching, bridging, and sharing the resources and assets of various services providers and complementors with the needs and demands placed on 6G by the users or other stakeholders of the future 6G ecosystem. This novel multi-sided market with some exemplary elements is depicted in Figure 2.

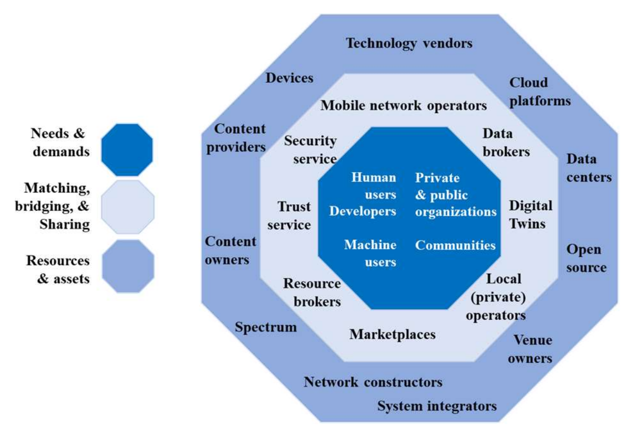

Fig. 2. Resource configurations for 6G.

III. DEFINING A FUTURE-PROOF 6G

The up-to-date proposed 6G visions increasingly address human-centricity and inclusivity, environmental and societal sustainability, and they highlight trustworthiness in terms of privacy, security, and safety, requiring resilience and expecting sovereignty. A potential source of controversy in the current 6G visions are the conflicting values and intentions inherent in the competing visions. These include statements on the need for precise social governance, global commercial and industrial initiatives under the present technology race, harmonization, regulations, national sovereignty, and military interests. Next, we proceed to defining a future-proof 6G.

A. Levels of Analysis for a Future-Proof 6G

Important themes for reaching a global 6G were reconciled in [1] by applying technology foresight, specifically causal layered analysis. At the surface level, 6G is envisioned as a general-purpose technology with globally harmonized standardization and agreed IP licensing policies, innovative spectrum sharing approaches, and sustainability-driven KPIs and KVIs. A common set of standards covering all industries and geographies will ensure consistency, extendibility, complementarity, and scale economies in the 6G rollout. Thus, collaborative research projects, demonstrations, and trials will be needed regardless of the prevalent geopolitical tensions and sovereignty concerns—or national policies for innovation, deployment, and regulation. Also, policymakers should not forget supporting the emerging new technology innovators' value capture. The massive diffusion of 6G to new application areas with increasing number of licensees and other stakeholders will create a more complex standard essential patent (SEP) licensing landscape, necessitating a novel, more precise rule for fair, reasonable, and non-discriminatory (FRAND) compliance [3]. The current 5G system disaggregation, softwarization, and cloudification have already revealed that the FRAND and its associated reasonable licensing fees are not defined precisely enough by the standardization organizations. In the 6G ecosystem the value capture potential of complementary assets may be further compromised as SEPs will increasingly be used to make technologies and platforms function. The mobile communication businesses are transforming and spanning their network-as-a-service business models across telecommunication, Internet, enterprise, and industrial domains utilizing software-led value creation and cloud-based delivery. In addition to MNOs, 6G networks will be designed, deployed, managed, and offered to markets also by new stakeholders such as local operators, cloud operators, and resource brokers.

At the social systemic level, future 6G needs to align the need for triple bottom line sustainability and trustworthiness with steady rules regarding the use of AI and machine learning (ML) and adopt anticipatory regulation that promotes open innovation and sustainability. At the deeper worldview-level, 6G could highlight legitimacy at the ecosystem level, and may empower human users, and citizenry-driven services to root 6G in the meanings, worldviews, metaphors, and attributes of a healing world, harmonious society, and advancement in general.

B. Fundamental Principles for Defining a Future-Proof 6G

Within mobile communications, human-centricity has traditionally been considered as quality of service (QoS) or experience (QoE). Extreme experience provided by the means of virtual (VR), augmented (AR), or extended reality (XR)—via haptic or empathic communications—has been anticipated in several 6G visions. However, human-centricity can also be considered a fundamental design principle, addressing the aim to enhance and extend human capabilities and rights, e.g., with the help of AI, rather than just seeing 6G as an enabler for novel applications. Additionally, human-centricity should be extended to include developers and authorities. Fig. 3. summarizes the forces driving the development toward a sustainable human-centric 6G.

