Collaborative Network 5.0: By Design Human Values and Human-Centred Based Extended Collaborative Networks

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Abstract. Collaborative Networks (CNs) as a new discipline play an important part in the continuing digital transformation of business and services, taking advantage of Information and Communication Technology's growing sociability and usability qualities to enable and improve partnership that results in competitive solutions. While CNs could get benefit from technological development, it could inherit its disadvantages, through violation of human-centeredness and human values. Recently proposed Collaborative Networks 4.0 addressed some of these issues in three-dimensional CNs. However, while the 4th generation of CNs putting ethics and intelligent autonomous systems into account, it does not assume "by design" approach in implementation of these characteristics as an obligation. It also overlooks the generation of communication technologies such as Extended Reality. The current article by introducing the four-dimensional, human-centred, human-value based, 5th generation of CNs aimed to cover the previous generations of CNs' constraints in dealing with society 5.0's challenges.

Keywords: Collaborative Networks 5.0 · Human-Values · Human-Centred · By Design Development Approach · Extended Reality · Emerging Technologies

1 Introduction

Collaboration is frequently acknowledged as a tool for enhancing competitiveness and hence boosting viability under unsteady market situations. A wide range of organizational entities (such as industrial businesses, educational institutes, public organizations) in different sectors are beginning to pool their resources and work together under a variety of collaborative models to deal with the market dynamic and intense global competition [1]. To obtain new competitive advantages and improve individual capabilities, these entities are leveraging individual strengths by sharing risks and resources and combining complementary talents and capacities. This collaboration has a definite influence on their

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performance [2] in a way that for example operations researchers have suggested that these entities especially industrial ones are no longer competing as individual businesses but as parts of collaborative network in their domain [3–5].

According to the Camarinha-Matos and Afsarmanesh (2005), a collaborative network (CN) is made up of a range of entities, including individuals and organisations, that are geographically dispersed, mostly independent, and diversified in terms of their working environment, culture, social capital, and objectives. Yet, these entities work together to attain compatible or shared goals more effectively, and their interactions are facilitated via computer networks. In contrast to other networks, CNs fosters purposeful cooperation since its members are convinced that working together would enable them to accomplish things that would be impossible or would be more expensive to do separately [6]. Technological advancement by improving connectivity and communication, increasing efficiency, enhancing collaboration, increasing ability of collecting, sharing, processing, and storing data, information, and knowledge, improving global reach, improving resilience in crises and disruption, improving collective creativity, and enhancing real-time working, have had a significant impact on CNs [7–10].

Like any other technology, implementing new technologies in CNs areas has many advantages, but it is also vital to consider any potential disadvantages and restrictions that these technologies may impose on CNs. For example, in the case of computer networks technology which is a fundamental building block of collaborative networks(CNs), they could impose considerable vulnerability regarding privacy and security factors [11–14] and concerns regarding Ethical factors [15, 16] such as Trust and Transparency [17–20], Equality, Fairness, inclusion [20–22], and Responsibility and Accountability [12–14] to the CNs. These issues and vulnerabilities could become more serious by integrating new technologies such as intelligent autonomous systems. Camarinha-Matos and Afsarmanesh (2021), as the leading scientists of the collaborative networks discipline, in their article entitled "The Evolution Path to Collaborative Networks 4.0", after synthesizing the background of CNs discipline and providing its taxonomy, divided the CNs evolutions concepts in four generations [23]. While the fourth generation of collaborative networks (Collaborative Networks 4.0) which is characterized by its three dimensions and hybridization, cognition, and resilience, assumed to address several issues and challenges faced by CNs and their implementation, it still cannot assure the human centralization, human-values based, secure, and privacy preserving creation, development, and implementation. It also does not involve the most recent communication and socializing technological development which creates an extended reality based meta world [24]. In addition, it is not clear about the CNs development approach. The differences of applying "by design" approach and "ad-hoc" approach could have significant consequences on CNs performance. The "by design" approach (in this context) refers to the practice of designing CNs with specific goals or outcomes in mind from the outset [25]. This means that considerations for key features such as human-centredness, human-values based, security, safety, privacy are integrated into the design process from the very beginning, rather than added as an afterthought or as a response to problems that arise later (which known as the standard approach) [26]. These shortages could limit CNs 4.0 in addressing the extending needs and requirements of individuals, organizations, and societies that are impacted by social evolution. For instance, while CNs 4.0 could be able to address

