



SNS OPS – Supporting the SNS JU Operations

D1.3: 6G Smart networks and Services European vision

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Abstract

This deliverable provides an overview of the strategic views of key European and global stakeholders with regards to the future of 6G and the next steps towards the evolution of future networks and services. It also considers the latest developments in R&I activities within the SNS-JU and around the world. Concluding from the analysis of these views and developments, key elements that are considered by the various stakeholders as the building blocks for 6G are highlighted. A picture is then drawn of the potential directions in which the 6G SNS vision could evolve, to reflect the current trends, views and developments within the various interacting communities that affect the future and impact of 6G.

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Executive Summary

The European 6G Smart Networks and Services (SNS) initiative is advancing towards a transformative vision. Rooted in insights gathered from diverse stakeholders including academic institutions, industrial partners and global associations, the vision for 6G SNS encompasses not only technological advancements but also societal, business, and policy imperatives. This comprehensive approach is essential for overcoming the shortcomings of previous generations and delivering a network ecosystem that meets the multifaceted needs of society.

Through a comprehensive analysis of stakeholder views, current global technological trends and world-wide Research and Innovation (R&I) activities, the SNS OPS team has identified the following key themes and strategic directions that permeate the discussions about the 6G vision:

- **Technological Convergence and Customer-Centric Solutions:** The ICT sector is witnessing a convergence driven by fundamental technologies, cloud computing and advanced connectivity. This convergence demands sophisticated solutions that go beyond traditional broadband subscriptions to integrated service models tailored to diverse customer needs.
- **Service Orientation and Interoperability:** The evolution towards 6G necessitates interconnected and interoperable smart networks and services. This requires openness in service provision across private and public domains, enabling seamless connectivity and service delivery across different network types.
- **Security, Privacy, and Resilience:** In response to geopolitical challenges, there is a critical emphasis on security, privacy, and resilience across all layers of 6G networks. Coordinated efforts among stakeholders are essential to mitigate risks effectively and ensure robust network performance.
- **Ecosystem Enablement and Sustainability:** Addressing the extensive demands of 6G requires fostering ecosystem development and evolution. This includes maturing business models for advanced services and adopting collaborative frameworks such as co-creation to drive sustainable innovation across sectors.
- **Collaborative Expert Community:** The strength of the SNS JU expert community in technological advancements is pivotal. Sustaining and enhancing this expertise across various technological opportunities and demands will be instrumental in achieving successful 6G deployment and adoption.

The process of updating the 6G SNS vision integrates insights from SNS JU projects, global stakeholders, peer associations, academic and industrial groups and initiatives by the 6G Infrastructure Association (6G-IA). Through intense interaction with several of these stakeholders in a number of key events around the world but also via the targeted Impact Assessment and Facilitation Action (IAFA) events organized by SNS OPS, the key steps of this process have been suggested as follows:

- **Analysis of Use Cases and Insights:** Utilizing results from SNS JU projects to understand use cases to be enabled by 6G, and gaining insights for a global holistic societal perspective.
- **Collaboration with Stakeholders:** Engaging with global peer associations, EU initiatives, and relevant bodies to align on updated vision elements.
- **Integration of Technological and Societal Aspects:** Incorporating advancements in technologies (microelectronics, photonics, AI/ML) with societal needs and sustainability goals to shape a comprehensive updated vision.
- **Preparation of Updated Documents:** Collaborating with the 6G-IA Vision and Societal Challenges (VSC) WG to update the European 6G SNS vision white paper, reflecting insights on technologies, architectural trends and business enablers.

The journey towards 6G SNS represents a complex endeavour requiring interdisciplinary expertise and global collaboration. The SNS OPS team is committed to monitoring developments on various fronts, including strategies like the NetworkEurope SRIA and global vision statements, to deliver a proper landscape analysis as well as a roadmap of concrete steps to be followed by the SNS stakeholders that will result in an updated vision, reflecting current trends and encompassing the different key views. This

iterative approach ensures that the evolving 6G SNS vision aligns with societal, economic, and environmental sustainability goals while meeting the diverse needs of stakeholders and end-users.

It should be noted that it is neither the role nor under the mandate of SNS OPS to define what the European SNS vision on 6G should be. The task was rather to aggregate available information, critically analyse it, and to present the insights gained in this process which can serve as input for the SNS community for shaping and updating the 6G SNS vision.

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Abbreviations

3CN	3C Network – Connected, Collaborative Computing
3GPP	Third Generation Partnership Project
6GF	6G Forum
6G-IA	6G Industry Association
AI	Artificial Intelligence
AIOTI	Alliance for IoT and Edge Computing Innovation
AR	Augmented Reality
ASIC	Application Specific Integrated Circuit
ATIS	Alliance for Telecommunications Industry Solutions
B5PC	Beyond 5G Promotion Consortium
B6GA	Bharat 6G Alliance
CCSA	China Communications Standards Association
CHIPS-JU	Chips Joint Understanding
CMOS	Complementary Metal-Oxide-Semiconductor
CSA	Coordination and Support Action
CSO	Civil Society Organization
DG-CNECT	Directorate-General for Communications Networks, Content and Technology
EC	European Commission
ECCC	European Cybersecurity Competence Centre
ECS	Edge Computing System
ECSSO	European Cyber Security Organisation
ESA	European Space Agency
ETP	European Technology Platform
ETSI	European Telecommunication Standards Institute
FEM	Front-End Module
FSTP	Financial Support to Third Party
HE	Horizon Europe
HPC	High Performance Computing
IAFA	Impact Assessment and Facilitation Action
ICT	Information and Communication Technology
IMT-2030	International Mobile Telecommunications - 2030
IO	International Organization
IPCEI	Important Projects of Common European Interest
ISAC	Integrated Sensing and Communications
ITU-R	International Telecommunication Union – Radiocommunication Sector
KPI	Key Performance Indicator

KSO	Key Strategic Orientation
KVI	Key Value Indicator
M2H	Machine-to-Human
M2M	Machine-to-Machine
MIMO	Multiple Input – Multiple Output
ML	Machine Learning
MNO	Mobile Network Operator
MR	Mixed Reality
NESSI	Networked European Software and Services Initiative
NGA	Next G Alliance
NGMN	Next Generation Mobile Networks Alliance
NGO	Non-Governmental Organization
NRT	Non-Real Time
NTN	Non-Terrestrial Network
NWE	NetworldEurope
PSCE	Public Safety Communications Europe
RAN	Radio Access Network
RIS	Reconfigurable Intelligent Surface
RT	Real Time
SB	Steering Board
SME	Small or Medium sized Enterprise
SNO	Satellite Network Operator
SNS JU	Smart Network and Services Joint Undertaking
SoC	System on a Chip
SRIA	Strategic Research and Innovation Agenda
TB	Technology Board
TF	Task Force
TN	Terrestrial Network
TRL	Technology Readiness Level
TSDSI	Telecommunications Standards Development Society
UAV	Unmanned Aerial Vehicle
VR	Virtual Reality
VSC WG	Vision and Societal Challenges Working Group

1 Introduction

One of the objectives of SNS OPS project Work Package 1: “Assessment and Planning” is to renew and revitalize the Smart Network and Services (SNS) Vision to reflect the views of the various stakeholders engaged in the SNS ecosystem, not limited to the project community but also stakeholders reached by e.g. the Impact Assessment and Facilitation Action (IAFA) work, as well as the priorities of the Public and Private sides in SNS as the SNS Joint Undertaking (JU) progresses into its next phases and its stakeholders interact with the broader global 6G ecosystem.

With first results and insights from the SNS JU projects becoming available, pointing at promising technologies, early insights into the potential performance of certain features and first measurements of Key Performance Indicators (KPIs) and Key Value Indicators (KVIIs), it is to be expected that the initial vision of the SNS on 6G networks would be shifted along with these developments. This deliverable provides an analysis of all relevant material, summarizing the views of key stakeholders and how the current insights and priorities set by the public and private sides could lead to potential shifts in the SNS vision, as well as how this may affect the roadmap of the SNS for the coming years. It should be noted that it is not the role or mission of SNS OPS to define a new SNS Vision on behalf of the SNS community, but simply to analyse the trends, priorities and key developments that might trigger the need for a renewed SNS vision and suggest the most prominent directions that should be investigated for the updated SNS vision based on the aforementioned analysis.

1.1 Purpose and scope of the deliverable

The purpose of this deliverable is to investigate and analyse how the priorities of the public and private sectors have changed since the beginning of the SNS JU in 2021, and what the views of various key stakeholders are that should be taken into account when revamping the SNS vision, to ensure that 6G networks will have a broad impact and applicability in multiple industries/sectors. As the SNS JU progresses in its journey to investigate and evaluate the most promising technologies for 6G networks, the suitable KPIs/KVIIs and the prioritised use cases and their expected performance, the generated knowledge and insights are able to lead to a re-assessment of the priorities of the various SNS stakeholders. Moreover, European and global developments on expected market impact, technological advancements and overall digital sovereignty strategies may lead to the shift of public and private sector priorities. As such, it should be examined if the initial SNS Vision on 6G networks is still valid or whether an update appears beneficial or even required, to reflect any changed priorities.

To achieve this goal, there are several sources of information that fall within the scope of the SNS OPS research that have assisted in the analysis of the current trends on 6G network vision, including:

- The NetworldEurope and the SNS JU Strategic Research and Innovation Agendas (SRIA)
- The SNS JU Work Programmes reflecting R&I trends
- The 6G-IA strategic & position papers
- SNS community & Working Groups White papers
- The SNS JU projects vision statements & generated insights
- Strategic/position papers from other (peer) EU initiatives and associations
- Stakeholder views & roadmaps from various related sectors (also acquired by targeted Impact Assessment and Facilitation Action events)

1.2 Context and background

This is the third deliverable of SNS OPS WP1 which focuses on the SNS vision. However, as the analysis performed takes into account information from various sources such as the NetworldEurope SRIA, the SNS OPS questionnaire, the 6G-IA and SNS JU strategic documents, the performed gap analysis, Impact Assessment and Facilitation Action (IAFA) events, etc., contribution from WP4 (responsible for IAFA events) was required as well. An update of this analysis (and the corresponding SNS vision trends) will be provided in D1.4 at the end of the project in March 2025.

2 SNS Vision process

In this section we describe the process of how the SNS vision is created and reviewed, how new input has been collected and suggested, and how the stakeholders have been involved in vision creation and updating.

The initial (and still current) SNS 6G Vision was formulated based on consultations within the EU and associated countries, and by strong involvement from the private sector, mainly via the NetworkEurope European Technology Platform (ETP) and the 5G Infrastructure Association (5G-IA, later renamed to 6G-IA). The important actors, stakeholders and inputs involved in establishing and shaping the SNS JU are illustrated in Figure 1, where relevant documents and information flows are also shown. The main inputs are from the NetworkEurope ETP which provides the industry views via the Strategic Research and Innovation Agenda (SRIA). Together with high level EU policies formulated in the Digital Europe and Horizon Europe programmes, this was the basis for the SNS JU SRIA followed by the creation of annual work programmes. Parallel to this the 6G-IA through the Vision and Societal Challenges Working Group (VSC WG) provides the industry vision of 6G. The role of the SNS OPS project is to facilitate and support the ongoing evolution of the programme vision when these are updated.

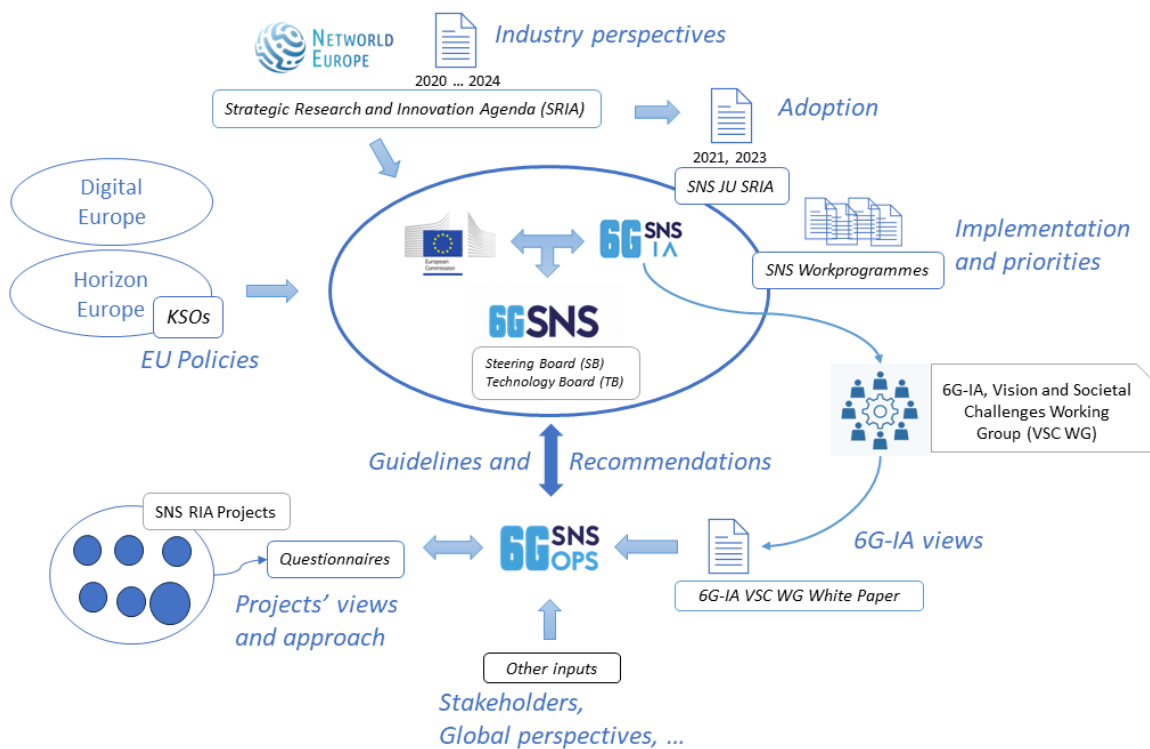


Figure 1 SNS Vision and Programme process, stakeholders and reference documents.

The EU stakeholders' vision of what 6G should be led to the SNS JU programme creation. This initial vision is elaborated by multiple contracted projects and the SNS JU community. The community's engagement and the natural priority separation, together with the technological innovation, is helping in the comprehension and in the improvement of the 6G vision. Several mechanisms are in place to improve the vision as time progresses, namely:

- The NetworkEurope SRIA [1][2] with the involvement of the broad community and respective actors. SNS OPS supports and helps this development via assistance in the NetworkEurope events and more.
- 6G-IA VSC WG and the forthcoming up-dated version of the "European Vision for the 6G Network Ecosystem" [3] white paper.
- The SNS OPS project's Monitoring Framework that allow assessing what the community and the projects are working on and their respective vision [4].

- The SNS OPS Vision retrospect / assessment based on the current and previous Work Programmes
- SNS JU online webinars which are used to provide explanations about the programme development, and to receive informal feedback from the community.
- NetworldEurope technical events, supported by SNS OPS, and that are regularly organized as sessions on technological challenges, to help building a community vision on the future.
- The SNS OPS organized Impact Assessment and Facilitation Action (IAFA) events, engaging experts from different backgrounds and aggregating their insights on specific topics.

