Future scoping of truly Human-Centric IoT and Intelligent Networks: A Foresight Approach

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ABSTRACT

As IoT and network technology become increasingly pervasive, intelligent, and thus more powerful, it will be crucially important for future, sustainable and Human-Centric IoT scenarios that humans and humanity stay in control and can exercise meaningful agency. However, despite a growing understanding that this is of crucial importance, there is no clear shared vision between the multiple stakeholders of what is preferable and how to get there. This paper therefore reports on the first intelligence gathering that is part of a larger foresight study in this respect. More concretely, we report on a horizon scanning study and expert interviews (N=9) conducted in Norway, aimed at identifying emerging issues, trends and developments that may affect future scenarios related to human-centric intelligent networks and IoT environments.

CCS CONCEPTS

• **Security and privacy** → **Human and societal aspects of security and privacy**; *Social aspects of security and privacy*; • **Computer systems organization** → *Sensor networks*; • **Human-centered computing** → *HCI theory, concepts and models.*

KEYWORDS

humanity-centric design, humane technology, Internet of Things, sustainability, empowerment, horizon scanning

1 INTRODUCTION

The Internet of Things (IoT) has a large potential to play a key role in the collective efforts towards reaching the United Nation's Sustainable Development Goals (SDGs)[41]. At the same time however, IoT and network technology become increasingly pervasive, intelligent, and thus more powerful. Therefore, it will be crucially important for future Human-Centric IoT scenarios that humans and humanity stay in control and can exercise meaningful agency in relation

with the technology [34, 35]. Currently, there is a growing concern linked to increasing digital consumption and its negative effects on human, social and societal aspects, e.g., concerning advanced surveillance and monitoring practices [49]. This concern has resulted in a increasing awareness and a change in "zeitgeist" among various actors in science, journalism, and special interest organisations [27]. Western societies are entering an era that opens for new visions concerning the relation between technology and society. For instance, it allows envisioning the design and adoption of intelligent network technologies that can ensure that humans' mind-space gets the highest form of protection to promote long-term well-being and build humans' ability to engage in democratic, free societies [16, 35]. The call for action is to create future technologies that can disallow the growth of unethical behaviour online [29], protect from digital harms [47], or even to fully disconnect from digital screens and applications [33]. As a result, it requires close interaction of those who design the technology with research communities and societal actors that have human behavior, human-technology experiences and human rights high on their agenda.

Despite this ambition, one of the prominent future expectations is that the protection mechanisms need to follow suit, as the network becomes more intelligent and automated. Otherwise, the negative impact is expected to grow in scale and may even have catastrophic consequences [47]. Accordingly, there is a need to act now to achieve a coherent future vision for genuinely humane network technology and next-generation IoT, based on a shared understanding of what that means and how this can be achieved. Although the literature in this respect remains somewhat fragmented, partly affected by challenges related to the multi-disciplinary collaboration needed to realize such shared visioning, we argue in this work that a first step should consist of mapping relevant ongoing developments and future trends that may influence future scenarios.

This paper, therefore, aims to identify and contribute to a better understanding the scope of how future technology road-maps can shift towards intelligent networks that are genuinely humane-empowering and fully human- and humanity-centered. Additionally, the work presented here aims to contribute to ongoing efforts to better understand the underlying issues and causes that will shape the practical future development of sustainable and human-centered intelligent networks. As a first step towards establishing a clear vision and associated technology road-maps that can guide this shift, this work adopts a ForSTI (i.e., Foresight in Science, Technology, and Innovation) approach [24]. Such an approach is based on understanding, exploring different scenarios to understand what are the plausible, probable, and preferable developments from multiple perspectives, how can we get there, and what is needed. The definition of Foresight is; "*The applications of systematic, participatory, future-intelligence-gathering and medium-to-long-term vision*

building process to informing present-day decisions and mobilizing joint actions"[23]. It typically considers multiple futures, has an action-oriented character, and aims to be based on participatory processes [24]. More concretely, the following research questions guided the work presented here:

(1) What are the emerging issues, trends, and developments that may affect the future of human-centric intelligent networks/IoT?

