Smart Networks and Services Joint Undertaking

Strategic Research and Innovation Agenda 2021 – 2027

2nd Edition

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1. Introduction

ICT in general, and networks (mobile and fixed) in particular, are a fundamental enabler of a modern society. The Smart Networks of the future will be the nervous system of the Next Generation Internet (NGI[1]) and other commercial networks and are the platform for driving the digital transformation. Future communication systems and networks (Smart Networks) are the foundation of the Human Centric Internet. They provide the energy-efficient and high-performance infrastructure on which NGI and other digital services can be developed and deployed. Smart Networks will apply intelligent software (Artificial Intelligence and Machine Learning – AI/ML) for decentralised and automated network management, data analytics and shared contexts and knowledge. Moreover, Smart Networks are expected to take advantage on innovative solutions in the areas High Performance Computing, (Cyber)Security and advanced Internet of Things (IoT) devices. Such infrastructures are the enabler for the future data economy. By virtualisation and strict policies, they will foster a free and fair flow of data, which can be shared whilst at the same time protecting the integrity and privacy of data, which is confidential or private: Users should be able to control their environment on the Internet and not to be controlled by the Internet.

The United Nations 2030 sustainable development goals[2] require Smart Networks in many different domains using various appropriate communication technologies to support the digitalisation of society and economy in developing and developed countries. The United Nations Broadband Commission for Sustainable Development has set deployment targets for 2025[3] to underline the importance of communication systems and networks.

Moreover, the evolving geopolitical environment has highlighted, even more than in the past, that network and service infrastructures are critical infrastructures and hence require to develop cybersecure infrastructures and to secure European sovereignty for supply chains in critical technologies and systems[4].

Consequently, the SNS Joint Undertaking (SNS JU) has been designed to address a strong European position on critical infrastructure supply chains (e.g., connectivity, cloud, data economy components and devices). The SNS JU is based on the Smart Networks and Services proposal[5], that was the result of joint efforts from the 6G Smart Networks and Services Industry Association (6G-IA), Networld Europe European Technology Platform (ETP), AIOTI, NESSI and CISPE.cloud. The first edition of the SNS JU SRIA was approved by the SNS JU Governing Board in 2021[6].

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[1] Next Generation Internet available at: https://www.ngi.eu/

[2] United Nations: Sustainable Development Goals, August 12, 2015, available at: http://www.un.org/sustainabledevelopment/sustainable-development-goals/

[3] United Nations – Broadband Commission for Sustainable Development 2025 Targets: ”Connecting the Other Half”

[4] European Commission: Secure 5G deployment in the EU - Implementing the EU toolbox. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, Brussels, 29.1.2020 COM(2020) 50 final, available at: https://ec.europa.eu/digital-single-market/en/news/secure-5g-deployment-eu-implementing-eu-toolbox-communication-commission

[5] Smart Networks and Services proposal, 30.06.2020 available at: https://ec.europa.eu/info/sites/info/files/research_and_innovation/funding/documents/ec_rtd_he-partnership_smart-networks-services.pdf

[6] SNS JU Strategic Research and Innovation Agenda (SRIA), 2021, available at: https://smart-networks.europa.eu/wp-content/uploads/2022/10/122021_sns_gb_decision_sria_including_annexdocx_89dnouztkolqi0m6dij7feh9da_82079_compressed-1.pdf

The current document presents the second edition of the Smart Networks and Services (SNS) Strategic research and innovation Agenda (SRIA). The document includes a detailed analysis of the intervention logic (including the objectives and the targeted impact, the expected outcomes and related deliverables and milestones), the monitoring framework, links to related HEU Partnerships, and the plans for future evolution and adaptation of the SNS SRIA.

The SNS SRIA has been developed from the collaboration of the 6G Smart Networks and Services Industry Association (6G-IA) and the Networld Europe European Technology Platform (ETP). These organizations, together with the supporting associations are representing more than 1000 entities, involved in the 5 % of European GDP, and are contributing to the definition of research areas especially in the domain of communication systems and networks. As it will be explained in the following chapters, Networld Europe has formed a detailed SRIA that was updated by the end of 2022[7] and together with its technical annex[8], provide a thorough coverage of challenges and technical topics for smart networks and services. The 6G-IA has taken the Networld Europe's SRIA into consideration and used it as the basis for the SNS JU SRIA. Since 28.04.21 the two organizations have setup a collaboration framework[9] that defines exactly this process for the preparation and adoption of the SNS SRIA.

Moreover, the current edition of the SNS SRIA has also taken into consideration the 6G-IA position paper on key strategies for 6G Smart Networks and Services[10]. This document is the product of the collaboration between DG-CNECT, the SNS JU Office and the 6G-IA.

2. Intervention Logic

The challenges that the SNS Joint Undertaking is addressing has been very clearly defined in the SNS Proposal[11] and the Impact Assessment Report[12]. The following sections present the key challenges to be addressed, the SNS JU Vision and how this is translated into the SNS SRIA.

2.1 Problem definition

2.1.1 What are the problems?

Given the scale of the challenges ahead for the transformation of the digital infrastructure, the current scientific, technological, and economic positioning of Europe in the field, and the overarching EU policy context, a set of problems have been identified where EU research and

[7] Networld Europe, Strategic Research and Innovation Agenda 2022, available at: https://bscw.5g-ppp.eu/pub/bscw.cgi/d516608/SRIA-2022-WP-Published.pdf

[8] Networld Europe, Strategic Research and Innovation Agenda 2022, Technical Annex available at: https://bscw.5g-ppp.eu/pub/bscw.cgi/d516614/SRIA%202022%20Technical%20Annex%20Published.pdf

[9] 5G-IA & Networld Europe ETP joint press release available at: https://5g-ppp.eu/the-5g-ia-and-networldeurope-etp-sign-collaboration-agreement/

[10] 6G-IA, Key Strategies for 6G Smart Networks and Services, position paper, available at: https://6g-ia.eu/plans-papers/

[11] Smart Networks and Services proposal, 30.06.2020 available at: https://ec.europa.eu/info/sites/info/files/research_and_innovation/funding/documents/ec_rtd_he-partnership_smart-networks-services.pdf

[12] Commission Staff Working Document, Impact Assessment Report, Proposal for a council regulation establishing the Joint Undertaking under Horizon Europe, European, 23.02.21, available at: https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/11899-Research-&-innovation-European-Partnership-for-smart-networks-and-services-Horizon-Europe-programme-_en

innovation and EU deployment policies and programmes in the field of Smart Networks and Services would have a specific role to play.

