White Paper on Business of 6G

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Abstract

6G vision and industry consensus of underlying technology enablers have come a long way and will shape the new access, networking, and service domains in future mobile communications. These novel features promise countless opportunities for service innovation and business efficiencies, creating an unprecedented impact on multiple vertical sectors. 6G will connect the worlds in novel and innovative ways - physical world and digital world will be deeply intertwined in real time, human biological systems seamlessly coupled, and, at the same time, there will be a new human sensory and cognitive dimension across the scenarios of 6G experience. Key technology enabling themes to be explored will include the pervasive leverage of machine learning and artificial intelligence across architectural domains namely, to flexibly define air interface as well as optimize service management and orchestration in 6G "network of networks" topology and platform ecosystem. Terahertz (THz) research is one of the prominent topics, in the sense of utilizing spectral bands of above 100 GHz for both communications and sensing purposes, thereby enabling connectivity data speeds in the Terabit/s range. We foresee millions of sub-networks and devices becoming the network in conjunction with extreme performance attributes in terms of both sub-millisecond latency, high reliability and time-sensitive determinism and advanced ways to assure security, privacy and trust.

In line with 6G vision and technology enablers, developing products, services and vertical applications for the future digitized society in the 6G era requires a multidisciplinary approach and a re-definition of how we create, deliver and consume network resources, data and services for both communications and sensing purposes. This development will change and disrupt the traditional business models and ecosystem roles of digital service providers, as well as open the market for key stakeholders in the 6G era like digital service operators, cloud operators and resource brokers. Furthermore, sustainable development is a highly complex area, which will call for major changes of industrialized society in the long run. This white paper discusses unprecedented opportunities of enabling and empowering multiple stakeholders to have a more active participation in the future 6G ecosystem via novel sustainable open ecosystemic business models with flexible integration of long tail services with tailored performance attributes. This research adopts a qualitative scenario planning method and portrays three scenario themes resulting in a total of 12 scenarios for the futures of the 6G business. We present both optimistic and pessimistic scenarios and assess their probability, plausibility and preferability. By focusing on key trends, their interactions, and irreducible uncertainties, scenario building generates perspectives for the futures within which alternative 6G business strategies were developed and assessed for a traditional incumbent mobile network operator and a novel 6G digital service provider stemming from redefined sustainable economics. Value-capture in the 6G era requires understanding the dynamics of platforms and ecosystems. Results indicate that, to reach some of the preferred futures, we should pay attention to the privacy and security issues related to business and regulation needs; public/governmental, corporate, community and user(s) perspectives to and aims of governance; ecosystem configuration related to users, decentralized business models and platforms; user empowerment; and the role of location-specificity of services.

1. Introduction

Novel digital era business models have been transforming and disrupting traditional industries with unprecedented speed, and the telecommunications industry is no exception. The wireless network technology evolution and revolution will transform industries through wireless services provided at hundreds of gigabits per second speeds, sub-millisecond latencies, support of a wide range of novel applications connecting billions of devices and objects, and versatility by virtualization, enabling innovative business models across multiple sectors (Ahokangas et al. 2018; 2019). Present 5G connectivity market continues to be characterized by incumbent mobile network operators (MNOs) whose business is structured around service mass provisioning with high advance investments in infrastructure and exclusive long-term licenses granted by the regulators. At the same time, the responsibility of delivering resources is being transformed from an MNO centric system into a dynamic mode of operation (Alvarez et al. 2019). This development is due to the 5G deployment of software defined networks (SDN), Network Function Virtualization (NFV) and network slicing, cloudification, the diffusion of novel local micro operator edge service business models, and the development of vertical service and application ecosystems (Yrjölä et al. 2018).

Futurists, management gurus, trade pundits and general internet intelligentsia have been emphasizing that industry 4.0, driven by networking and connectivity, will have a disruptive impact on society. In this line of thought , ideally 6 G technologies are positioned to have a massive impact on communications sector. However, from the viewpoint of alternative futures research, we have to envision 6G technologies holistically from the viewpoint of interaction between technology ad society. In the past decade, there is a growing consensus about the convergence between nano-Bio, Infor- and Cogno- based technologies (NBIC convergence). The 6G technologies will no doubt ride upon this convergence but also add to the fabric of the society in a very fundamental manner. In turn, this will result in newer forms of business engagements, opportunities and strategies for micro-entrepreneurs, MSMEs and large conglomerates. From the standpoint of business, a marked that 6G will bring about will be in terms of greater opportunity in different vertical sectors to generate a considerable revenue pool. The application of big data, artificial intelligence, and cloud computing at the edge of the network with ubiquitous near real time wireless connectivity will change many aspects of our personal and working lives and the structure of the economy. In particular, the diffusion of information and communication technologies into the physical industries is poised to increase stagnated productivity growth especially from close integration with digital twins.

Furthermore, the future of 6G telecommunications will be shaped by the growing societal requirements like inclusivity, sustainability, resilience and transparency; a highly complex area, which will call for major changes of industrialized societies in the long run (Latva-aho & Leppänen 2019). As the basic connectivity service continues to be commoditized being essential for any standard of living, the telecommunication industry is exploring new ways to better position itself for digital transformation and going beyond the traditional role of connectivity provisioning (Ahokangas et al. 2019). A bit surprisingly, compared to other infrastructures like energy or water supply, the commoditization is happening only after five decades of deployments of mobile communication infrastructures. Access to data and data ownership are increasingly the major factors in value creation, and limiting such access is a means of control and restricting empowerment. Creating a 6G system that transforms how data is collected, shared, analyzed and act upon in real time can create strong drivers for future value, introduce novel stakeholder roles, but may also lead to serious privacy and ethical concerns over the location and use of data. The pervasive influence of artificial intelligence will not just reflect what something looks like but also its context, meaning and function, creating Internet of skills, Internet of senses and digital twins while enabling trust and assuring security and privacy (Latva-aho & Leppänen 2019).

The preceding discussion is indicative of increased importance of novel business model thinking in 6G from the triad of design, engineering and economics perspectives. Most successful technologies will be at the intersection of this triad. Design practice is of crucial importance to 6G technologies as it will be the tipping point for many businesses in the 6G ecosystem. Design fuels innovation, consumption and development of newer forms of interaction that will have a crucial impact towards developing a supply focus mentality. Such a mentality will enable the creating, leveraging and sustaining value for the customer and society as a whole. With the rapid convergence of media technologies –radio, television, print, computers, internet, mobile—in the past decades, there is a shift in the public consumption of media and

interaction with technologies. Marshall McLuhan's dictum of "medium is the message" is rapidly coming to the fore. Governments, businesses and users alike are clamoring for a human-centered design of technologies. As a result, we may be observing a rise of a new demographic of 6G consumers whom we label as "*experentials*". These experentials are similar to other target demographic labels used by businesses to make sense of their potential consumers; such as "millennials", "netizens", among others. However, the "experentials" are different from other labels because of their central focus on appropriate user-experience. They may derive from different walks of life and occupations such as a factory worker or a homemaker, but they will all be joined together around user experience as the central idea of interacting with 6G technologies. These demographics will in turn have a massive impact on the manner in which design, engineering and economics have to be addressed coherently, opportunistically and strategically.

Engineering research, stemming from product and manufacturing platforms and lately service modularity (de Mattos, Fettermann & Cauchick-Miguel 2019), is focusing on components and interfaces aiming at creating economies of scale. In parallel, the economics research discusses how to connect demand and supply in order to grow in sustainable manner and enter or create new markets (Gawer 2014). What both streams agree on is that platforms create an ecosystem around them, paving the way to see platforms and ecosystems as intertwined (Teece 2018). Furthermore, recent study (Yrjölä, Ahokangas & Matinmikko-Blue 2019) discusses how the transformation from current network-for-connectivity business models towards network-of-services model builds on platform with data and algorithms.

The existing 5G business studies focus on traditional MNO business models and discuss 5G in rather technical and general terms, mostly at the industry level (Koumaras et al. 2018), while platform or ecosystemic business models have seldom been examined (Ahokangas et al. 2018; Yrjölä et al. 2018). Collaborative business models have been introduced (Noll & Chowdhury 2011) as well as related system integrator, neutral host, and brokerage roles (Ballon 2009; Rasheed et al. 2016; Valtanen, Backman & Yrjola 2019). Operators' capabilities to expose network functionalities through adopting web-based service models are analyzed (Gonçalves & Ballon 2011); likewise, utilization of cloud business model (Zhang et al. 2015). Moreover, the localized nature of the 5G services has emerged as a characteristic in these studies (Ahokangas et al. 2016) and introduced the micro-operator concept (Matinmikko et al. 2017). Beyond technicalities, the discussed business models can be seen to represent two basic mobile operator business models, including connectivity service provider and its differentiation (Ahokangas et al. 2013, 2016). As an emerging field, 6G business models have not been widely discussed in literature to date, however vision papers on future communication needs, enabling technologies, the role of AI and emerging use cases and applications have been recently published (Viswanathan & Mogensen 2020; Latva-aho & Leppänen 2019; Saad, Bennis & Chen 2019; Letaief et al. 2019; Katz, Pirinen & Posti 2019). Discussion was recently expanded to 6G indicators of value and performance (Ziegler and Yrjölä 2020), the role of regulation and spectrum sharing (Matinmikko et al. 2020), and the antecedents of the multi-sided transactional platforms (Yrjölä et al. 2020).

Building on the above discussion, with roots in engineering and economics research, this white paper seeks to develop alternative scenarios for the Business of 6G over 10-15 years (by 2030-2035) and derive the key trends and uncertainties shaping the future. Furthermore, theoretical research question of this paper is: How could the 6G business transform from closed connectivity driven business towards novel open sustainable ecosystemic business models in 6G? This research follows the anticipatory action learning method (Stevenson 2002; Inayatullah 1998, 2005) and adopts scenario planning process (Schoemaker 1995; Schwartz 1991). The data utilized in this paper is based on a set of virtual future-oriented white paper expert group workshops organized by the 6G Wireless Summit 2020 (6G Summit 2020). The paper is structured as follows. Section 2 describes the research methods and theory frameworks adopted. Sections 3 discusses identified trends and uncertainties and present developed scenarios. In Section 4, the implications of the scenarios and their strategic options are analyzed. Section 5 draws conclusions and highlights perspectives for future research.

2. Methods and theory frameworks

2.1 Scenario planning process

Exploratory scenarios describe events, trends, and choices as they could evolve based on alternative assumptions as to how these events, trends, and choices may influence the future. Exploratory scenarios provide a plurality of plausible alternative futures and they can be created through the *anticipatory action learning process* (Stevenson 2002; Inayatullah 1998, 2005), in which professionals from different fields come together to generate scenarios. The

alternative futures presented in this white paper were created and assessed through group work, and special attention was paid to the coherence, variation, and validity of the scenarios (Stewart 2007; Collins and Hines 2010). The data for the alternative business of 6G futures presented in this paper were mapped within the 6G Flagship programme at University of Oulu, funded by Academy of Finland. The scenarios were generated by professionals in facilitated scenario workshops between the first four months of 2020. The scenario work process discussed in this chapter was carried out in teleconference sessions and individual homework consisting of the following steps (Schoemaker 1995; Schwartz 1991):

- Selecting the focal issue and time frame: Business of 6G year 2030-2035
- Discovering and identification of driving forces
- Identification and evaluation of forces by choosing key trends and uncertainties based on their anticipated impact and predictability of consequences and uncertainty
- Setting up the scenario logic representing the most significant uncertainties of the overall system under scrutiny by selecting two unrelated polar dimensions
- Creating the scenarios by building on different perspectives and identification of trends and uncertainties and by crossing their outcomes in a scenario matrix
- Assessment and evaluation of different scenarios based on their internal consistency, depth, richness, plausibility, and key stakeholders' behavior (Voros 2003)
- Broadening and deepening scenario futures thinking, utilizing Causal Layered Analysis (Inayatullah 1998) and Integral Theory four perspective models (Stewart 2007).

A total of 146 forces were identified and 12 scenarios were generated by the workshop participants. The workshop composition ensured a wide variation in the participants' backgrounds that included research, standardization and development, academia, telecoms industry, government and verticals. Created scenarios were *backcasted* (Dreborg 1996) to technology themed 6G White Paper workshop results to analyze key strategic technology options and frames against scenarios. This enabled the outlining of research targets and questions, and to select indicators and signposts to monitor progress. Backcasting means defining a desirable future and then working backwards to identify policies and programs that will connect that specified future to the present. Foresight scenarios, by definition, are future-focused and its reliability and validity cannot be directly controlled. Instead, the quality of the research can be evaluated by how *probable*, *plausible* and *preferable* the outcome appear to be. These views have been incorporated for scenario planning process in Section 3.