the social requirement of 4th generation of society, it will have difficulties in fulfilling the needs, expectation, and requirements of society 5.0, considering its due to its emphasis on human-centredness and human-values [27]. It is worth to mention that while Society 4.0 focuses on the integration of advanced technologies for efficiency and productivity, Society 5.0 takes a human-centric approach to leverage technology for sustainable development, societal well-being, and collective problem-solving.

In this regard, the current article aimed to answer the following questions:

[RQ1] Which are the main constraints of the 4th generation of collaborative networks?
[RQ2] What are the building blocks and definition of the 5th generation of collaborative networks?

This *Conceptual Expansion Research* work by applying a *Mixed-Methods*, Literature Review and Focused Group Brainstorming will answer the above RQs in the following three core Sects. 2, 3, 4.

- The literature review involved conducting a thorough search for published research relevant to the RQs. It began with defining the RQs and developing a search strategy. Relevant literature is identified and screened, and selected sources are critically evaluated. The literature is then organized, analysed, and synthesized to identify key findings and themes. The findings are summarized and presented in a coherent manner within the literature review, which is continuously revised and edited.
- To execute Focused Group Brainstorming authors assembled a diverse group (including 14 experts from different research field Social Science and Humanities, Computer Science and Software Engineering, Collaborative Networks, Cybersecurity, Computational Creativity, ICT solution Verification and Validation, Extended Reality, Business Intelligence, Industrial Engineering, AI, and Data Science), set ground rules, and encouraged participants to generate their ideas regarding the RQs. The experts' suggestions and ideas are discussed, grouped, and prioritized based on relevance and feasibility. Actionable plans are developed, and follow-up evaluation is conducted.

The first Section of this article is dedicated to the Research Context, RQs, Research Methodology, and Research Roadmap. Section 2 is dedicated to a critical literature review and state-of-the-art development, to provide a better understanding of the background, existing scientific efforts, evidence, and initiatives. Following the knowledge achieved in Sect. 2, Sect. 3 after presenting the evolutionary path of collaborative networks will identify the main constraints of the fourth generation of collaborative networks and this answers the first research question [RQ1]. By creating its foundation on Sect. 3, Sect. 4 proposes the fifth generation of collaborative networks, define it, and identify its possible characteristics. By this, authors answer the second research question [RQ2]. The article is concluded by providing a short summary of the research achievements and responses to the research questions, reporting its limitation, and proposing future possible research opportunities.

2 State-of-the-Art

The development of collaborative networks dates back to the early 20th century when researchers and professionals started looking into fresh methods for managing complex systems and organisations. The 1918 publication of Mary Parker Follett's book "The New State: Group Organisation, the Solution of Popular Government," which promoted a more cooperative and democratic approach to public management, was one notable early work [28]. The idea of inter-organizational collaboration gained popularity in the 1950s and 1960s, especially in the areas of logistics and supply chain management. The emergence of new technologies, such as computer networks and ICTs, made it easier for organisations to share information and resources and enabled the creation of cooperative networks [29]. The development and use of CNs increased in the 1990s and 2000s as a result of the expansion of the internet and the globalisation of commerce. The idea of remote work and virtual collaboration spread, and new technologies like social media and cloud computing made it easier for people to connect and collaborate beyond organisational and geographic borders [29–31]. Today's CNs are still developing and adapting to fresh opportunities and problems, such as the expanding usage of emerging technologies like Artificial intelligence (AI), Internet of Things (IoT), Intelligent Autonomous Systems, Blockchain technology, Internet of Trust, Extended Reality (XR), and Metaverse. Building relationships, exchanging information and resources, and using the skills and capacities of various stakeholders are still the major priorities in order to accomplish shared objectives [7, 32–34]. During this century of evolution of CNs, a significant number of scientific documents published in this field, for instance, by May 2023, a search on the academic search engine Scopus using the keyword "collaborative networks" resulted in 1023 scientific document's titles (documents are published between 1969 to 2023) which L.M. Camarinha Matos and H. Afsarmanesh are the leading scientist researchers in this field based on the number of published scientific documents in Scopus. Since 1999, these researchers by organizing the annual PRO-VE conference developed one of the most important CNs initiatives which has had a critical role in shaping this discipline.