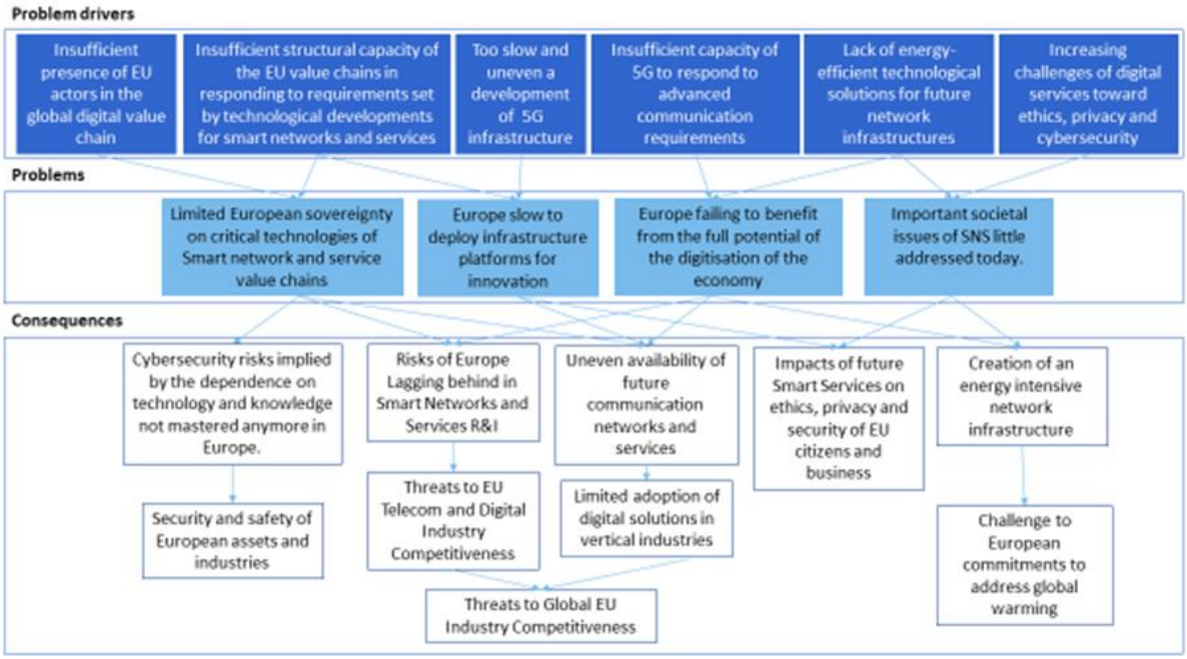

Figure 1: Problem Tree for the Smart Networks and Services Initiative[13]

2.1.2 Europe's challenges to benefit from the full potential of the digitization of the economy

The economic potential in the field of SNS is huge. In 2035, they are predicted to enable $12.3 trillion of global economic output and the global SNS value chain is predicted to generate $3.6 trillion in economic output and support 22.3 million jobs in 2035[14]. Further estimates predict a global potential economic impact of IoT between €3.5 and €11 trillion per year by 2030 across multiple business domains[15].

These opportunities, largely represented by the Industrial IoT (IIoT), need SNS as a versatile "connectivity platform" that will become a constituent part of the business process. The Strategic Forum put in place by the European Commission[16] also underlines the need for a better integration of several technological domains, notably cloud computing, connectivity and devices (robots, drones) to reach the full potential of industrial IoT. It also requires performance far beyond the capabilities of the current 5G solutions, e.g., in terms of positioning accuracy, response time, data rates, reliability or automation, which are not available today and will shape the essence of a next generation of mobile and cloud systems towards 6G.

Although Europe has currently a strong position in telecommunications, an analysis is needed on how to maintain and grow European strengths toward 6G especially. The SNS JU is such a means to keep industry in Europe at the forefront of development and to catchup in areas, where

[13] Commission Staff Working Document, Impact Assessment Report, Proposal for a council regulation establishing the Joint Undertaking under Horizon Europe, European, 23.02.21, available at: https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/11899-Research-&-innovation-European-Partnership-for-smart-networks-and-services-Horizon-Europe-programme-_en

[14] https://cdn.ihs.com/www/pdf/IHS-Technology-5G-Economic-Impact-Study.pdf

[15] McKinsey: The Internet of Things, mapping the value beyond the hype

[16] Strengthening strategic value chains for a future ready EU industry, 6 Nov 2019.

Europe is behind. It is worth noting the world is facing some significant geopolitical changes. Countries or regions openly target a certain level of technological sovereignty to implement co-dependency and to improve resilience. At the same time today's economy is strongly globalized, and modern big companies are naturally multinational and active across many regions. A diversity of sources achieved as a combination of own capabilities and trade seems to be a viable way to achieve resilience. This resilience is also desired so that European values on regulatory aspects such as security, privacy, lawful intercept, competition law, net neutrality, etc., as well as policies related to climate change, sustainability, and inclusion are implementable. These are important aspects that affect the planning of R&D actions and require the mobilization of all European actors from the private and public sides.

2.1.3 Limited European sovereignty as regards critical technologies of smart network and service value chains

SNS technology becomes increasingly contemplated for numerous vertical digital use cases, but Europe has to rely partly on technologies developed elsewhere, putting European sovereignty at risk.

