ESTABLISH AN OPEN PLATFORM TO FOSTER 6G INNOVATION AND RESEARCH

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INTRODUCTION

As an open research and innovation hub, the one6G Association aims to develop, promote and demonstrate the enabling technologies for the next 6th generation mobile communication system (6G). By supporting global research and standardization efforts, the goal is to contribute to the development, adoption, and overall market penetration of 6G, while addressing societal and industry-driven needs for enhanced connected mobility. Additionally, the ambition is to develop new services and applications for the 6G era, with focused domains such as advanced autonomous driving, smart manufacturing, advanced wireless e-health, remote education, etc.

Currently, the one6G Association is working along several dimensions: (1) 6G enabling technology development in multiple domains, e.g., radio access, system architecture, native intelligence, sustainability, etc. (2) Technology planning, elaborating principles for technology selection, roadmap evolution, and spectrum allocation requirements. (3) Technology validation, joint innovation and prototyping activities leading to integration, verification, and trials. (4) Requirement engineering, defining and harmonizing use cases, business plans, and go-to-market ideas. (5) Regulatory aspects contributing to the evolution of related policies in accordance with the needs and possibilities due to technology development.

FUTURE USE CASES, MARKET AND BUSINESS SCENARIOS AND REQUIREMENTS

With the vision to empower the vertical industries, 5G has successfully attracted attention from various industry sectors, e.g., smart manufacturing, agriculture, healthcare, logistics, and entertainment. While industries are considering how to make commercial use of 5G in their domains, some challenging use cases might not be fully addressed in 5G and, hence, are likely to initiate 6G discussions. Technical challenges (e.g., ultra-high industrial-grade requirements with guaranteed service level agreement, etc.) along with other aspects such as social acceptance, enhancing communications between humans and things, expanding communication from terrestrial to non-terrestrial and improving cyber-physical fusion are driving many research directions to start thinking about visions and considerations for 6G. To realize these visions around 2030 and beyond, when 6G is anticipated, we have to enable support for the novel use cases and applications from vertical domains/industries, either by exceeding the capabilities of 5G or by finding methods to meet conflicting requirements. Typical vertical use cases and scenarios investigated by one6G include healthcare, maritime and aerial, factory, education, agriculture, and transportation/logistics, which details are explained in [1]. In 2023, one6G started to investigate additional new use cases in the robotic sector, recognizing the growing demand, which is considered as one of the most promising business areas predicted for 2030 [2].

ENABLING TECHNOLOGIES

Within one6G, enabling technologies related to work items are promoted by its members based on their interests. At this moment, the following work items are established and under investigation [3].

Higher frequencies: sub-THz and THz communication addressing the spectrum beyond 100 GHz have been subject to intense research. While initial studies have focused on propagation and channel characterization, in the more recent years several demonstrators have proven the tremendous potential of THz communications for achieving extremely high data rates. Still, there are significant challenges to be addressed. High-gain antennas are required to overcome the high path loss experienced in this frequency range. This hampers the applicability of THz communications to mobile applications, where device discovery, beam steering, and beam tracking are even more challenging than at millimeter waves. Operating in non-line-of-sight conditions is also very challenging; in this context, the use of reconfigurable intelligence surfaces integrated into buildings can play an important role in THz communication.

6G radio access: The next generation of networks will face significantly higher requirements and KPIs than 5G regarding data rates, latency, reliability, security, sustainability, etc. Meeting these challenges will require new and enhanced technologies such as waveform, modulation and coding, non-orthogonal multiple access, full-duplex, new radio access network (RAN), AI/ML empowered physical layer and air- interface design, and antenna architecture. In this context, research is required to break through the theoretical limits and to realize practical system design.

Next-generation multiple-input multiple-output (MIMO): MIMO is anticipated to continue its journey as a key enabling technology for 6G. one6G will analyze the promising new concepts around MIMO, for instance, dual massive MIMO (base station and user equipment with massive MIMO), near-field communication, multi-frequency cooperated MIMO, full duplex and sub-band full-duplex MIMO, cell-free MIMO, RISs, AI/ML-enabled distributed MIMO, as well as new trends and solutions in antenna technologies.

Integrated sensing and communication (ISAC): ISAC is the concept of developing a unified system capable of performing both functions concurrently, utilizing the same spectral resources and hardware. This integration offers attractive benefits such as reducing costs, power consumption, latency, and space requirements for these functions.As 6G technology progresses towards higher frequencies (above 52.5 GHz and into the THz bands), which offer significantly larger bandwidths (> 1 GHz), 6G will be able to facilitate the provision of sensing functionality with high-resolution capabilities. Therefore, there is significant value and justification in exploring potential solutions in this direction and the business implications of the new use cases and services enabled by ISAC.