This is a cyclic process where experiences from the implementation is used to renew the SRIAs and 6G Vision looking forward, in which the community is involved, and in turn impacts the community and technical groups through the issued reports and results. The process also impacts the writing of the future Work Programmes and thus, that can guide the SNS JU overall. Furthermore, this is important input to the 6G-IA Board and the 6G-IA Vision and Societal Challenges Working Group (WG) ambitions, as well as the SNS projects Sustainability Task Force.

Further activities should also be addressed by the relevant WGs, Subgroups, Task Forces (TF), bodies and activities by e.g., the Steering Board (SB) and Technology Board (TB) and related activities to advance the vision.

The creation of the SNS JU results from a consultation on partnerships among Member States (including Iceland and Norway) performed by the EC in 2019 following the creation of the Horizon Europe (HE) programme [5]. Important objectives for the creation of the SNS JU was to:

- Reinforce research on new generation networks and services;
- Include large-scale infrastructures deployments;
- New value chains, and ecosystems across sectors;
- Demonstrate a clear European added value;
- Include ethical, legal and social issues;
- European technology sovereignty.

The SNS Proposal from 2020 [6] provides the main motivations and objectives with a common vision and ambition, including a Europe fit for the digital age, and supporting the European Green Deal.

In the creation of the partnership and the following annual Work Programmes, the definitions of the Key Strategic Orientations (KSOs) from the Horizon Europe programme [7] together with the above-mentioned mechanisms have been central.

The documents [6] and [7] mentioned above are more in-depth presented in chapter 3, together with other relevant inputs.

Following the initial formulation, an update of the SNS 6G Vision will be based on existing and planned updates of the mechanisms above (the NetworldEurope SRIA, the VSC WG White Paper, and the SNS OPS Monitoring Framework). Both NetworldEurope and the 6G-IA VSC WG are working towards updates of the documents, while the Horizon Europe programme has adopted the second strategic plan (2025-2027) [8], where new KSOs are formulated:

- The Green Transition;
- The Digital Transition; and
- A more resilient, competitive, inclusive, and democratic Europe

Other inputs and sources are the responses to the annual questionnaires which SNS OPS submits to the running SNS JU projects, where the projects (among others) are asked about how they address and contribute to the SNS Vision. The first iteration with 33 Call#1 projects was done in 2023. Its results have been presented in SNS OPS deliverable D1.2 [4] and in a webinar on 23rd November 2023 [9]. The second iteration where also Call#2 projects were included is still ongoing. Based on learnings from the 1st survey, the questions in the Vision section were re-shaped.

Highlights from the initial analysis can be summarised as below:

- *Energy and carbon footprint and neutrality* are considered the most important societal challenges.
- *Sustainability* is considered the most important societal value, with economical sustainability and innovation on top.
- *Most projects will use trials and experiments* to assess Key Value Indicators (KVIs).
- *Affordability, scalability, flexibility and efficiency* are most important contributions to the 6G Vision.
- *Industry, Innovation and Infrastructure*, together with Sustainable Cities and Communities, are most important UN SDGs.

3 Review of the current 6G vision in Europe and in the World

This section focuses on analysing the views of the most important European and global stakeholders regarding the 6G vision, the prioritised use cases and directions, and key technologies envisioned to enable future networks. Through the analysis of the stated vision and roadmaps of these stakeholders it became possible to extract some key commonalities and differences which highlight the parts of the 6G vision that already seem to achieve consensus and the parts that more alignment will be required.

The following sections delve into the key points of the 6G vision as stated by relevant associations, working groups, 6G initiatives and global stakeholders, while section 3.5 provides the summary of the insights gained along with a comparative analysis.

3.1 The NetworldEurope Strategic Research and Innovation Agenda

NetworldEurope (NWE) is one of the institutions that aims to address the challenges brought by this increased intertwining of ICT and society. NetworldEurope brings together almost one thousand stakeholders of the area, ranging from SMEs to large industries, to the academia, and tries to engage with other relevant bodies in order to contribute to the establishment of consensual views about the future of this new connected Europe. In this context, NetworldEurope has worked with the 6G Infrastructure Association (6G-IA), and established liaisons with other European and international bodies (such as AIOTI, NESSI, ECSO, ETSI, and CCSA) in order to build a Strategic Research and Innovation Agenda (SRIA) for communications and services [1][2].

Part of the immediate impact of this effort will be reflected in the European research Work Programme of the Smart Networks and Services (SNS) Joint Undertaking (JU), driven by the European Commission and the 6G IA. But the contents of this SRIA can impact other European Work Programs, both at national level (where we see a widespread effort by European countries to fund national 6G initiatives) and at international level (either in Horizon Europe, or in other Joint Undertakings/Public-Private Partnerships besides SNS). As a deeply technological vision on communication and services, NetworldEurope Strategic Research and Innovation Agenda (NWE SRIA) can be explored in different dimensions, in different technological and application domains.

The new NWE SRIA Technical Annex is currently being updated. According to Figure 2 we can see that the Visions for Future Communications Summit (VFCS 2023)² held in Lisbon on the 07th and 08th November 2023 was the trigger for the new NWE SRIA update. This led to triggering the formal process of the NWE SRIA update and we expect to have the NWE SRIA version n°1 available by May 2024. The next step is to have stakeholder feedback to revise and enhance the 1st stable version, and this will lead to the final version of the NWE SRIA Technical Annex, which will be ready by July 2024. The NWE SRIA Technical Annex draft versions will trigger the NWE SRIA Whitepaper's development, which is expected to be available by the end of July 2024.

² <https://futurecomresearch.eu/>

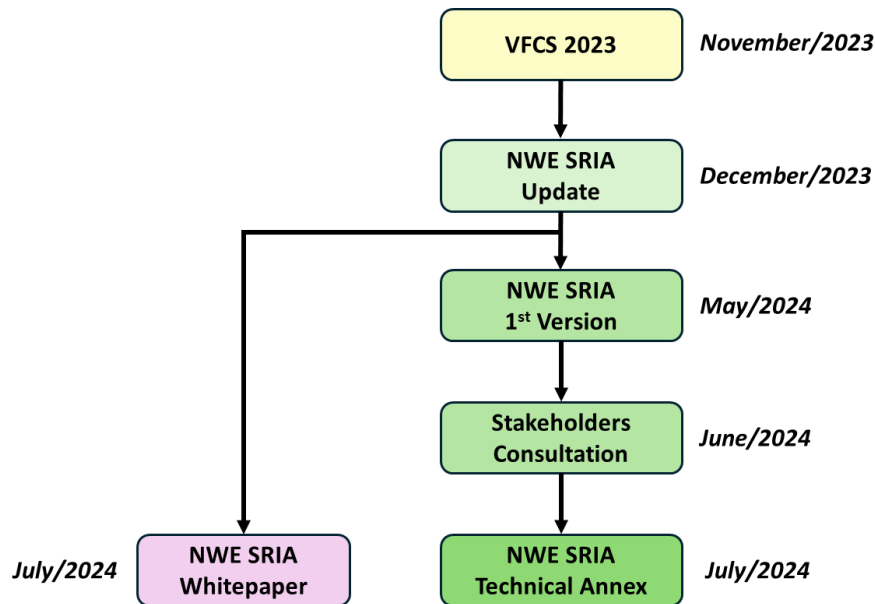


Figure 2 NetworldEurope SRIA 2024 documents being developed.

As we can see in the previous figure, NWE SRIA consists of 2 parts: a Technical Annex and a Whitepaper.

1. **The NWE SRIA Technical Annex** discusses concepts and technologies essential for developing innovative services. The diversity of technological domains required for future communication infrastructures highlights the relevance of multiple innovation domains for European Research. In this document we have nine different domains, each one of them with a set of identified research challenges:

- **System Architecture** – analysing the evolution of systems towards dynamically composed, multi-stakeholder environments, with an increasing softwarisation and intelligence of the whole system, and the accompanying challenges.
- **Network Enablers** – this chapter will address network protocols and network services interfaces. This chapter is a novel introduction over the previous NWE SRIA 2022 [2] document and as such the whole content is completely different from the previously published content on the SRIA.
- **Network and Service Security** – discussing the paths on the increasingly relevant aspects of security in our infrastructure.
- **Software Technologies for Telecommunications** – addressing the software related challenges of the ongoing network softwarisation, the increasing system complexity, and the enabling of adaptive and customized services.
- **Radio Technology and Signal Processing** – where the challenges and potential solutions perceived for the future wireless (and mostly cellular) communications are discussed.
- **Optical Networks** – a critical component of the backbone (amongst other potentialities) and its perceived evolution.
- **Non-Terrestrial Networks and Systems** – discusses the upcoming closer integration of 3D networks into the overall communication system.
- **Opportunities for Devices and Components** – tackles the unavoidable challenges at the fundamental element level, which will constrain and limit all system developments.
- **Future Emerging Technologies** – discussing promising technologies that may bring structural changes across all the current communication concepts. Some of these technologies are already being researched but have not yet a clear path (if ever) to the transformational impact it is expected by their wide adoption.

2. **The NWE SRIA Whitepaper** is a separate document relying on the SRIA Technical Annex. This document will have a different target audience being oriented towards interested stakeholders and not only technical experts. The whitepaper will provide the overall system vision for 6G, including expected performance improvements for the future.

3.2 The SNS JU Strategic Research and Innovation Agenda

The SNS JU SRIA [11] relies on the NetworldEurope SRIA. This is because the NetworldEurope has a significant basis of industrial, research, academic and SMEs members, thus reaching out to significant part of the European ICT community and expertise. Also, its scope constitutes a superset of topics compared to the scope of the SNS JU. As mentioned in the previous section, NetworldEurope is updating its SRIA every two years.

As described in the MoU between the 6G-IA and NetworldEurope [12], the NWE SRIA will be used as the basis for the SNS JU SRIA. The plan for doing this adaptation contains the following steps that have taken place in 2023 and are expected to be followed in the future as well:

1. Consultation with the 6G-IA members to select the most relevant topics from NetworldEurope SRIA to populate the SNS JU SRIA.
2. Formation of a group of experts from the 6G-IA, NetworldEurope, AIOTI, NESSI, PSCE and the public side to select and prioritize the most promising topics for the future of telecommunications in Europe. This will serve as the basis for the updated versions of the SNS JU SRIA.
3. Dissemination of the SNS JU SRIA in dedicated workshops/webinars and organization of a stakeholder consultation process, so as to receive comments from all interested public and private European Stakeholders.
4. Finalization of the SNS JU SRIA based on the outcome of the stakeholder consultation.

The whole process is supported by the SNS CSA project active at each time, which currently is the SNS-OPS project.

3.2.1 SNS Priorities set by the private and public sides

The 6G-IA, representing the European private sector has prepared the proposal for the SNS JU [6]. This proposal is closely linked with the vision of the European private side for the evolution of networks and services [3]. Moreover, 6G-IA has developed a position paper to a comprehensive set of key strategic reflections and recommendations for 6G smart networks and services, capturing the views and priorities from the members of the 6G-IA [13]. The goal is that this document will be used to further elaborate the SNS JU SRIA as well as the R&I Work Programmes. It also aims to offer directions for collaboration opportunities for European Stakeholders that will go beyond the scope of the SNS JU. In its recent version the following areas are considered and analysed.

- 6G Technological Sovereignty which includes, in addition to the EU strongholds in radio and fixed networking systems: a) components and microelectronics, b) open SNS solutions, c) cloudification and distributed computing, d) network intelligence, e) security and privacy and f) addressing the skills shortage in Europe
- Sustainability which captures all aspects of environmental, societal and economic sustainability

Moreover, in the context of the SNS-OPS, 6 IAFA workshops have been organized to create initial roadmaps on the abovementioned topics (the insights gained from these events are summarized in Chapter 4). The results of these workshops are used in 6G-IA consultations to create solid plans on SNS technological topics that will capture the European private side priorities for future SNS R&I Work Programmes.

These Work Programmes support clear, public side objectives. More specifically the SNS JU targets the following Key Strategic Orientations, as outlined in the first Horizon Europe Strategic Plan [7]:

- KSO A, ‘Promoting an open strategic autonomy by leading the development of key digital,

enabling and emerging technologies, sectors and value chains to accelerate and steer the digital and green transitions through human-centred technologies and innovations.’

- KSO C, ‘Making Europe the first digitally led circular, climate-neutral and sustainable economy through the transformation of its mobility, energy, construction and production systems’

In addition, the SNS JU is expected to contribute to the following goal:

Open strategic autonomy in digital technologies and in future emerging enabling technologies, by strengthening European capacities in key parts of digital and future supply chains, allowing agile responses to urgent needs, and by investing in early discovery and industrial uptake of new technologies.

The SNS JU targets a reinforced European leadership in the development and deployment of next generation network technologies, connected devices and services, while accelerating European digital industry and Public Administrations digitization. It aims at positioning Europe as a lead market and positively impact the citizen’s quality of life, by supporting key Sustainable Development Goals (SDGs) while boosting the European data economy and contributing to ensure European sovereignty in this critical supply chains.

Finally, the public side is calling for a coherent HEU Programme that will enable synergies among related Partnerships that are dealing with the evolution of networks and services as well as their key technological enablers to maximize the desired outcomes.

3.2.2 Key SNS goals and drivers

The main goal of the SNS JU is to define and implement the research, innovation and deployment roadmaps that will enable Europe to lead in the creation of the next generation of smart network technologies and services. These will be designed and implemented in such a way that European values like security and privacy are safeguarded, and European technological sovereignty is further strengthened. The Joint Undertaking also focuses on the full digitization of European society including vertical industries and public administration. Thereby, the SNS JU targets to have a positive impact on the quality of life for European citizens and boost the European data economy. The SNS drivers [3] are depicted in Figure 3.