(2) To what extent can these be classified as potential drivers and barriers towards a genuinely empowering human-centric network/IoT

(3) What are the underlying implications and issues considering multi-disciplinary (relational perspectives) and operational aspects of future network development?

(4) What are the implications for future research?

To understand the contextual factors affecting the future critical areas of focus in ForSTI, an Environmental Scanning (ES) exercise is undertaken. ES refers to a future-oriented, and broad intelligence gathering exercise [24]. The methodology starts with a so-called "horizon scanning" and with conducting expert interviews as part of the scoping exercise [43]. Thus, the first step and starting point of this broader research is a horizon-scanning exercise aimed at identifying weak and stronger trends manifesting themselves from different perspectives and that will likely play a role in potential future scenarios.

In this study, we have therefore conducted a qualitative, ad-hoc, horizon scanning exercise, looking for emerging issues, trends, and influencing factors in the broader environmental context that may affect the future of human-centric intelligent networks and IoT. We also present selected findings from an exploratory study based on semi-structured interviews with experts from the IoT landscape in Norway. The semi-structured interviews deep-dive into various underlying issues and causes from multi-disciplinary experts' points of view.

The rest of this paper is organized as follows: Section 2 introduces the relevant background perspectives and developments and is followed by Section 3, which describes the methodological approach that was followed for the horizon scanning and for the semi-structured interview study. Section 4 presents the key results of both studies, which are briefly discussed in Section 5. Finally, Section 6 shares implications for future research and concludes the paper.

2 BACKGROUND

2.1 The current evolution

Prior studies have investigated future issues and technological developments in the area of intelligent environments and human-centered, sustainable design of Internet of Things services and products. For instance, previous work has focused on personalized services, end-user programming, user acceptance [7], on the design integration of sustainability and human values [35], and on planning, designing for and encouraging civic participation and empowerment for the benefit of all stakeholders [13, 45]. In this respect, [7] discussed the historical, technological development, as well as present and future issues related to Internet of Things-based products from a user-centric perspective. This overview includes issues ranging from the introduction of Artificial Intelligence to

human privacy issues in Internet of Things environments. This evolution is rooted in HCI developments in the area of IoT during the period 2012-2014 [7], where user-centricity applied to network design is focused on delivering an optimal network and application service performance, enabling optimized and smooth Experiences [26], supporting Quality-of-life [31], and enabling individual users' sustainable well-being [48].

Before the Internet of Things can take the next leap toward a new ubiquitous networked society with ambient intelligence, ending up with internet of everything, there are however several grand challenges to be addressed [35]. These include better understanding the social, technical, economical, political, values, and environmental implications of intelligent network systems [9, 16] and defining ways and mechanisms to mitigate potential negative impacts [29]. Here, the role of HCI in network technology design lies in the intersection of HCI, IoT, and AI system technology [33]. It can play a key role in the integration of sustainability factors into technical design of intelligent network systems to achieve long-term value for not only individuals, but also communities and the wider society [36, 37].

2.2 Existing sustainable design foundations

A challenge to the above is that - even though the human-centered approaches to networking have taken a new turn - the current definition of what "Human-centric" translates into in a networking context has diverged into multiple interpretations, without a clear agreement on what principles, practices, and outcomes apply. Even so, the dominant notion of "human-centredness" primarily appears to have originated from a "technology" and positivist understanding [22], with clear limitations to how social and human aspects are considered in the design [42].

Existing human-centric technical solutions in next-generation networks predominantly focus on advancing intelligent and pervasive sensing technologies embedded everywhere [14]. Such approaches aspire to the heights of technical, rational, and objective decision-making [32]. Intelligent networked machines and the associated user-interaction modalities determine, monitor, and push/nudge the people in the environment it serves towards what is considered good for their well-being and quality of life [48]. A prerequisite for re-aligning human-centred approaches towards network technology that can genuinely raise human empowerment, is to transform the technical requirements and mechanisms to reflect human values, needs and behaviors [46], and to ensure that these mechanisms contribute to safeguarding human and societal interests, first and foremost[32]. However, there is little empirical evidence of human and humanity-centric theory being translated into technical configurations, resulting in genuinely human-empowering network system design, with the associated methods, process, techniques, mechanisms, and solutions.