The implications of developed scenarios for future businesses were discussed utilizing *simple rules strategy framework* (Eisenhardt & Sull 2001; McGrath 2010). Simple rules framework consists of six themes as rules: nature of *opportunity* rule, *how-to* rules for conducting business, *boundary* rules for defining the boundaries of the business, *priority* rules that help to identify and rank the criteria for decision making, *timing* rules that help in identifying, sequencing, *synchronizing* and pacing things, and *exit* rules that help in identifying the basis for exit or selecting things to be stopped/ended or given up. This viewpoint for future 6G business has been developed further in Section 4.

2.2 Business model concept and value configuration

The business model concept centering the value creation processes has become the tool for making boundary-spanning analyses in contemporary business research (Zott, Amit & Massa 2011). Traditional business model definitions from the activity perspective (Onetti et al. 2012) assume a focal firm, "*we define the business model as the way a company structures its own activities in determining the focus, locus and modus of its business*" while more recent views, e.g., (Amit & Zott 2001) do not necessitate a focal point: "*a business model depicts the design of transaction content, structure, and governance so as to create value through the exploitation of business opportunities*". Furthermore, business models are seen to connect to three strategic choices and related key activities of firms within ecosystems: 1) *opportunities* to be explored and exploited, 2) *value* to be created and captured, and 3) *advantages* to be explored and exploited (Morris , Schindehutte & Allen 2005; Teece 2010; McGrath 2010; Zott, Amit & Massa 2011). Exploring and exploiting opportunities and advantages can be seen to motivate ecosystemic inter-action from a dynamic capability perspective (Gomes et al. 2018); whereas, the value creation, delivery, sharing and capture are considered the key elements of a functioning business model (Osterwalder & Pigneur 2010). Similarly, successful business models are considered to have three strategic consequences: 1) *scalability* (Stampfl, Prügl & Osterloh 2013), 2) *replicability* (Aspara,

Hietanen & Tikkanen 2010), and 3) *sustainability* (Schaltegger, Hansen & Lüdeke-Freund 2016). The growth of business is frequently connected to scalability and replicability. While scalability refers to an internal growth potential and flexibility, replicability indicates its external flexibility to adapt. Moreover, sustainability stems from a business model's feasibility, viability and environmental or societal impact.

In the scenario analysis, this white paper is utilizing the integrated business model configurations and value configurations framework (Xu 2019). The classical business model conceptualization and value discussions build on Porter's (1996) value chain theory and a *supply-focused* mentality which sees the business model as a means to capture value from customers (Massa, Tucci & Afuah 2017), and where the producer with the system of activities and resources is the sole creator of the value, a focal firm (Casadesus-Masanell & Ricart 2011). In contrast to the classical approaches, the *demand-focused* view shifts away from the supply-focused business model configuration emphasizing the utilization of customer interaction mechanisms to enable value co-creation incorporating a means of creating and delivering value to a target group of consumers, and a means of using existing resources and processes to promote the stable interaction of mechanisms (Bereznoi 2015). This white paper adopted a service-dominant logic and service ecosystem thinking to analyze developed scenarios and the possibility of the wireless industry transformation from traditional supply-focused regimes towards the ecosystem focused models. Vargo and Lusch (2016) define a service ecosystem as a self-adjusting system of resource integrating actors connected by shared institutional arrangements and mutual value creation through service exchange. This demonstrates the systemic and institutional nature of value co-creation and resource integration: in order to all actors/stakeholders to be willing to bring their resources to the common pool, i.e. continue collaboration within the ecosystem, they all need to experience value from it. The value perspective of the *ecosystem-focused* business model is about value co-creation and co-capture to maximize the overall ecosystem value, which in turn will increase the value shared and acquired not only by a focal firm, but by the actors within the ecosystem (XU 2019). From a structural perspective the ecosystem can be seen to have four aspects: 1) network governance, 2) the platform keystone agents and complementors, 3) open interfaces and pool of innovative capabilities and resources, and 4) a modular core and periphery design (Mazhelis & Mazhelis 2012). These aspects of the ecosystems shaped our analysis and is further discussed in Sections 4 and 5.

3 Developed Scenarios for 6G Business

3.1 Forces - Trends and uncertainties

In order to gain understanding on the drivers for future 6G business, a total of 146 forces were discovered and identified by the workshop participants. These participants represented research, standardization and development, academia, telecoms industry, government and other related verticals. As a secondary data, selected recent trend analysis work were utilized (ABI Research 2020; Analysys Mason Research 2020; Business Finland 2020; DTTL 2017; Dufva M 2020; Ericsson 2020; ESPAS 2020; FG-NET-2030 2019; Frost and Sullivan 2020; GSMA 2019, 2020; Huawei 2019; McKinsey Global Institute 2019; Oliver Wyman & Nokia 2020; Ripple W. J et al. 2017; UN 2019; WEF 2020). Key trends were selected from the identified forces by identifying those with the highest impact/importance and the lowest uncertainty discussed. The trends by definition appear in all the developed scenarios. On the other hand, key uncertainties were selected from the forces based on the highest impact/importance, highest uncertainty, and the highest variances in the participants ranking. The summary of the evaluation of all considered forces is depicted in Fig.1 and the key trends and uncertainties identified from these forces are shown in Fig. 2 using the PESTLE framework.
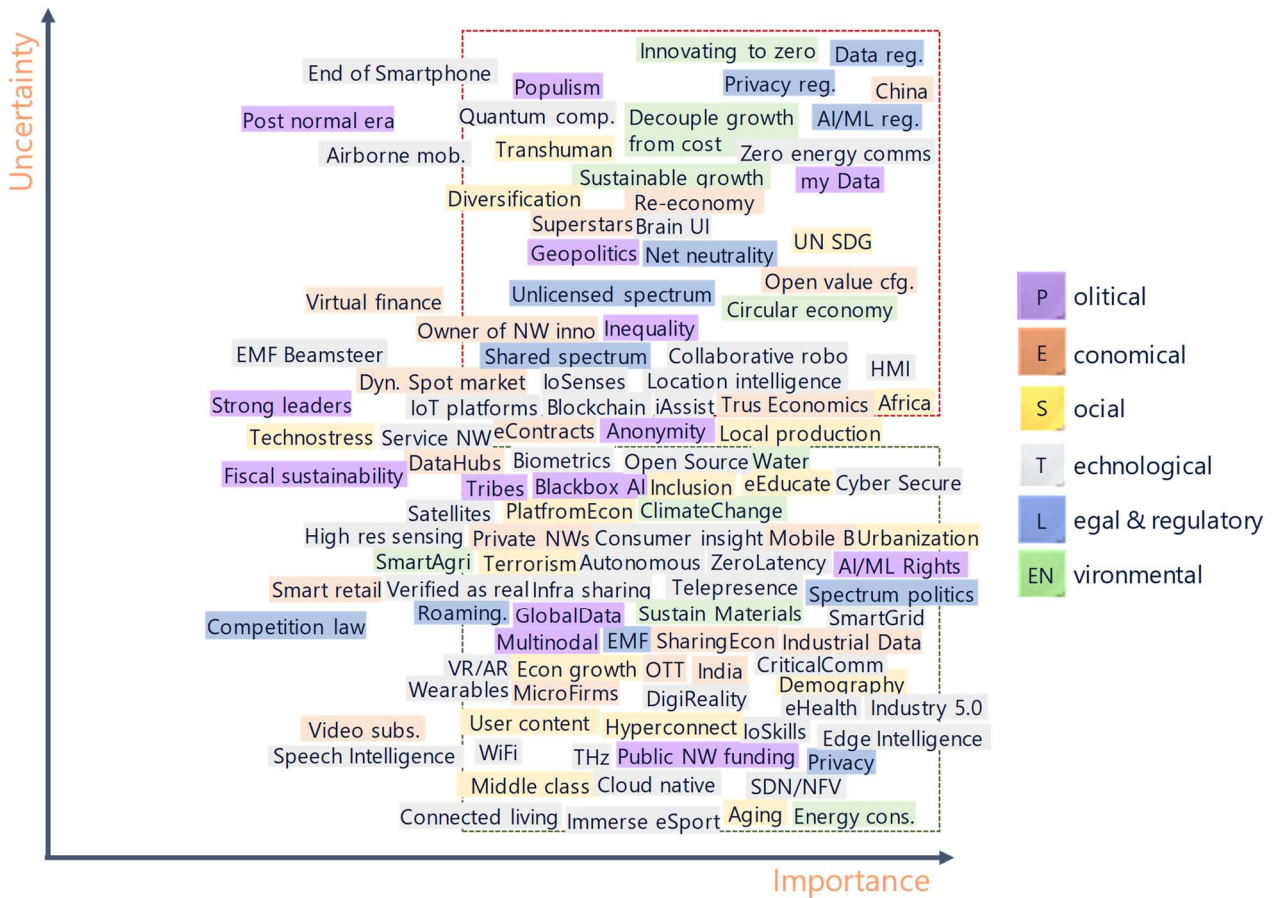
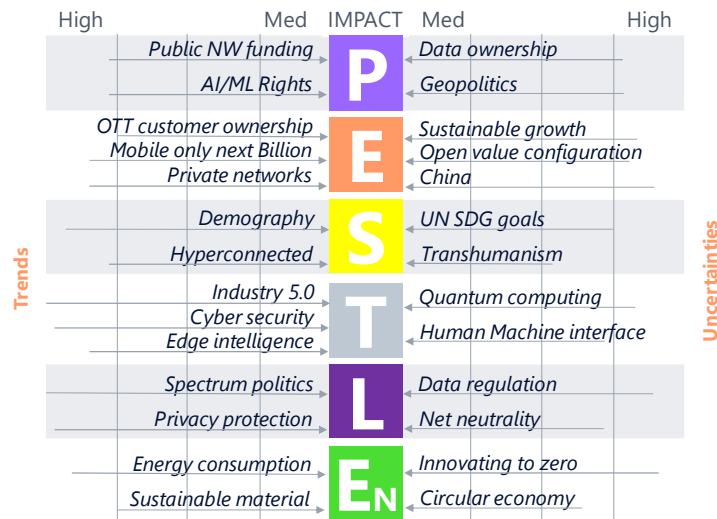Figure 1. The summary of the evaluation of forces on uncertainty and importance.

Figure 2. Identified key trends and uncertainties from the forces.

Key trends

Based on the ranking of forces, several trends were identified as shown in the left-hand side in Figure 2 and are further discussed in the following. *Public network funding* has traditionally been directed to unserved and underserved areas in

terms of broadband access and coverage. Lately support for deployment programs has extended to policy areas, such as smart city community development, worksites and ecosystems/hubs (such as harbors and airports), advanced health services, logistics and transport, Smart Cities, public safety and critical infrastructure at length. It is expected that at the current state of growth, in the future, smart grids will be extended to a variety of sectors including electricity, internet and healthcare. All of these are expected to be hyperconnected and completely automated. They will serve as a middle layer between humans and natural environments enhancing the capabilities of both. These networks will be put together with public-private-personal ownership funding model with a view towards sustainable growth and usage of digital infrastructure.

Artificial intelligence rights trend has contrary interpretations. Assuming the availability of appropriate data sets for training purposes, artificial intelligence has the ability to propose solutions to increasingly complex problems that can serve as the source of great economic growth, shared prosperity, and the fulfilment of all human rights. In the alternative future, it drives inequality, inadvertently divides communities, and is even actively used to deny human rights.

Over-the-top (OTT) companies will utilize their customer data, cloud infrastructure and AI/ML capabilities to challenge traditional operator's customer relationship ownership as users value service experience and perceive connectivity as basic utility. In addition to the media space, OTT players are offering basic telco services such as voice or messaging and are active in growth areas, such as cloud space and services, competing with telcos for clients and revenue. They are tying customers to their own ecosystems with carrier-neutral connectivity, while making reliance on traditional operators a thing of the past.

In *Mobile only next billion,* ubiquitous cheap phones and increasingly affordable network connection in mega cities and rural areas will be helping another billion users join the internet and access applications and digital content increasing at non-English speaking markets. Currently, for many, mobile is the primary or only channel for accessing the internet and services. With its unprecedented scale and growing impact on daily lives, mobile is a powerful tool for achieving the United Nations' Sustainable Development Goals (SDGs) and drive sustainable economic growth.

In 2015, 85% of global GDP was generated in cities. *Urbanization* will bring 5 billion people together to live in cities by 2030 occupying 3 per cent of the Earth's land but accounting for 80 per cent of energy consumption and 75 per cent of carbon emissions. 95 per cent of urban expansion in the next decades will take place in developing world where 883 million people live in slums today. Rapid urbanization is exerting pressure on fresh water supplies, sewage, the living environment, and public health. Future *demographics* divide the world of 8.6 billion by 2030, into two camps: one which is growing Sub-Saharan Africa and South Asia, and another which is stalling and decreasing including Europe, Russia and peaked China. Future cities will be hungry, global economic engines and the economic powerhouses of the global economy. Cities are increasingly functioning as autonomous entities, setting social and economic standards. Urban identity will grow in importance compared to national identity.