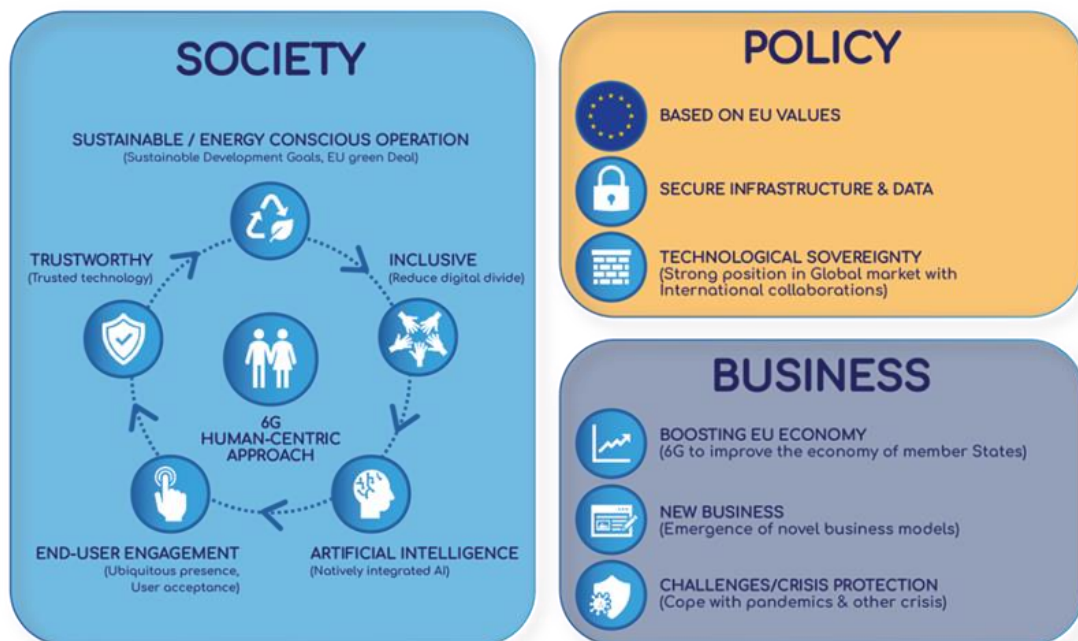


Figure 3 SNS JU drivers [11]

The SNS JU ambition is fully aligned with key policy objectives of the strategic planning for Horizon Europe [14]. The vision is based on the socio-economic evolution of SNS platforms which are critical infrastructure for the economy, on the need to retain technological leadership in Europe and to address

societal concerns [6]. The corresponding strategic objectives are illustrated in Figure 4:

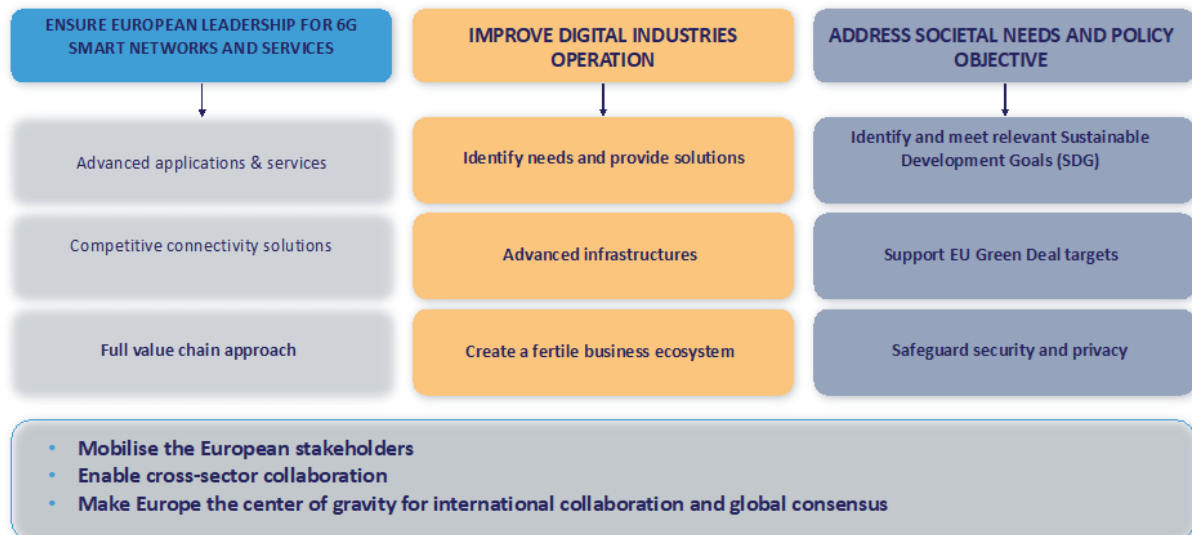


Figure 4 SNS JU Strategic objectives [11]

These objectives will be met by carefully planning the SNS SRIA and the annual Work Programmes to mobilise the European stakeholders, establish the cross-sector collaboration and ensure that Europe will be once again the centre of gravity for international collaboration to reach global consensus on 6G technologies.

The Horizon Europe SNS JU targets a reinforced European leadership in the field of next generation network technologies (6G), connected devices and services, while accelerating European digital industry uptake and digitisation of economy and society. It aims at positioning Europe as a lead market and positively impact the citizen's quality of life, by supporting key SDGs while boosting the European data economy and contributing to ensure European sovereignty in these critical supply chains.

6G technologies aims to tackle the challenges we will face in 2030 and beyond. Mobile communications is becoming pervasive and will play an even bigger role in our day-to-day lives than today. This means that 6G will have to achieve much more than just providing fast mobile Internet access. These goals include radically new applications capabilities supported by:

- The convergence of physical, human, and digital worlds in 6G with support for digital twinning, immersive communication, cognition, and connected intelligence.
- 6G needs, where required, to significantly advance the KPIs that 5G can achieve now.
- More emphasis on value creation by the introduction of Key Value Indicators as a different measure.
- Flexibility and programmability should be at the heart of 6G for optimised service implementation as a function of varying application requirements.
- Deterministic 6G end-to-end services as needed for real time critical applications.
- Integrated sensing and communication to enable high accuracy localization and high-resolution sensing services and should ensure Privacy at the same time.
- Significant reduction of 6G footprint on energy, resources, and emissions and facilitate more sustainable industrial application through improved networks, also bringing better services to society as a whole.
- 6G needs to become a truly trustworthy infrastructure that will become the basis of societies of the future.
- To ensure that 6G can be inclusive for all people across the world, it needs to be scalable and affordable.

All these goals are illustrated in Figure 5 [3].

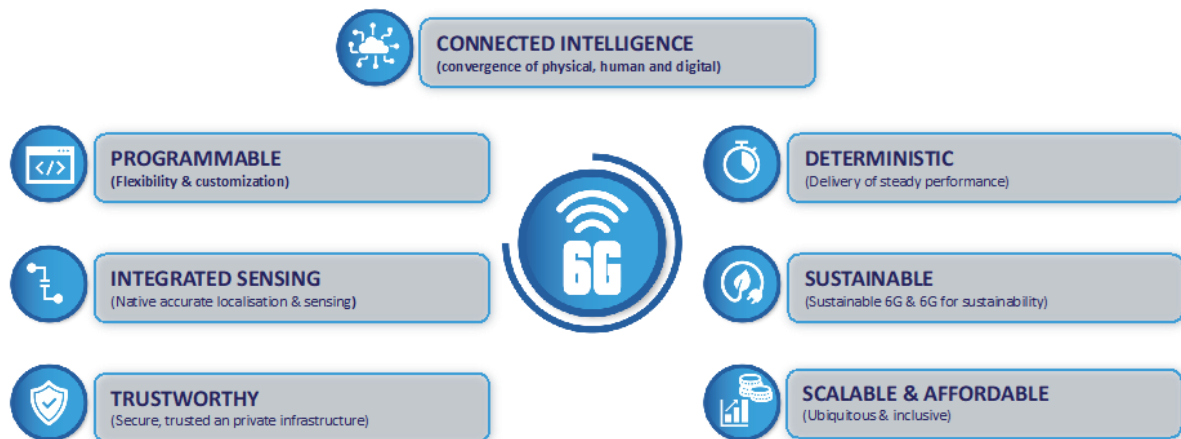


Figure 5 Main goals of 6G smart networks and services

3.2.3 SNS Annual Work Programme

The SNS draft WP2025 is currently under definition with the target to be converged and released in October 2024. The SNS OPS D1.2 summarized the overall SNS WP2024 definition from March to November 2023. The draft WP2025 is engaging an overall detailed process with multiple successive and converging draft versions, multiple sources (e.g. 6G-IA Workshops, NetworldEurope 2024 SRIA...), interactions (including 6G-IA, EC, SNS Office, Members States (MSs) States Representative Group (SRG)...), 6G-IA Members consultations, SNS Call 2024 Coordinators Survey, dedicated SNS workshops and SNS CSAs inputs... The overall SNS WP2025 definition will be summarized in the forthcoming SNS OPS D1.4 (targeted summary like for WP2024 in D1.2).

3.3 The 6G-IA Vision and Societal Challenges WG White Paper

The current and primary European 6G vision whitepaper developed by the 6G SNS Industry Association (6G-IA) community [3] was produced and released back in June 2021 (and at that time, by 5G-IA). It envisages a future in the 2030s of “billions of things, humans, and connected vehicles, robots and drones ... 6G will be dealing with more challenging applications, e.g., holographic telepresence and immersive communication, and meet far more stringent requirements”.

The whitepaper provides visionary prospects enabled by 6G considering a broad spectrum of topics from societal needs and value driver to technical enablers. In short, the societal oriented vision was formulated as “6G will be one of the basic foundations of human societies of the future. To enable a sustainable progress for society, in line with the United Nations Sustainable Development Goals, it is crucial that 6G addresses effectively pressing societal needs, while delivering new functionalities. This (r)evolution must be in line with Europe’s primary societal values, in terms of e.g., privacy, security, transparency, and inclusiveness. Digital technologies are also becoming a critical and essential means of ensuring countries’ sovereignty. The development of Europe based 6G infrastructures and solutions is one of the keys to secure European sovereignty in critical technologies and systems.”.

The whitepaper starts from societal, business and ecosystem perspectives, potentials, and ambitions which also considers regulatory perspectives: – “... The deployment of services using new 6G capabilities and the emergence of millions of specialised and localised subnetworks may require further clarification for what concerns the applicability of net neutrality rules and of the data protection regulation (ePD and GDPR), potentially adding a new dimension to the current scope of Net Neutrality. The emergence of new European players should be supported, and sovereignty and security requirements shall be well identified and enforced. AI-based sophisticated automation to deliver services in 6G networks will require additional regulations, based on ethics principles that conform to European standards.”

In this context the whitepaper presents further details on the motivation for these developments and changes, and then elaborates on envisaged technological enablers, features, and mechanisms, such as a) System network architecture and control; b) Edge and ubiquitous computing; c) Radio technology and signal processing; d) Optical networks; e) Network and service security; f) Non-terrestrial networks communication; g) Special purpose networks / sub-networks; and h) Devices and components. Moreover, it provides a 6G architectural outlook, analysis, and vision, while completing the whitepaper by suggestions on timeline and recommendations. The recommendations also address public – private collaboration and investments, perspectives and requirements on global standardization, and finally the needs of skills and a competence pool across a holistic and broad portfolio of topics, while pushing for diversity and inclusion.

Complementary to the “European Vision for the 6G Network Ecosystem” whitepaper there are several Working Groups (WGs) that through their work and more recent whitepapers also contributed to the broader portfolio of key topics, and accordingly their visionary perspectives³. Here, we highlight the work and whitepapers of the following WGs or Sub-Groups.

- The Societal Needs and Value Creation Sub-Group (SG of the Vision and Societal Challenges WG) producing the “What societal values will 6G address?” white paper [15].
- The Business Validation, Ecosystems, and Models Sub-Group (SG of the Vision and Societal Challenges WG) producing the “5G and beyond 5G Ecosystem Business Modelling” white paper [16].

3.4 Review of major running 6G initiatives

Various global and regional entities have publicly disclosed their strategies and shared their perspectives on use cases and requirements for 6G. Some have been in the landscape for long, such as the **Next Generation Mobile Networks Alliance (NGMN)**. Other entities evolved from earlier 5G research initiatives in different regions of the world and evolved towards 6G. Counterparts taking care of 6G issues outside Europe include the **Next Generation Alliance (NGA)**⁴ in the USA, part of the **Alliance for Telecommunication Industry Solutions (ATIS)**⁵, the **IMT 2030 (6G) Promotion Group**⁶ in China, the **Beyond 5G Promotion Consortium** in Japan (B5PC)⁷, the **6G Forum** in South Korea (6GF)⁸, and the **Telecommunications Standards Development Society**⁹ in India (TSDSI), the **Bharat 6G Alliance (B6GA)**¹⁰ in India and **Brasil 6G** in Brazil (B6G)¹¹. These initiatives involve local key network operators and service providers, manufacturers, system integrators, research institutes, and universities. They are depicted in Figure 6. On top of these initiatives some industrial actors have published their visions.

The diverse approaches are briefly presented focusing on 6G use cases, starting with the NGMN alliance. Approaches are not always similar. The Republic of Korea and Japan approaches are based on requirements for the future ecosystem, highlighting key topics addressed by research rather than giving details on use cases, but in the end seem to identify quite similar use cases, integrating AI capabilities, aiming at higher data rates, lower latency and a higher number of connections of objects than in 5G.

Information comes from desk research. There may be initiatives that were not public or remained

³ <https://6g-ia.eu/6g-ia-working-groups/>

⁴ Next G Alliance “Next G Alliance” <https://www.nextgalliance.org/>

⁵ ATIS – www.atis.org

⁶ IMT 2030(6G) Promotion Group “IMT-2030(6G)推进组 (imt2030.org.cn)” <https://www.imt2030.org.cn/>

⁷ Beyond 5G Promotion Consortium “Beyond 5G Promotion Consortium (b5g.jp)” <https://b5g.jp/en/>

⁸ 6G Forum “6G Forum” <http://www.5gforum.org/html/en/main.php>

⁹ Telecommunications Standards Development Society, India (TSDSI). Telecommunications Standards Development Society, India - India's Telecom SDO (tsdsi.in)

¹⁰ Bharat 6G Alliance “Bharat 6G Alliance” <https://bharat6galliance.com/>

¹¹ Brasil 6G <https://inatel.br/brasil6g/>

confidential at the time of searching. Information presented below depicts the different approaches and key objectives that seemed relevant based on the author's knowledge. Information mentioned in the following sections cannot thus be exhaustive and should not be considered as such. The reader may consult the original documents and websites to get additional information.

Apart from these regional initiatives, the **ITU-R** reached an agreement on recommendations for the new "IMT-2030 Framework" in November 2023. It sets the stage for activities such as 6G development, standardisation, and deployment. In the ITU-R framework for IMT-2030, six "usage scenarios" are outlined [17], three evolving from IMT-2020 and three introducing new capabilities.

These scenarios include:

- Immersive Communication,
- Hyper Reliable and Low-Latency Communication,
- Massive Communication,
- Ubiquitous Connectivity,
- Integrated AI and Communication,
- Integrated Sensing and Communication.

Each scenario is supported by four overarching aspects:

- Sustainability,
- Connecting the unconnected,
- Ubiquitous intelligence,
- Security and resilience.

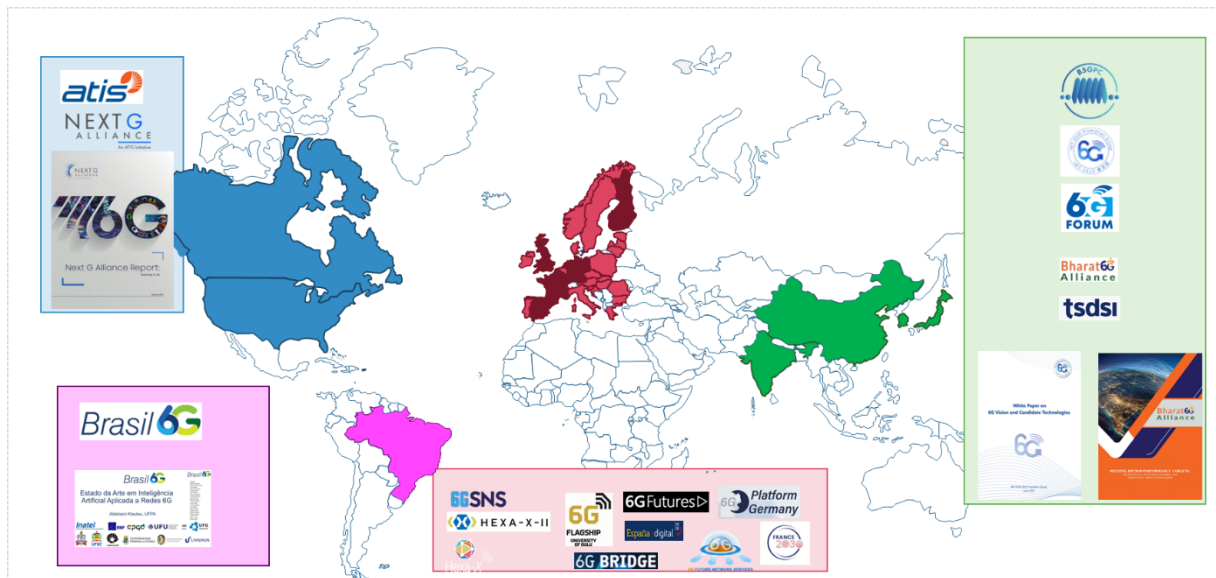


Figure 6 World global activities in 6G

These aspects serve as design principles embedded in all scenarios. Immersive Communication enables rich interactive video experiences, while Hyper Reliable and Low-Latency Communication caters to specialised use cases with stringent reliability and latency requirements. Massive Communication focuses on connecting numerous sensors and actuators, and Ubiquitous Connectivity aims to bridge the digital divide. Integrated AI and Communication emphasises distributed computing and AI-powered applications, while Integrated Sensing and Communication facilitates new services requiring sensing capabilities.