2.3 Emerging and stubborn challenges to design differently

The most obvious solution is to introduce careful planning, design and regulation of the Internet of Things, and future intelligent environments. However, due to their highly dynamic nature, this is very challenging to governments, meaning that legislation inevitably trails technology [7]. Thus, the technical design decisions

are largely self-regulating, and not required to uphold the most stringent ethical requirements [11]. Still, legal divergences exist regarding the obligation and limitations upon private and public actors [11], the most glaring being a fundamental power dis-balance created between those who deploy and develop the technology, and those who are subject to it [22]. With the addition of intelligent and automated features to the ubiquitous network, the more the power gap widens, even to a point where humans and communities no longer can resist or challenge the systems' power[6].

Given the above, and as different communities and stakeholders need to be aligned, there is a need for thoroughly understanding the starting points and for jointly developing and discussing different scenarios: what are plausible, preferable, possible outcomes? What are undesired outcomes and what might trigger them? And how can developments be steered in the desired direction?

3 METHODOLOGY

The paradigm shift towards developing intelligent network environments that can primarily serve human and societal priorities is just emerging [30, 32]. Therefore, the nature of a ForSTI (i.e., Foresight in Science, Technology and Innovation) methodology was the most suitable starting point to begin extrapolate a range of possible human-empowering network technology issues, trends, and developments in the near, mid and long-term horizon [24].

We started two strands of research activities that belong to the intelligence phase of a more comprehensive foresight study; namely horizon scanning and expert interviews [43]. The methodological focus, for the purposes of this paper, was solely on the initial phase, intelligence-gathering and analysis. For applying the horizon scanning method, we followed the recommendations by [1] for combining the exploratory scanning with issue-centred scanning approaches. Combined, these approaches build on identifying trends according to their anticipated development path [1]. The exploratory approach builds on the identification of *Weak Signals* and *Wild Cards* [28]. The issue-centred scanning approach builds on previously identified primary signals, that are *Strengthening* or *Weakening*. An exploratory case study approach enabled us to study trends (i.e., *"gradual forces, factors and patterns that are pervasively causing change in society"* and the drivers that influence them, emerging and weak signals (i.e., *"first indications of an emerging future change associated with society, technologies, innovations or other domains"[24]*, as well as potential Wild cards. The latter are more unexpected and unlikely to happen but have a potentially high impact if they occur [24] and therefore should not be completely ignored, as they may help to increase the overall ability and readiness to react.

The recommended methodology during the input or preparatory phase of foresight activities in the early phase of trend diffusion is to extract various perspectives on possibilities or issues pulled from foresight industry sources, press releases, web monitoring, niche academic publications, conference events, and selected interviews with experts [18, 21]. Before we started the scanning, we therefore framed the intelligence gathering from a multiple stakeholder perspective to reflect different worldviews, with particular emphasis on representing the industry, technology, policy, academic, and activist views. Representing a range of original worldviews allowed the analyses to account for the disperse interpretations, and associated technical requirements and mechanisms, manifesting themselves

in the context of human-centred networking [18]. Therefore, these methodological considerations focus the horizon scanning on the emerging, novel, and unexpected developments in the future global network industry, technology, policy, academic, and activist environments [1].

3.1 Horizon scanning

The conducted horizon scanning research activity was exploratory and ad-hoc in nature, focusing on obtaining qualitative insights from secondary desk research, incorporating existing foresight industry reports. The secondary research included an in-depth future trend analysis provided by the future's platform (an industry library of future trends and phenomena completed by industry and peer-reviewed futurists), complemented with a one-off web-monitoring, conducted in a four to six weeks time frame, starting from 20.04.22 to 31.05.22 [18]. It did not purport, however, to represent a part of continuous quantitative monitoring that identifies changes over time, as the scanning hits were not collected in large numbers but curated on the grounds of early identification of signals [18] that have the potential to lead to emerging trends and developments.