Private networks driven by industrial digital automation calls for standalone networks for high reliability, high performance in terms of both bandwidth and reliability, secure communications and data privacy, fulfilling business and mission critical needs. The solutions enable integration of processes, data and diverse devises such as sensors, machines, in-vehicles and hand-held devices across a wide range of applications for industry enterprises. Private networks can be established without direct MNO involvement. Furthermore, demands of privacy in personal space, may also create private networks that rarely connect with public Internet.

Hyper Connected globe will continue to feel ever smaller in 2030: Globally 90% will be able to read and have access to Internet and are on the move. The aim is to recognize that 6G will transform urban and rural living existing at the intersection of geopolitics, growth of nationalism, rights to information transparency and information citizenry. Thus, once the infrastructure of 6G is in place, the content growth will be in terms of supporting multiple social and technological identities of people in through a variety of media. This would require a mindful view on decision making and regulation of future, data, information, media and network usage in light of sustainable growth for economy. Thus, the human in 6G worlds will be increasingly sophisticated in terms of their media and service consumption while being rooted in their local economies. Connectivity will therefore be not only virtual and digital, but also physical. Furthermore, the upcoming opportunity of redefining human machine interface will enable connecting the biological world in novel ways.

Industry 5.0 (I5.0) will allow collaborative human-machine interaction (HMI) across services and industries as human intelligence is in perfect harmony with advanced, cognitive computing. With real-time data, effective data monetization and digital automation of the manufacturing process, businesses will be able to shift focus towards generating higher revenues from *servitization* of products. Advanced manufacturing capabilities will help to overcome design complexities and with its ability to facilitate extreme long tail of mass customization and further return the control back to customers and in a haptic way. Furthermore, I5.0 will require highest standards of safety and environmental protection.

The need for *cybersecurity and trust* will be ubiquitous in the hyper connected world 2030. Even a temporary loss of technology may have, not only a productivity impact, but also a psychological impact on our lives. Furthermore, the subversion or corruption of our technology could result in the disastrous harm to our lives and businesses if, e.g., medical treatment devices deliver the wrong medication, educational systems teach propaganda, or work automation cause us injury or damage our products and businesses. In particular, expectations to protect and safeguard society and critical infrastructures from emergency situations by means of technological advancements are anticipated to grow.

With the growth of *Edge and extreme edge intelligence* the proliferation of ever more powerful communication, computing and analytics resources at the edge of the network will turn architecturally disaggregated 6G access networks into a rich service provisioning and access platform. Hyper-local services, such as augmented reality scenarios, do not require connectivity to distant service platform but, instead, perform better with local real time service access. Furthermore, the person will be supporting part of shared information processing and edge intelligence networks that address collective problems for humanity, such as genome sequencing, through shared resources (à la citizen science). The individual will emerge as a node in the network of intelligence relations rooted in the local physical world while connected to the hyper-real 6G intelligence networks. This adopts a viewpoint of a public good through digital infrastructure of 6G supported through an ecology of information devices, products and services of IoT/IoE.

Wireless spectrum politics and spectrum management in the 6G era will reveal a new level of complexity that stems from the variety of spectrum bands and spectrum access models with different levels of spectrum sharing. Local deployments of networks by a variety of stakeholders is expected to further grow in 6G. The timescales of international-level spectrum management will no longer be enough with the rapid technology development of mobile communication networks and changing user needs. Spectrum sharing will play increasing role in accommodating new 6G systems with existing spectrum users. Furthermore, in national technology politics, spectrum regulation is used to gain competitive advantage (Matinmikko-Blue, Yrjölä & Ahokangas 2020).

Privacy regulation is strongly linked with the rising trends of platform data economy, p2p sharing economy, intelligent assistants, connected living in smart cities, transhumanism and digital twins' reality at length. "I own my data" is expected to grow particularly in Europe based on GDPR evolution, though severe differences in the global data privacy laws are expected to be living on borrowed time. E.g. the US is unique among major countries in not having a unified set of data privacy laws in spite of a large number of global web-scale companies and China having Cybersecurity Law (CSL) that applies not only to conventional data handlers, but also to telecom, radio, and television operators being unique in that Chinese authorities must be informed if data indicates any prohibited activities.

Sustainable material will contribute towards *Innovating to zero* and *circular economy* mega trends. Towards 2030, companies will shift focus and develop products and technologies that innovate to zero, including zero-waste and zero-emission technologies. The full life cycle carbon footprint of the ICT industry represents around 2% of worldwide emissions and is projected to grow at a 6% annual compound growth rate. 6G net positive impact and sustainability are expected to be through enabling increased efficiencies and improved environmental performance in other sectors. Technologies of computing will be miniaturized to the extent that they sustain on the power generated through everyday human activity. The everyday activity of walking, jogging and everyday housework produces energy to support the person's information devices which in turn monitor the person's vitals from time to time as well as cater to information and entertainment needs through over-the-top connectivity.

Key uncertainties

As a result of force ranking, key uncertainties were identified as shown in the right-hand side in Figure 2.

In *geopolitics* the tension between the globalization, networking power and the urgency of the ecological reconstruction is linked to the balance between centralized decisions and the strengthening of inclusion and democracy. Towards 2030,

power configuration may be transforming from a multi-polarized world to a poly-nodal world where power will be determined in the economic, technological and cultural networks and interaction. Political and societal systems are facing growing tension on how to respond to the instability of the financial situation, the ecological sustainability crisis and uncertainty about future complex world. Societies may be struggling to find a balance between quick-moving decision making, community engagement and the reasserting of democratic values and commitments. On the one hand, it is hoped that strong leaders will bring simplicity to the complex problems, but on the other hand, there could be increasing efforts to influence things in communities from the grass-roots level. Furthermore, with increasing polarization, the ageing emerged first in developed countries and diversification of the population, new tribes and communities will emerge around various imaginary groups representing wide variety of values, place of residence, political opinion, consumption choices or lifestyles. It may happen that weakened and fragmented future prospects, the absence of togetherness and the polarizing effect of social media leads to a rise in populism, skepticism towards changes in the environment and in the worst case, extreme attitudes. At the same time, environmental awareness among people and companies may increase and could be reflected in a growing number of people and communities changing their habits and companies taking corresponding actions to offer customer experience. Vehicles of open value creation and open source paradigm in particular may provide a powerful avenue to reinvent civil society participatory process in conjunction with regulatory capability.

Resource orchestration and configuration relates to the power over development and adoption of innovations and technology that ubiquitously embedded in society and our daily life. Data is increasingly accumulated, and its value and significance are growing. Technology may increasingly be seen as a geopolitical issue of power and the questions of future resource orchestration power emerge: who will own the continuously accumulating data? who will get to decide on technology? and who sets the rules and regulations?

Open value configuration emphasizes value co-creation and co-capture to maximize the overall ecosystem value, which in turn may increase the value shared and acquired not only by a focal firm, but by the actors within the ecosystem. Utilizing sharing and circular economy trends co-creation utilize existing resources and processes to promote the stable interaction of mechanisms. Towards 2030, platform ecosystems will not only offer search, social media and ecommerce, but also provide an infrastructure on which innovation and transaction platforms are built. Novel decentralized business models do not necessitate a focal point but depicts the design of transaction content, structure, and governance to create value.

Transhumanism reflects the rise of technology-driven evolution at an unprecedented speed of change, propelling deeper questions into what it is to be human from biological, behavioral and human-machine evolutionary perspectives. By 2030, we could find greater societal focus on the sustainability, nature of humanity, values, creativity and self/social fulfillment and empowerment (Kinnula & Iivari 2019). Cognitive intelligence revolution via ascendancy of sentient tools and further possibly human orchestrated self-directed selection in biological, neurological, and physical evolution.

Approaches of alternative compute such as *Quantum computing* as compared to the classical "calculus" computers is at its best in sorting, finding prime numbers, simulating molecules, and optimization, and thus could disrupt segments like finance, intelligence, drug design and discovery, utilities, polymer design, AI and Big Data search, and digital manufacturing. For long the technology may be limited to selected industries, such as military, national laboratories, and aerospace agencies while other alternative approaches of compute to help handle greatly increasing level of parallelism in algorithms may be available more widely.

According to *Net neutrality,* ruling Internet access providers should treat all traffic equally irrespective of sender, receiver, content, service, application or device in use. At the same time, the 5G evolution is already developing a network that can be extremely tailored to specific use cases intending to treat traffic differently for each use case. This legislation creates uncertainties by impacting companies' capabilities to create and capture value in virtualized network-based services between telecom operators and cloud providers. One of the key uncertainties is how should edge computing be provided under strict Net neutrality, e.g., as in Europe. Furthermore, it impacts capabilities to provide cyber security needed for the era of merging the physical and the digital worlds that is now happening (Kantola 2019).

3.2 Novel 6G Business Scenarios

Based on the collected data and identified trends and uncertainties, the following six scenario logic dimensions and their end points were selected to develop future 6G business scenarios as summarized in Fig.3. Identification of forces

was done   by choosing key trends and uncertainties based on their anticipated impact and predictability of consequences and uncertainty. The scenario logic was selected to represent the most significant uncertainties of the overall system under scrutiny by selecting two unrelated polar dimensions. The six scenario dimensions were categorized into three themes in order to develop a total of 12 alternative 6G business scenarios which are discussed next.

	Scenario theme#1 – User experience	
Standardized	User experience (E)	*Customized*
Societal / corporate	Resource orchestration (P,L)	*Individual*
	Scenario theme#2 – Business	
Incumbent customer lock-in	Value creation (E)	*Webscales/OTT, Novel service providers*
Supply-driven, Proprietary	Value configuration (E)	*Open Ecosystem driven*
	Scenario theme#3 – Sustainability	
Stagnation	Sustainability goals (S, EN)	*Redefinition of economy*
Centralized power	Power configuration (P)	*Poly-nodal world*

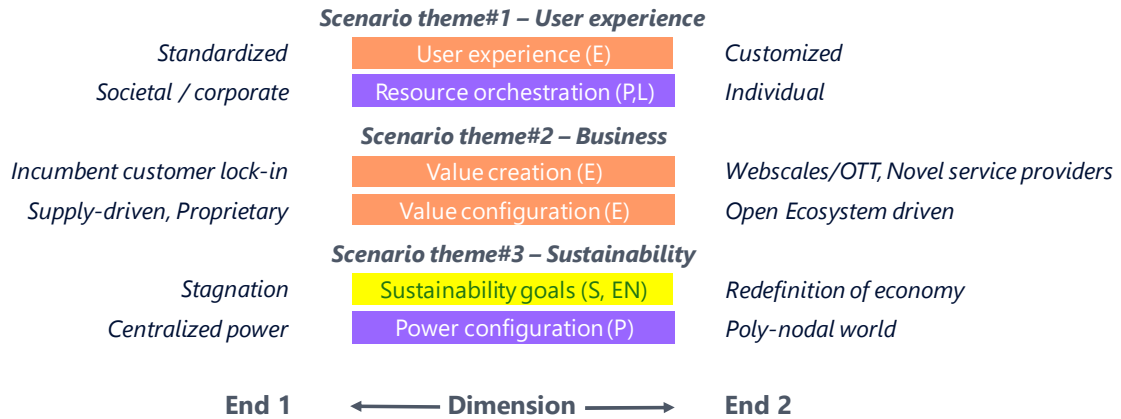**End 1** ⟵——— **Dimension** ———⟶ **End 2**

Figure 3. Summary of selected scenario logics.

3.2.1   Scenario theme#1 – User experience

In the user experience scenario theme, we chose horizontal dimension to present resource orchestration and vertical axis user experience as depicted in Fig.4. Opposite polar dimensions of the resource orchestration axis are societal / corporate and individual driven orchestration. User experience logic ends are traditional standardized service provisioning and the opposite driving customer engagement with customized long tail service experiences. Using these two scenario dimensions, we have developed four scenarios as shown in Figure 4 and discussed in the following.
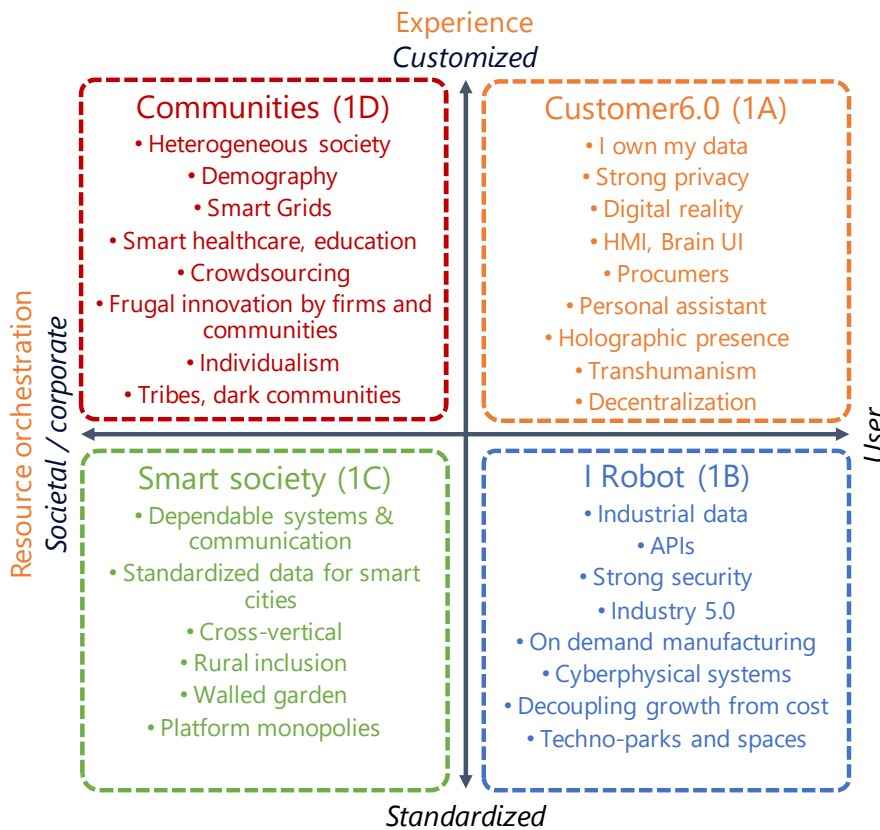

Figure 4. Scenarios based on user experience and resource orchestration.