These and many other published scientific documents in the CNs discipline demonstrate that during the last decade, they are becoming an emerging solution in different domain and scientific environment. Indeed, they have taken a crucial role in transforming the traditional supply chains into more dynamic value chains and global supply networks able to better support enterprises, companies, business ecosystems, public sector, and industries. Their distributed services are many times able to improve citizens, and society in general, life of doing and living. Due to their adaptability, flexibility, and usability successful stories about the CNs adoption come from several application domains. Without pretending to be exhaustive, 10 application examples are listed below, which five of them are mainly can be characterised by their economical nature and others by having wider perspectives cover different disciplines.

- *Rural and Agricultural Domains* [35, 36]: CNs have many positive effects and consequences on agricultural cooperative producers for preserving, regulating, and supporting ecosystem services and actors with primarily ecological and collective interests.

- *Healthcare*: [37–39]: CNs can be used to connect different healthcare providers, such as doctors, hospitals, clinics, and pharmacies, to improve patient care, outcomes, and healthcare research.
- *Manufacturing Industries* [40, 41]: Agility or responsiveness and optimize performance are some of the most important difficulties facing modern manufacturing organizations as they attempt to deal with the unstable economic environment they are currently experiencing. The collaborative networks may boost the industrial sector's responsiveness and agility, as well as the performance.
- *Education* [42, 43]: CNs could be consider as students, teachers, and educational institutions connecting tool to facilitate knowledge sharing, collaborative learning, and research collaborations.
- *Government and Public Services* [35, 44, 45]: CNs can be used to connect different government agencies, public service providers, and community organizations to improve service delivery and civic engagement.
- *Supply Chain Management* [46, 47]: CNs facilitate communication, coordination, and collaboration among different organizations involved in the supply chain, such as manufacturers, suppliers, distributors, and retailers.
- *Creativity and Innovation* [48, 49]: CNs can be used to develop collective creative solution in different fields such as art, product design, computational creativity, cyber-physical systems development, Industry 4.0 solutions, etc.
- *Research and Development* [48, 50–53]: CNs can be used to connect researchers, scientists, and engineers from different organizations and disciplines to collaborate on research projects, share resources, and exchange ideas. It also could help in promoting responsive research and innovation.
- *Disaster Management* [54, 55]: CNs can be used to manage disaster and create a new generation of rescue teams which known as Disaster Rescue Network (DRN). Being ready to respond quickly and effectively is essential since disasters are by their very nature unpredictable. DRNs may emerge because of the adoption of the collaborative networks' p*aradigm in disaster management.*
- *Cybersecurity Management* [56, 57]*:* CNs can have an important role in implementing and assuring the cybersecurity governance and management practices in several context. CN main purpose is to assure a correct and compliant sharing of sensitive or confidential information and provide means and facilities (such as encryption, multi-factor authentication, and other security protocols). In addition, CNs can be used for regular training and education on best practices for cybersecurity, as well as to monitoring and testing cybersecurity quality level.

During the lifetime of CNs discipline in the literature, it can be tracked back to several related concepts and theories. Some of the key concepts that have influenced the development of CNs include supply chain management [58–60], virtual Enterprise/organizations [6, 61, 62], inter-organizational cooperation [63–67], and network theory [68, 69].

3 Collaborative Networks Evolution

The evolution of collaborative networks which was impacted by evolution of technology, industry, emerging business models, economic landscape, and evolving needs and aspirations of individuals, organizations, and society, can be classified in three main periods:

1. *Before 1980s*: during this time of economic recession and social upheaval, by early development of computer networks and other digital technologies the modern perspective toward collaborative network is shaped. In this period still most of collaborations and communications took place through traditional means such as face-to-face meetings, phone calls, and emails. This period could be characterized by centralized control, limited collaboration, and a hierarchical organizational structure [28, 29].
2. *1980s-early 2000s*: by wide spreading the digital technologies such as email, instant messaging, and online forums, as well as the rise of internet and increasing availability of computing power and storage capacity, collaboration on a larger scale became feasible and decentralization of organizational structures became much easier [29–31].
3. *Mid-2000s and continues to evolve today*: During this period, by the widespread availability of mobile devices, the rise of Social Media, IoT, Cloud Computing, the increasing use of AI and machine learning (ML), the collaboration could take place on a global scale and development of highly decentralized organizational structures facilitated. In this period, CNs could be characterized by open and inclusive collaboration, digital and mobile communication, and a networked organizational structure [7, 32–34].