To ensure a broadening of multiple worldviews and to find open-minded and unbiased sources [24], the web-monitoring aim was to detect emerging change with pre-selected keywords outside of the industry futurists' remit. Here, we used the web aggregator tool, feedly.com, to detect and curate emerging change with pre-selected keywords. The keyword combinations were:

- Next-generation internet
- Next-generation IoT
- (Humane and Human-centred AI) or Human-centred network
- Digital human rights

From these words, queries were automatically submitted to an automated web scanning software that searched websites, Bookmarks, RSS feeds, and auto-linking to Twitter from the 20th of April to the 31st of May 2022. Applying web-based horizon scanning complemented, rather than replaced, the secondary desk research and expert interviews for the primary purpose of triangulation [43]. By looking at secondary foresight reports, futures platform databases, and a separate web-scanning, we hypothesized that we could retrieve documents of high relevance [25, 43].

3.2 Semi-structured interviews with experts

The second research activity involved interviewing experts representing industry, policy, regulatory, and academic perspectives, who were tasked with digitization and IoT in a Norwegian national setting. A total of nine respondents were recruited, as the recommended number is up to ten participants that should take part in an early foresight intelligence gathering phase. The recruitment selection criteria singled out experts who had leading, decision-making roles, such as product design leads, industry decision-makers, policy-holders, specialist scientists, and regulatory compliance officers. Another key selection criteria was for them to be actively working on aspects related to the development of next-generation network technology. A semi-structured interview method was used to gather data on a) the current human-centred

design of Internet of Things/intelligent networks and pivotal limitations b) human-centred design developments. More specifically, the experts were for instance asked about their views on current design processes and to which extent and how desired outcomes such as trust and meaningful human agency/autonomy are on the agenda. The interviews further covered aspects like the potential role of regulatory frameworks and anticipated consequences and risks for people and society linked to different future scenarios. The interviews were transcribed ad verbatim and iteratively coded for themes. In this qualitative research activity, and after studying the secondary source scanning hits related to future sustainable and human-centred network technology, and fully recognizing the awareness of the research subject, the most critical factors affecting the integration of human-centred aspects in the technology design were extracted through theme analysis.

4 MAIN FINDINGS

Figure 1 combines the early signal, weak signal, and wild card analysis with existing primary (strengthening and weakening) signals to identify the broader drivers and barriers that can have an impact on future network technology road-maps that are genuinely human-empowering. The sources were classified as strengthening (marked green), weakening (marked blue), early (marked grey), or wildcard signals (marked red). The likely future development originated from opinion leaders in credible institutions (i.e., World Economic Forum, UNESCO, EU Commissioned reports, World Futures Studies). Emerging ideas developed from credible fringe sources (i.e., Humane AI Net, One Zero, Tech crunch). Both were triangulated against the anticipated assessment of the future trend time-frame and signal classification by 10+ futurists operating in the futures platform database [40]. Each phenomenon in the database was peer-reviewed by professionally trained futurists applying a systematic research process [40].

4.1 Broader trends for future design directions

In the near future, the overall design logic of intelligent networking technology appears more likely to become increasingly scrutinized [3], and diverge depending on the value framework of the actors that deploy them, as observed in Figure 1. Moreover, in the medium to long-term horizon (outer circles), conflicting visions of future trends and developments seem to depend on the stakeholder perspective [40].

In the medium to longer-term future, the developments seem to differ to a greater extent with respect to who and what methods, tools, and mechanisms should facilitate the role of protecting the interest of the human user and society. The bulk of primary signals that originate from industry/technology/technology perspectives were mainly sourced from technology experts (e.g., Tim Berners Lee), industry (e.g., Shaping Tomorrow, The Futures Platform), and investor communities (e.g., The World Economic Forum). Here, a recurring theme is envisioning the inevitability of 24/7 privacy invasion [12] in trustless, hybrid societies. The technology itself takes on the role of public governance as a response to a decline in trust in official authorities and the rule of law, and the role of the general public is passive (see Figure 1).
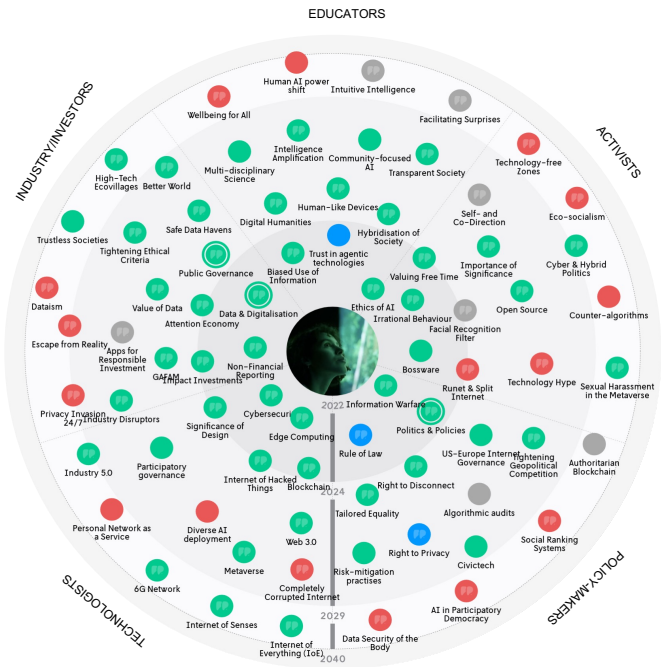