Customer6.0 (1A) Customized experience & Resource orchestration by user

In scenario Customer6.0, user experience is customized, and resource orchestration is user centric. 6G technology has penetrated most parts of the world. IoT devices and sensors controlled by AI are a normal part of environment nearly everywhere. Automatic collection of different kinds of data from humans as well as from our environment and its analysis are used for highly sophisticated products and systems that make people's lives easier and provide better user experience through convenience as everything is automated. Prices of the systems are very reasonable due to opened up interfaces and standardized cheap components. Technologies of computing are miniaturized to the extent that they sustain on the power generated through everyday human activity to support the person's information devices which in turn monitor the person's vitals from time to time as well as cater to information and entertainment needs through over-the-top connectivity. The media and service consumption are being rooted in local economies, and users of such products and systems are used to living with them and cannot imagine their lives without them.

Hyperconnected and completely automated networks have been put together with public-private-personal ownership funding model with a view towards sustainable growth and usage of digital infrastructure. As counterforces to the creation of platform monopolies decentralized platform co-operatives, the peer-to-peer economy and sharing economy models and the progress of a human-driven fair data economy has emerged. Transhumanism reflects the rise of technology-driven evolution at an unprecedented speed of change, propelling deeper questions into what it is to be human from biological, behavioral and human-machine evolutionary perspectives. By 2030, we could find greater societal focus on the sustainability, nature of humanity, values, creativity, self/social fulfillment and empowerment. Cognitive intelligence revolution via ascendancy of sentient personal assistant and further possibly human orchestrated self-directed selection in biological, neurological, and physical evolution. Emerging opportunity of redefining human machine and brain-UI interface enables connecting people and the biological world in novel ways. Holopresence systems can project realistic, full-motion, real-time 3D digital twin images of distant people and objects into a room, along with real-time audio communication, with a level of realism rivaling physical presence. Images of remote people and surrounding objects are captured and transmitted over a 6G network and projected using laser beams in real time.

There is a serious threat of digital divide and inequality related to access and skills to use new technologies, knowledge, digital services and materials in individual level as well as between countries if access to new technologies is restricted. This may reflect one's working career, which also assumes activity of employees to educate individuals. High priced products and systems might not ever be a norm, but both local businesses as well as citizens can create their own frugal adaptations of the products and systems, suitable for their living conditions where even electricity may still be a scarce resource. This is supported by the global do-it-yourself culture where sharing of blueprints and working processes is encouraged. 6G will transform urban and rural living existing at the intersection of geopolitics, growth of nationalism, rights to information transparency and information citizenry. The content growth will be in terms of supporting multiple social and technological identities of people in through a variety of media. This would require a mindful view on decision making and regulation of future, data, information, media and network usage in light of sustainable growth for economy and human empowerment.

I Robot (1B) Standardized experience & Resource orchestration by user

In scenario I Robot, user experience is standardized, and resource orchestration is user centric. With the convergence of nanotechnology, biotechnology, information technologies and cognitive science (NBIC), newer application areas, goods, services and systems will proliferate. This convergence has resulted in our present development of cyberphysical systems and IoT based technologies, along with 3D printing and on-demand manufacturing, among other instantiations. In the next two decades, the growth of 6G enabled technologies will aid in the explosion of biological-based intelligence along with artificial intelligence in industrial setups. This biological intelligence will rely upon a mixture of biological-based self-programmable natural and artificial neural networks and micro- and nanobots that can be used in tandem with existing AI based automated systems. Interaction with these hybrid bio-industrial automated systems will constitute the next major revolution in programmable smart factories and industrial systems and be the source of value creation, configuration and resource utilization. In a rapidly changing reprogrammable and reconfigurable world, businesses will have a short to medium level change horizon, expected performance indicators and return on investments. The market of mid-level businesses in the industrial sector will be increasingly facilitated via agile and scalable techno-parks and spaces. The people, processes and resources required for such mid-scale businesses and services will require flexibility and rapid learning in order to transfer the learning from one job to another. This will

enable the overall value optimization to be based on the level of units of businesses housed in one techno-park regardless of their individual sectors.

While countries will continue the movement of goods in a globalized world, the nature of transfer will have a marked impact. In a world enabled with 6G technologies and 3D printing, the blueprint will be delivered to proprietary machines which will print products as required in a model of edge-based manufacturing with designs supplied and monitored through remote setups. Thus, new statements of design and manufacturing could be possible with the fine print on goods being read as "*genetically programmed in Uruguay, grown in India, to be consumed in Nepal and Bhutan*". Local-demand-supply-consumption models will become prominent in an already globalized world with a marked emphasis on localized spatial circular economies. In order to ensure independency, assurance and resilience local manufacturing is decentralized to several manufacturers, which compose together a crowdsourcing production ecosystem. Smaller manufacturers deliver items of their specialty to bigger assembling manufacturer who delivers the final products. Orders can be handled fast and dynamically based on each stakeholder's timely capacity to deliver items. The robotized production plants can be operated remotely through virtualization. Managing the ecosystemic network of small manufacturers utilizes blockchain technology for supply chain management, smart contracting and transactions. Production sites can be transported to new locations enabling remote controlled worksites and heavy-duty vehicles. The production models are driven by sustainability, resilience and circular economy.

I5.0 will allow collaborative human-machine interaction (HMI) with robotization across services and industries as human intelligence is in perfect harmony with advanced, cognitive computing. With real-time data, effective data monetization and digital automation of the manufacturing process, businesses will be able to shift focus towards generating higher revenues from servitization of products. Open interfaces and advanced manufacturing capabilities will help to overcome design complexities and with its ability to facilitate extreme long tail of mass customization and further return the control back to customers and in a haptic way. Furthermore, trustworthy quantum enhanced I5.0 networking and services will provide highest standards of safety and environmental protection.

The use of programmed organisms is becoming increasingly common in production. Genetic engineering and synthetic biology enable the creation of new kinds of organisms as well as the modification of existing organisms for specific purposes in food production, chemical processes, textiles and in the pharmaceutical and construction industries, for instance. This will decouple growth from cost and resource usage. In interaction with the hybrid bio-nano-artificial intelligence the operators and maintainers of industrial technology will be forced to adopt a special synchronicity with these technologies, which in turn are adaptive to the workers. Unlike the industrial revolution of the 1900s where the human had become subjugated to the rhythm of the machine and brought about a backlash on the mechanistic life brought about by modern times, the new technological revolution of industry 5.0 enabled by 6G technologies will bring about a new rhythm that links the biological dimension of the machine to that of the human. This will impact the human at sub-awareness levels bringing about heightened nervousness, anxiety and generalized discontent. However, unlike the early 1900s, the humans will not be able to point to any immediate cause of general malaise. The toll on the psychological health may be enormous but hidden in plain sight.

Smart society (1C) Standardized experience & Resource orchestration by society/corporations

In scenario Smart society, user experience is standardized, and resource orchestration is society/corporations centric. Technology is developing rapidly, changing production methods and operating models. More and more things can be automated, production and operations can be decentralized, and interaction can take place remotely or via a virtual environment. This assumes continuous learning from individuals to keep track on development and to evolve one's professionalism. Making use of technology increasingly calls for changes in thinking models and operating methods. Gamification of working life may offer motivation for some people frustrated by the changes. Smart society builds dependable systems and communication where standardized data is utilized by walled garden platform monopolies across verticals. Smart city focus is extended to rural inclusion. Multi-locality is a norm to combine city life and isolation from crowds. 6G will transform urban and rural living existing at the intersection of geopolitics, growth of nationalism, rights to information transparency and information citizenry.

Dependable communication system that allows remote work and telepresence in a real-time mode results in knowledge-based jobs and other net-based service sectors to shift towards a bucolic life where urban and rural life remains in a healthy balance. The change in lifestyles will enable an emphasis on the collaboration for the common

good and making society more inclusive of the requirements of disparate cultures and subcultures. In this regard, there will be a marked shift towards appropriate data and privacy regulation to support vested interests and motivations. In this smart economy, consumer insights, virtual finance, carbon free consumption, low energy consumption and global and fiscal sustainability will take center-stage. Thus, there will be an expansion of social intangible economy that involves several types of online gaming, social media exchange, interaction in virtual holo-presence interactions, and other forms of exchange in digital currency. There will also be a rapid convergence of these various interactions such as making online groups, communities and institutional rules that will aid in information citizenry and a reciprocal impact on real world global issues.

The most important global concern will be ensuring mutual respect to people from all strata of society. This will be possible through digital inclusion in all sectors ranging from finance to education. The aim will be to create a just and egalitarian society through the use of appropriate regulation of information and mutual distancing through the creation of safe and creative collaboration spaces that support the interests of like-minded groups. Actions at the level of individuals supported by 6G technologies will provide a morally sustainable world, where every citizen will be a self-aware informed citizen having a dual-identity: recognizing the allegiance to the nation as well as living within the constraints of the global pan-dimensional virtually connected world.

Communities (1D) Customized experience & Resource orchestration by society/corporations

In scenario Communities, user experience is customized, and resource orchestration is society/corporations centric. The sense of community created by 6G technology and the ability to directly collaborate with others enables humans to participate and act in society in an unprecedented way in the countries where access to new technologies is a norm due to competencies and skills to use new technologies. The sharing economy, crowdsourcing and crowdfunding are expanding the space for new forms of organization and innovation.

In the heterogeneous society, social networks and the trust and reciprocity they foster are highlighted from the perspective of well-being as well as working life. Public network funding has traditionally been directed to unserved and underserved areas in terms of broadband access and coverage. Lately support for deployment programs will be extended to policy areas, such as smart city community development, worksites and ecosystems (such as harbors and airports), advanced health services, logistics and transport, public safety and critical infrastructure at length. Hyperconnected and completely automated smart grids are extended to a variety of vertical sectors including electricity, internet and healthcare serving as a middle layer between humans and natural environments enhancing the capabilities of both. These networks have been put together with public-private-partnership funding model with a view towards sustainable growth and usage of digital infrastructure. Human body is a vital part of internet of senses, and increased data enables more personalized and preventive care where AI assisted analysis monitors personal indicators and compares with larger population data offering medical doctor consultation by a specific indicator trigger point. Biological processes and communication systems integrate with technical communication systems giving us on-line information of vital transactions guiding us to take specific actions to stay healthy. In case of infection we receive continuously updating diagnosis to be shared in real-time with the health care professionals, who base their consultancy on artificial intelligence driven analysis. Furthermore, for example, new treatments are being developed based on genome editing and modifying the microbiome, for example.

Countries with less restrictive legislation act as resource pools for corporations by providing cheap labor force, natural resources, and (private) data of humans (use data, biodata, biological data, etc.). Frugal innovations are developed to serve the growing customer base in low-income countries. Internet of skills and internet of senses powered education enables specialization from early grades of school system. Learning is tightly connected to personal data to react to any disturbance and to ensure successful study track based on individual interests. Students can choose virtual courses and degrees from any university globally and visit the digital twin campuses for interactions. Global networking during the studies support international career planning, which is partly done remotely.

A number of ethnic communities have struggled to maintain their existence in everyday and virtual spaces. The nature of communities will change in varieties of ways and in terms of a varying timescales: fragmentation of communities, dynamic tension between the individuals and communities, morphing of community values and identity, among many others. Radicalized groups have emerged spreading terror both online and offline. The spread of cyber terrorism could possibly effect all of networked systems of the world resulting in a global crisis and devastating effect on world economy.

In the wake of disasters (terrorist attacks, tsunamis, diseases, etc.) 6G technologies may also support the victims. Growth of human-body-powered networked devices will help a community to establish informational relations that aid the troubled and enable the community to show resilient behavior and bounce back quickly.