Flexible programmable infrastructures: explores the foundations of infrastructures programmability frameworks for their suitability for 6G, focusing on several aspects, such as (1) Holistic, unified view on resources as a distributed set of compute, network, and terminal elements at the scale of a typical 6G deployment; (2) Resilient, flexible, and in-band control realized as a distributed system on such a common set of resources; (3) Support for dynamic (e.g., on the fly) inclusion and removal of resources; (4) declarative, more expressive network infrastructure programming approach. The specific interest in programmability — or flexible repurposing of all resources — is rooted in a number of requirements and expectations that 6G is sought to fulfill, such as, among others, the need to provide support for full ICT service execution rather than supporting just connectivity sessions between points in the network; the observed diversification of authority domains involved into the actual service provisioning; the insistence on resource efficiency and sustainability of the installed base. Besides, combining resilience and efficiency requirements translates into the need for informed,

runtime resource selection decisions for service requests (service scheduling) as part of system operation, which would enable automation, efficient usage of resources, and better service quality as seen by the end user.

Intelligent user plane (IUP) and in-network computing (INC): The new 6G architecture featuring full "application-computation-communication" integration will be impacted by the introduction of IUP and INC in mobile networks. In 5G, like in 4G, the 3GPP network topology is an overlay on top of the transport network: in the 5G network topology, the User Plane data may need to traverse a far-end 3GPP user plane function even if two end-user devices are camped in the same access node or adjacent radio access nodes. IUP refers to research directions to enable flatter topologies for the next-generation mobile network User Plane, which shall support very low latency and efficient use of transport plane resources for applications like haptic interpersonal communication and immersive virtual reality. INC, which describes the paradigm of delegating application-layer processing to compute resources in the data plane, is seen as a key enabler for future immersive media. To exploit the availability of compute resources in the network data plane (INC), Telco Edge Cloud and end-user devices, the 6G system shall support coordinated allocation of communication and compute resources for each service session. The application layer may delegate computation-intensive tasks to high-performance INC resources (with HW accelerators), which enable adaptive partitioning of application workload. Improved application performance can be achieved, such as reduced latency for 3D video streaming (by executing 3D video rendering in dedicated INC resources) or reduced inference time of AI-based applications (by executing Neural Network layers in dedicated INC resources).

6G non-terrestrial networks (NTN): NTN specifies radio access networks, where the access nodes (in particular base stations) are carried on airborne (drones, balloons, or aircrafts) or spaceborne platforms (satellites). The latest technological advances of NTN communication and its integration into terrestrial networks (TN) facilitate ubiquitous connectivity for nearly all types of services, which enables novel use cases with guaranteed service availability any time and everywhere. These types of novel use cases and the related challenges shall be elaborated, and novel technologies toward the integration of NTN and TN shall be investigated.

Distributed/federated AI: In a distributed platform, e.g., in carrier networks, performing centralized learning is not optimal and often too costly due to data gathering overhead, considerable energy supply requirements at the centralized data centers (to be shouldered by the responsible tenant/owner), and privacy issues. Distributed learning techniques seem more natively suitable for a typical, large-scale multi- tenant mobile system deployment and, hence, should be investigated to enable learning over a pool of possibly heterogeneous resources (e.g., computing, connectivity, storage, data, and energy resources) distributed from the core to the deep edge. The energy source shall be especially considered, e.g., the nature of the resources to be used to achieve a preferential usage of renewable energy sources (such as local wind and solar energy) for compute-intensive AI computations, thus making the innate 6G AI greener and more sustainable.

Sustainability: novel approaches for energy consumption and carbon footprint reduction of ICT services is an essential aspect of 6G. It should begin with the understanding and description of the current ecosystem around energy consumption and carbon dioxide equivalent (CO_2e) production in the ICT industry. This includes applicable legislation, the requirements for energy consumption and CO_2e reduction, currently available approaches to energy reduction, etc. one6G aims to come up with novel suggestions and concrete approaches to reduce energy consumption and CO_2e. These may include novel mechanisms for energy consumption metering, usage of the metered data to perform energy consumption minimization or reduction, methods to enable integration and explicit use of green energy sources, etc. Lastly, economic approaches to incentivize eco-aware ICT service usage may also be considered.