Figure 1: Broader Trends for Future Design Directions

Contrary, strengthening and primary developments, issues and trends, leading to empowerment for all stakeholders involved, originate from educators/activists/policy-makers who represent visionary scientists (e.g., [15, 27, 30, 32], interest organisations (e.g., Distributed AI Institute, Centre for Humane Technology), artists/authors (e.g., Cory Doctorow), policy actors (e.g., Humane AI Net) and human rights' advocates (e.g., Susie Alegre). These groups are alerting for significant change in the willingness to enhance human capabilities ahead of intelligent technologies, technically referred to as intelligence amplification (see Figure 2). Their future visions incorporate mitigating mechanisms that allow humans to stay in control while complimenting tasks with AI automation. However, there appears to be a split in value frameworks, moving towards new hybrid technology systems opposing each other. The break arises in hacker/activists communities vs. state institutions, identified as " Cyber and Hybrid Politics" [2, 8, 17], centralized control, direct commands vs. self-organized, decentralized networks, exemplified signals being "Runet & Split Internet" [19, 20], the Western vs. Chinese and Russian internet oversight, with signals such as "Tightenting Geopolitical Competition" detected [38].

More uncertain early signals and Wild cards similarly dispersed in the longer time frame of 2030-2040 can contrast the value framework of multiple stakeholder perspectives. Policy-makers and academics imagine a future where well-being for all is achieved with the help of humanized hybrid intelligent technology. Signals detected are "Human AI power shift" and "Well-being for all", which adjusts the design logic towards civic and community-focused requirements that eventually lead to a multi-stakeholder participatory intelligent system (see Figure 2). Industry/investors/technologists present a world driven by human-centric dataism, with signals moving towards "24/7 Privacy Invasion" [5], where the highest value

is freedom of information, leading to a global brain or some form of universal intelligence (see Figure 2). Finally, niche tech communities and experts address the risk that the internet can become corrupted entirely, referring to the signal "Completely Corrupted Internet" (see Figure 1), without measures to save it, where people have lost control over personal data [4, 10].
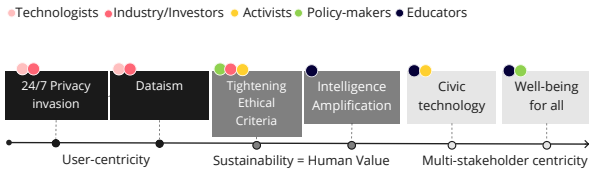

Figure 2: Emerging drivers on the scale of human- empowering design

4.2 Future development issues in the Norwegian context

The second study that was conducted included a case study, where we extracted a set of observations made by digitization experts in the Norwegian context. The in-depth interviews aimed to bring to light challenges or conflicting thinking in forward-looking human-centered technological design. The emerging issues that were discussed relate to the design of tools and systems and the potential implications to humans and society in an IoT context. One core question is the role of protecting human users and society's interest in the network technology design logic.

In the developer context, the current technical design model is challenged when considering human users and societal interests, both in the development process and the product specifications. As it was coined by one of the experts: *"The most significant gap in today's development of IoT solutions is that it's challenging to develop and maintain the software to get everything working in conjunction with fulfilling the human and social requirements specified"* (Industry developer).