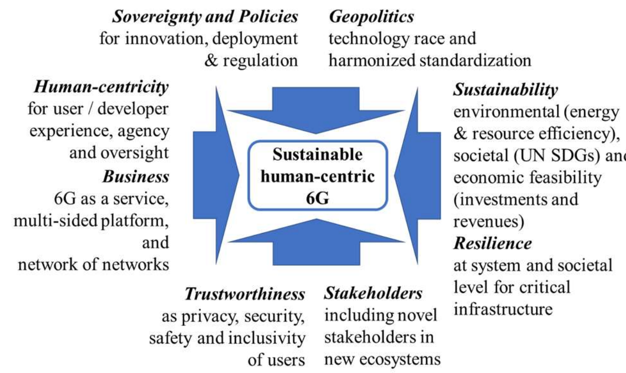

Fig. 3. Forces driving toward sustainable human-centric 6G.

To complement human-centricity, 6G could also be designed to highlight trustworthiness for both individuals, machines, and society, rather than seeing it from the perspective of technical trustworthiness. In line with the harmonized regulation and ethical guidelines presented for AI, a value-based policy for trustworthy 6G can be envisioned, building on transparency, fairness, accountability, robustness, safety, human agency and oversight, privacy, and data governance as values. To achieve user and developer-centric 6G, the technical processes and related decisions need to be explained to stakeholders. The documentation of datasets and AI/ML decisions must be done in a standardized manner to enable traceability and auditability. Also, governance mechanisms must support human oversight, and users/developers should be given reasonable knowledge and tools to comprehend and interact with the systems. Privacy, security, and safety can be seen to be relevant at the individual level, but they also embrace the societal perspective with the need for inclusivity in its utilization but are also related to possibilities to opt out from communications by the users.

Sustainability in mobile communications has traditionally meant energy-efficient networks, but increasingly it has also focused on protection against harmful electro-magnetic field (EMF) exposure as well as the enablement effect in other sectors. Despite industry's continuous attempts to develop and implement more energy efficient technology solutions, ever-increasing end user data demands (resulting in increased energy consumption) can jeopardize the benefits achievable from the efficiency improvements due to overconsumption. Therefore, 6G needs to consider the triple bottom line of sustainability covering in parallel societal, environmental, and economic sustainability perspectives [12] and direct the developments towards fulfilling sustainable end user requirements, instead of emphasizing the overconsumption of mobile data.

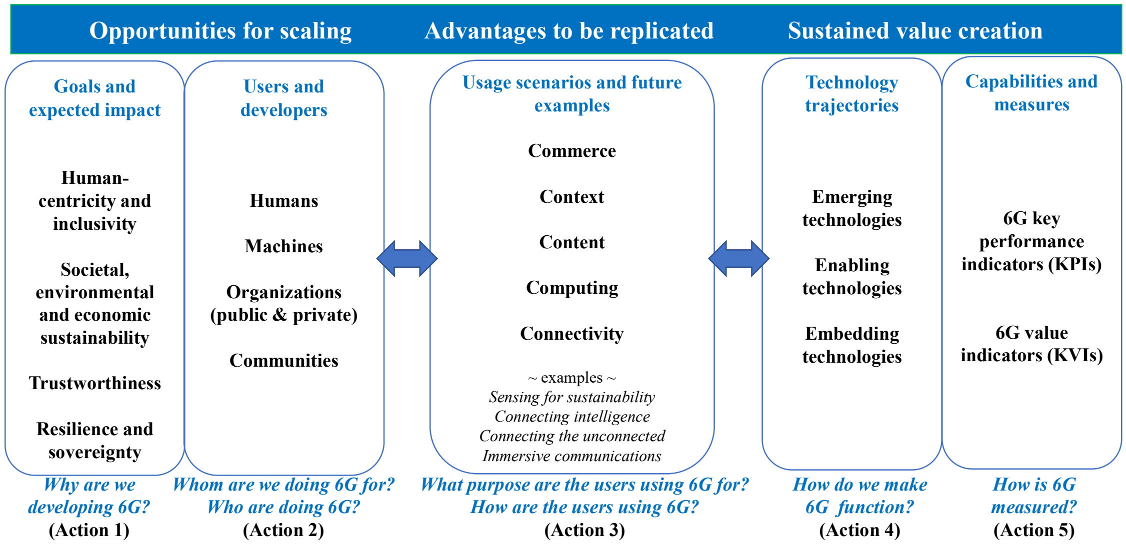

Fig. 4. The proposed 6G visioning framework.