At the level of communities, interaction will be in the form of interacting with media and will result in the intensification of activities related to public opinion-shaping. These include hate speech and fake news getting transmitted but also being experienced somatosensorily. This holistic experience of various forms of malevolence will have a much stronger impact in mobilizing people towards crime and terrorism though virtual technologies than ever before. The presence of online communities formed as special interest groups will continue to proliferate. However, with the 6G experiential technologies, these special online communities will move towards a more accelerated and hyper-real set of interactions. The hate speech and associated activities will not only be symbolic but also tangible. A final twist in the life of communities propelled by 6G technologies will be in terms of the "wisdom of crowds". In normal circumstances, this "wisdom" allows for a more egalitarian and informed decision making and empowerment. However, with hyper-real experiential hate of the 6G enabled vitality, the "wisdom" may become perverted without bounds resulting in a bleak communal life.

3.2.2　Scenario theme#2 – Business

In the business scenario theme, we chose horizontal dimension to present value configuration and vertical axes value capture logic as depicted in Fig.5. Opposite polar dimensions of the value configuration axes are traditional closed supply value chain focus and open ecosystemic driven configuration. Value creation customer attraction and lock-in logic ends are incumbent mobile operator dominated model and the opposite is expanded model with OTT, cloud, I5.0 and novel digital service provider stakeholders.
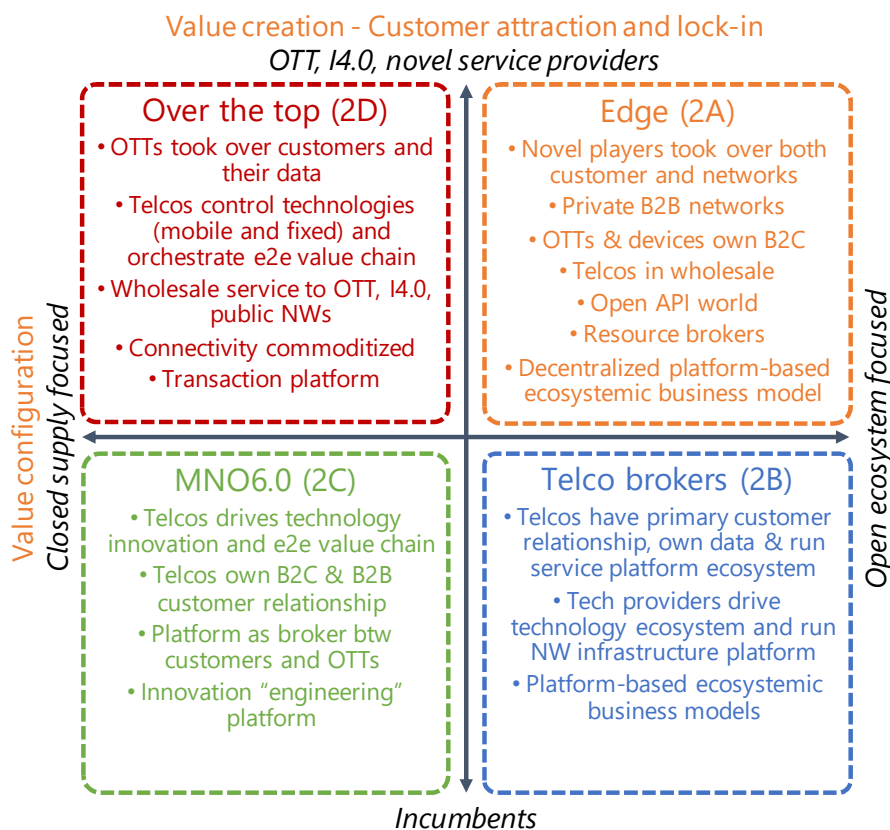

Figure 5. Scenarios based on value configuration and value creation.

Edge (2A) Value creation by novel service providers & Open ecosystem value configurations

In scenario Edge, value creation is customer attraction and lock-in driven, and value configuration is open ecosystem focused. This scenario stems from decentralized open value configuration and ecosystem- driven business models. Novel players have taken over both customer ownership and networks. OTTs & device vendors own B2C customer

relationship while local tailored private cloud native networks attract B2B customer. Telecommunication operators have role as a wholesale connectivity service provider. Technology and innovation ownership are expanded fully leveraging open API world and novel resource brokerage.

Furthermore, the edge-resources may be operated by local communities and special interest groups, e.g., in expanding services into remote rural areas or into universities and research organizations deploying their own edge resources to speed up local innovation. Nomadic sub-network edge elements will provide sustainable and ecologically efficient deployments. E.g., communities that do not desire to have invasive technologies amidst them, may hire edge-enhanced systems for high quality capture and streaming of local events once-in-a-while. Banks, health-care centers, governance points may extend the regular telecom networks for affordable inclusion of the masses. Onboarding, billing of customers via digital cash and keys can be done by these local entities, who in turn may pay the wholesale service providers for wider connectivity. These semi-autonomous 6G sub-network deployments will be heterogenous in nature, often encouraging innovative products and services. There will be specific network areas, zones. We can have very personal zone by in-body communication applications producing data for daily diagnosis for individuals or shared merely with private medical doctor. Wider zone could be a common family network, which is shared strictly between family members at home offering tailored services. Moreover, there will be particular network zones shared with various interest groups enabling dynamic management based on personal preferences and changing requirements of groups. Security, trust and Identity management in such heterogenous edge deployments will be a challenge and the opportunity for sustainable, novel business models.

Telco brokers (2B) Value creation by incumbents & Open ecosystem value configurations
In scenario Telco brokers, value creation is driven by the incumbents – the existing operators, and value configuration is open ecosystem focused. Telco brokers have kept primary customer relationship and have focused on monetizing data via service platform ecosystem. Technology providers are driving technology ecosystem and offer efficient network infrastructure via platform-based ecosystemic business models. Decoupling of technology platforms have lowered the entry-barrier allowing multiple entities to contribute to innovations envisaged with 6G. Moreover, fine-grained modularity and open source, allows highly specialized long-tailed solutions and services from smaller payers to be widely deployed, leading towards innovation and possibly to commoditization.

MNO6.0 (2C) Value creation by incumbents & Closed ecosystem value configurations
In scenario MNO6.0, value creation is incumbents driven, and value configuration is closed supply focused. In this scenario telecommunication firms drive technology innovation and controls traditional e2e value chain and own customer relationship in both the B2C and the B2B segments. It is strongly under MNOs' business driven decisions how the advanced services enabled by 6G technology are available for various verticals. Key technology enablers utilized as prerequisite for decoupling of cost from growth are automated network slicing and leverage and usage of higher frequency bands in conjunction with network densification. In addition to technology innovation platform, they have established a transaction platform position between customers and OTT players. This tightly coupled deployment may provide optimal efficiency with respect to efficiency, environmental sustainability and technology exploitation at the connectivity layer. Via opening up network interfaces, the telecom firms co-develop within their value chain and open source software to address long-tail of specialized local and industrial use cases.

Over the top (2D) Value creation by novel service providers & Closed ecosystem value configurations
In scenario Over the top, value creation is customer attraction and lock-in driven, and value configuration is closed supply focused. In this scenario OTTs have taken over customers from the telecom operators through utilizing their access to customer data. On the other hand, operators continue to control both the mobile and fixed connectivity technologies that are commoditized and orchestrate related e2e value chain. Commoditized connectivity drives operators to create partnerships with OTTs, I5.0 service providers, public networks and to provide wholesale services utilizing their transaction platforms. OTT players offer novel free or subsidized connectivity business models, utilizing revisited net-neutrality principles, expanding their reach to the bottom four billion in an affordable manner.

3.2.3 Scenario theme#3 – Sustainability
The sustainability crisis, which refers to the deterioration of the environment and exceeding Earth's carrying capacity, may significantly change our operating environment towards 6G era. This scenario theme particularly recognizes the UN SDGs as important drivers for 6G, but the approaches vary. Responding to the increased environmental awareness

requires changes in culture and practices and has been accompanied by a polarization of views. Hybrid military, economic, technological and cultural powers have become overlapped, and exercise threats and hybrid influence. In the sustainability scenario theme, horizontal dimension represents power configuration and vertical axis sustainability development as depicted in Fig.6. Opposite polar dimensions of the power configuration axis are centralized power and poly-nodal configurations. Ends of the sustainability dimension are redefinition of economy and its opposite of stagnation.

Sustainability
Redefinition of economy

The race (3D)
- Creative destruction
- Vibrant mega cities
- Unicorns, superstars
- Innovation competition
- Time to market
- Eco-dictatorship

Gaia (3A)
- Transhumanism
- Real time economy
- Circular economy
- Societal resilience & trust
- Restorative economy
- Innovating to zero
- Fair distribution of wealth
- Broad empowerment
- Values driven

Power configuration — Centralized power ← → Poly-nodal world

Dystopia (3C)
- Backlash
- Rage against machines
- Populism
- National interest first
- Consumption culture
- Monitoring world
- State corporations

Multi-local (3B)
- Emerging economies
- Distributed production
- Public private partnership
- Transformation of work
- Fragmentation of economy
- Tribalization
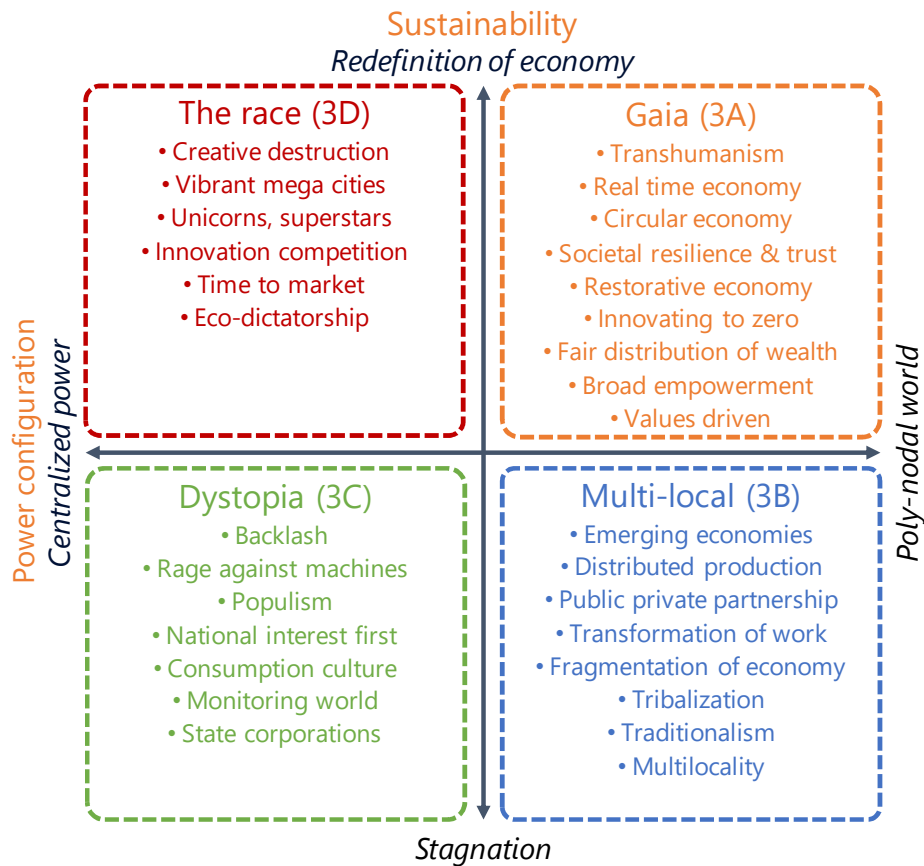- Traditionalism
- Multilocality

Stagnation

Figure 6. Scenarios based on sustainability and power configuration

Gaia (3A) Sustainability by redefinition of economy & Poly-nodal power configurations
In scenario Gaia, sustainability is redefinition of economy driven, and power configuration is poly-nodal world focused. Environmental awareness among people has increased and resulted in corresponding actions. Dissatisfaction with the current measures taken with respect to climate change and biodiversity has motivated a growing number of people to voice their opinions and participate in demonstrations. Instead of individual poles of power, the emphasis in global politics is on relationships and interaction. In addition to governments, other players, such as businesses, lobbyists, think tanks, international institutions and cities, activist organizations, play a significant role in this. In 6G enabled real time economy all the transactions between business entities are in digital format, generated automatically, and completed as they occur without store and forward processing. In innovating to zero, the cost of renewable energy and storage is falling. Energy production will also become increasingly decentralized as more and more people produce their own energy and sell what they do not need. The circular economy in which production and consumption are planned in a way that prevents waste from being generated while materials and their value remain in circulation via sharing, leasing, repair and reuse. In this context deploying 6G could mean for example an application area to provide ultra-low-power communications through energy harvesting or wireless power to very small devices. The counterforces to winner-take-it-all monopolies include platform co-operatives, the peer-to-peer economy and sharing economy models and the progress of a human-driven fair data economy and fair distribution of wealth. This restorative economy will lead to a society characterized by broad empowerment, greater equality, a higher level of well-being and better sustainability. Internet of senses and internet of skills utilize advanced human machine interfaces to enhance human intellect and

physiology towards transhumanism. In Gaia scenario, societal resilience provides the ability to cope with and overcome adversities, ability to learn from past experiences and adjust to future challenges and ability to craft sets of institutions that foster individual welfare and sustainable societal robustness towards future crises.