This classification is evaluating the influence of emerging technology in the period, the level of decentralization of organizational structure, and the scale of collaboration, in each period. Camarinha-Matos and Afsarmanesh (2021) also proposed another classification entitled "collaborative networks development generations" [23]. According to these authors, there are several types of CNs that can be globally classified into: 1) Collaborative Networked Organizations (CNOs), in which the network's members' organizational structure is explicitly created, and 2) Ad-hoc CNs, without predefined organizational structure. They classified CNs into four generations of CNs, covering a 40-years period of time (1980-Present) [23]:

1. *First Generation (1980s-2004):* This generation of CNs represents the initial stage of CNs, which primarily concentrated on goal-driven networks and encompassed the early indications of three building blocks of CNs which are dynamic supply chains, extended enterprises, virtual enterprises/organizations.
2. *Second Generation (2004–2012):* This generation of CNs are marked by the strategic network concept of virtual organizations that create breeding environments. This includes various sub-classes such as business ecosystems, industry clusters, industrial districts, and professional virtual communities.
3. *Third Generation (2012–2020):* Co-creation and open innovation networks, as well as hybrid value systems networks, were among the CNs addressed in CNs 3.0. It also focused on addressing issues like "servitization" of multiple suppliers, inheritance, and transition between CNs, among others.

4. *Fourth Generation (2020-Present):* The authors' most recent generation of CNs prioritises innovation in managing distributed cognitive systems, accountability and ethics, risk management, data handling, monetizing collaboration, cultivating a collaborative culture, encouraging creativity in collaboration, mass collaboration, collaborative value creation, and creating new business models. Its main emphasis is on how intelligent autonomous systems and people may work together.

The criteria that are used to develop the fourth generation of collaborative networks [23] include the process of digital transformation in industry and services, and the most common characteristics of the CNs. While the authors consider this generation of CNs as the most emerging one, they emphasize on their unclear characteristics.

As reported in this Sect. 3, even if CNs are extensively adopted, their evolution is continuously improving to be in line with the novel technologies and research discoveries. Considering the first research question introduced in section one: *"[RQ1]. Which are the main constraints of fourth generation of collaborative networks?"*, the following main constraints and issue are identified by the focused group:

***Unclear Development Approach (By Design VS. Ad-hoc Approach)*:** From the definition of CNs 4.0 [23] can be understood that the 4th generation of collaborative networks are not necessarily by design secure, safe, privacy preserved, trustworthy, human-centred based, and human-value based entities. Despite the authors clearly recognize some of these characteristics (e.g., ethics) integrated in the collaborative networks 4.0, it seems that it is sufficient to have ad-hoc based integration. This unclarity in the integration of characteristics of 4th generation of collaborative networks could cause different outcomes from their practices. For example, Ad-hoc security integration involves implementing security measures reactively in response to specific security incidents or threats as they arise. This approach is generally less effective because it is more difficult to anticipate and prevent security incidents when security measures are not designed and implemented in a comprehensive and systematic manner from the outset. On the other hand, a by design approach to security integration involves implementing security measures proactively as an integral part of the development process. This approach involves anticipating potential security risks and threats and designing security measures to prevent or mitigate them. By designing security into the computer network from the beginning, potential vulnerabilities can be identified and addressed early on, reducing the likelihood of security incidents, and improving the overall security of the network.