Increased protection of human users is experienced as a technical obstacle, where preference for self-regulation is evident. The development process focuses on making the technical sensors, actuators, and data flow work while ignoring the important human and social aspects. Some developers suggest the existing user protections in place are sufficient; others say industry disruptors, such as Apple, will lead the way to increase user privacy as a strategy to achieve competitive advantage. In comparison, the interviewed academics raise the issue of lack of regulation, particularly regarding machine-to-machine metadata, where there is currently no legal standard. Generic technical standards are also lacking for making the user experience better. As one interviewee frames it: *"There are so many different solutions in Smart home, that it is not important to improve the experience for the user. The priority is to sell more devices and products"* (Academic 3). One of the interviewees from the regulators perspective pinpoint the potential to increase understanding, transparency, and involvement among regular users. Human participation both in the interaction and deployment of future network technology is considered significant: *"There is definitive potential to improve users understanding of how their data is*

used and how, trough more informative communication, via pop-ups or similar" (Regulatory compliance officer 1).

4.3 Indications of change

Across the various stakeholder perspectives, there is a recognition of a need to enhance human-centered aspects in designing IoT technology solutions. For example, one of the developers involved in the study argued: *"Understandably, IoT is not very human-centric yet, as the technology is not mature enough yet. The normal innovation process is to test different technology potentials. Only after the technology and methods are mature enough can the developers start to put the user in the center. More precisely, to think about how humans can benefit and be protected by using the whole system. So it's natural that we're not in that stage yet, but it's good to start thinking about this even if the technology is not mature enough"* (Industry developer 8).

In the case of Norway, the majority of interviewees representing the different stakeholders intend to truly meet the needs and problems of human users and society first and foremost. As one of the academics put it: *"We should not normalize this thing that we (humans) are helpless".* and *"it's important that people who are using those devices must be aware of consequences of bringing these devices home"* (Academic 2). However, the ability to respond actively, and translate the technical solutions toward a coherent human or humanity-centric design vision, seems to a certain extent, not to be exhibited: *"Our ambition is not to change how users live their lives in connected environments, and by adding intelligent automation that runs in the background, nobody needs to create new rules"* (Industry developer 7).

The question is whether the Norwegian players possess the necessary motivation and ability to act on good intentions to shape genuinely human-centered IoT technology solutions in practical terms. As indicated by one of the regulatory experts: *"As a general procedure, we only get involved if there is a private complaint of a privacy breach. The company must regulate how it looks after its users' interests and follow regulatory requirements"* (Regulatory compliance officer 1). Therefore, overall, and even if the actual intent is there, what the various actors practically do is insignificant to include considerations for human and societal protection in the design.

5 DISCUSSION

Future intelligent networks rely on autonomous and perceptive functionalities, which will directly impact people's lives. However, the extent of control allowed to the pervasive and intelligent functionalities versus human users and society varies according to the perspective of various stakeholders' design imaginations and processes.

5.1 Future intelligent network technology imagined as over-powering or all-empowering?

The drivers indicate a movement towards more human-empowering design in the context of the Internet of Things or intelligent networks. Increasingly, across multiple actors, with various agendas, sustainable design criteria to reflect human and social values and civic involvement are on the agenda (see Figure 2). The drivers for

future intelligent network technology can be placed on a continuum of human-empowering design evolution, where on the one side, human-centered design considerations have been reduced to being passive or even nonexistent. In contrast, on the other, a design correction has ensured that intelligent technology systems tackle the power asymmetry created towards individual human users and communities by technical design (See Figure 2).

To illustrate, privacy protection, which is a commonly agreed upon pre-requisite for human empowering as part of the development of future intelligent networks, as a concept in itself, is removed in its entirety in several future signals related to intelligent networked societies. The driving forces and potential barriers to achieving more human-empowering design are globally dominant industry players, geopolitics, and advanced legacy technology resources and capabilities, among others. This privacy-less future imagination can be traced back to industry, and technology perspectives, but also government perspectives where technologists, investor communities, and governments have a keen interest in commercial and technological development as a priority above all others, or in some cases of authoritarian regimes, total control of individuals and society.