Multi-local (3B) Sustainability by stagnation & Poly-nodal power configurations
In scenario Multi-local, sustainability is stagnation driven, and power configuration is poly-nodal world focused. A shift has happened in global politics from a multipolar world to a poly-nodal world. Transformation from geopolitical power blocs, US, Europe and China, towards networked world with nodes comprising countries, emerging economies, corporations and other non-state actors. In the face of disruption, people turn to more and more polarized tribes and bubbles formed around values, place of residence, political opinion, consumption choices or lifestyles for guidance. Fragmentation of economy, transformation of work and new organizational models with sharing and platform economy have challenged the traditional relationship between the employer and the employee and how the benefits are. Working life is becoming increasingly diverse and there is an emphasis on ensuring people's livelihood and competence building. Universities offer tailored virtual augmented education environments to enterprises and private entrepreneurs. Consumers favor domestic or local products and can choose themselves where and how the goods and products are manufactured. 3D -printing allows to manufacture many products at home or in the neighborhood. Distributed local production, is on one hand practiced by enterprises using a network of geographically dispersed manufacturing facilities that are coordinated using 6G, and on the other hand a local manufacturing by prosumers. Traditionalism developed as a response to the disorder and favors public private partnership.

Dystopia (3C) Sustainability by stagnation & Centralized power configurations
In scenario Dystopia, sustainability is stagnation driven, and power configuration is centralized power focused. We continue living in consumption culture where nature is seen as a free resource that we use as we wish. The wealth generated by economic growth is not distributed in a sustainable manner concentrated in the hands of a shrinking minority. Occasional large disasters do not make wealthy people to act if they are not threatened themselves. Weakened future prospects, the fragmentation of the political map and the polarizing effect of social media have led to a rise in populism, which emphasizes the division between the elites and the masses. The benefits of internationalism are not acknowledged as considered too indirect, and the negative aspects are emphasized in the discussion. Globalization has also led to an opposing reaction in the form of increased nationalism, emphasis on national borders and favors state corporations. Democracy is challenged by ideas of practical autocracy and technocracy as well as by the notion that democracy is too slow or ineffective to respond to the urgent questions of our time. The need for rapid, major changes and a yearning for simple solutions have made strong leaders more popular, presenting a challenge to individual freedom and democracy. The amount of disinformation is growing and efforts to influence opinions are increasingly geared towards instigating confusion and discord. Digitalization backlash has happened, and people are raging against machines.

The race (3D) Sustainability by redefinition of economy & Centralized power configurations
In scenario The race, sustainability is redefinition of economy driven, and power configuration is centralized power focused. The urgency of climate and sustainability action has led to eco-dictatorship and creative destruction because a voluntary change in people's behavior is considered to be so unlikely. The population becoming concentrated in a small number of growth centers, where vibrant mega cities and unicorn superstars dominate innovation addressing individual technologies and the ecosystems they form. The process of innovation competition incessantly revolutionizes the economic structure from within having time to market advantage.

3.2.4   Scenario summary

12 alternative future scenarios were designed under three embedded scenario logic themes: User experience, Business and Sustainability depicted in Fig.7. User experience can be seen as a subset of Business in the middle of Fig.7, and Business as a subset of Sustainability that forms the widest contextual level for all scenarios. To summarize the discussion on the scenarios for the business of 6G, the team proffered both optimistic and pessimistic scenarios having varied reasons for optimism and pessimism by scenario. The scenarios were assessed at the end of the workshop series. First, the likelihood of the created scenarios coming into being was assessed. The *probability* of the scenarios arising was evaluated against the identified forces influencing the scenarios. Next, the *plausibility* of the scenarios was assessed based on the coherence of the scenarios by looking at the potential alternative futures for business of 6G events that could occur within them assessing. The third step in the assessment was to see what scenarios were the most preferred

within the teams. The *preferability* assessments of the scenarios were based on the values and choices the teams made regarding the alternative futures. Teams appraised the different scenarios largely in similar way. Probability and plausibility were assessed as clearly correlating, whereas the preferable scenarios were only considered probable or plausible in a few cases even though seen as something ought to thrive for.

Both the most probable and the most plausible scenarios stem from evolutionary supply driven trends towards multi-local networked world based on strong trends with low anticipated uncertainty. The most probable and plausible business scenarios OTT (2D) and MNO6.0 (2C) were building on the balance between competition and protective market views. In the sustainability themed scenarios, the multi-local scenario sharing both the dystopic and utopist themes was seen at the same time the most probable and plausible. All the preferable scenarios Gaia (3A), Edge (2A) and Customer6.0 (1A) represent revolutionary demand driven transformations towards sustainability, empowerment and open ecosystems. They are based on high impact forces with higher uncertainty compared to most probable and plausible scenarios.
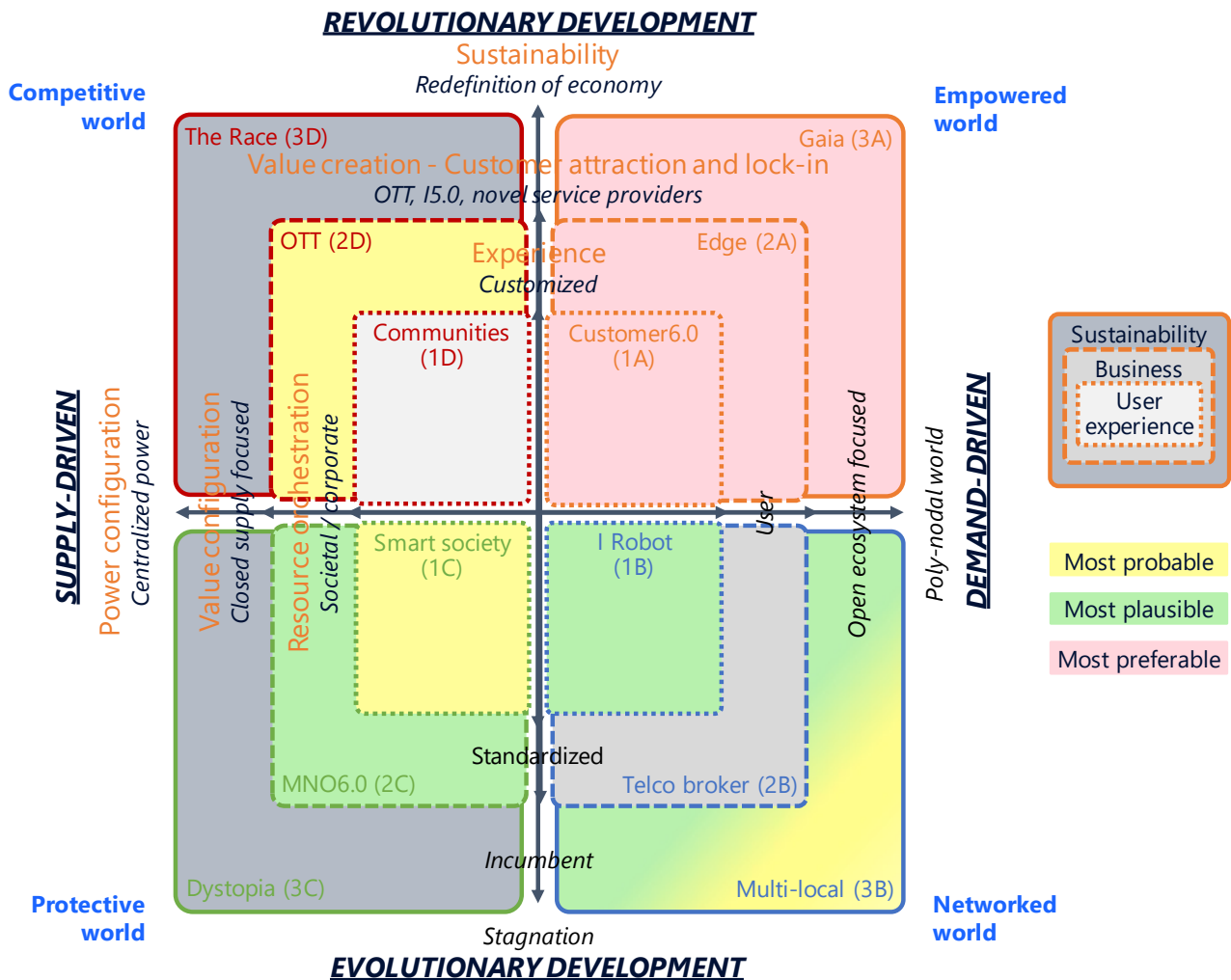

Figure 7. Summary of three scenario logic themes: User experience, Business and Sustainability.

In the preferable 6G future automatic collection of different kinds of data from humans as well as from our environment and its analysis are used for highly sophisticated products and systems that make people's lives easier and provide better user experience through convenience as everything is automated. The edge-resources will be operated by local communities expanding services into remote rural areas or research organizations deploying their own edge resources to speed up local innovation. 6G will enhance platform co-operatives, the peer-to-peer economy and sharing economy models and the progress of a human-driven fair data economy as well as fair distribution of wealth. To summarize, we identified drivers, barriers and challenges regarding the choices for developing the preferable business of 6G future

depicted in Fig. 8. These drivers, barriers and challenges could potentially concern all stakeholders in future 6G business. Key transformative global *drivers* concern climate change, sustainable development goals, and decentralization towards networked poly-nodal world. External *barriers* to preferable future scenarios are uncertainties related to power of dominating platforms, rights of AI and HMI, and regulation of resources. How to build disruptive business model leveraging sharing economy antecedents while coping with the empowered users' rights were found as key internal *challenges*.
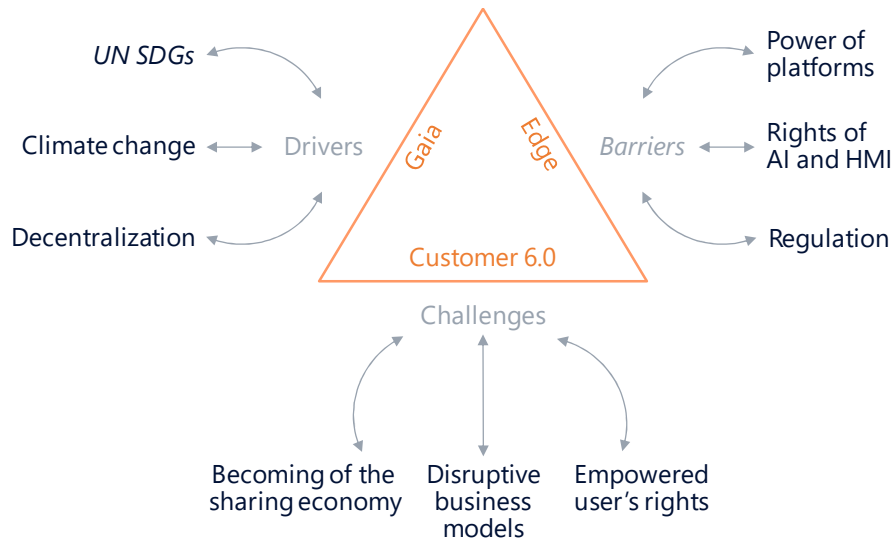
Figure 8. Essential choices for developing preferred business of 6G futures.

4. Implications

4.1 Scenario backcasting to key technology trends and enablers

Created scenarios were backcasted to key strategic technology trends identified in the scenario process and outlined in technology themed 6G White Paper workshop results (6G white papers 2020). In backcasting, the team worked backwards to figure out what key 6G technology trends and their technology enablers are needed to reach to the created preferable future scenarios from the current state. Identified 6G technology trends and enablers are summarized in Fig. 9. and positioned utilizing network architecture domains (Ziegler & Yrjölä 2020) and the phase of the technology development.

Key technology enabling themes to be explored will include the pervasive leverage of machine learning and artificial intelligence across architectural domains namely, to flexibly define air interface as well as optimize service management and orchestration in 6G "network of networks" topology and platform ecosystem. THz research is one of the prominent topics, in the sense of utilizing spectral bands of above 100 GHz for both communications and multi-modal sensing purposes, thereby enabling connectivity data speeds in the Terabit/s range. We foresee millions of sub-networks (and devices becoming the network) in conjunction with extreme performance attributes in terms of both sub-millisecond latency, high reliability and time-sensitive determinism and advanced ways to assure security, privacy and trust. In a future flexible cognitive network with self-optimizing radios, AI and ML can be used in concert with the radio sensing and positioning to learn about the static and dynamic components of the radio environment, to predict link loss events at high frequencies, to proactively decide on optimal handover instances in dense city networks and to find optimal network spectrum and radio resource allocation for base stations and users. With strong sustainable focus on human needs and global inclusion, non-terrestrial networks (NTN) extend to uncovered areas of earth and space. Furthermore, GEOs, MEOs, LEOs, HAPS and drones will be used for extreme 6G system reliability and resiliency for public safety and critical infrastructures.