3.4.1 The NGMN Alliance

The NGMN alliance announced the launch of a project on visions and drivers for 6G back in October 2020. The first deliverable was released in April 2021. In 2022 and 2023, the alliance published deliverables on 6G use cases and analysis [18] and on 6G requirements and design considerations [19]. In these deliverables NGMN has outlined four use case families based on their common characteristics: A brief description of the four use case families is provided in the following.

In February 2024, NGMN published a White Paper “ITU-R Framework for IMT-2030: Review and Future Direction” on its 6G Views covering vision, usage scenarios and essential capabilities, particularly related to practical and sustainable deployment and harmonised standards for 6G. It is important to mention that a close alignment is observed between the IMT-2030 Framework from ITU-R and the NGMN’s vision for 6G [20].

With regards to the use cases, NGMN has outlined four use case families including:

- *Enhanced Human Capabilities* with use cases able to enrich human communications including immersive experience, telepresence, multimodal interactions.
- *Enhanced Machine Communication* with the increasing use of robots, autonomous machines which communicate around themselves with humans and peers.
- *Enabling Services* deal with use cases requiring additional features (high-accuracy location, mapping, environmental, or body sensing data).
- *Network Evolution* describes use cases related to the evolution of core technologies including AI as a service, energy efficiency, and delivering ubiquitous coverage.

Environmental impacts of 6G as well as energy efficiency or ubiquitous coverage (“connectivity for all”) are key aspects for NGMN.

3.4.2 Brazil

The *Brasil 6G* Project is an initiative supported by the National Institute of Telecommunications (INATEL), the Ministry of Technology and Innovation (MCTI) and the Brazilian Network for Education and Research (RNP). It issued an action plan for 6G in Brazil in 2023 with BRL60 million (EUR11.4 million) investment in the competence centre responsible for 5G and 6G.

6G is also mentioned in the programme (as well as Semi-conductors, datacenters, generative AI and advanced robotics) <https://www.bnamericas.com/en/news/made-in-brazil-govt-unveils-us60bn-program-to-boost-local-industry> launched by the Brazilian government to stimulate domestic industry with BRL 300 billion (EUR 51.5 billion) through loans, grants, direct subsidies and preference for national products in public procurement processes.

The first part of the Brasil 6G effort was to issue use cases and define requirements. INATEL has already secured use cases for 6G such as Robotic applications for agriculture, real-time transmission of high-resolution drone images, sensor-based control of real and virtual entities in hazardous areas.

The 2nd part aims at developing a platform where solutions will be tested in a 6G environment.

3.4.3 China

In China, the IMT-2030(6G) Promotion Group which represents the frontier progress of 6G technology and industry development in China published a white paper in June 2021 on “6G Vision and Candidate Technologies” [21].

In May 2023, it released another White Paper on “6G Usage Scenarios and Key Capabilities” [22] . Four driving forces are identified:

- i.sustainable economic development,
- ii.sustainable social development,
- iii.sustainable environmental development,
- iv.technological innovation and development,

and five usage scenarios are identified in the deployment of 6G:

- i. *Super Mobile Broadband*: meant as an evolution of eMBB (enhanced Mobile Broadband) capabilities known in 5G. Objectives are to provide human-centric immersive communication experience and also to achieve seamless coverage anywhere in the world.
- ii. *Ubiquitous Machine Connection*: also meant to go beyond the 5G massive Machine-Type Communications (mMTC). 6G will be able to allow diversified transmission rates everywhere enabling a higher variety of applications than 5G mMTC.
- iii. *Superlative Ultra-Reliable and Low-Latency Communications*: builds on 5G Ultra Reliable and Low-Latency Communication (uRLLC). It is not only a demand for lower latency and higher reliability, but also for capabilities of medium and high-speed data transmission and ultra-high precision positioning.
- iv. *Quality Guaranteed Network Artificial Intelligence*: is a brand-new scenario with integrated AI communication and computing capabilities.
- v. *Integrated Sensing and Communication*: integration of sensing capabilities aims at providing enhanced capabilities such as high-precision positioning, environment reconstruction, imaging and recognition. This gives the opportunity to create new services and also to improve the performance and efficiency of communications by being able to adapt and optimize radio resources in a changing environment.

See also the Hexa-X-II project deliverable D1.2 on “6G Use Cases and Requirements”, section 2.3.4 [23].

3.4.4 India

The Telecommunications Standards Development Society in India (TSDSI) presented India’s 6G vision in a White Paper in June 2021 [24]. Four main goals for 6G were defined:

- i) facilitate a ubiquitous intelligent mobile connected society,
- ii) bridge the digital divide of the society,
- iii) personalise and localise services, and
- iv) provide native support for data ownerships and hierarchies.

6G will have to build on 5G success and do so in a more efficient, economical, scalable and sustainable way. The paper also provided a list of priority use cases encompassing:

- *Ubiquitous Connectivity and Compute Experience* will push for collaborative network/compute entities assisted by semantic interoperability interfaces. This will allow integration of smart city platforms, macro networks, private networks, cyber-physical entities, private verticals, aerial network/compute entities and possible intermediaries.
- *Enabling Smart Village / Remote Area Accessibility Including e-Health and Education* will enable remote medical assistance for humans & farm animals, weather monitoring and warning systems.
- *Automated Transportation* will enable use cases on autonomous driving and transportation mechanisms, aiming at improving safety, relieving traffic congestion among others.
- *Industrial Internet* will be deployed among key industry sectors and will focus on very low latency and ultra-high data rates.
- *Immersive Interactive Experience* will be mainly based on Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR) experiences to be deployed in the entertainment, medicine, science, education, and manufacturing industries.
- *Supply Chain and Logistics* will be enhanced using ultra-low indoor or outdoor positioning latencies for real-time tracking.
- *Surveillance for Industries and Civic Crime Control* will enable management of crowds’ prevention of crimes using Artificial Intelligence (AI) and Machine Learning (ML) capabilities.

- *Native AI and ML in Networks* will enable integrating AI into use cases at different levels.

In March 2023, within six months of 5G roll-out, the Indian Ministry of Communications released the “Bharat 6G Vision” [25], see Figure 7. The Bharat 6G Alliance (B6GA) is an industry-led body consisting of public/private companies, academia, research institutions and Standard Development organizations.



Figure 7 Bharat 6G Vision

The paper gives a plan for 6G research topics and lists key must-have capabilities including low latency, high bit rate, use of VR/AR, AI, Mobile Edge Computing, and Machine to Machine (M2M)/Machine to Human (M2H) interactions. The paper also highlights two principles, as depicted in Figure 7:

- ubiquitous connectivity is one of the key goals. It consists of providing connectivity everywhere but also to seamlessly connect all types of networks including non-terrestrial ones,
- sustainability, i.e. reducing the carbon footprint and having in mind social and economic aspects is also a key principle (Figure 8).

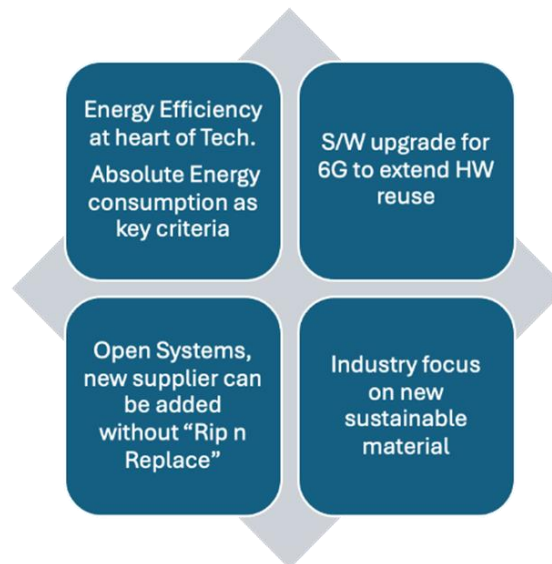


Figure 8 Bharat 6G Alliance sustainability principles, 3GPP SA Workshop, 8-10 May 2024, Rotterdam, Netherlands [26].

3.4.5 Japan

In Japan, the White Paper “Message to the 2030s” [27] published in March 2023 by the Beyond 5G Promotion Consortium (B5PC) offers a different approach. It rather builds on market trends in key industry sectors, than focusing on use cases or use case families.

The Japanese approach is more focused on depicting the future ecosystem than on explaining use cases. Depending on industry requirements, several use cases and usage scenarios have been identified. In the end, six major requirements have been selected covering:

- *Mission Critical Communication*: this scenario refers to use cases requiring very stringent transmission reliability and latency characteristics (remote surgeries, autonomous vehicles among other examples)
- *Ultra Massive Connection*: this scenario aims at handling a very large number of devices for sensing and measuring purposes.
- *Ultra-Broadband Communication*: this scenario aims at providing extremely high data rates and low latency to support applications including holographic communications, immersive experiences, and remote surgery.
- *Universal Coverage*: the scenario refers to providing ubiquitous connectivity and universal 6G coverage (in land, over water and in the air).
- *Ubiquitous Sensing*: this scenario embarks technologies that integrate sensing with communication systems. Some of the main capabilities include advanced localization, positioning, tracking, and mapping (autonomous driving, warehouse management, or automatic construction).
- *Intelligent Connection*: this scenario incorporates AI capabilities into the networks and into applications. AI capabilities will be helpful in zero-touch operations, enhancing predictability for systems, inference for collaborative robots, and distributed learning.

3.4.6 Republic of Korea

The government of Korea started national R&D projects back in August 2020, two years only after the 5G launch. It announced 6G technology trials for 2026 and commercial service in 2028.

In 2023, the government of Korea announced its 6G R&D strategy with the ambition to achieve the “World’s first 6G commercialization”. In addition, a long-term network strategy called the “*K-Network 2030 Strategy*” [28] was announced in February 2023 by the government to utilize not only 6G but satellite, open Local Area Networks, and quantum communication.

Like Japan, the government of Korea approach focuses on describing the future ecosystem and the key topics the research will address. Five main categories and three cross-cutting principles were identified:

- *Wireless Communication*: South Korea aims to deploy wireless communication the upper-mid frequency band (7~24 GHz) aiming to overcome capacity limitations in the 3.5 GHz range and the coverage limitations in the 26-28 GHz range pushed by Extreme Massive MIMO (Multiple Input, Multiple Output).
- *Mobile-core*: the country will focus on developing software-centric network technologies to adapt to the transition from hardware-centric to cloud and software-driven communication networks. Additionally, AI-based mobile network technology for autonomous network management and service quality control will also be studied.
- *Wired-Network*: the Republic of Korea is conscious that network performance of the wired network has also to be enhanced. Wireline and wireless will both be considered by researchers to improve high-speed and high-capacity optical transmission systems and component technologies.
- *6G Systems*: the main goal here is to realize seamless interoperation between all network components (wireless, wireline, and mobile-core networks segments connecting the end-user device to 6G-integrated services) and to integrate natively AI capabilities. They are expected to be used for distributing and interconnecting resources and ensure a service-based customised performance.
- *6G Standardization*: compatibility of developed 6G technologies with international standards will be a major focus.

The three cross-cutting principles on focus will be *safety* and *trustworthiness* in all research areas and *environmentally friendly*-approaches and solutions.

3.4.7 USA

In a 2022 paper called “6G Applications and Use Cases” [29], ATIS analysed drivers of future 6G use cases, including *Everyday Living*, *Experience*, *Critical Role*, and *Societal Goals*.

In brief, 6G use cases are expected to improve the quality of life. Using service robots may help delivering assistance (*Everyday Living*). They also will be able to enhance user experiences (*Experience*) using Mixed Reality (MR) entertainment, encourage human-machine interactions, improve healthcare (more and enhanced assistance), enhance gaming experiences, education, transport & logistics, etc. Robotics will help improve the quality of technology around healthcare, industry 4.0, agriculture and public safety applications (*Critical Role*). All in all, 6G use cases will help reaching societal and environmental goals (*Societal Goals*), including reduction of CO2 emissions, digital equity, energy efficiency, zero-energy devices, longer battery lifetimes, etc.

The Next G Alliance Report set out *6G Applications and Use Cases* which include four categories of use cases:

- i) Network-Enabled Robotics and Autonomous Systems,
- ii) Multisensory Extended Reality,
- iii) Distributed Sensing and Communications,
- iv) Personalised User Experiences,

and fourteen related use cases:

- i) Online Cooperative Operation among a Group of Service Robots,
- ii) Field Robots for hazardous environments,
- iii) Ultra-realistic interactive Sport-Drone Racing,
- iv) Immersive gaming/entertainment,
- v) Mixed reality Co-design,
- vi) Mixed reality telepresence,
- vii) Immersive education with 6G,
- viii) High-speed wireless connection in aerial vehicle for entertainment service,
- ix) Remote data collection,
- x) Untethered wearables and implants,
- xi) Eliminating the North American digital divide,
- xii) Public safety application,
- xiii) Synchronous data channels,
- xiv) Healthcare in body networks.

3.5 Summary of vision review

The development of 6G networks is gaining momentum globally, with various organizations and initiatives outlining their visions and objectives for the future of telecommunications. This section attempts to summarize the key aspects of the vision of each of these stakeholders and to explore their commonalities and differences. In doing so, a clearer picture regarding the global roadmap towards 6G becomes visible which may in turn assist European stakeholders and the SNS JU with “calibrating” their own views and to assist in the formulation of an updated SNS JU vision which will maintain the European priorities but also will attract allies in the battle towards a single 6G standard.

Table 1 below provides an initial summary of the key points expressed in the vision of the major global regions as well as NGMN’s. This facilitates the cross-comparison of approaches towards 6G as well as the extraction of useful insights based on the commonalities and differences observed around the world.