***Limited Emerging Technologies Adoption*:** The latest technological developments considered to be adopted in the 4th generation of collaborative networks, are intelligence autonomous system which have capacity of interacting with humans. These technologies alongside with other technologies in the cyber world, computer networks, and digital distributed (cognitive) systems, address and reflect in the physical world practices and contexts. While these technologies are part of most emerging technologies, the authors are not considering important emerging technological development in the Extended Reality (XR) and Metaverse world which could be considered as another environment (dimension) that collaborative activities could be executed inside its environment.

***Limited Human-Centred approaches Integration*:** While the 4th generation of collaborative networks deeply depends on the humans in different ways, they are not obliged

to follow a human-centred approach which involves putting people's needs, desires, and experiences at the centre of the design process, and creating solutions that address these needs in a user-friendly and accessible way. The basic practice of all generation of collaborative network is bringing together multiple stakeholders to work towards a common goal. This can include individuals, organizations, and society. In the latest version of CNs, a hybridization and collaboration between humans and intelligent autonomous systems, will be reflected on several ends, which some of them are human-centred and some not. Considering that CNs should play their role in the society it should be prepared for the possible future societal requirements, in particularly Society 5.0 as a vision for a future society seeking to balance economic development and social progress with the well-being of individuals and the environment. A human-centred approach is essential to achieving the goals of Society 5.0, as it puts people and communities at the centre of the technological transformation that is driving this vision. In this regard, overlooking involvement of human-centred approach in CNs could put them under the view of societal evolution.

***Limited Human Values Integration*:** Human values are often at the core of CNs, as they are focused on achieving social, environmental, or economic goals that are important to people and communities. For example, a collaborative network focused on improving public health might prioritize values such as equity, access, and community engagement. Similarly, a collaborative network focused on sustainable agriculture might prioritize values such as environmental stewardship, social justice, and economic viability. However, the 4th generation of collaborative networks and the previous ones, are not emphasizing the necessity of respecting and integrating human values in their practices. For example, they are not obligated to be gender-equal, inclusive, fair, trustworthy, privacy/security/safety preserved by design entities. While in the collaborative networks 4.0, accountability and ethics have been seen are a reflection of the hybridization of collaboration between human and intelligent autonomous systems, but it still missing the deep integration of these factors are foundation of CNs.

4 Fifth Generation of Collaborative Networks

Collaborative networks are complex systems that involve a variety of components and factors that must work together effectively to achieve shared goals. In line with what was discussed in the previous section (Sect. 3), and to reply the second research question, "*[RQ2]. What are the building blocks and definition of the 5th generation of collaborative network?*".

4.1 Fifth Generation of Collaborative Networks' Building Blocks

The building blocks of the next generation of collaborative networks which proposed by expert focused group are the following:

***Enforce a By-Design Development Process*:** As discussed in the previous section (Sect. 3), the next generation of collaborative networks should consider the experience and the lesson learnt from the software engineering research field [26, 70, 71] and make

the by-design the mainstream development approach. CNs need to "by-design" include the fundamental quality capabilities and properties in their specification to reduce, as much as possible, modifications, failures, and maintenance cost. They have also to include the definition of the important design patterns for the realization of the different functional and non-functional properties (like security and privacy) at architectural level. Finally, CNs have to anticipate in the early design stage of the development the strategies, tactics, and patterns useful for fulfilling specific requirements and peculiarities. In this way the conceived CNs will include at every layer the guiding development principles, component, and interactions necessary for implementing desired features and quality and can avoid future corrective costly actions and countermeasures in case of problem or failures.

***Focus on Human-Centred Goals*:** To align with the next Next-Generation of IoT, individuals and humanity need to be more involved in the development of CNs [72]. Indeed, in the "human-centred" approach, individuals will be not just the final users/participants/stakeholders of CNs, but also their co-designers, co-developers, and co-tester. This facilitate humans express their specific needs and wishes, to customize and assemble CNs components, and collect pieces of evidence about the CNs quality which should be included in the CNs architecture. The new human-centred vision of the CNs will personalize more the goals that participants can work towards and align their efforts towards a more precise and effective common objective, ensuring satisfaction, trustworthiness, and success.