Sub-networks, edge cloud computing and extended devices consisting of multiple local entities in unison enable a local and instant information service e.g., for a fast discovery of people, services, devices, resources and any local information

near the user that cannot be collected by centralized search engines. Such edge intelligence and information service platform could be used e.g., in creation of a highly local and dynamic marketplace for content, services, resources and information. Edge computing capabilities address specific service demands including bandwidth management, latency, sensitivity, security and privacy, local control and service continuity, analytics and digital automation, and support for constrained environments and energy efficiency. Digital Trust, enabled by quantum computing and distributed ledger technologies like blockchain and smart contracts provides business in a secure and predictable digital society with world-class cyber security, public safety and fintech solutions. Cloud and network providers' cloud native edge computing can become natural central points, representing the source and destination of much of the demand combined with context analytic-enabled optimization capabilities. This can create a new competitive advantage over centralized OTT services through content caching, optimized local content distribution, location services, video analytics, AR and IoT application for existing customer segments as well as for the new vertical business segments. Furthermore, autonomic security functions will be more and more applied at the network edge to protect the network by reacting to threats locally. Hierarchical security and privacy methods allow the networks to monitor and adjust network slices, virtualized elements and sub-networks according to detected security threats without human intervention.

In the cognitive network management and orchestration (MANO) layer, there are intelligence needs in self-configuration, optimization and orchestration of virtual resources and sub-networks to meet highly specialized dynamic content, contextual and event defined needs. Programmable network will utilize a digital twin as an exact digital replica of complex physical assets, processes and systems, providing a detailed understanding of how the real system is behaving and predict what it will do next. Resources and assets needed to meet the versatile needs of the network are then provided by different stakeholder roles providing physical infrastructure (facilities, structures like street furniture or indoor walls), equipment (devices, networks), data (content, context), under the regulatory framework set by the policy makers. Demands and resources are brought together through the matching/sharing stakeholder roles including different kinds of operators (local or vertical-specific operators, fixed operators, mobile network/satellite operators), resource brokers, and various service/application providers such as trust/security providers. This is supported by open accelerated platform extended from elements and interfaces towards data and algorithms leveraging IT practices and reuse of their large open source heritage.

6G technology will provide digital value platforms for the delivery of advanced extended reality applications supporting immersive mobile media experiences that stretch over the entire continuum of digital computer-generated virtual worlds. A key emphasis in the growth of digital value platforms is the convergence of multi-modal engagement with media and the physicality of lived experience (embodied interaction, mixed-media interaction, tangible interaction, among many other interaction design-based computing approaches). The related human-centered visual, audio, and interactive computing applications are seamlessly accessible through human-machine interfaces engaging the five human senses of sight, sound, touch, smell, and taste. Individual and collaborative holographic presence together with virtual 3D sound environments revolutionize multimodal media experiences and communication practices including virtual 3D teleportation in real-time. Users can seamlessly switch among any form of immersive mobile extended reality encompassing virtual reality (completely virtual world), augmented reality (enriched real world), and mixed reality (interact with virtual and augmented objects). Touch sensation for immersive mobile digital realities stretch well beyond conventional external devices like gloves, shoes, joysticks, and others but allow for much more sophisticated haptics that essentially engage the entire body. In view of the large complexity associated with a human-centered ecosystem with respect to interconnected immersive digital reality applications, a variety of visual and interactive computing technologies are employed, e.g., computer graphics, virtual acoustics and reverberation effects, advanced haptics, mobile digital reality enabled devices, and 6G connectivity. Applications of these digital realities can be identified in every vertical industry including advertising, architecture, automotive industry, design, education, engineering, healthcare, interior design, libraries, marketing, media, medicine, music, news, real estate, retail, sports training, television and film, and travel. These immersive digital realities facilitate novel ways of learning, understanding, and memorizing subjects in many sciences such as chemistry, physics, biology, medicine, and astronomy. It can move customers back in history, dive into actual artifacts of ancient times and experience related stories or propel into the future to explore exciting new worlds. Healthcare benefits from mobile digital realties using holoportation along with novel haptics for both diagnosis and treatment. Real-time shopping experiences allowing to immerse into and be present in a virtual store including interaction with products to eventually perform an actual purchase.
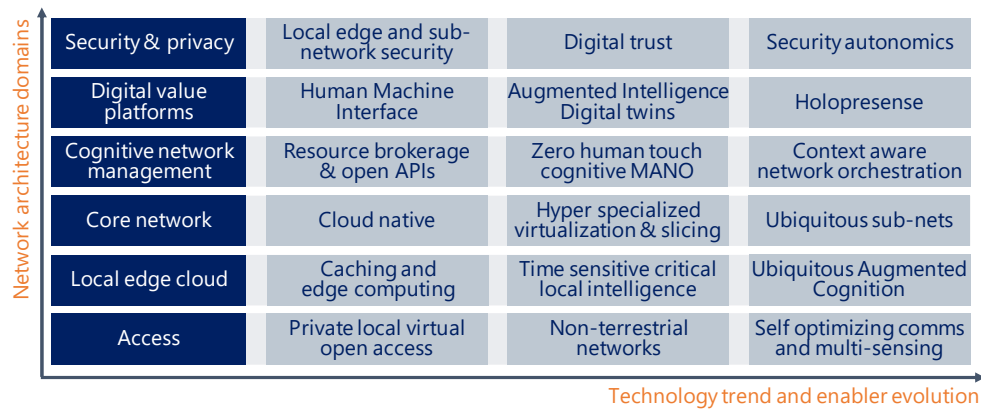
Figure 9. Backcasted key 6G technology trends and enablers by architecture domain.

4.2 Strategic options

The range of opportunities of disruptive solutions described in the preceding chapter opens up the question how to commercialize them and who are in the position of doing so; incumbent operators already present in the mobile communications ecosystem, new entrants form other ecosystems or start-ups developing novel business models. To answer these questions, the business of 6G drivers, barriers, challenges and opportunities of the selected business scenarios were further analyzed utilizing *simple rules* strategy framework (Eisenhardt & Sull 2001). Simple rules strategic options including opportunity, how to, boundary, priority, timing and exit related rules were created for the most plausible scenario MNO6.0 (2C) and the most preferred scenario Edge (2A).

Simple rules for the most plausible scenario MNO6.0.

Simple rules for the traditional mobile network operator evolution in the *Scenario MNO6.0 (2C)* is depicted in Fig. 10. The opportunity for businesses can simply be seen to lie in the utilization of MNOs' wide existing customer base with growing demand for capacity. Fast access to new wideband spectrum, preferably avoiding coverage obligations, enables to continue the utilization of the dominant position in the markets. Dynamic flexibility, shortened time-to-market as well as massive cost optimization will be enabled by leveraging a paradigm of automation and dynamic instantiation of thousands of slices on demand. An automated marketplace of resources, services and performance attributes will be enabled. ML/AI based analytics and cognition will be driven by metadata architecture and federation, and predictive triggering of corrective measures from intent/usage-based prediction of new services/business needs will become the norm. In such a scenario, verifiability and trustworthiness of the network will require security guarantees and proofs. Service driven network management as well as automating related network management tasks for efficient and flexible extraction of value is likely to be at the heart of MNO6.0. Dynamic service provisioning is a key enabler for automating monetization of available performance capacity. For spot markets of resource with certain performance attributes, automated service management is expected to be the key enabler across the network with full KPI granularity. In some locations, enhanced small cell deployments can be used for providing premium quality of service (QoS) connectivity. All investments should be made to strengthen customer lock-in and dominant market position in connectivity and as regulation allows enhanced with customer data. This could be reached by acquiring, if possible, all available spectrum, and by combining existing and new spectrum assets to deliver high data rates. Also, becoming a wholesale and hosting platform provider for other operators could enhance utilization of the dominant market position. To strengthen market boundaries, dominators could leverage their installed base, existing sites, and Third Generation Partnership Project (3GPP) evolution in the build-up of spectrum-sharing-based asset businesses. MNO6.0 could also try to turn novel connectivity service providers into mobile virtual network operators (MVNOs). Direct contact with the regulator is needed to remind the regulator that earlier investments in the networks have long enough payback periods. A supply-side platform -based regulation logic is called for and lobbied as a means to define and provide a required level of privacy and security for the users. Regarding decision priorities, retaining control over the network technology and related spectrum and keeping cognitivity in the network is essential. In order to serve verticals edge computing will become a new control point. Local sharing with other Webscales and OTTs could follow the potential for internal asset leverage has been reached in order to reach media content and industrial data. Regardless of the business model utilized, MNO6.0 should never give up spectrum — even if not fully utilized and customer data.

Opportunity	How to	Boundary	Priority	Timing	Exit
Premium connectivity	Scale, dominancy	Existing assets	Keep spectrum control	Heterogeneous networks	Keep exclusive spectrum
Personalized data and media	Leverage all spectrum assets	Scale and harmonization	Share from other domains	Offloading	Protect network data
Wholesale and hosting	Virtualization and slicing as-a-S for new segments	Lobby policy	QoS sharing	QoS sharing	Monetize customer and telco data
Telco data monetization	Broker telco data to verticals and enterprises	Delay horizontal sharing	Keep sharing voluntary	Wholesale & hosting	
Innovation technology platform	Drive technology innovation and e2e value chain	Delay neutral hosting	Enhance QoE	Complement TV & media delivery	
Brokerage btw customers and OTTs	Partner with broadcasting and media	Co-opetition with novel operators	Premium ARPU services	Broadcast replacement	
			Serve verticals		
			Broadcasting asset synergies		

Figure 10. Simple rules for the traditional mobile network operator in the MNO6.0 (2C) scenario.

Simple rules for the most preferred scenario Edge

For the novel 6G operator in the *Scenario Edge (2A)*, the opportunities are quite different from those for the MNO6.0 as depicted in Fig. 11. The opportunity is in the utilization of new, local, and specialized demand challenging the incumbent MNOs in narrow business segments specializing in governmental, municipal, vertical, or enterprise customers, or differentiation with special mobile devices, mission critical communication or Web-scale cloud-based services. Furthermore, vertical differentiation can create advantage in specific industry segments like education, health care, manufacturing, logistics, mining, energy, media and entertainment and eSports. The users of the 6G will expect that future interactions will be built around human-centered end-to-end experience as a dominant concept. In addition to human-machine-interface to networks and devices, empowered "Experentials" value access to "internet of skills" expertise and the ability to evaluate and reflect on the technologies and their role in the user's own life as well as more widely in the society. Experentials' experience of being able to influence things and feel that they are important is essential in all forms and work sectors, whether they revolve around entertainment or factory work. For a company to succeed, the questions asked will be in terms of "what makes our process unique for experentials"? Managers will be involved in addressing the boundary rules required for focusing on which aspect of user experience will they cater to or assign ranks to various modes of customer experience. They will also require a set of timing rules to tune into the market and exit based on their anticipation of key modalities in customer experience.

Thinking and acting locally, close to the customer, and promoting resource sharing and utilizing lowest cost spectrum and virtualized cloud infrastructure may open opportunities to scale-up from local operations to multi-locality business. The benefits of deploying private networks include: security and data control with full separation from public networks, access to premium services in locations not reached by public networks, extreme flexibility, scalability and customization via novel orchestration interface and automation, trustworthy reliabilities and latencies and autonomous deployment planning of cluster-based and dense networks with node level intelligence as well as predictive analytics of system reliability and link quality will help to comply. ML/AI will be a pervasive enabler for such scenarios of cognition. Furthermore, predictive analytics could be used to adjust physical layer communication and wireless networking cooperative protocols. Access points and distributed units will act as a huge distributed sensor to locate users and machines with very high precision and get clarity about their physical states. The option of fusing other sensors such as optical and sound into such scenario will greatly contribute to augmented reality vision and digital twin vision. Organizations can build and operate their own sub-networks, buy solutions from equipment vendors, systems integrators, cloud providers or as-a-service from a wholesale provider. Networks are likely to be extreme-edge and edge centric as well as data flow-based across the network. Workloads will be dynamically scheduled to different tiers in

hierarchy of data centers across network topology. Network functions and service function chains will be assigned dynamically based on the optimal balance between consumed and available resources, connectivity and latency requirements and energy consumption targets through on-line multi-object optimization algorithms. Service discovery must operate at the transaction time level to match the changing context and resource allocation situation across the distributed cloud facilities: this may lead to refactoring and distribution of network functions. Networks can be deployed as standalone (sub-)networks, or integrated/semi-integrated with existing public operator networks taking a complementary role in the markets. This calls for a multi-sided platform -based regulation that goes beyond spectrum regulation to govern the more important privacy and security of users even on rules based on community governance. As some will build the network but outsource operation, maintenance or support. They could also adopt a boundary-reinforcing role by seeing the local regulation as an opportunity and trying to turn service fragmentation into a source of competitive advantage. Regarding priorities in decision making, Edge must pay attention to customer value and quality of experience (QoE). By focusing on operational efficiency, zero touch slicing and automation, and investment minimization, they could try to do business where and when free of low-cost spectrum is available spectrum commons, local licensing or sharing. As an exit plan, Edge could consider becoming virtual operators focusing on customer ownership and control point at the edge.