Table 1: Summary of the key elements of the 6G Vision around the world

Region/body	Summary of 6G Vision
Europe	<ul style="list-style-type: none"> • Focus on technological advancements such as AI integration, sustainability, and improved connectivity. • Collaboration with industry, research, and public sectors to drive innovation and standardization in 6G development. • Emphasis on addressing societal needs and promoting European technological sovereignty.
China	<ul style="list-style-type: none"> • Prioritisation of sustainable economic, social, and environmental development. • Identification of usage scenarios like Super Mobile Broadband and Ubiquitous Machine Connection. • Emphasis on integrated sensing and communication, and Quality Guaranteed Network Artificial Intelligence.
Japan	<ul style="list-style-type: none"> • Focus on market trends in key industry sectors to drive 6G development. • Identification of major requirements like Mission Critical Communication and Ultra-Broadband Communication. • Emphasis on ubiquitous sensing, intelligent connection, and universal coverage.
South Korea	<ul style="list-style-type: none"> • Ambition to achieve world's first 6G commercialisation. • Key areas of focus include wireless communication, mobile-core development, and wired-network enhancements. • Prioritization of safety, trustworthiness, and environmental friendliness in research areas.
India	<ul style="list-style-type: none"> • Goals to facilitate a ubiquitous intelligent mobile connected society and bridge the digital divide. • Priority use cases encompass ubiquitous connectivity, smart village accessibility, automated transportation, and immersive interactive experiences. • Principles of ubiquitous connectivity and sustainability are emphasised.
USA	<ul style="list-style-type: none"> • Focus on improving quality of life through 6G use cases like Everyday Living, Experience, Critical Role, and Societal Goals. • Alignment with societal and environmental goals such as reducing CO2 emissions and promoting digital equity. • Emphasis on network-enabled robotics, extended reality, distributed sensing, and personalised user experiences.
NGMN Alliance	<ul style="list-style-type: none"> • Identification of four use case families including Enhanced Human Capabilities, Enhanced Machine Communication, Enabling Services, and Network Evolution. • Close alignment with the IMT-2030 Framework from ITU-R for harmonised standards and practical deployment of 6G. • Emphasis on environmental impacts, energy efficiency, and ubiquitous coverage.

Based on the information provided in this section and the analysis performed there from, a few key commonalities and differences can be detected in the 6G vision of the various global stakeholders / regions.

Key commonalities:

- **Focus on Societal Impact:** All initiatives emphasise the importance of addressing societal needs and enhancing the quality of life for citizens through advanced network technologies. This includes enabling immersive experiences, enhancing communication capabilities, and improving connectivity across various sectors.
- **Technological Advancements:** There is a shared emphasis on technological advancements

such as AI integration, higher data rates, lower latency, and increased connectivity compared to 5G. These advancements aim to support emerging applications like immersive communication, telepresence, and autonomous systems.

- **Environmental Sustainability:** Many initiatives highlight the importance of sustainability, aiming to reduce the environmental footprint of network technologies and promote energy efficiency. This includes efforts to minimise energy consumption, optimize resource utilisation, and address environmental concerns in network deployment.

Key Differences:

- **Regional Priorities:** While there are common goals across initiatives, regional priorities and approaches vary. For example, South Korea and Japan focus on describing the future ecosystem and key research areas, while China and India emphasise specific usage scenarios and driving forces for 6G deployment.
- **Use Case Emphasis:** Different initiatives prioritise use cases differently based on regional needs and objectives. For instance, South Korea emphasises wireless communication advancements, while India prioritises smart village accessibility and automated transportation.
- **Standardization approach and timelines:** The level of detail regarding standardisation efforts varies across initiatives. While the importance of standardisation is highlighted across all regions, the exact timelines, focus on pre-standardisation efforts and standardisation priorities per region cannot be considered clear or aligned at this point.

While there is significant progress in 6G development at regional levels, there may be opportunities for increased global collaboration and alignment. Ensuring interoperability, harmonised standards, and shared best practices could accelerate the development and deployment of 6G technologies worldwide.

Some visions may benefit from further exploration of policy and regulatory frameworks to support 6G deployment. This includes addressing issues like data privacy, net neutrality, and spectrum allocation to enable the widespread adoption of 6G technologies.

In terms of the way forward, the collaborative ecosystems that bring together industry stakeholders, research institutions, and policy makers to drive innovation and standardisation in 6G development seem to provide the most promising direction. The initiatives from NGMN and other associations, and the ITU-R IMT-2030 workplan and study groups provide platforms for such collaboration, facilitating the exchange of ideas and best practices across regions.

In conclusion, the vision for 6G development is characterised by a shared focus on societal impact, technological advancements, and environmental sustainability. While there are differences in regional priorities and approaches, there is a growing consensus on the need for global collaboration to realise the full potential of 6G networks. Moving forward, fostering collaborative ecosystems and addressing potential gaps in vision will be key to achieving the goals outlined by SNS JU and other leading initiatives in the field.

4 Stakeholders' views and ideas

In this section the various stakeholders in 6G are identified and analysed. This includes those involved in the projects and activities of the SNS JU ecosystem, including the SNS JU projects in HORIZON-JU-SNS-2022 and HORIZON-JU-SNS-2023 and the Financial Support to Third Party (FSTP) open call projects in Streams C and D. It summarises the stakeholders' views on the current 6G vision, and ideas for updates, interests, and ambitions collected from the SNS OPS Monitoring Framework's questionnaires. It also includes other stakeholders' views through the Impact Assessment and Facilitation Action (IAFA) events supported by SNS-OPS for the spectrum of stakeholders on a cross-cutting range of topics.

4.1 Stakeholders involved in SNS JU projects

An analysis has been done to identify the stakeholders in both the Call 1 and Call 2 SNS JU projects and the running FSTP Open Call projects funded by the SNS JU Stream B and SNS JU Stream D. The organisation types of the participants were categorised by the definitions as expressed in the *EU Funding and Tenders Rules for Legal Entity Validation, LEAR Appointment and Financial Capacity Assessment* [31]. The following six stakeholders have been identified:

'Small or medium sized enterprise (SME)' means a micro, small or medium-sized enterprise as defined in the EU SME Recommendation 2003/361, i.e.:

- engaged in an economic activity, irrespective of its legal form (including, in particular, self-employed persons and family businesses engaged in craft or other activities, and partnerships or associations regularly engaged in an economic activity) and
- employing fewer than 250 persons (expressed in 'annual working units' as defined in Article 5 of the SME Recommendation) and which have an annual turnover not exceeding EUR 50 million and/or an annual balance sheet total not exceeding EUR 43 million.

An entity is considered to be engaged in an 'economic activity', if it proves to be involved in any form of trade or activity done for remuneration or pecuniary interest on the market. Thus, in general, any activity consisting of in (directly or indirectly) offering goods or services on a given market is an economic activity.

'Private for-profit entities', means an entity established under private law engaged in an 'economic activity' (excluding Higher or Secondary Education Establishments). Note: while SMEs fall within this category also, for the purposes of this analysis, we are separating the categories into two separate categories).

'Higher or Secondary establishment' means an entity that is recognised as such by its national education system and is able to deliver diplomas recognised by the State.

'Research organisation' means an entity that:

- is established as non-profit organisation and
- carries out research and/or technological development as its main objective.

'Public body' means an entity established as a public body by national law, or an international organisation.

'Other' means an entity that does not fall within a clear category as above. These include e.g. non-governmental organisation (NGO), Civil society organisation (CSO), or international organisation (IO), amongst others.

A comprehensive analysis on the types of stakeholders can be found in the following charts.

4.1.1 SNS JU projects for HORIZON-JU-SNS-2022 and HORIZON-JU-SNS-2023.

The stakeholder data has been analysed from the Horizon Dashboard [30] for the details of the overall stakeholders' categorisation breakdown. The following figures show the breakdown of participants in terms of overall number of participants and percentage of stakeholder categories.

Table 2: Stakeholders statistics for HORIZON-JU-SNS-2022 and HORIZON-JU-SNS-2023

SNS-JU Call	SME		Private for-profit entities (excluding Higher or Secondary Education		Higher or Secondary Education Establishments		Research Organisations		Public organisations		Other		Total stakeholders	
	Number	%	Number	%	Number	%	Number	%	Number	%	Number	%	Number	%
HORIZON-JU-SNS-2022	88	16 %	247	46 %	110	20 %	85	16 %	0	0 %	11	2 %	541	100 %
HORIZON-JU-SNS-2023	75	22 %	116	33 %	98	28 %	53	15 %	0	0 %	5	1 %	347	100 %
Total	163		363		208		138		0		16		888	

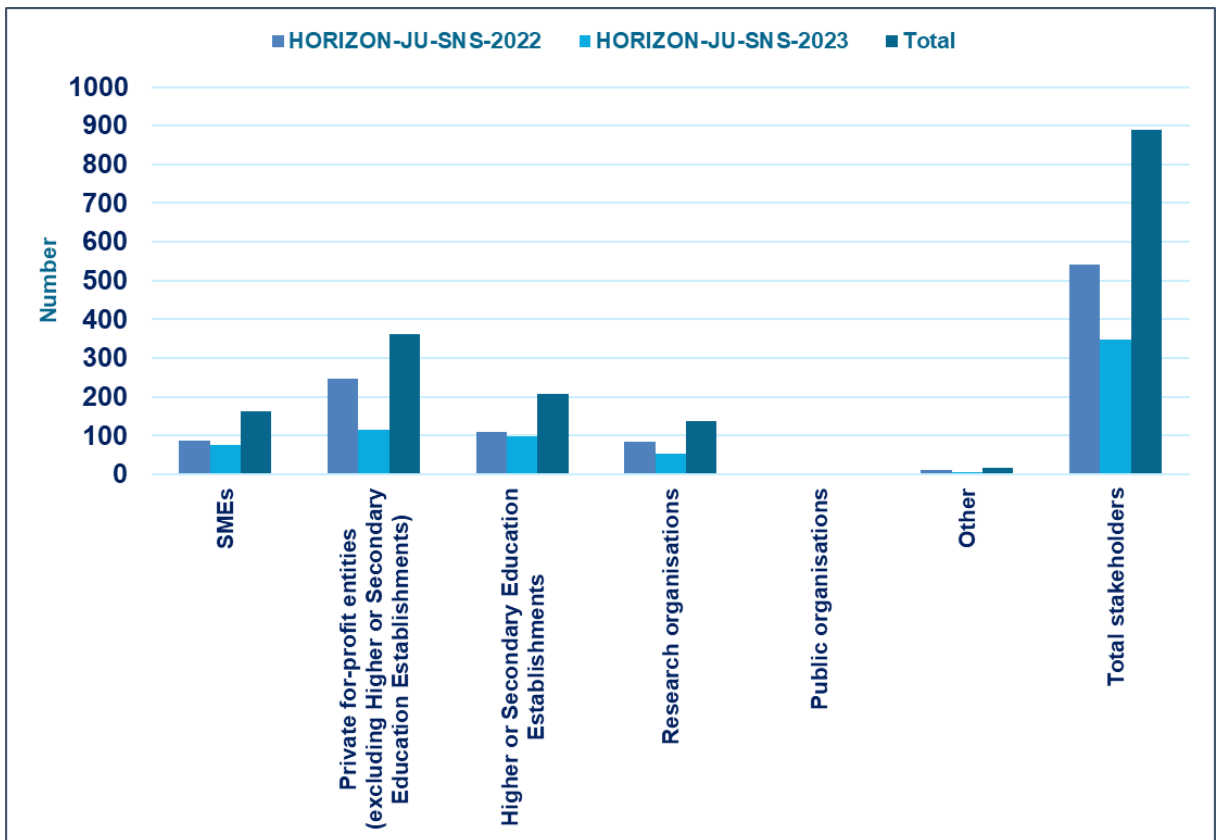


Figure 9 Stakeholders breakdown per organisation type and number

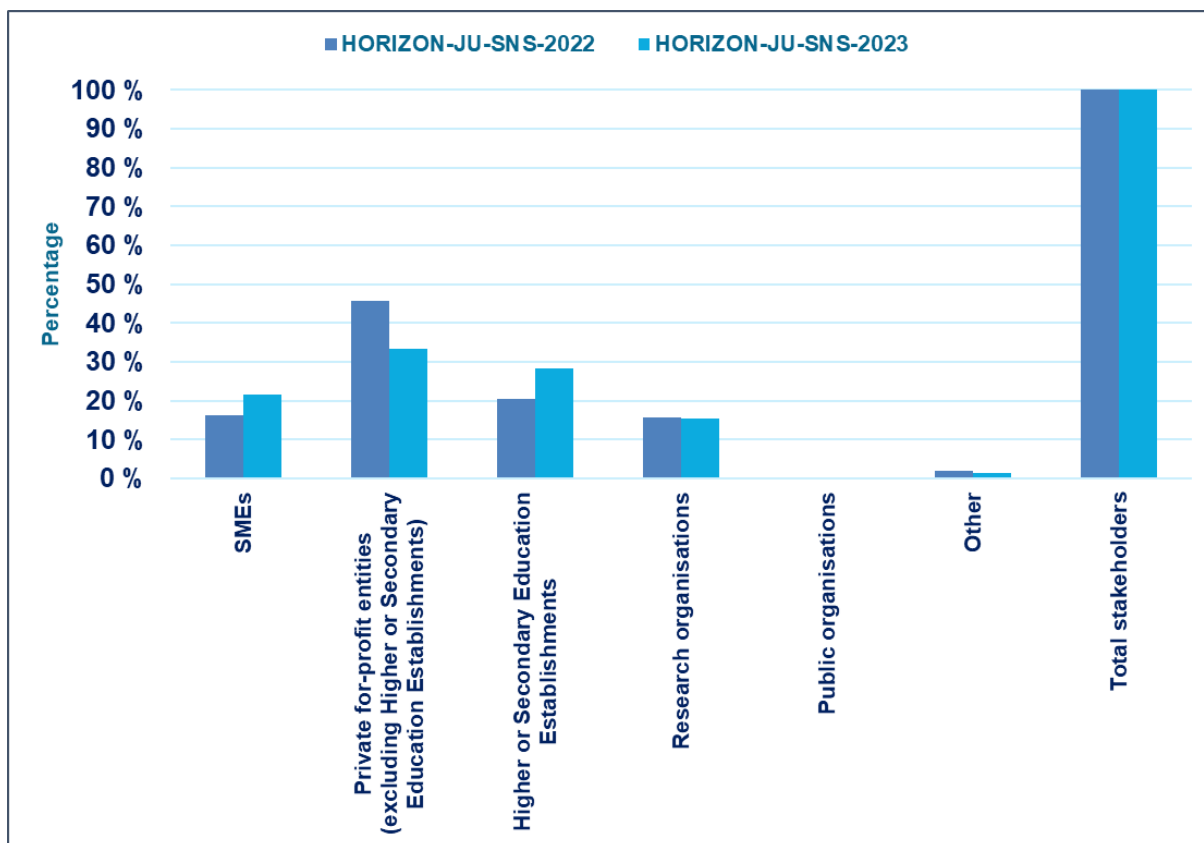


Figure 10 Stakeholders breakdown per organisation type and percentage

4.1.2 Stakeholder breakdown for Stream C and Stream D projects.

The SNS Open Calls Task Force has collected information from the coordinators of a large number of the Stream C and Stream D projects who have implemented Financial Support to Third Party (FSTP) projects. From this data, the stakeholder breakdown of the FSTP participants has been analysed and the following figures show the breakdown of participants in terms of number of participants and percent of stakeholder categories. Note that two of the Stream C projects (6GBricks and 6G-XR) had not provided information at the time of writing.