***Adopting Emerging Technologies*:** As in many research and application environments [73], CNs should increase the progression in the use of contemporary digital technologies such as AI, ML and blockchain to enhance their quality and effectiveness. Additionally, as visioned in the 2002 seminal work of [74], virtual reality (nowadays evolved into Expended Reality), should be the future evolution of the CNs. These emerging technologies will introduce in the CNs a new way of experiencing the co-working, and co-creation and co-collaboration, providing different shared perspectives and interactions. These new approaches can also improve communications by creating new virtual channels (such as Metaverse meetings, conferences, or rooms where participants can interact, exchange information, ideas, and feedback). Additionally, AI and ML can be used for improving CNs processes and procedures (like decision-making, dispute resolution, network leadership and other critical processes), and better manage the flow of information and activities within the network.

***Enhancing Human Values*:** values like ethics, privacy, security must be implemented as fundamental attributes of CNs especially, when possible, vulnerabilities can cause severe economic losses or security risks. CNs should enforce access control system for ruling resources and data access [75]. Indeed, an unauthorized access to personal data or surveillance of network activities, could harm seriously the privacy of the individual or organizational components of CNs. Malware, viruses, and Hacking are some of the security threats for computer networks which could compromise sensitive data of the CNs members and cause significant harms to them [11–14]. Additionally, use of networks imposes to CNs to face and control ethical concerns in CNs by integrating by-design facilities and countermeasure. For instance, CNs should be protected against violation

of personal data by means of computer networks' stakeholders or should avoid the use of algorithmic decision-making machines that could impact participants' decisions and their way of thinking [15, 16].

***Increase the Trustworthiness*:** Trust and transparency are critical building block of collaborative networks. CNs should provide evidence to participants so that they can trust each other and work together effectively, share information, and perceive a common goal. CNs should provide facilities to protect sensitive information through computer networks, which can raise concerns about trust and transparency. This can avoid stakeholders or participants to be hesitant to share the required information or knowledge, or cause conflicts of interest between different members [17–21].

***Improve Equality, Fairness, Justice, and Inclusion*:** CNs should provide evidence or include facilities for guaranteeing equal, fair, just, and inclusive use of CNs from each participant. Equity and fairness issues may come up, especially if some stakeholders and participants are more powerful or influential than others. Computer networks could emphasize the digital divide in CNs, where certain stakeholders are disadvantaged and unable to fully participate in the benefits of the CNs. Lack of access to high-speed internet of other technological infrastructure, could put limitation on ability of some of stakeholders in CNs activities or access to information and services. This can create a significant disadvantage, particularly for individuals in low-income or rural areas. The problem of prejudice and discrimination in algorithmic decision-making is another difficulty. Algorithms are frequently used by computer networks to make decisions. However, if these algorithms are trained on biased data or they reinforce pre-existing social biases, they may be biased or discriminating. Due to this, there may be large disparities and ongoing prejudice against particular populations [20–22].

***Focusing on Measurable Quality*:** useability, acceptability, and sustainability, responsibility and accountability are just some of the measurable quality attributes that can characterize a CNs and its impact on the market and adoption. Issues in satisfying these quality attributes may have a big effect on people or society. Evidence of quality increase participants satisfaction and CNs accountability in deeds or network's results. Additionally including in the CNs facilities for letting the participants able to self-validate and verify the CNs quality and self-assess their privacy and security can emphasize the global acceptability responsibility, and accountability. For instance, participants could verify who is responsible of their personal data, assess the protection, check their appropriate use, particularly if multiple individuals or organizations are involved in the network [12–14, 76].

The identified characteristics are the building blocks of the fifth generation of collaborative networks (Collaborative Networks 5.0 (Fig. 1)) and are in line with the evolving requirements and needs of human society, particularly society 5.0. This answers the first section of the research question two [RQ2].

4.2 Fifth Generation of Collaborative Networks' Definition

By identifying the building blocks of collaborative networks 5.0, we can now define the proposed new generation of CNs as: "emerging technologies-based" collaborative

networks which are mainly characterized as "by-design" "human-centred" and "human-value-based" "extended collaborative network"[1] and can facilitate collaboration and hybridization between human and most emerging smart technologies through physical, cybersecure, and mixed realities' tools. By putting humans and their needs at the centre of the design process these CNs involves co-creation, user-centred design, and ethical considerations to ensure that the CNs meet the needs of all stakeholders and are accessible to all. By this authors answer to second section of research question two [RQ2]. The fifth column of Fig. 1 is showing the proposed collaborative networks 5.0.