Europe's main technological assets in the SNS value chain is the telecom supply industry, which is challenged both by global competition and by risks of control[17] by non-EU actors. Devices and cloud computing are not mastered by Europe, but opportunities exist to develop EU industrial capabilities, through IoT devices and edge computing platforms. New industrial initiatives like Open RAN aiming at providing network functions through cloud-based software implementations, a domain where EU industry has less assets today, is also an important area to develop capacities in Europe as otherwise such solutions could seriously affect the European Telecom business.

The challenge is further aggravated by the trend to design connectivity systems through a vertically integrated perspective from device to service provision, pushed by the very high-performance level required in industrial and professional use cases. Non-European actors, who already master vertically integrated value chains, may clearly be at an advantage. The pressure will only increase over time, as the international competition in this domain is fierce, with geo-political approaches promoted by some of our main competitors, looking for dominance of the full SNS value chain.

2.1.4 Europe is slow to deploy infrastructure platforms for innovation

In the wake of 5G developments, SNS are expected to become platforms for innovation, with a level of openness allowing innovators to develop new applications on top. In spite of technological excellence, the deployment of 5G infrastructure in Europe is not as fast as in other regions, due to the uncoordinated efforts of both industrial and institutional initiatives and the limited investment capabilities of the European operators. However, new players in the vertical domains could potentially invest in new 5G infrastructure, but the complexity of integrating such technology with a complete connected ecosystem require significant time to fully validate the solutions in operational conditions.

[17] https://www.justice.gov/opa/speech/attorney-general-william-p-barr-delivers-keynote-address-department-justices-china

2.1.5 Important societal issues of SNS little addressed today

There is a potential conflict between the industrial incentive to develop and deploy SNS, and the concerns of European citizens about the impact of these infrastructures on the environment and on their fundamental rights.

Citizens are increasingly concerned about the use of personal data, by the electro-magnetic field exposure generated by wireless systems and such concerns are already slowing down the adoption of new technologies like 5G.
Sustainability is a main area of concern. It needs to be considered through three dimensions: (i) environmental sustainability, targeting the minimisation of environmental impact; (ii) societal sustainability, aiming at providing value to people and society thanks to new use cases powered by 6G, including support for the digital inclusion of fragile and marginalized groups, and (iii) economic sustainability, where 6G will be an enabler for business value. 6G should cater for both sustainable 6G networks as well as on all sectors that it will be used (i.e., "6G for sustainability").

2.2 What are the drivers for the challenges?

2.2.1 Insufficient capacity of 5G to respond to future communication requirements

Future digital use cases in professional environments will have very demanding connectivity and service requirements exceeding the most advanced capabilities of 5G roadmaps[18].
These future use cases include:

- Super-immersive multimedia and super high-definition video.
- Holographic telepresence. (up to 100 Gb/s needed, 100 times what 5G offers per user).
- XR Experience: virtual reality (VR), augmented reality (AR) and mixed reality (MR).
- Massive-scale communications (IoT) for anything and anywhere: 6G networks will support extreme massive connectivity.
- Smart City and cooperative mobility.
- Use cases requiring ultra-high precision 3D positioning, e.g., in factories.

For such a long-term perspective, early requirement for future networks and services combining next generation cloud and 6G mobile systems are emerging, with performance improvement factors of at least 10 (positioning, latency) or 50 (capacity, speed) requiring major evolutions beyond the state of the art and across multiple industry sectors, including the reduction of costs for complete social inclusion.

2.2.2 Insufficient presence of EU actors in the global value chain

The uneven presence of EU actors at each level of the SNS value chain threatens the future European technological sovereignty. This challenge is fuelled by several factors:

- **A fragile position of European actors in the global digital ecosystem:** European leadership in 5G R&D relies on two major 5G infrastructure manufacturers and an associated strong ecosystem of academics and R&I centres. However, reaching out more systematically to vertical industries is necessary to address comprehensive value chains. More collaboration is needed with cloud and device players, as new devices

[18]See e.g ITU FG2030 White paper: https://www.itu.int/en/ITU-T/focusgroups/net2030/Documents/White_Paper.pdf

(such as IoT) provide an opportunity for Europe to regain a presence in the device industry as well as the software and cloud domain. This also requires strategic links with the microelectronics industry.

- **High risk R&D reinforces the risks for European actors:** Connectivity and IT equipment sectors have high research intensity on average around 15% and going up to 30% for some actors[19]. This is comparable to other R&D intensive sectors such as semiconductors with R&D processes involving significant risks and important upfront investment. The stakeholders' consultation confirms the high-risk R&D level of the domain, with particular relevance of public-private risk sharing approaches for long term R&D, as practiced by our main competitors (Asia and USA).
- **A need for critical mass in standardization:** Since its inception end of 2015, the global 5G standardisation in 3GPP[20] has generated more than 60,000 industry contributions and thousands of essential patents. European vendors are at the forefront for contributions and patents[21] and have been supported by the 5G-PPP programme. However, this place remain fragile, and Asia has a strong position on 5G patents and launched 6G programmes. Maintaining European position in global standardisation will require additional European participation, notably more massive involvement of vertical industries and of complementary industries like the EU microelectronics sector, which missed the opportunity to contribute in the early phases of 5G standardisation.