Table 3: Stakeholder statistics from SNS Stream C and Stream projects

Stream	SNS-JU project	SME		Private for-profit entities (Large industry)		Higher or secondary education establishment		Research Organisations		Public Organisation		Other		Total stakeholders		# of OC projects
		Number	%	Number	%	Number	%	Number	%	Number	%	Number	%	Number	%	
C	6G-SANDBOX	5	56 %	1	11 %	2	22 %	1	11 %	0	0 %	0	0 %	9	100 %	19
D	FIDAL	17	50 %	4	12 %	7	21 %	3	9 %	2	6 %	1	3 %	34	100 %	19
D	IMAGINE-B5G	10	53 %	7	37 %	0	0 %	2	11 %	0	0 %	0	0 %	19	100 %	15
D	TRIALSNET	19	51 %	5	14 %	7	19 %	4	11 %	0	0 %	2	5 %	37	100 %	22
D	TARGET-X	29	88 %	4	12 %	0	0 %	0	0 %	0	0 %	0	0 %	33	100 %	33
	Total	80		21		16		10		2		3		132		99

It is interesting to note that many of the Open Call FSTP projects have enabled a significant increase in the number of SME participants into the consortia of the Stream C and D projects (in many cases, over 50% of the funded participants in FSTP are SMEs).

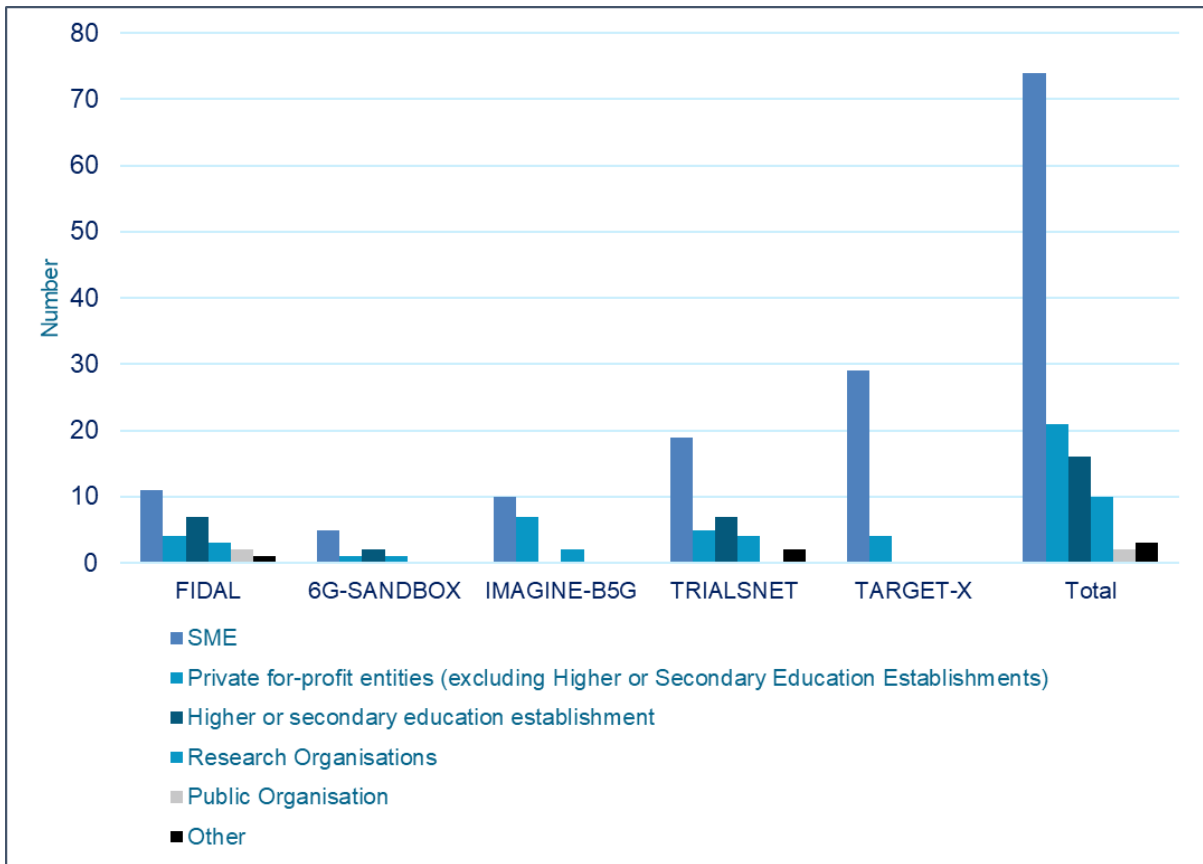


Figure 11 FSTP Stakeholders breakdown per project (number of Org types supported)

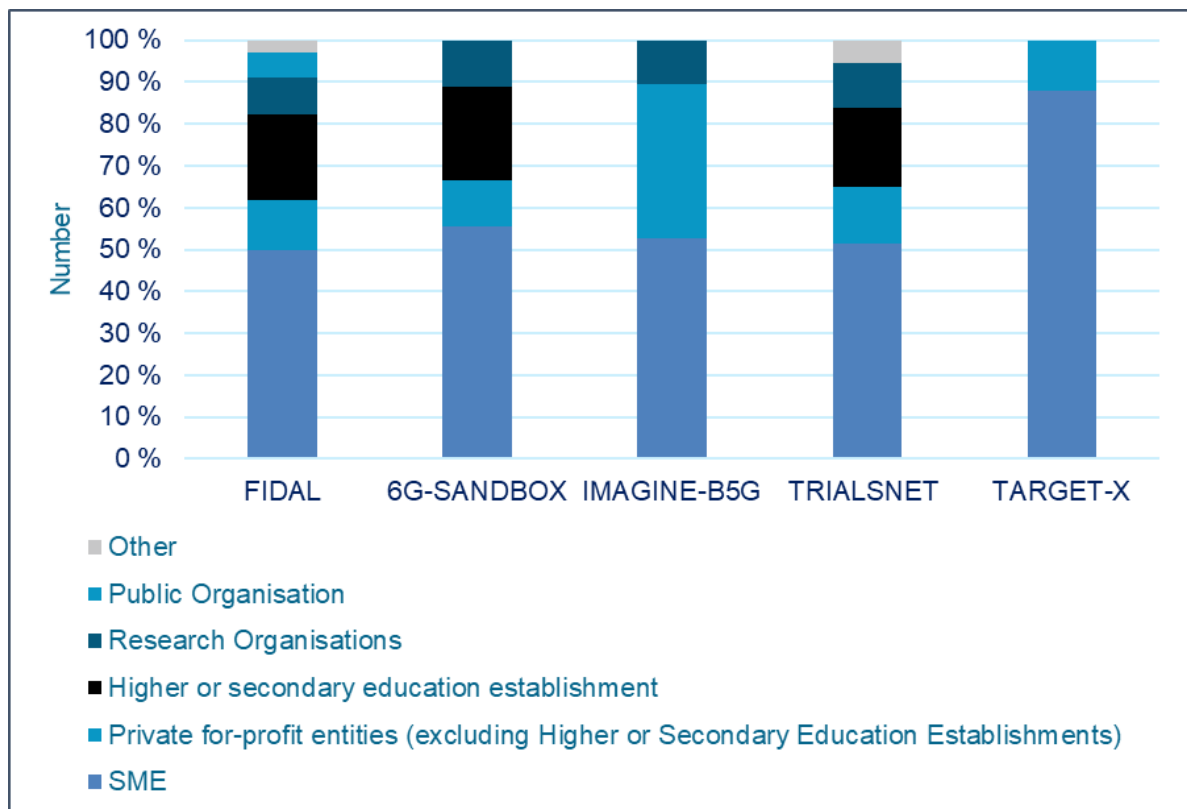


Figure 12 FSTP Stakeholders breakdown per project (% of organisations types supported)

As mentioned in section 3, a number of IAFA workshops has been organised by SNS OPS to identify potential roadmaps for various 6G technological areas. In these IAFAs experts from the industry, academia and SMEs are invited, to share their specific vision and roadmap for their respective sector. Also, in these workshops, representatives from DG-CNECT, the SNS JU Office and related associations (e.g., Photonics21, ESA, Cloud Alliance, etc.) and partnerships (e.g., Chips JU) as well as SDOs (ETSI) participated in order to facilitate identifying potential synergies and contribute to a coherent overall Horizon Europe Programme. These roadmaps are fully compatible with the NetworldEurope SRIA as well the public and private side 6G priorities and policies. The results of these workshops are fully public [31] and used in 6G-IA consultations to ensure that the final version has the support of the 6G-IA community. A summary of the shared vision, extracted insights and identified way forward from these workshops is captured in the following subsections:

4.2 Research Priorities on Microelectronics for 6G networks R&I Activities

In this workshop held on 16th October 2023, 24 topics have been identified related to **microelectronics for 6G networks R&I Activities**. These topics have been further analysed, grouped and prioritized. The submitted contributions clearly emphasizes future transceivers, integrated heterogeneous technologies, the technologies enabling cost/energy efficient operations at mm Wave and up to D band (as a starting point), and the tools to manufacture such technologies. From the perspective of the received contributions, such an area of work would major on European know how, especially for III-V technologies and CMOS integration, with one weak point being the packaging and integration. It is also interesting to note that such work does not start from scratch, as relevant work is being implemented under both the SNS and Chips JU (and in some IPCEI's to an extent). ***The core proposals hence consist of a joint SNS-Chips coordination, with focus on a consistent subset of complementary topics, extracted from the list of 24 topics. These topics suggest a Front-End Module initiative for the next three years including topics for the SNS like high throughput/capacity fronthaul, joint communication and sensing new spectrum and associated challenges. The report also identifies complementary activities for the Chips JU in the areas of ultra-high transmit power/system, mmWave radio integration system in a package, cost-effective III-V Si for power and low-noise amplifiers, and wide-band amplifiers and integration of several frequency bands. These findings have been presented in the SNS JU and Chips JU Boards. The SNS JU Board has clearly endorsed the findings.***

4.3 Research Priorities on Photonics

In this IAFA workshop held on 10th April 2024, 14 high level priorities have been identified related to **Photonics**. The 14 high-level priorities are not clearly separated or independent, several are related to each other. In summary, the highest level of interest was related to:

- Optical wireless communication and access systems (however, a comment was made that so far, no real market is available especially for LiFi),
- High performance and highly efficient passive optical network including xhaul and
- Signal processing in the optical domain (which can be combined with optical wireless communications).

4.4 Research Priorities on NTN

Based on the findings of this IAFA workshop held on 11th April 2024, it is proposed to focus the next stages of NTN activities under the SNS-JU on a “TN-NTN Unification Initiative” that would cover architectural and technological issues requiring a very tight cooperation between the SNO and the MNO's, towards a seamless TN-NTN communication continuum, and catering for a multiplicity of possible business models across the various domains. The initiative should eventually deliver end to end service capabilities either through a TN segment or through an NTN segment, depending on relevant parameters including coverage, RT or NRT constraints, bandwidth, sustainability aspects, etc.

The proposed initiative should cover both R&I issues for low TRL topics and plan, towards the end of the SNS implementation, for demonstration of critical technologies and applicability to specific use cases, with ESA partnership or national initiatives where possible, possibly using low-cost demonstrators such as KeplerGen2, Cubesat etc.

4.5 Research Priorities on Wireless

In this IAFA workshop held on 15th April 2024, 14 topics have been identified related to **Wireless**. In the light of the discussions maintained during the workshop, in upcoming calls of the SNS R&I Work Programme priority should be preferably given to topics which are technologically relevant, and exhibit a broad consensus, namely,

- MIMO/Massive MIMO/MIMO evolutions.
- AI & Semantic communications.
- Spectrum sharing and RAN co-existence.
- Open RAN.
- Network as a sensor and position provider.
- Multi-processor SoC/accelerators; flexible HW architectures.
- Physical layer technologies for enhanced spectral efficiency.
- Sustainability, as a horizontal aspect.

In doing so, particular attention should be paid to the gap analysis in the current project portfolio, and to the corresponding TRL levels of such technologies. It is also worth mentioning that several subtopics listed under multi-processor SoC/accelerators and flexible HW architectures go well beyond the scope of the SNS JU. This includes for instance, the development of RAN silicon or energy-efficient ASIC developments, or the development of hardware acceleration platforms themselves for the 6G compute continuum, which are mostly to be integrated/used by SNS projects. Currently, SNS' Front-End Module (FEM) initiative, which is aimed at establishing synergies with the Chips JU, does not cover those aspects. Therefore, one possible way forward would be to address those developments as part of the Chips JU efforts, for instance in relation with its cross-sectional technology 2.1 (Edge Computing and Embedded Artificial Intelligence) in the ECS Strategic Research and Innovation Agenda 2024. On the contrary, Efficient support of mmWave and sub-THz communications (T-02) and RF technologies for FR3 implementation (T-13) could make a better fit into the FEM initiative or, alternatively, in selected parts of the CJU Workprogramme in relation with e.g., its cross-sectional technology 2.2 (Connectivity) in the ECS SRIA.

4.6 Research Priorities on Security

The outcomes of two IAFA workshops on Security held on 24th January 2024 and 12th April 2024, outlined key priorities for a strategic approach to 6G security research and innovation, recognising its critical role in building a secure and trusted next-generation digital infrastructure. The presented focus areas prioritizes both timeliness and potential for collaboration with other instruments within Horizon Europe and Digital Europe initiatives. Here below, one can also find, topics not embedded in priorities table but suggesting collaboration with other communities or instrument.

- While certain 6G security vulnerabilities may manifest at the physical layer (radio or optical), true security demands a holistic approach. Jamming detection, for example, necessitates countermeasures beyond the physical, potentially leveraging reconfigurable intelligent surfaces (RIS) and AI-based management for optimal network defence. Similarly, research on physical layer fingerprinting could inform broader actions like blacklisting suspicious devices.
- The same way Hardware (HW) security, including potential root of trust coming with Confidential Computing (and also binding with virtualisation technologies) may be handled through dedicated programs or at least with a fraction of it dedicated to 6G.

- 6G being at the crossroad of multiple technologies and architectures, there are several opportunities to collaborate and optimise synergies in the following areas:
 - Security of cloud continuum/6G with corresponding existing IPCEI and/or other HPC HE/DE initiatives
 - This critical area transcends 6G, offering valuable cross-cutting synergies. Research efforts should leverage existing regulations and initiatives on AI and data security. 6G's role as infrastructure for critical applications and data-intensive AI operations demands a particularly strong focus on this aspect.
- AI and Data Security are also the purpose of many initiatives including regulations. 6G deserves at least two main reasons to collaborate in this field:
 - 6G will serve as infrastructure and services for critical application.
 - 6G will be AI-based manipulating large amount of data impacting privacy.
- Some of the 6G architectures such as 3D have a natural overlap with space domain programs. Quantum topics and quantum technologies integration may be handled through existing flagships and initiatives.
- Finally, 6G security has specific application of numerous security topics which fit under the umbrella of the European Cybersecurity Competence Centre (ECCC). It is strongly recommended to reinforce synchronize the actions in research and Innovation (both HE and DE) and even beyond for regulation/certification.

4.7 Research Priorities on Cloud technologies

The topics discussed during the IAFA workshop held on 16th April 2024 were grouped under two pillars. The first is related to cloud solutions development, and the second is related to service provision. Both groups were discussed in a time-plan of short-term (e.g., future calls for projects that will start their activities in 2026) and medium-term (e.g., future calls for projects that will start their activities in 2027) priorities. Potential synergies were also discussed in relation to other funding instruments.

To plan for a way forward some key priorities were identified. These were:

- Minimise the dependencies from the Hyperscalers for the European stakeholders.
- Rely on open source solutions to reach faster the target of European wide accepted solutions.
- Target the standardisation of the results so that future solutions will abide to the European rules for security, privacy, sustainability etc.
- Identify synergies among European funding instruments to maximize the impact of their activities and shorten the delivery of well-studied and tested solutions.
- Solutions should Investigate efficient implementations of regulations (EU data act, EU AI act, CRA, etc.).