Thus, environmental sustainability should not overrun economic progress (e.g. affecting the feasibility of investments and revenues) and societal progress measured in terms of United Nations Sustainable Development Goals (UN SDGs); societal values should not compromise economic and environmental sustainability; and finally, economic sustainability should be sought with the intention to avoid negative societal or environmental consequences. Triple bottom line sustainability is also relevant for achieving system and societal-level resilience, e.g., for critical infrastructures.

The combined effects of human-centricity, trustworthiness and sustainability have implications for designing innovation policies and guiding regulatory developments in the future. The economic perspective is crucial for businesses that aim to build 6G as a multi-sided platform and enable 6G as a network of networks that allow for enlarging the ecosystem for novel stakeholders.

IV. Proposed New 6G Visioning Framework

Next, we propose a new framework and agenda with actions to be taken for building the joint 6G vision. Motivation for this 6G visioning framework stems from the need for stakeholders of the future 6G mobile communications ecosystem to be able to communicate their needs, aims, and visions in an understandable and inclusive way. The objective of the 6G visioning framework is to contribute to the successful innovation and commercialization of 6G and, especially, the advancement of a human-centric and environmentally, societally, and economically sustainable digitalizing world. To achieve this, Fig. 4 depicts the proposed top-down visioning framework to arrive at a future-proof 6G.

A. The Visioning Framework

To start with, a future-proof 6G vision needs defined ***goals and expected societal impacts*** (Action 1). The proposed 6G visions have addressed a) human centricity and inclusivity, b) societal, environmental, and economic sustainability, c) trustworthiness in terms of privacy, security and safety, and d) resilience at societal and system levels as well the issue of sovereignty. Although the presented visions have given different priorities and meanings for these goals and expected impacts, they nevertheless provide a purpose for 6G by answering the question of what we are developing 6G for.

Second, related to goals and impact, the ***users/developers*** of future 6G including humans, machines, communities, and organizations of different kinds need to be defined (Action 2). This answers the questions of who we are doing 6G for and who will be using or making 6G. Each of these users and potential developers might think differently of 6G and use or develop it for different purposes that may share differing communication needs and patterns. The inclusion of users and developers is needed for defining a future-proof 6G. Without a clear understanding of the goals, expected impacts, known users and developers, the opportunities for scaling 6G-enabled solutions and services will not be understood.

Third, for defining a future-proof 6G questions need to be answered about the purpose of 6G for users and how they will use it. This helps to define the ***usage scenarios*** and ***future examples*** for future 6G (Action 3). The aim of this part of the framework is to determine the advantages 6G should bring to the users and achieve the wider goals and expected impacts of 6G for creating practically replicable solutions. 5G-Advanced will enable experimentation on many of the new 6G use cases such as XR/VR or AI or ML to optimize networks, but 6G will be specifically designed to fill the gaps and extend the user experience. Already, the published vision works present numerous different use cases, and potentially there will be an unlimited number of them to be identified in the future. The framework presented in this research helps to guide 6G innovation toward defining and creating deployable and commercially successful solutions. The key understanding in this part of the framework are the different layers including connectivity (access), computing (infrastructure-based), content (data or equipment-based), context (location or service-specific), and commerce (platform-based ubiquitous as-a-services) business models or any combination of them.

Fourth, the ***technology trajectories*** of 6G need to be identified that answer the question of how we will make 6G function and with which technologies over time (Action 4). This aims to clarify how 6G will enable sustained value creation for users and the society. Emerging breakthroughs and enabling complementary technologies and trends for AI-native communications, integrated sensing and communication, converging computing and communications, device-to-device communications, efficient spectrum utilization, and energy efficiency are examples of technologies envisioned for 6G. This list will be expanded in the future along with embedding open innovation efforts in the extended mobile communications ecosystem.

Finally, related to technology trajectories, the technical ***capabilities and measures*** of 6G, answering the question of how 6G will be measured, need to be defined (Action 5). Extant work on 6G measures has focused on traditional KPIs or sustainability-oriented KVIs that are directly linked to the technical capabilities of 6G in the various usage scenarios and future examples of 6G. However, there is a lack of consensus on what the indicators for 6G should be.