2.2.3 EU value chains are not integrated to include all actors important for the development of future smart networks and services

The future SNS will be a critical infrastructure to be developed with actors beyond the traditional telecommunication value chain, both from a technological and application perspective:

- **A future infrastructure relying heavily on multiple advanced digital solutions:** The development of an infrastructure able to fit the needs of the future smart services requires cooperation with other fields of research beyond pure connectivity infrastructure research (5G-PPP). This implies connection to R&I in IoT, edge computing, artificial intelligence, cybersecurity and cloud, and to address the raising importance of software technologies in networks as well as that of microelectronics.
- **An infrastructure critical for the adoption of digital solutions in many industries:** SNS is set to become a critical infrastructure for numerous industries that are transforming themselves by progressively adopting digital technologies. Future research beyond 5G and 6G capabilities has to systematically take into account the requirements from the vertical players, beyond initial research on 5G. The integration of the vertical industries into smart networks and services research will need to be strengthened.
- **An infrastructure that will require structural changes in various value chains:** Rapid changes triggered by the deregulation of markets affected the communication

[19] Source: Strategy& PwC, The 2018 Global Innovation 1000 study, analysis of the 1000 largest corporate R&D.
[20] 3rd Generation Partnership Project, the global standard development organisation for mobile coms. ETSI is member.
[21] Estimated that out of the 4 main vendors (Nokia, Ericsson, Huawei, ZTE) EU has about 55% of the essential patents

industry, increasing competition and technological innovation. As a result, the mobile ecosystem has transformed in a complex network of specific companies involved at different stages in the value chain. The increasing trend towards software implementation and openness of network functions and interfaces opens prospects for new supply side actors, and new business models to emerge.

These changes in the value chain can disrupt existing businesses, and threaten established European actors, but they also provide an opportunity for Europe to reposition its industry and to take a larger part in the digital value chain by relying on its strong existing industries.

2.2.4 Too slow and uneven development of 5G infrastructure

Leadership in technology and deployment through lead markets need to go hand in hand to ensure the development of a comprehensive European digital market. Deployment of 5G in Europe is though facing barriers:

- **Lack of investment in the deployment of the new infrastructure:** China has 163 5G base stations per 100.000 inhabitants (2,36 times more than the EU). South Korea has the most 5G base station per head of population which is six times more than the EU[22]. Europe has approximately 310.000 5G base stations. Although these numbers have improved in favour of Europe, compared to the 2019 values, further effort is needed through viable business solutions. It is worth noting that the number of indicative 5G subscribers per 100.000 inhabitants appear to be the lowest for Europe compared to the other regions. In addition, EU 5G deployments are mainly based on the NSA option whilst Asia is aggressively deploying the SA option, which allows to take advantage of all 5G innovations. These could be remedied by a new class of investors, like the industry verticals or new value chain actors.
- **Insufficient synergies between national and European initiatives supporting 5G as well as EU deployment programmes:** The European 5G Public Private Partnership (5G-PPP) represents €3.5 billion of investments including €700 million of public support. Many European countries have launched national R&D programmes, supporting 5G research and deployments, at national or regional level, and are following up with the setting up of 6G national initiatives in various countries. They are generally restricted to national participants, and often overlapping with European programs. There is a risk of duplication, and missed opportunities for synergy and coordination. Moreover, deployment programmes such as CEF2 and DEP as well as InvestEU should be coordinated with R&I to achieve a coherent approach. More cooperation at European level would help to optimise the use of resources dedicated to SNS. A consistent strategy for these two pillars R&I and deployment has been missing to develop an impactful industrial policy in Europe in this field.

2.2.5 Increasing challenges of digital services toward ethics, privacy, and cybersecurity

The development of advanced digital services poses several challenges for the EU citizens as to their privacy, data protection, cyber-security, or ethical concerns. Several fundamental human aspects can be challenged, such as: Identity and Reputation, Relationships, Culture, Motivation and Attention, Responsibility, Fairness, Safety and Privacy. Future integrated

[22] https://5gobservatory.eu/observatory-overview/interactive-5g-scoreboard/#pioneer-chart

connectivity platforms will have to consider such ethical/societal issues from the start and make them part of the design principle. This in turn requires inclusion of stakeholders with new competence profiles from the onset.

2.2.6 Lack of energy efficient technological solutions for future network infrastructures

The systematic inclusion of additional frequency bands to radio sites is expected to double the energy needed per site, a trend further intensified by expected network densification. Coupled with extended computing service platforms, reports indicate a 10-fold increase of network and computing energy consumption, without accounting for the devices. This is exacerbated by a lack of integrated industrial approach towards energy value chains.

2.3 How will the challenges evolve?

- ***Limited European sovereignty on critical technologies:*** in 20 years, the number of European telecom suppliers shrunk from 4 to 2, with increased competition mainly from China and low margins. Also, Europe lost the smartphone industry and did not manage to create an Internet service industry. Over the coming decade, this trend will be excerbated. China, Japan, USA, South Korea have all started 6G initiatives, some of which (China) with massive public budgetary support. A strong EU policy including R&I is required to maintain the European ability to compete. The SNS JU together with related HEU Partnerships and the national initiatives are important pillars to strengthen Europe's position in a globally competitive environment.
- ***Europe is slow to deploy infrastructures for innovation:*** this challenge in the SNS domain is driven by regulatory and financial issues. On regulation, spectrum availability is key to lead deployment, as demonstrated by the aggressive 5G spectrum auction policy in the US. Without early coordinated approach at European level, there is a risk of a patchy "4G-like" deployment of future infrastructures. On finances, European operators have lower revenues compared to their US counterparts. Investments by vertical industries, as pioneered in Germany for 5G, would provide new financing sources for deployment. Involving these actors upstream in the R&I process is hence key.
- ***Europe failing to benefit from the full potential of the digitalisation:*** Reaping the full benefit of digitisation of the industry requires availability of technologies beyond the state of the art to address the most demanding use cases. Deploying such technologies in complex systems takes time and efforts. Should European research on the next step of digital communications and services lag behind, the long-term future deployments will be affected, limiting the availability of future infrastructure in Europe and having negative impact on the industries that will require it. Finally, the development of capabilities of 6G networks and services would be essential to limit the energy consumption and environmental footprint of the network whilst enabling energy savings in other sectors.
- ***Important societal issues not addressed:*** citizens' concerns like accessibility, security, trust, privacy, energy footprint or exposure to electromagnetic radiations will be even more exacerbated in the future. Several of these will have an impact on the development of 6G networks. For example, radiation limits should be considered from the start of the development, because transmitted EIRP and achievable radio range depend on these limits. The ability to translate these essential requirements into technology will provide

a clear competitive advantage to those companies and regions mastering them. Failure of the European research to address these concerns and to bring them into products and services may leave European policy makers potentially dependent from technological solutions specified elsewhere. Whilst regulation can provide an ex-post solution, early involvement of European public actors in the definition of future SNS provides opportunities to visibly address citizens' concerns ex-ante from a European perspective.