As discussed in the previous sections, apart from the SNS JU activities in this area, the following related activities were also considered:

- the IPCEI-CIS.
- the cluster 4 activities on advanced computing and big data.
- the anticipated cluster 4 call on large scale-trials for e2e infrastructures.

Based on the above analysis, a detailed plan has been designed. It is worth noting that one of the key findings of the IAFA workshop was the consensus that **new telco cloud solutions would benefit from open-source solutions and trustful standardised interfaces among services, clouds, networks, and computing resources.**

4.8 Series of IAFA events on Pre-Standardisation

The series of IAFA events were held on Pre-Standardisation activities on the following dates:

- Event #4-1 First Step: 6G Research and Vision, Date: 12th March 2024.
- Event #4-2 Interim Steps: 6G Standardisation Requirements, Date: 9th April 2024.
- Event #4-3: Next Steps: 6G Trials & Testing, Date: 13th May 2024.

This online workshop series, organised by SNS OPS as part of its IAFA initiative in collaboration with ETSI and HSbooster.eu, tackled relevant topics linked to challenges in standardisation in the context of 5G/6G developments. The events featured the participation of experts sponsored through HSbooster.eu premium service programme and tackled topics such as SDOs' future 6G Agendas, SDOs 6G Work Items, verticals and standardisation, including the advancements and support of services enabled by 5G and 6G. The standardisation of 5G and the advancement towards 6G technologies pose considerable challenges, particularly in meeting the diverse requirements of industry verticals ranging from automotive to public safety. Ensuring these technologies and their services align with end-user needs requires a meticulous standardisation process, accounting for the capabilities and performance characteristics vital for different applications. This necessity highlights the importance of collaboration between industry experts and standardisation communities to produce globally recognised standards that facilitate interoperability and enable the full potential of 5G and 6G applications.

The three-event series provided information on the initial phase of 6G technology, highlighting the latest research and the future goals for 6G, while considering lessons learned from 5G deployments and service evolution. It aimed to address the challenges and opportunities in the early stages of 6G development, discussing the potential applications and innovative aspects that 6G could bring to various industry sectors. Experts shared insights into how 6G could transform communication systems and services, and the importance of aligning this new technology with the specific needs of different industries.

The main learnings were encapsulated in a final report, providing policy recommendations for policymakers, the R&D community and SDOs [31]. In brief, the key takeaways from the workshop series, especially with reference to standardisation topics, are listed below:

- Key message #1 –Early Engagement and Standardisation: emphasise the importance of early engagement in standardisation activities to align 6G research with industry standards services such as the Horizon Standardisation Booster (HSBooster.eu) for effective collaboration.
- Key message #2 –Advanced Native Features and AI Integration: focus on the challenges of integrating advanced native features and AI into 6G architectures to enhance network efficiency and sustainability, requiring a shift in network solution development and standardisation.
- Key message #3 –Industry-Specific Solutions and Sustainability: highlight the need for 6G research to be tailored to specific industry needs, addressing the unique challenges of each sector with a strong emphasis on sustainability and energy-efficient technology development.
- Key message #4 –Multidisciplinary Collaboration and Global Standards: foster multidisciplinary collaboration across various fields, such as AI and cybersecurity, and enhance engagement with global stakeholders to harmonise standards and promote international interoperability.
- Key message #5 –Regulatory Support and Infrastructure Development: advocate for comprehensive regulatory frameworks that support developing and deploying 6G technologies, ensuring safety, efficiency, and global competitiveness while encouraging innovation through supportive policies.

4.9 EC Whitepaper on ‘How to master Europe’s digital infrastructure needs?’

A feedback period has been open from 22nd February 2024 – 30th June 2024 for downloading and gathering feedback on The White Paper “*How to master Europe’s digital infrastructure needs?*” [32],

which analyses the multiple challenges Europe currently faces in the rollout of future connectivity networks. It presents possible scenarios going forward to address those challenges, attract investment, foster innovation, increase security and achieve a true Digital Single Market.

Against this background, this White Paper identifies challenges and discusses possible scenarios for public policy actions, such as a possible future Digital Networks Act, that aim to encourage building the digital networks of the future, master the transition to new technologies and business models, meet future connectivity needs of all end-users, underpin competitiveness of our economy and ensure secure and resilient infrastructures and the Union's economic security as reflected by the common commitments of the EU Member States in the Digital Decade Policy Programme [33].

All feedback received will be summarised by the European Commission and presented to the European Parliament and Council with the aim of feeding into the legislative debate. Feedback received will be published on this site and therefore must adhere to the feedback rules [34].

5 Impacts and potential directions on the vision update

In this section an attempt is made to discuss the outcome of the information collection and analysis and suggest the way forward for the European and 6G SNS vision, and to outline the process (and the elements comprising it) that may lead to an updated vision for maximising the impact of SNS JU projects and approach. This has been and will be accomplished by:

- using insight from the previous sections to capture key observations, and to suggest overarching updates and potential directions for the relevant bodies to consider.
- discussing what are the anticipated implications and envisaged consequences, both in scope, and potential needs on elaborating and updating existing topics and/or introducing new focus topics.
- in the steps to follow (and for the coming D1.4), elaborating on anticipated implications for the SNS JU Programme and calls, way of work, and research disciplines, and suggesting how to engage with the 6G SNS community on updating the SNS vision, during the current and upcoming phase, also considering communities outside of 6G SNS JU. The process in place that is followed to create the follow-up SNS JU Work Programmes, plays a major role in this step.

In the previous sections, the vision of the public and private sectors has been presented taking into account the views of multiple stakeholders including established organizations and associations, industrial and academic stakeholders, peer-associations, other global regions and scientist of multi-disciplinary backgrounds. As expected, the resulting insights with regards to the vision of 6G SNS paint a complex picture comprised of comprehensive technological advancements and strict targets requiring novel *intelligent and multi-disciplinary architecture* paradigms, *AI-enabled functionalities* across all domains, *integration with* existing (NTN, Optics/Photonics, Cloud continuum) and upcoming *technologies* (ISAC, RIS, etc.), use of *new spectrum*, evolution of *interoperable networks & services* and leverage upon *new HW components*. It is also clear that the vision of 6G SNS does not only encompass technological aspects, but societal, business and policy aspects play a critical role as well. *Sustainability* in all three of its forms (environmental, societal, economical) has been hailed as a cornerstone of the new generation of networks, while *Hyper-Reliability*, *Security*, *Privacy* and *Resiliency* are crucial targets for 6G which must be accomplished.

Several sources or documents have identified overarching societal targets and objectives for the SNS JU as described in sections 2 and 3. The *Societal Needs and Value Creation* sub-group of the VSC WG has established an initial approach to the key societal values (Key Values) and Key Value Indicators (KVI). Through this early but important work the JU partnership programme (the projects, WGs, Sub-Groups, also those driven by the 6G-IA) have now a baseline methodology for following up on the overarching societal targets and objectives. This will allow the community to combine both a top-down as well as a bottom-up approach to the vision update, which will further guide the detailed per project targets, their work, and outcome.

We also observe that the scope and definition of 6G or the 6G system and the services offered by it is indeed work-in-progress. Considering “beyond connectivity” service enablers the SNS JU expert community is working towards a 6G system that will integrate and offer “beyond connectivity” services or service enablers in an integral and more powerful way than what was possible with 5G. Still, “beyond connectivity” service enablers can also be adjacent (e.g. “on-top-of”) and complementary to the 6G system. This latter approach can also benefit 5G advanced enabled services and deployments. Hence, when speaking of 6G SNS Vision the scope will be seen from a holistic perspective, supporting a variety of implementation, deployment and evolution scenarios and options, while ensuring interoperability across smart networks and standardized services.

Based on the presented vision aspects and the corresponding analysis it has become clear that the transition from (B)5G networks to 6G smart interoperable networks and services requires a focus on technological, as well as on societal, business and policy aspects, to avoid shortcomings of previous generations and to deliver a network of networks meeting the needs of the entire society. The SNS OPS team has attempted to depict the key elements that will drive this transition towards 6G SNS, based on the various insights collected from the previous analysis, as depicted in Figure 13.

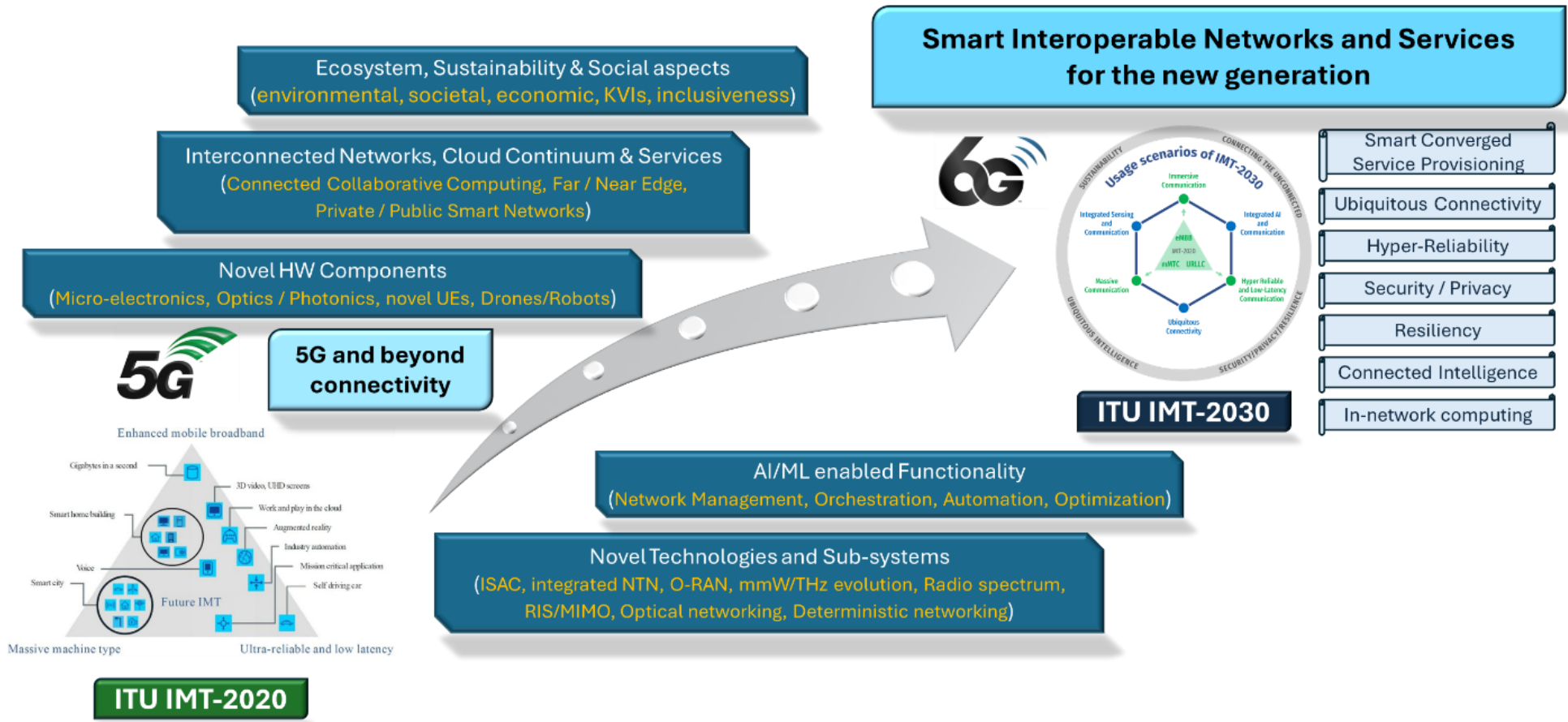


Figure 13: The vision for the transition from 5G to 6G SNS

The domain of HW components (micro-electronics, optics/photonics, etc.) provides enabling technology elements or HW components by which the SNS JU can develop and compose into higher-level sub-systems and solutions. Collaboration with peer associations (e.g., CHIPS JU) is already ongoing while specific SNS JU projects on e.g., micro-electronics have already been commissioned.

The domain of *Interconnected Networks, Cloud Continuum, and Services* comprises capabilities, enablers, and services from across multiple interoperable (public and private) networks, again considering both connectivity and beyond connectivity elements and services, while also highlighting the importance of integration with the cloud continuum and network edge-ification.

The *Ecosystems, Sustainability and Societal Aspects* domain shows the importance that non-technological aspects have acquired for the development of 6G SNS. Firstly, it is clearly shown that sustainability and societal targets are not simply considered as a KPI that needs to be met but are treated as one of the building blocks of the new generation networks, that permeates its architectural design and all technical considerations from the very beginning. Secondly, sustainability is not merely treated as an “energy-efficiency” issue but is rather considered in its full form, addressing environmental, societal/social and economic sustainability issues.

The *Novel Technologies* domain is of course one of the cornerstones of the development of 6G SNS. Significant R&I efforts are already in progress from the global community to fully develop and successfully integrated novel technologies that will realize the expected performance for this new generation of networks. Besides technological enablers themselves, this domain also contains other technical aspects and considerations that will allow us to reach the full potential of 6G such as integration with other systems (NTN, UAVs, etc.) for ubiquitous coverage and use of new spectrum for extended services.

Finally, the *AI/ML enabled Functionality* domain indicates the pervasive nature and critical role that AI will play in this new generation of networks, as AI functionality is expected to permeate all aspects and layers of 6G networks. From RAN optimization, automation and failure management to SW resources orchestration and overall network management, AI is expected to be one of the main building blocks that will allow for 6G SNS to reach its ambitious performance goals.

Along with this map we put forward the following key observations, of the fundamental needs that are implied by stakeholders, and accordingly, suggest / desired high-level directions for the 6G SNS vision update. This is based on our analysis of the sections above, also considering observations from the current market and industry status.

- **Convergence and new customer needs:** We observe a continued and strong convergence across the ICT sector, where fundamental technologies, cloud & virtualization, and advanced connectivity open up new opportunities. The end-customers and vertical sectors, demand advanced solutions for connectivity and networking, often in a “demand-for-a-solution-as-a-service” way. This goes far beyond the typical Mobile Broadband Subscription thinking from previous generations.
- **Service orientation, both horizontally, and vertically:** 5G and 5G Advanced have triggered the general attention and demand for new services. Considering user and service endpoints, they are often located in different network domains. Thus, there is a need for interconnected and interoperable smart networks and services, both related to private and public networks, as well as a need for openness of services. There is a need for a stronger and structured service orientation, both horizontally among and across different networks, and vertically to respond to the needs of a broader set of customer segments.
- **Security, privacy, and resilience:** The geopolitical and societal challenges call for a strong orientation and focus on both security, privacy, and resilience. The risks, problems to be solved, and their solutions and potential services should be considered across all layers, which calls for coordination and alignment across the stakeholders.
- **Facilitating ecosystem enablement, evolution, and sustainability:** Delivering upon the vast set of new demands and requirements is challenging, for the individual business actor or stakeholder, as well as when looking across sectors and communities. Business models for advanced 5G enabled services are largely immature and new ways of work (e.g. co-creation) can also be challenging to master. New frameworks and methodologies can be considered, to

enable and facilitate ecosystem development and evolution, to be seen as an important entry point for a success with 6G.

