Human-Centric Networking: From Device-Centric 5G Networks to Full Cyber-Physical Convergence in 6G

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Abstract: *This paper outlines a novel vision of human-centric networking with the potential to drive a breakthrough in the way of designing and delivering future networks and services. New concepts of "Collective-Intelligence" and sociotechnical design are introduced as key pillars driving future network architectures.*

Introduction

It is universally recognised that communication networks are a critical part of our global social and economic fabric. In current communication networks such as the Internet (network-centric) or mobile networks (device-centric), devices (e.g., computers and smart-phones) have been developed assuming services for the end-user as major driver of applications. Applications have also been largely bounded to the capabilities of these devices.

However, increasingly end-users associate not only with one but with multiple (10s or even 100s) machines/devices (personal or within their surrounding environment, mobile or static). It is envisaged that the number of connected devices will reach 500 billion by 2030[1], which is about 59 times larger than the expected world population (8.5 billion[2]) by that time. Examples of connected machines include vehicles, robots, drones, home appliances, smart sensors in cities/hospitals/factories, wearable, implantable, etc. Devices can portray in different forms such as augmented reality (AR) glasses, virtual reality (VR) headsets or holograms.

As devices are becoming dominant users of the network, industry and network service providers are already developing solutions to address massive machine-to-machine communications (see 5G and more on 6G) as their main "customer". In a future world dominated by machines, how do we ensure that human-users' demands will be central to the design of future communications networks and services?

A Human-Centric Network Vision

We propose that service provisioning to human-users should be in response to "inference of service-intent" formulated by information collected by personal and surrounding devices. This requires continuous awareness of context and situation which will drive "human-centric" service requests. By definition, such service requests will continuously evolve requiring dynamic provisioning of evolving services, raising challenging demands for flexible networking as well as security and privacy to fit said dynamic environments. Such advancements on service provisioning will only be possible with wide adaptation of solutions, such as automation and programmability– all powered by various forms of artificial intelligence (AI). It will usher an unprecedented paradigm shift in the design of digital connectivity infrastructure and services, from today's network/device-centric to truly human-centric.

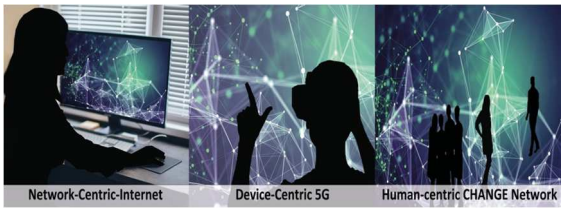

Fig. 1: Towards Human-centric Networks

In this proposition, human users are becoming central to the network service definition. Service requests will be derived through intelligent interpretation of "human-intents", which will consider users and their environment (smart devices, real-time data, social media etc.). Continuously evolving usage will require dynamic service response, and the knowledge acquired over time will reveal bottlenecks in the network service provisioning and associated infrastructure. In such a dynamic environment, networks need to respond in real-time to compose services from available resources. In addition, network innovation needs to be considerably faster than the industry standard times to alleviate bottlenecks, e.g., shortening the 7-10yr between cellular network generations (G) into months/weeks/days/min, and therefore eliminating the notion of G in mobile networks, which for decades has dominated evolution of the global networking infrastructure.

As a result, the proposed human-centric design will drive a revolution in the design of Future Networks, which will augment the importance of communication networks as social infrastructure and expect them to respond and play a pivotal role in addressing key social challenges

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concerning work, education, inclusion, equality, and react to emergencies such as pandemics[3]. Hyper-connectivity and the ultimate human-centric experiences will enable persistent personalised access to digital services and resources both virtual and physical without constraints of time and physical location. A wide deployment will reduce differences in regional infrastructures and economic opportunities and will contribute tremendously to the quality and opportunities of human life.

Such research will need to rely on an inter-disciplinary end-to-end design methodology, embedding technological and social considerations into the design of future network infrastructure and services.

At the heart of a "Human-Centric" network architecture will be its ability to fulfil dynamic and customised network service requests formulated explicitly or implicitly through aggregate information collected from users and their environment ("human service intent").

An advanced Network-Edge will enable real-time response and will host local storage and processing of user(s), network status data and ML tools to facilitate derivation of "Human-Centric Network Intent".

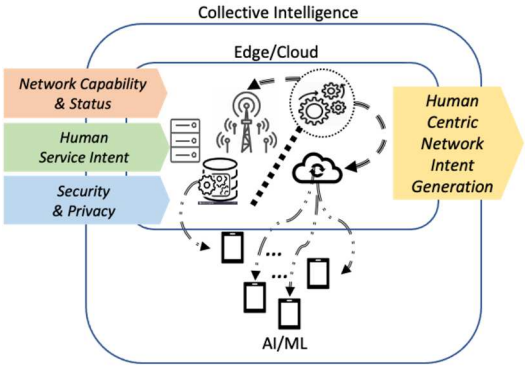

Fig. 2: Human-centric Network Edge

These intents will be directly and dynamically applied if resources exist or will utilise programmability to evolve the network assets and drive customised service provisioning. In this context, a "human-service-intent" will be derived through user(s)' devices and their surrounding environment in the form of aggregate abstraction that embodies all allowable data and actions captured by network devices and virtual/software entities. Data hosting, processing and machine learning are executed at the network edge where knowledge of network attributes also resides.

We call this combined knowledge of the human-service-intent and the network status as Collective Intelligence which derives human-centric-network-intent that in turn drives provisioning of customised network services given the combined temporal and spatial statuses of both the human user(s) and the network.

Sociotechnical considerations

A human-centric network vision raises critical social questions, at both individual and societal levels: How will networks understand and shape human intent? How will networks be designed, engineered and experienced as 'human-centric'[4], managing multiple and competing demands on a complex privacy landscape? How will individuals, industry and regulators know, understand, and engage with such networks to ensure public engagement, accountability and fairness, and to allow human agency within the network? These are significant challenges, at the intersection of social research, technical research and network literacy, and how they are addressed now will have enormous consequences for the future.

New interdisciplinary research[5] is needed to understand the implications of human-network relationships, with all their human and technical complexity, and to explore the possible futures that will result. This will specifically involve novel integration of sociological theory and empirical evidence with data collection and analytics to address the challenge of 'intent'. Challenge is in (a) what data (b) interpreting data (c) changes over time – not least sociotechnical landscape changes. To address this, we need to draw on social theory[6] and empirical evidence to drive our understanding of 'intent' and data analytics.

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