In conclusion**,** a coordinated EU policy converging visions and objectives across the multiplicity of SNS stakeholders alleviate the potential negative challenge evolution outlined above.

2.4 What are the priorities from the European private side?

The 6G-IA, along with the supporting associations, has acknowledged the aforementioned challenges and drivers for the development of 6G networks and smart services for all vertical sectors (e.g., transportation – including naval, aviation, railway, automotive -, industry 4.0, ehealth, media and entertainment, public safety, smart cities, agriculture, education, etc.). This is why, in conjunction with the EU Commission, it has developed the proposal for the SNS JU[23]. This proposal is closely linked with the vision of the European private side for the evolution of networks and services[24]. 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[25]. 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. It is the plan of 6G-IA to use this as a "living document" where topics will be updated or highlighted (by producing specific strategic documents) in the coming years, following the technological advances, market uptake and ecosystem evolution. 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
- The document[26] provides an analysis of each area and proposes concrete recommendations. The key observations and recommendations of the document are summarized as follows:
- Technological sovereignty on components and microelectronics: The target should be to find solutions through research activities that will ensure that SNS supply chains for products, components, materials and know-how are diversified. In terms of European

[23] Smart Networks and Services proposal, 30.06.2020 available at: https://ec.europa.eu/info/sites/info/files/research_and_innovation/funding/documents/ec_rtd_he-partnership_smart-networks-services.pdf

[24] 6G-IA, European Vision for the 6G network ecosystem, available at: https://5g-ppp.eu/wp-content/uploads/2021/06/WhitePaper-6G-Europe.pdf

[25] 6G-IA, Key Strategies for 6G Smart Networks and Services, position paper, available at: https://6g-ia.eu/plans-papers/

[26] 6G-IA, Key Strategies for 6G Smart Networks and Services, position paper, available at: https://6g-ia.eu/plans-papers/

research, the way to address this is through the identification of synergies with related EU Partnerships, so that coherence among research efforts is achieved.

- Technological sovereignty on open SNS solutions: Further strengthening of research and innovation activities are needed, ensuring that the results from current activities are capitalized on, to reach sound and widely accepted conclusions. All research efforts should work under the assumption of technology-neutral regulation, not mandating any architectures but rather pursuing the most suitable and efficient solutions for European stakeholders.
- Technological sovereignty on cloudification and distributed computing: Further research efforts are needed to ensure interoperability between cloud infrastructures. In this way it will be possible to have different independent cloud infrastructures that are separately optimised for a specific task or market. Additionally, it is important to identify open-source activities that will allow European solutions to eventually acquire a global role in a market that is currently heavily dominated by non-European players. Therefore, it is key to ensure that, where relevant, the produced solutions are integrated with the research and innovation actions being developed in the context of the SNS JU.
- Technological sovereignty on network intelligence: Existing results from the 5G,PPP era have indicated the need for a globally accepted framework where AI/ML will be benchmarked and validated. Additionally, appropriate training data sets are needed to support such a framework. These can be developed in the context of the research and innovation actions in the context of the SNS JU. To allow interconnection and interoperation of AI, digital twins and other intelligent components across different stakeholders, open solutions and well-selected standardised interfaces are needed for training and execution of AI models.
- Technological sovereignty on security and privacy: It is important to create a collaborative environment for key public and private forces to cover the complete range of needs from research activities, develop security solutions in critical hardware and software modules and foster end-to-end solutions that will conform to European policies and legislation.
- Technological sovereignty on knowledge expert base: Research and innovation activities should actively contribute towards a timely integration of the knowledge produced by SNS R&I activities in the educational process at the European level.
- Sustainability: This is globally accepted as a key target for 6G, although not clearly considered yet in the current early phase of standardisation (6G vision). Sustainability as a term encompasses both new solutions for sustainable Information and Communication technology (ICT) as well as ICT innovations to support sustainability on all vertical sectors. Therefore, it is imperative to develop a framework that will serve for the quantitative evaluation of solutions designed to support environmental, societal and economical sustainability. For 6G networks societal stakes and issues need to be clearly addressed from the start in order to avoid the reactions witnessed during the launch of 5G. To do so, 6G technologies must be built around environmental stakes and address adequately societal sustainable values.In follow-up work and position development the implications of the above will be addressed in the context of and for the anticipation of future developments of the service provider ecosystems and multi-stakeholder service platforms.

2.5 What are the priorities from the European public side?

The Smart Network and Services Joint Undertaking (SNS JU) is part of Horizon Europe (HE) and it should support the following Key Strategic Orientations, as outlined in the first HE Strategic Plan:

- 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 Smart Networks and Services 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. Key elements of the SNS SRIA

Both the European public and private sides have collectively created the SNS SRIA to address the abovementioned challenges. This section analyses the key elements of the SNS SRIA including the goal and drivers, the objectives and the targeted impact, the related technological areas as identified by the Networld Europe SRIA and how these are considered to form the SNS JU SRIA.

3.1 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[27] are depicted in Figure 2. These drivers arise from three main areas namely:

- **Society**: 6G networks and smart services are needed to provide 6G human-centric solutions including technological breakthroughs to support sustainable and energy conscious operations, reduce the digital divide, manage complex tasks using native AI solutions in a trustworthy manner and engage end-users by increasing user acceptance.
- **Policy**: Provide secure/resilient/trusted infrastructures and services, and strengthen European technological sovereignty serving EU values.
- **Business**: 6G smart networks and services are needed to boost the EU economy, secure EU industrial leadership in the field, and enable the emergence of new business models as well as provide solutions to tackle challenges emerging during crises (e.g., pandemics, etc.)