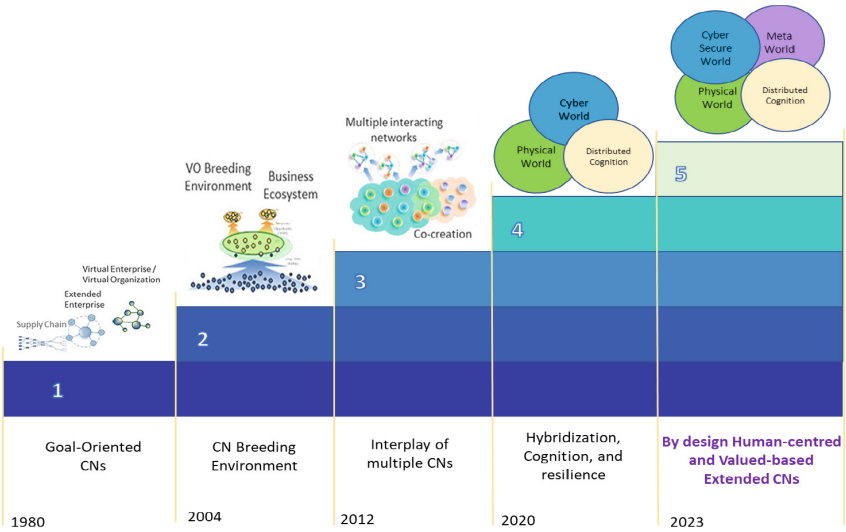

Fig. 1. Collaborative Networks Generations (Adapted from [23])

5 Conclusion

In response to shifting social, economic, and technological contexts, collaborative networks have undergone significant evolution over time. While early collaborative networks were frequently informal and depended on interpersonal connections and in-person communication by utilizing digital platforms and communication tools as technology developed, they became capable to connect and interact beyond organizational and geographic borders. CNs have evolved over the past few decades to become more purposeful and goal-driven, with an emphasis on solving difficult societal problems through collective actions. As the challenges facing the human societies continue to grow in complexity, there is a growing recognition of the importance of CNs as a tool for addressing these challenges. The evolution of CNs reflects a broader shift towards

[1] Extended Collaborative Network refers to collaborative networks that are empowered and active over the Extended Reality (XR - which includes Virtual Reality (VR), Augmented Reality (AR) and Mix Reality (MR)) platforms and environments as well as physical and cyber environments.

more collaborative and participatory forms of governance, which prioritize the needs and perspectives of individuals and communities. Parallel to evolution of CNs, scholars identified and differentiated the characteristics of CNs in different periods. One of the most recent classification of collaborative networks, proposes four stages/generation of development for CNs. The current work, after reviewing the background and state-of-the-art of the CNs, executed a critical evaluation in the last generation of CNs that proposed by the scholars. This evaluation identified four main issues including: Unclear development approach, Limited Emerging Technologies Adoption, Limited human-centred approach integration, and Limited Human-values integration. In response to these constraints and limitations, a new generation of CNs (Collaborative Networks 5.0) is proposed, that is characterized "by-design" "human-centred" and "human-values-based" extended CNs which are active on four dimensions (physical world, cyber secure world, meta world, and distributed cognition). CNs 5.0 can be considered as the adequate CNs for society 5.0 and for developing human-values-based solutions that are predictive, preventive, personalized, and participatory by-design.

Considering that the outcomes of this research paper is based on a mixed methods (literature review and focused group brainstorming), the proposed characteristics, and dimensions of CNs 5.0 are based on a theoretical framework and have not been empirically tested. Further research is needed to validate the effectiveness and social implementation of CNs 5.0 in addressing complex societal challenges. Additionally, possible future research works include empirical studies on the effectiveness of CNs 5.0 in addressing specific societal challenges, as well as examining the role of different stakeholders in the development and implementation of these CNs. Research also could focus on the ethical and social implications of CNs 5.0, as well as the potential risks and challenges associated with the adoption of emerging technologies in collaborative problem-solving.

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