- **A strong collaborative SNS JU expert community:** The SNS-JU expert community is strong, especially on the technology side that covers a broad portfolio of topics and opportunities. A strong mix of competence across the stakeholders is important. Moreover, it is important to ensure and maintain this strength as new technology opportunities appears along with new demand.

A good summary of the overarching societal targets and objectives is already provided at the SNS JU webpage¹² and provide a positive drive for strong societal and industrial outcomes and impacts, while considering all the pillars of sustainability.

The 6G-IA VSC WG is currently preparing an updated version of the European 6G SNS vision white paper. We expect that the updated whitepaper will leverage on the advancements in the SNS JU projects, and the insights gained by the SNS JU experts. Updates and clarified positions are expected along the pillars of social, economic, and environmental sustainability, and the drivers for 6G SNS, along with more mature insights on key technologies, main architecture trends and key technological and business enablers. The SNS JU projects' analysis of use cases enabled and strengthened by 6G, together with latest insights gathered from other regions of the world will allow for a better understanding of the use cases and how to approach them from an end-to-end and holistic societal perspective.

The SNS OPS team, has attempted to collect and critically analyse the available information from SNS JU projects, EU and global stakeholders, global organizations and associations, and 6G-IA members. Based on the performed analysis the key elements that drive the development of 6G SNS and comprise the -ever evolving- vision for the next generation networks have been highlighted, while the expected path for the transition from (B)5G to 6G SNS has been sketched.

It should be appreciated that understanding and attempting to map the evolution of the 6G SNS vision and the various EU and global forces that drive it, is a very complex process involving multi-disciplinary subject matter experts, and global stakeholders. The SNS OPS team will follow the developments and the expected updates in multiple relevant fronts (updated NetworkEurope SRIA, the updated 6G SNS Vision white paper by the 6G-IA VSC WG, SNS JU projects results and insights, updated vision statements from global peer-associations, etc.), and will provide a final update of the 6G SNS Vision key elements and path forward in deliverable D1.4.

¹² <https://smart-networks.europa.eu/missions-and-objectives/>

6 Conclusions

Creating, maintaining and updating the European and SNS vision on 6G and future networks and services is anything but a trivial task. The SNS OPS team has attempted to map the process to be followed to achieve such an endeavour highlighting the “*key pieces of the puzzle*” and the complex ecosystem relationships to be taken into account. This process includes several **European associations, industrial and academic stakeholders, SMEs, expert Working Groups, European projects and national initiatives** and of course the **European Commission** itself. The mechanisms in place tasked with forming and updating the 6G vision were also introduced, including the **NetworldEurope SRIA**, the **6G-IA WGs and strategic/position papers, CSA projects** and direct **community input** (via events, consultations, etc.). As the SNS JU now has a few dozen active projects working on multiple technical, market and vision aspects of 6G, their view on future developments becomes increasingly important for the shaping of the next stages of the SNS vision.

As the ultimate goal of the European stakeholders is the creation of a single global 6G standard, it becomes imperative to understand the European and global ecosystem in which we operate, to be aware of the vision of the various global regions with regards to 6G development and to identify potential allies as well as pitfalls that should be avoided. The SNS OPS team has performed an analysis of the expressed vision of key global regions, associations and working groups (within Europe and outside) in order to identify commonalities and differences among the key stakeholders when it comes to the vision of future networks and services.

The analysis indicates that the visions expressed by most of the key stakeholders share a focus on **Environmental Sustainability** and **Societal Impact** when it comes to the expectations of the next generation networks as well as a shared emphasis on **Technological Advancements** such as AI integration, higher data rates, lower latency, and increased connectivity compared to 5G. On the other hand, attention should be paid to the apparent differences in vision that emerge from **Regional Priorities** and **Standardization Approaches** which in turn lead to **Emphasis on Different Use Cases**. Such differences, although understandable and well-founded, should be openly discussed and consensus should be pursued on the way forward to avoid fragmentation of technical solutions and standards on a global scale.

Furthermore, the SNS OPS team has gone in great effort to obtain, understand and analyse the views of key European stakeholders both from within the telecom/wireless community as well as from sectors outside of the immediate realm of telecommunications but directly linked to it (taking the “network of networks” view into account). Through the organization of several physical IAFA events, experts from various fields such as **Wireless communications, Microelectronics, Photonics, Non-Terrestrial Networks, Security, Cloud, Standardization** and more were asked to offer their view on how their field is expected to impact the development of future networks and services, which aspects they consider the most critical for successful integration and which are the research priorities within their field that are also relevant for 6G and that will contribute to its success. The key points presented in this report help draw a roadmap of the next steps to be taken to update the European SNS vision on 6G, to encompass the views of the extended European R&I community, while also maintaining an alignment with the global views and being aware of key differences that require additional attention.

It has to be noted that it is not the role of SNS OPS (or any CSA project for that matter) to dictate what the European/SNS vision on 6G should be, but rather to aggregate available information and critically analyse them, offering substantial insights that will assist the community into forming and updating their own vision. Based on the information and analysis presented in this report, the SNS OPS team has drafted some initial recommendations on potential directions that could be followed for the update of the SNS vision, however it is ultimately up to the SNS stakeholders to critically evaluate these recommendations and to shape their own path towards the updated SNS vision.

References

- [1] NetworldEurope SRIA 2021-2027 (2020 edition), September, URL: <https://smart-networks.europa.eu/wp-content/uploads/2022/11/networld2020-sria-2020-final-version-2.2-compressed.pdf>
- [2] NetworldEurope SRIA 2022. URL: <https://bscw.sns-ju.eu/pub/bscw.cgi/d95660/SRIA-2022-WP-Published.pdf>
- [3] 6G-IA Vision Working Group, White paper. “European Vision for the 6G Network Ecosystem”, June 2021. URL: <https://5g-ppp.eu/wp-content/uploads/2021/06/WhitePaper-6G-Europe.pdf>
- [4] SNS OPS Deliverable D1.2. First Period Assessment and Planning Report. January 2024. URL: https://smart-networks.europa.eu/wp-content/uploads/2024/04/ops-d1.2_first-period-assessment-and-planning-report_v1.0.pdf
- [5] European Partnerships under Horizon Europe: results of the structured consultation of Member States. December 2019. URL: https://www.era-learn.eu/documents/final_report_ms_partnerships.pdf
- [6] Smart Networks and Services proposal, 30 June.2020, URL: https://research-and-innovation.ec.europa.eu/system/files/2020-07/ec_rtd_he-partnership_smart-networks-services.pdf
- [7] European Commission. Horizon Europe Strategic Plan 2021-2024. URL: https://www.eeas.europa.eu/sites/default/files/horizon_europe_strategic_plan_2021-2024.pdf
- [8] European Commission, Directorate-General for Research and Innovation, Horizon Europe strategic plan 2025-2027, Publications Office of the European Union, 2024, <https://data.europa.eu/doi/10.2777/092911>
- [9] SNS-OPS Survey Results on Technical, Vision and Market aspects of Phase 1 SNS Projects. URL: <https://smart-networks.europa.eu/event/sns-ops-survey-webinar/>
- [10] SNS JU Strategic Research and Innovation Agenda (SRIA) 2021-2027 (1st edition). 15 December 2021. URL: <https://smart-networks.europa.eu/wp-content/uploads/2023/12/sns-ju-sria-2020-2027-first-edition-2021.pdf>
- [11] SNS JU Strategic Research and Innovation Agenda (SRIA) 2021-2027 (2nd edition). 2023. URL: <https://smart-networks.europa.eu/wp-content/uploads/2023/12/sns-ju-sria-2021-2027-second-edition-2023.pdf>
- [12] 5G-IA & NetworldEurope ETP joint press release available at: <https://5g-ppp.eu/the-5g-ia-and-networld-europe-etp-sign-collaboration-agreement/>
- [13] 6G-IA, Key Strategies for 6G Smart Networks and Services, position paper, available at: <https://6g-ia.eu/plans-papers/>
- [14] European Commission: Orientations towards the first Strategic Plan for Horizon Europe, December 2019, pp. 70, available at: https://ec.europa.eu/info/sites/info/files/research_and_innovation_strategy_on_research_and_innovation/documents/ec_rtd_orientations-he-strategic-plan_122019.pdf
- [15] 6G-IA “White Paper: What Societal values will 6G address?” May 2022. <https://zenodo.org/records/6557534>
- [16] 6G-IA White Paper. “5G and Beyond 5G Ecosystem Business Modelling”. Version 1.0, May 2023. URL: <https://zenodo.org/records/7640478>
- [17] ITU-R WP5D. “The ITU-R Framework for IMT-2030. Recommendation ITU-R M.2160”, November 2023. https://www.itu.int/en/ITU-R/study-groups/rsg5/rwp5d/imt-2030/Documents/IMT-2030%20Framework_WP%205D%20Management%20Team_WEB%20POST%20v2_11-2023.pdf
- [18] NGMN Alliance. “6G Use-cases and Analysis”, February, 2022. URL: <https://www.ngmn.org/wp->

- [content/uploads/220222-NGMN-6G-Use-Cases-andAnalysis-1.pdf](#)
- [19] NGMN Alliance. “6G Requirements and Design Considerations”, February 2023. URL: https://www.ngmn.org/wp-content/uploads/NGMN_6G_Requirements_and_Design_Considerations.pdf
- [20] NGMN Alliance. ITU-R Framework for IMT-2030: Review and Future Direction, V1.0. February 2024. URL: https://www.ngmn.org/wp-content/uploads/ITU-R_FRAMEWORK_FOR_IMT-2030.pdf
- [21] IMT-2030 (6G) Promotion Group. “6G Vision and Candidate Technologies”. URL: http://www.caict.ac.cn/english/news/202106/t20210608_378637.html
- [22] IMT-2030(6G) Promotion Group “6G Usage Scenarios and Key Capabilities”, May 2023. Available at: <https://www.imt2030.org.cn/html/default/en/Publications/Whitepaper/>
- [23] Almodovar, J, and Vinagre, C, (eds). “6G Use Cases and Requirements”. Hexa-X-II Deliverable D1.2, December 2023. URL: https://hexa-x-ii.eu/wp-content/uploads/2024/01/Hexa-X-II_D1.2.pdf
- [24] TSDSI. 6G Use cases and Enabling Technologies”. White Paper 2021. URL: <https://tsdsi.in/wp-content/uploads/2022/10/6G-White-Paper-12-Pages-Digital.pdf>
- [25] Government of India. “Bharat 6G Vision”. March 2023. URL: “<https://bharat6galliance.com/img/Bharat-6G-Vision-Statement-copy%201.pdf>
- [26] 3GPP Stage-1 Workshop on IMT-2030 Use Cases. Rotterdam, Netherlands, 8-10 May 2024. URL: <https://www.3gpp.org/technologies/stage1-imt2030-uc-ws>
- [27] Beyond 5G Promotion Consortium “Message to the 2030s”, March 2023 https://b5g.jp/doc/whitepaper_en_2-0.pdf
- [28] “MSIT Launches the K-Network 2030 Strategy”. February 2023. URL: <https://www.msit.go.kr/bbs/view.do?sCode=eng&mId=4&mPid=2&bbsSeqNo=42&nttSeqNo=783>
- [29] Next G Alliance “6G Applications and Use Cases”, May 2022. URL: https://www.nextgalliance.org/white_papers/6g-applications-and-use-cases/
- [30] Horizon Dashboard. URL: https://dashboard.tech.ec.europa.eu/qs_digit_dashboard_mt/public/sense/app/d58f3864-d519-4f9f-855e-c34f9860acdd/sheet/7a2acdb7-ee97-4161-affe-302abc4888bb/state/analysis
- [31] De Majo, C., Giuffrida, M., Elktob, M., Dagiuklas, T., and Boswarthick, D. “6G Pre-standardisation: Challenges, requirements and future steps.” DOI 10.5281/zenodo.11402317.
- [32] European Commission. White Paper. “How to master Europe’s digital infrastructure needs?”. COM(2024) 81 Final. 21 February 2024. URL: https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/14168-White-Paper-How-to-master-Europes-digital-infrastructure-needs?_en
<https://ec.europa.eu/info/law/better-regulation/>
- [33] European Commission. Decision (EU) 2022/2481 of the European Parliament and of the Council of 14 December 2022 establishing the Digital Decade Policy Programme2030, OJ L 323, 19.12.2022, p.4.
- [34] European Commission. Rules for feedback and suggestions. URL: https://ec.europa.eu/info/law/better-regulation/rules-feedback-and-suggestions_en
- [35] European Commission. Proposal COM(2021)87 - Regulation; 23 February 2021, URL: <https://www.eumonitor.eu/9353000/1/j9vvik7m1c3gyxp/vlgkodah31yz>
[https://www.eumonitor.eu/9353000/1/j4nvke1fm2yd1u0_j9vvik7m1c3gyxp/vlgkn6s23lwb/v=s7z/f=/com\(2021\)87_en.pdf](https://www.eumonitor.eu/9353000/1/j4nvke1fm2yd1u0_j9vvik7m1c3gyxp/vlgkn6s23lwb/v=s7z/f=/com(2021)87_en.pdf)
- [36] EC. “European Commission and European ICT community present a new 900million Euro joint undertaking to develop 6G in Europe”. June 2021, URL: <https://5g-ppp.eu/european-commission-and-european-ict-community-present-a-new-900million-euro-joint-undertaking-to-develop-6g->

[in-europe-2 /](#)

- [37] EC. Council Regulation (EU) 2021/2085; 19 November 2021. URL: <https://www.eumonitor.eu/9353000/1/j9vvik7m1c3gyxp/vloe7pc4e6yb>
<https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32021R2085>
- [38] SNS JU office/Governing board (GB). November 2021. URL: <https://smart-networks.europa.eu/gouvernance/>
- [39] SNS JU. Annual work programmes. URL: <https://smart-networks.europa.eu/reference-documents/#annualworkprogrammes>
- [40] SNS JU R&I Work Programmes. URL: <https://smart-networks.europa.eu/reference-documents/#callrelateddocuments>

Appendix A Additional info on the initial vision process

Table 4: Events, regulations and documents towards the establishment of the SNS JU and the first annual Workprogramme 2021-2022

What	Type	Source	Year	Month
European Partnerships under Horizon Europe: results of the structured consultation of Member States [5]	Consultation	Commission Services	2019	5-12
Smart Networks and Services proposal, 30.06.2020 [6]	Document	5G-IA and others	2020	6
NetworldEurope SRIA 2021-2027 (2020 edition) [1]	Document	NW Europe	2020	9
Proposal COM(2021)87 - Regulation; 23 February [35]	Regulation	EC	2021	2
6G-IA Vision and Societal Challenges Working Group, white paper[3]	Document	5G-IA Vision WG	2021	6
European Commission and European ICT community present a new 900million Euro joint undertaking to develop 6G in Europe [36]	Event	EC, 5G-IA	2021	6
Council Regulation (EU) 2021/2085; 19 November [37]	Regulation	EC	2021	11
SNS JU office/Governing board (GB) [38]	Organization	EC	2021	11
SNS JU Strategic Research and Innovation Agenda (SRIA) 2021-2027 (1st edition) [10]	Document	SNS JU	2021	12
Annual work programmes (multiple) (after approval by GB) 15 December [39]	Document	SNS JU	2021	12
SNS JU R&I Work Programmes (calls) [40]	Document	SNS JU	2021	12