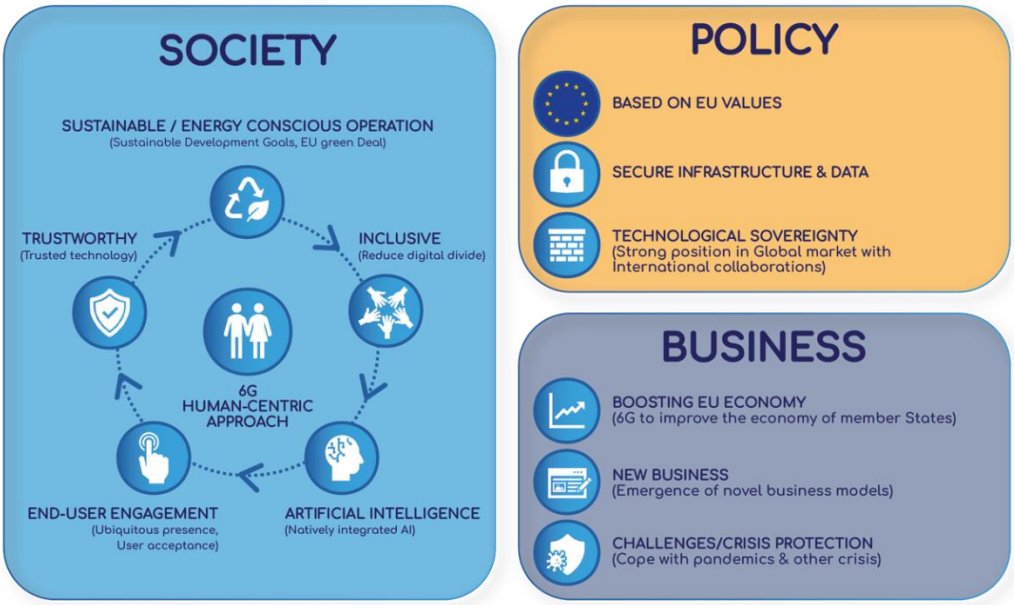

Figure 2: Smart Networks and Services JU drivers

6G is the mobile network generation that will help us to tackle the challenges we will face in 2030 and beyond. Mobile communications are 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 a lot more goals 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.
- 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.

[27] 6G-IA, European Vision for the 6G network ecosystem, available at: https://5g-ppp.eu/wp-content/uploads/2021/06/WhitePaper-6G-Europe.pdf

- 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 improve sustainability in other parts of society and industry.
- 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 3[28].

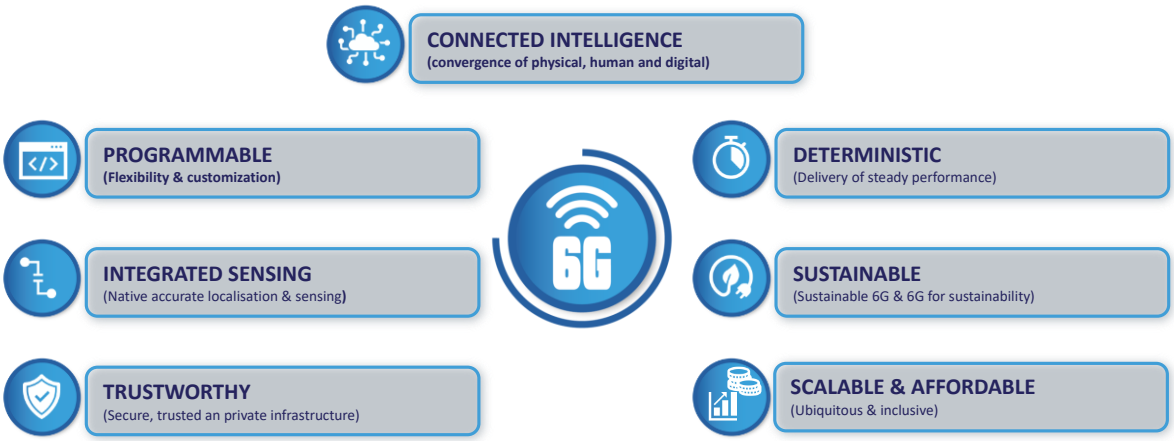

Figure 3: Main goals of 6G smart networks and services

The SNS JU ambition to address the problem statements as described in Section 2 is fully aligned with key policy objectives of the strategic planning for Horizon Europe[29]. 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[30]. The corresponding strategic objectives include (Figure 4):

- Ensuring EU competitive edge and sovereignty of the EU industry through a value chain approach covering EU technological capabilities in devices (IoT), networks, microelectronics and service platforms (edge computing);
- Supporting large-scale digitisation of EU industry through SNS platforms covering the most demanding use cases;

[28] 6G-IA, European Vision for the 6G network ecosystem, available at: https://5g-ppp.eu/wp-content/uploads/2021/06/WhitePaper-6G-Europe.pdf

[29] 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

[30] Smart Networks and Services proposal, 30.06.2020 available at: https://ec.europa.eu/info/sites/info/files/research_and_innovation/funding/documents/ec_rtd_he-partnership_smart-networks-services.pdf

- Supporting the emergence of new classes of applications, opening new economic opportunities;
- Addressing societal needs, notably as outlined in the Green Deal and UN SDGs;
- Supporting European access and inclusion to new high skilled experts;
- Promoting Europe as a lead market for specific use cases (focus on automotive to leverage CEF2 activities).