Multi-modal communication: Multi-modal (including haptic) communication enriches interactions in various vertical use cases, such as industrial remote operations. Consider a user in a controller domain who utilizes the controlled devices (actuators, e.g., robotic arm) for performing operations remotely. Here, the resulting bi-directional, multi-modal communication poses extreme and/or conflicting stringent requirements on the underlying communication, such as ultra-low latency and ultra-high reliability, availability, and security. Key research aspects of this topic include (1) Multi-modal communication use cases for remote operation over 6G, including multi-user, multi-device applications, and their requirements and performance indicators; (2) 6G functionalities required to support multi-modal sensing and interaction use case requirements and device multi-modal technologies and capabilities; (3) AI/ML solutions towards meeting the main KPIs of multi-modal communications; (4) Architecture impacts featuring full integration sensing-computation-communication-actuation.

Evaluation, Testbeds, and Pilots

To facilitate research and innovation, it is essential to develop a networked, virtualized simulation and trial platform for the deployment and testing of 6G use cases and scenarios, with demonstrable benefits and a vision when the proposed solution becomes mature. For this reason, one6G initialized relevant activities on evaluation, testbeds, prototyping, and pilots of 6G key technologies.

6G connected simulation and trial platform: this initiative aims to define a methodology for a sharable research, demonstrations, and prototyping infrastructure, whose elements will be made available to members, even if the full set of tools is still under development. In addition, a virtualized and distributed testbed will be established based on the agreed interfaces and APIs. Moreover, an appropriate methodology will be defined to enable the connection of real-time capable testbeds and prototypes provided by one6g members. Such technology cooperation is not limited to simulation; more intensive collaboration can also include the exchange of measurements, stored sensing data with different waveforms and frequency band and AI training data, or even the interconnection of prototypes from other partners and to invite for hackathons events

Evaluation guidelines for all simulation, emulation, and prototyping: one6G has defined a set of guidelines for simulation and emulation-related validation and testing, which aims at collecting relevant inputs from enabling technologies described above regarding validation and testing purposes. Essential definitions are to be aligned to minimize the level of misunderstandings in the joint 6G technology cooperation via a multidisciplinary approach. Furthermore, a methodology framework for simulations, emulations, and demonstrations is proposed with references to 3GPP for system and link-level simulation assumptions. Additionally, guidelines for verification and validation based on prototypes (including the definition of different test types) are targeted.

Technology demonstration: Since the foundation of one6G, members from different continents and continents are motivated to demo their 6G use cases and key technologies via running testbed in the one6G annual flagship event — one6G Summit [4].

Ecosystem Building

one6G aims at building a "6G innovation hub," which will drive the effort in designing and implementing novel solutions in an open and collaborative manner. one6G creates a hub for stake-

holders networking, co-creation and collaboration in the context of addressing societal, business, and development needs in a digital world. Sustainable growth and shaping the vision of future digital worlds based on industry consensus will be indicative outcomes of the one6G activities. Novel technology enablers will create opportunities for radical service innovation and business efficiency. The issue of building a common "language" influencing effectively the 6G features based on business scenarios from the vertical sectors and cross-domain requirements. The one6G Association is paving the way to establish such an ecosystem via its members as well as its close collaboration with other relevant industry forums and organizations.

Summary and Outlook

6G should be ONE sustainable, affordable, accessible, and ultra-high-performance system. In pursuit of this goal, one6G commits to the vision of 6G as a flexible yet standard, resilient yet sustainable, performant yet efficient ICT service provisioning platform providing trustworthy ICT service execution for everyone, everything, and everywhere. It is crucial that deploying, operating, monitoring, and managing 6G networks and services are cost- and energy-efficient, easily accessible, and fully automated. one6G will empower smart connectivity for a better future. Such initiative will help to unlock the full potential of both public and private organizations in the digital decade and empower international co-creation. one6G will foster the participation of visionary researchers from academia and industry, global operators, major market players in selected verticals, regulatory agencies, market analysts, as well as innovative SMEs. one6G will continue on-boarding major players from vertical industries for their valuable involvement to engage them in 6G at an early stage, and one6G will promote cutting-edge technologies through joint initiatives, working groups, pre-standardization efforts, testbeds, user engagement, trials, demonstrations, dedicated liaisons, and other activities.

References

[1] one6G White paper, "6G Vertical Use Cases - Descriptions and Analysis," June 2022.
[2] one6G White paper, "6G & Robotics — Use Cases and Potential Service Requirements," June 2023.
[3] one6G White paper, "6G Technology Overview," 3rd edition, Oct. 2023.
[4] one6G Annual Flagship Event: one6G Summit 2023; https://summit2023.one6g.org/.