Opportunity	How to	Boundary	Priority	Timing	Exit
Mass-tailored end-to-end services to various B2B segments	Innovation and transaction platform	Leverage new policies and regulation	Gain access to (shared) resources and assets (not to own)	Where locally licensed, shared spectrum available	Keep access to edge cloud control point
Connectivity with guaranteed security and privacy, local data and optimized quality of service	Cloud native services at edge	Utilize long tail service fragmentation as advantage	Value of services and QoS SLAs	Lease from license holders	Protect and monetize customer data
Edge cloud as a platform	Plug-and-play fast time-to-air	Co-opetition with cloud providers	Serve verticals	Partner with wholesale	Leverage industrial data, digital twins
Serve empowered "experentials"	Automated MANO of local services		Extreme automation for efficiency	Utilize resource brokers	Become virtual operators focusing on customer ownership and control point at the edge.
	Leverage access to local spectrum assets		Cloud asset synergies		
	Partner with application developers				

Figure 11. Simple rules for the novel 6G operator in the Edge (2A) scenario.

5. Discussion and future research topics

Next, the developed scenarios are analyzed and positioned utilizing the integration of ecosystem-focused business model configuration and open value configuration framework (Xu 2019) as summarized in Fig. 12. Gaia, Edge and Customer6.0 scenarios can be seen to transform business towards open ecosystem focused configuration stemming from customized user experience, attraction and lock-in by OTTs, I5.0, novel service providers and building on sustainability, empowerment, and redefined economics values and networked poly-nodal decentralized power configuration. Centralized and community-based OTT, Communities and Race scenarios utilize mixed value configuration and demand focused business models while keeping the focal point of value capture. Protective scenarios MNO6.0, Smart Society and Dystopia build on closed supply focused value and power configuration. These incumbent-power-based stagnated scenarios are evolved towards opened demand focused networked business in scenarios Telco Brokers, Multi-local and I Robot.

When analyzing the scenarios, we find main forces, trends and uncertainties, to stem from common 5 meta trends identified by Sitra (Dufva 2020): *the need for ecological reconstruction; the strengthening of relational power; the ageing and diversification of the population, the redefinition of the economy, and technology is embedded in everything*. Furthermore, the scenarios at each level – user, business, sustainability can be seen as parallel as they do not exclude the existence of the other scenarios. Therefore, additional insight can be achieved by cross-examining their contents, linkages and tensions at different levels such as markets, verticals/industries, ecosystems/networks, business models/strategies, products/services, customers/segments and different types of users. This cross-examination reveals a consistency in the importance of privacy and security issues related to business and regulation needs across all scenarios; public/governmental, corporate, community and user(s) perspectives to and aims of governance; ecosystem configuration related to users, decentralized and community business models and platforms; user empowerment; and the role of location-specificity of 6G services. To summarize, we identify five key perspectives and themes as indicators and signposts that can provide advanced insight into how or which of these scenarios will actually unfold. First, time to market in 6G via monitoring what of the businesses in Fig. 12. will emerge first? Second, complementarities, potentially large spill-over effects and the competitive landscape within the industry in particular to observe platform wars expected to emerge. Third, analyzing appropriability regime, bottleneck assets, and who is profiting from innovation and how. Fourth, assessing the antecedents of the sharing economy, and finally, the recognition and deployment of sustainability goals and redefined economy.
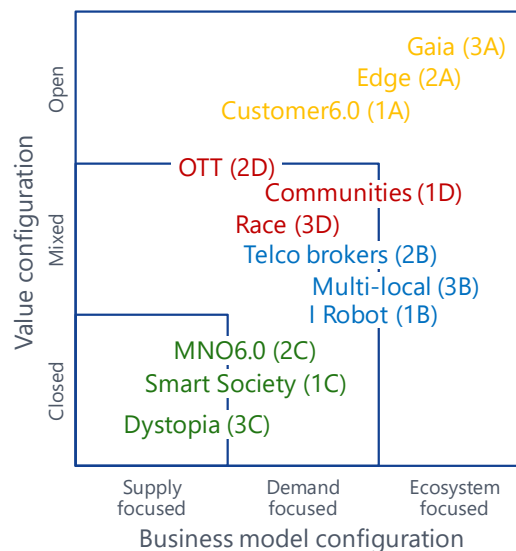

Figure 12. Scenario positioning in the integration of ecosystem-focused business model configuration and open value configuration. Framework adapted from (Xu 2019).

The practical implications of the research are twofold. First, the twelve alternative integral business scenarios presented can be used as a baseline for conceptualizing potential novel ecosystemic business models for emerging 6G business ecosystem. Second, the simple rules strategic framework utilized to deepen scenarios will allow ecosystem stakeholders to create strategic options and indicators in exploring novel 6G opportunities. The previous chapters indicate of a multitude of alternative future business opportunities and models for different 6G ecosystem stakeholders. Due to this, we propose to pay attention to business models as a way of thinking and pay attention to ecosystem stakeholders' business model related choices regarding opportunities, value add and capabilities and expected consequences as scalability, replicability and sustainability. With right business choices opportunities are identified to be related to novel and unmet needs, new types of customers and service providers as well as interfacing humans to machines. New value add is seen to come from real-time and trustworthy communications, local data and intelligence, and the commodization of resources in 6G as the competitive advantages of 6G include extreme capacity and security, transaction and innovation platformization and ubiquitous access. The expected business consequences of scalability may be related to the long tail of services, dataflow architecture, automation, and open collaboration between partners; in terms of replicability to purposefully designed modularity and complementarity within platforms; and sustainability

to empowering users and communities and the utilization of sharing economy mechanisms in the markets. Fig. 13 summarizes these key elements of business model thinking.

Opportunities
- Private networks
- Unmet local service needs
- Human-machine-interface
- Serve "experiential" prosumers

Value
- Real time trustworthy
- Immersive human experience
- Network as a multi-sensor
- Local data & intelligence
- Resource marketplace

Advantage
- Extreme capacity
- Security, privacy & trust
- Transaction platform
- Ubiquitous cognition access

6G Business

Scalability
- Dataflow design & arch.
- Zero touch automation
- Specialized tail of services
- Open collaboration

Replicability
- Cloud native platform
- Native I5.0 support
- Service agility
- Modularity & complementary

Sustainability
- Sharing economy
- UN SDG impact
- Empowered users and communities
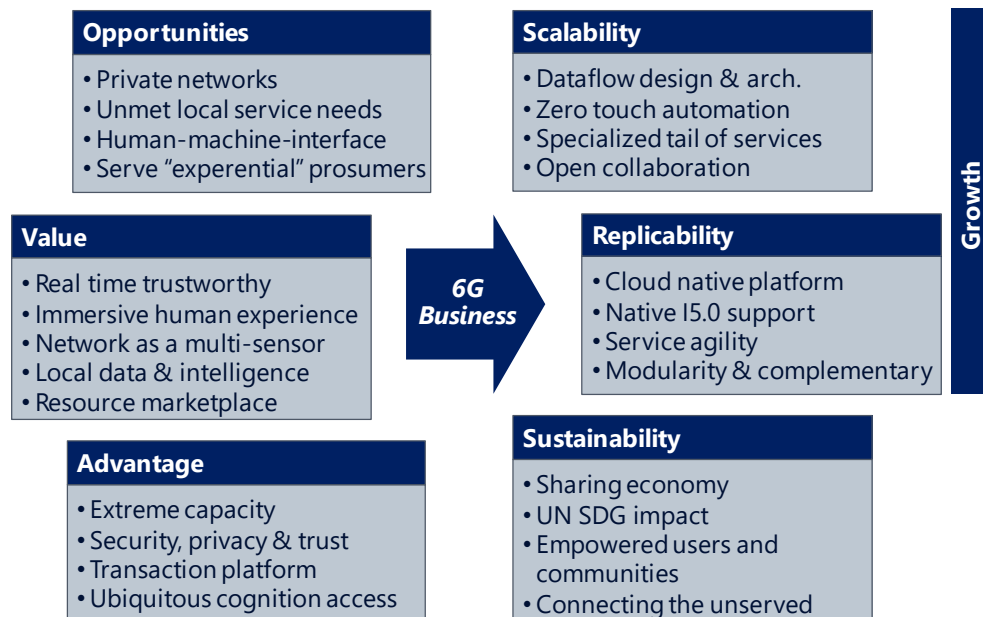- Connecting the unserved

Growth

Figure 13. Strategic 6G business model choices, activities and their consequences summarized.

The scenario, simple rules and business model analysis leads attention to the dynamics of platforms and ecosystems in 6G. The business models as enablers of ecosystemic interaction and open value configuration is well established in the business model literature (Gomes et al. 2018; Xu 2019). However, digital convergence across industries and multi-level platforms and ecosystems in 6G are creating complex strategic environment that can lead to incomparable and distinct opportunities as well as emergent problems. In particular, there are unanswered questions relating to the ecosystemic business models in the context of sustainability. According to our findings, business ecosystem that aim to bring together stakeholders to solve systemic sustainability problems will need open ecosystem focused value configuration and decentralized poly-nodal power configuration focusing long tail of specialized user requirements that crosses a variety of industries. Furthermore, based on the results of the simple rules strategies, opportunity-driven business models of the novel digital service providers serving customer of the future are seen as a sound point of departure to initiate discussion for designing the ecosystemic business model.

To reach an actionable 6G future, types of multi-level platform interaction need to be reconsidered as it is not only platform owners' business models that are of importance as also platform developers, integrators, managers, and users need to be able to reach scale and scope benefits in 6G to be successful. In profiting from 6G innovation pervasively, collaborative standards development, modularity and complementarity of technological solutions are of importance. This raises difficult openness, transparency and control as well as collaboration vs. competition issues especially in the use of data and algorithms, such as AI, as evolution of complementarities of different kind are needed for reaching the network effect. In addition, technological complementarities are needed so that the various technological innovations created complement each other in commercialization. This is important if we wish 6G to become a pervasive general-purpose technology rather than just an enabling technology with complex technical dependencies that are difficult to avoid when separate companies are commercializing different parts of 6G technologies and solutions (input oligopoly complementarity). Finally, consumer and production complementarities are required to efficiently regulate, standardize and balance supply and demand of 6G services.

However, it is not enough that the technical, service and business infrastructures will exist in the future 6G era. It is essential to consider whether users have real access to these services: that they have the needed devices and they also know how to use those as well as the available services. There is a serious need to consider also non-users and the reasons why they are excluded; is it by their own choice or for some other reason. A deeper understanding of technology

in form of design and development skills such as e.g., programming or digital fabrication also further enhances the users' possibilities to take an active role in the ecosystem and make and shape technologies for their personal needs. This helps the users also to evaluate and reflect on the technologies and their role in the user's own life as well as more widely in the society: Who benefits from technology or service use, and how? Who experiences value? What is the real price and is it worth paying?

The limitation of this study is that the studied case, i.e. 6G, is in its birth phase of a business ecosystem (Moore 1993), thus the focal elements of ecosystemic business model scenarios will be different in phases further along in their lifecycle. Building on the discussion presented in this white paper, with roots in design, engineering and economics research, there is a need for foresight research that explores deployment of the ecosystemic business model in the 6G context with a special focus on our three nested levels of experience, value-creation and sustainability. Major questions that could shape future research are as follows:

- Who owns the networks and has incentives in making investments in infrastructure?
- Who owns the radio spectrum and virtualized network resources, and how can these be utilized more dynamically in an affordable manner?
- Who owns the data and digital twins, how to get access to data and what added value can be generated using the data in communication networks?
- How can somatosensory experience of 6G technologies support new businesses models to derive value?
- How and why and what kind of platform-based ecosystemic business models can emerge in the future wireless systems context?
- How to build and what kind of successful open strategies and business models could emerge for 6G? What role redefined sustainable economy or sharing economy principles can play for future wireless?
- What kind of new business ecosystems could arise around 6G?
- How new 6G ecosystem roles and business models may emerge and change in different scenarios also for others than platform owners?
- What kind of dynamic capabilities will be needed in 6G to sense and seize opportunities?
- How 6G could become a true general-purpose technology instead of an enabling technology?
- How to ensure equal access to the offered services, rather than only for those living in highly developed countries?
- How to ensure user empowerment in this context, so that users have a genuine possibility to take an active role in the ecosystem including design techniques for experimenting, making and shaping technologies for their personal needs?
- How to help users to take a reflective stance to technology use, so that they are able to evaluate and reflect the role and value of technology in their everyday life contexts and more widely in the society?
- How novel regulation and governance principles such as community governance may emerge in 6G?
- How to regulate ubiquitous connected cognition bridging the physical, biological and the digital world?
- How the emerging and needed privacy and security regulation can act as trigger or barrier for new ecosystemic 6G business models?

Acknowledgement

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