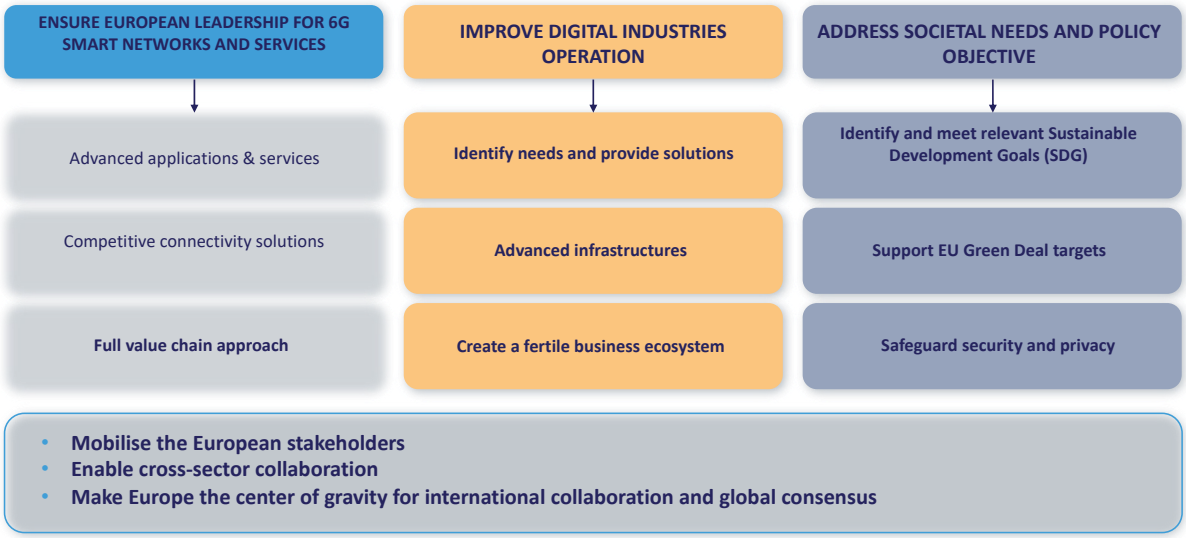

Figure 4: SNS JU Strategic objectives

These objectives will be met by carefully planning the 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[31] 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 Sustainable Development Goals (SDGs) while boosting the European data economy and contributing to ensure European sovereignty in these critical supply chains.

Whilst 6G R&I and strategic programmes have been launched in many regions of the world with the objective of securing leadership on several technologies considered as strategic (notably in the USA, Japan, Republic of South Korea, China, India) there is still no globally unified 6G vision nor any declared commercial deployment initiative. ITU is currently working on a unified 6G vision that should be available during 2023 as well as the related KPIs. Visions of 6G take up ecosystems are also subject to intense R&I activities at this stage. From a standardisation perspective, it is expected that 6G standardisation study work will start around 2025, which provides a significant window of opportunity to study in detail the multiple technologies that are called upon to realise future 6G systems.

31 https://smart-networks.europa.eu/

Within this broader context, the SNS SRIA and corresponding Work Programmes address the technological and business realisation of the 6G vision, targeting massive digitisation of societal and business processes through intelligent connectivity across the human, physical and digital worlds[32]. This covers several facets:

a) Industrial, economic and business aspects

The goal is to address notably:

- Moving beyond a simple increase in speed or performance and reduced latency of connectivity platforms, and beyond 5G capabilities bringing unique new service capabilities with wider economic implications. It requires capabilities for completely new services and applications, aligned with sustainability targets and a human-centric approach. This will eventually lead to 6G services, like the "Internet of Senses", realizing a fusion between the communication and sensing environment, massively scalable immersive environments, like XR/VR, digital twins, and holographic-type communication. The current basis for this 6G vision has initially been developed in the context of the EC H2020 5G Infrastructure PPP / ICT-52 projects, including the Hexa-X Flagship project[33], and is currently being elaborated in SNS Phase 1 projects including the new flagship Hexa-X-II project and in related national 6G programmes. These developments are to be harmonized to form the common European Vision of 6G.
- The integration of future connectivity and service platforms into larger globally applicable infrastructures, whilst preserving European competitiveness and sovereignty. The implementation of networks will increasingly take place across heterogeneous domains and the challenge will be to keep a strong EU influence whilst ensuring service delivery and control from an end-to-end perspective.
- Trust, security, resilience and communication privacy-enhancing technologies, processes and architectures as required for massively heterogeneous, virtualised and software platforms of the future, as well as the associated enablers for such developments.
- Bring new actors from, and beyond the verticals. Contributions from industry, RTOs, Universities and Small and Medium-sized Enterprises (SMEs) actors in the connectivity, IoT and cloud/IT domains are expected to be complemented by appropriate participation of the microelectronics and photonics industries, in view of their potential impacts in the standardisation process.
- A stable experimental framework towards minimising R&I risk and validating core technologies to stimulate early take up and EU as lead market.
- A unified consensus framework promoting a European approach towards 6G, facilitating international cooperation and placing Europe on par with other regions having started bold 6G initiatives in the precompetitive domain.
- A strong European impact at future downstream 6G standardisation stages, including a Europe-wide consensus of 6G Key Performance Indicator (KPIs) and Key Values Indicators (KVIs) that will frame future developments. Within 2023 the consensus on KPIs will be outlined in key documents like the ITU IMT 2030 Vision document. Therefore, the SNS Work Programmes will focus on (1) the validation of the KPIs

32 https://5g-ppp.eu/wp-content/uploads/2021/06/WhitePaper-6G-Europe.pdf

33 https://5g-ppp.eu/ and https://hexa-x.eu/

where a consensus has been established and (2) the further definition of the specific European KVIs, that are not (yet) reflected in international consensus. The integration of concepts and technologies originating from the Cloud/IT/Microelectronics environments to support massive device (IoT) connectivity and ultra-reliable communications and services on top of enhanced mobile broadband services is needed to address a comprehensive value/supply chain materialised by an IoT device-connectivity-service platform.

- The stimulation of strategic alliances, with vertical (industrial) sectors to build and offer powerful and persuasive Business to Business (B2B) and Business to Consumer (B2C) propositions. This should leverage upon general, local, regional, or even global smart interconnected public and private networks and services. A strategic goal of the SNS JU is to empower many vertical domains with capabilities beyond what is currently possible with 5G networks. Participation and contribution of these actors to the SNS R&I WP's are considered important, both to drive the requirements and to validate the technologies and their versatility in specific business contexts.