In summary, the proposed visioning framework with its inter-related elements and proposed actions creates a holistic and systematic way for the mobile communications ecosystem—from its developers and users to regulators—to communicate their needs, aims, and visions in an understandable and inclusive way. The goals, impacts, users, and developers define the 6G usage scenarios and future examples. Additionally, technology trajectories, capabilities, and measures should reflect the usage scenarios. The objective is to contribute to the successful innovation and commercialization of 6G and, especially, via the actions, the advancement of a human-centric and environmentally, societally, and economically sustainable digitalizing world. In doing so, we aim to turn around the technology-driven thinking that starts with technological advantages and then seeks opportunities for value-creation and capture, and we aim at the user experience, sustainability, or resilience. Discussing the nature of technology, the author in [15] paid attention to combining, recursiveness, and emerging phenomena in new technologies. 6G has the potential to combine and converge new technologies for a myriad of uses by competing stakeholders, creating a novel multi-sided marketplace where stakeholders can both compete and collaborate with each other at the same time.

B. Future Examples of 6G Usage Scenarios

Next, we present future examples of what 6G could be used for.

Sensing for sustainability. First, to tackle the sustainability challenge, 6G will become a powerful measurement tool with its flexible sensing capabilities and collecting indicator data for sustainability improvements in different sectors of society, for example utilizing context-specific data in public organizations to be measured with selected KVIs.

Connecting intelligence. Second, 6G will be built on AI and ML and connect intelligence from several sources such as machines for digital twinning. 6G will connect the physical and human worlds with real-time synchronized digital twin models based on massive-scale deployment of sensing, AI and ML. Digital twin models will enable users to monitor, analyze, and simulate the physical world, anticipate needs, and then take necessary actions in the physical world.

Connecting the unconnected. Third, currently, there are 2.9 billion people still unconnected, which constitutes a business and policy challenge. Connecting the unconnected remains an important example use case for 6G and introduces different operator and deployment models. Communities will be able to deploy their own networks for connectivity in challenge areas.

Immersive communications. Fourth, communication is a fundamental need for human interaction, which can be enhanced by advanced XR, bringing new senses such as touch and emotions to traditional communication. Immersive communications will change the nature of work and influence organizational agility and efficiency.

Related to all 6G examples, digitalization and software will be everywhere, and scarce developer capacity will become increasingly important. Cloud-nativeness has changed how companies purchase software, bringing developers more control over major technology decisions and what is being purchased. In many cases, being successful requires building a developer ecosystem. Many companies are altering their expensive top-down go-to-market approach to a bottom-up approach, where customers can easily try out and expand the product usage over time. Finding the right problems to solve and business models to fit is hard, and platform models need to be leveraged.

V. CONCLUSIONS

The current visions of 6G cannot be fully integrated due to technology policy competition, which calls for a holistic approach to joint 6G vision building. 6G will face challenges related to the emergence and scaling of killer applications to ensure its uptake, cost-efficient deployments, and sustainable business models. Therefore, business/market and regulation/policy perspectives need to complement the traditional technology and techno-economic perspective in the future 6G context. Envisioned as a general-purpose technology platform of platforms—or network or networks—6G has the potential to affect economies at a global level and fundamentally change societies and the prevalent economic and social structures. Together with the increasing pressures toward combined economic, social, and environmental sustainability as well as resilience, it is of fundamental importance to define, take action, and communicate about 6G in a sustainable, human-centric, and future-proof manner.

Creating 6G as an AI-enabled system that changes the ways data is collected, shared, analyzed, and used and combining the human, physical and digital worlds will create strong drivers for novel scalable opportunities, replicable advantages, and sustained value creation, triggering new roles and the emergence of novel stakeholders in the mobile communications ecosystem. 6G will exhibit modular structures that can be developed independently with different design principles and goals, leading to conflicts between the modules and recursiveness that may affect the experienced user value or raise serious ethical/privacy concerns regarding the sources, usage, and storing of the processed big and small data within 6G. Emerging phenomena, such as the expected large number of local networks of different stakeholders that may employ diverse business models, may also lead to legitimacy challenges: the novel 6G technologies, solutions and business models need to be accepted by the mobile communications ecosystem stakeholders—the users and developers, private and public organizations including regulators and policy developers, and communities such as standardization bodies.

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