5.2 Technical intervention delayed

The more human-empowering technical developments are future design imaginations that can influence operational engineering decisions and practices early, with diverse participation and governance, to configure the protection of human and societal interests technically. In practice however, as observed among actors participating in the digitization of Norway, the operational design priorities primarily revolve around the development of technological innovation and functionalities led by technical experts. There is no significant forward-looking challenge by the digital policy/regulatory/governance design stakeholders regarding bridging the human aspects with the practical technological realities of intelligent network design early and throughout the innovation process. Despite issues developing related to the loss of power among regular human users, building meaningful protections early and consistently continues to be an afterthought.

Inevitably, this raises critical and urgent questions concerning the certainty of a future where human and humanity-centered intelligent networks work to benefit humans first and foremost, supported by established coherent practices that safeguard human interests. Next, the weak and early signals identified need to be situated in a continuous foresight methodological framework. Within this framework, multi-disciplinary experts can assess the likelihood of genuinely humane future design directions and associated scenarios, guiding further actions and road mapping toward the desired future scenario.

5.3 From vision to technical design: holistic collaborative foresight

Drawing on these findings, the visions, ideation, and technical design configurations of future human-centric intelligent networks are elements that extend beyond facts and empirical proof. Reflecting on how futures are understood and by whom, the relations between actors influencing future-focused idea exchanges and collaboration in pursuing holistic goals (those benefit communities) come to the foreground. A better understanding of genuine human-centered design principles, methods, techniques, and processes, not only in intelligent network/IoT design but also more generally in digital policy institutions and private technology organizations, is intended to allow the relevant stakeholders and impacted communities to find common ground, to enhance genuinely human-empowering technology solutions.

6 CONCLUSION AND DIRECTIONS FOR FUTURE RESEARCH

Envisioning the future can be described as agents of social change were images of the future "act" by affecting how images are imagined and constructed in the present. The various stakeholder groups that are influential in creating the future vision for intelligent networks are increasingly considering a more human-empowering design that incorporates human and social values as design criteria, supported by multi-stakeholder involvement. Even so, the perspectives diverge concerning future perceptions, motivations, and actions for a realized sustainable networked society, for instance, between academia and industry stakeholders.

As a result, the dominant future technical translation of intelligent networks continues to lean heavily towards meeting the interest of industry, technology, and government actors that rarely consider essential human and social aspects in early design considerations and operational, technical development. Even so, future technology solutions are envisioned to govern and represent humans and society in all societal, technological, environmental, ethical, political, and value aspects. Alternative future visions are emerging, although more uncertain, where the emphasis is on technical design as an ongoing experiment to ensure priority to human and societal well-being to bring a diverse, equal, fair, intelligent networked world. Follow-up work should focus more in-depth on such visions for the next-generation IoT and explore multiple future design imaginations and processes in a more extensive, rigorous, and inclusive way. This means among others the involvement of various stakeholders but especially also to have human users in the driver's seat. Drawing on critical social theory, a multi-stakeholder perspective can reveal underlying structures that influence probable or desirable images of the future and how these are generated and imposed on others. The following research phase should involve a wider group of multi-disciplinary participants in futures thinking [39]. To refine the thinking about the future, Foresight methodology workshops can allow prioritization and trade-offs of the issues, developments, and trends that affect the desirable futures of intelligent networks/IoT [18].

Moreover, future research should address the challenge of prioritizing human users and societal interests in the practical technical design of intelligent networks. Participatory foresight can contribute to a coherent human-centered translation that works technically. The future dynamics for creating genuine human-centered intelligent networks need to be explored in more depth to evaluate the present certainty and future uncertainty [18]. To define the importance of a future shift in the role of HCI in the technical design of IoT/intelligent networks, driver mapping and axes

of uncertainty are research methods and tools that may be relevant to apply [43]. As the technical design obstacles are significant when human and societal interests are not considered early in the development phase, future research should also investigate the development of a consensus-driven collaborative innovation model [39]. Exploring the frameworks and methods that can achieve a shared understanding in early ideation and insight processes allows for better synchronizing of human and technical innovation systems [44]. In addition, scenario development can explore how the initial technical design requirements can support or constrain a future, coherent human-centered vision in practice.

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