The work is also relevant in the context of several European policies[34], most notably:

- Europe's Digital Decade, Path to the Digital Decade Policy Programme[35] and the Gigabit Infrastructure Act[36].
- EU Cybersecurity Act[37] (Resilient Communication Privacy via Developing Proper Security Strategies), Network and Information Security (NIS2)[38], EU Cyber Resilience Act[39].
- European Chips Act [40] (Microelectronic components).
- Artificial Intelligence (AI) [41, 42] .
- Data, Cloud and Edge Computing[43,44].
- High Performance Computing (HPC)[45].
- Internet of Things[46].

b) Sustainability aspects

[34] https://digital-strategy.ec.europa.eu/en/policies
[35] https://ec.europa.eu/info/strategy/priorities-2019-2024/europe-fit-digital-age/europes-digital-decade-digital-targets-2030_en#the-path-to-the-digital-decade
[36] https://digital-strategy.ec.europa.eu/en/policies/eu-rules-reduce-cost-high-speed-broadband-deployment
[37] https://digital-strategy.ec.europa.eu/en/policies/cybersecurity-act
[38] https://digital-strategy.ec.europa.eu/en/policies/nis2-directive
[39] https://digital-strategy.ec.europa.eu/en/policies/cyber-resilience-act
[40] https://digital-strategy.ec.europa.eu/en/library/european-chips-act-communication-regulation-joint-undertaking-and-recommendation
[41] https://digital-strategy.ec.europa.eu/en/policies/artificial-intelligence
[42] https://digital-strategy.ec.europa.eu/en/policies/regulatory-framework-ai
[43] https://ec.europa.eu/info/strategy/priorities-2019-2024/europe-fit-digital-age/european-data-strategy_en
[44] https://digital-strategy.ec.europa.eu/en/policies/cloud-alliance#:~:text=Cloud%20and%20edge%20technologies%20are,on%20cloud%20and%20edge%20technologies
[45] https://eurohpc-ju.europa.eu/index_en
[46] https://digital-strategy.ec.europa.eu/en/policies/iot-policy

The 2030 Agenda for Sustainable Development and the related UN Sustainable Development Goals (SDGs)[47] aim to strengthen the social, economic and environmental dimensions of sustainable development.

The objective is to support key United Nations Sustainable Development Goals (SDGs)[48] from the SNS perspective:

- **SDG 8**: Promote sustained, inclusive, and economic growth: achieve higher levels of economic productivity through diversification, technological upgrading, and innovation.
- **SDG 9**: Build resilient infrastructure, promote inclusive and sustainable industrialisation and foster innovation, upgrade infrastructure and retrofit industries to make them sustainable with increased resource-use efficiency and greater adoption of clean and environmentally sound technologies and industrial processes.
- **SDG 11**: Make cities and human settlements inclusive, safe, resilient, and sustainable.
- **SDG 13**: Climate Action: Support smart low carbon lifestyles, monitoring emissions, and shaping demand in transport and energy, enabling resilient mission critical communications in extreme weather (vertical markets: transport, health, and public safety).

These SDGs are indicative and provided as an example, though they are deemed to be those where SNS impact is potentially significant. In addition, complementary societal issues, such as ethical issues in the context of privacy or Electric and Magnetic Fields (EMF) awareness and reduction, are targets of the SNS R&I WP's.

Supporting Societal KVIs such as safety, security, trustworthiness, inclusiveness, and sustainability are described in further detail below. Several factors form the basis for new research and innovation targets underpinning the evolution of 5G and the design of 6G networks. Some of them include full industry digitisation, supply chain resilience, and the need to address European and global societal challenges.

Beyond the above objectives reinforced by the European Green Deal[49], which sets out a target for the EU to achieve climate neutrality by 2050, research on Smart Network and Services needs to address how 6G will be sustainable ("Sustainable 6G") and how it will contribute to the sustainability of other sectors ("6G for Sustainability").

Given the prominence of the twin green and digital transition for the EU and how sustainable digital technologies could enable achieving the EU carbon-neutral objectives by 2050, the SNS R&I WP's considers the latest developments in the field, notably the Digitalising the Energy Systems Action Plan[50], which includes further action to explore the possibility to develop common indicators for measuring the environmental footprint of the electronic communication services (planned Q4 2023) and the establishment of an EU Code of Conduct for the sustainability of the telecommunications networks (planned Q4 2025).

[47] https://www.un.org/development/desa/dspd/2030agenda-sdgs.html
[48] http://www.un.org/sustainabledevelopment/sustainable-development-goals/

[49] COM(2019) 640 final
[50] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52022DC0552&qid=1666369684560

Sustainability is increasingly becoming a key target for the design of 6G, driving the choice of technologies and conception of the system to reach effective 6G solutions, with reduced energy, climate and environmental impact. While already initially addressed in the SNS WP2022 and WP2023 (mostly focusing on energy efficiency and associated carbon emissions), a systematic approach to sustainability (including other sustainability requirements) should continue and be considered globally, encompassing, for instance, also:

- Energy, climate and environmental sustainability, aimed at minimising such impacts of technologies (e.g., energy consumption and energy efficiency, carbon footprint, use of renewable energies, recyclability, repairability and, use of available resources).
- Societal aspects, enabling people to engage, evolve, live healthy lives and ensuring their long-term social well-being by providing value to the society.
- Economic aspects, aiming at supporting long-term economic growth.

The heterogeneity of resources and services in 6G, comprising e.g., communication, computing, control, and sensing, calls for an end-to-end cross-layer design and optimisation, taking into consideration the entire 6G network (core, transport/aggregation, access, and network equipment/devices) during the entire life cycle [51] with the parallel need of sustainability being an integrated network design criterion and supporting the sustainability-by-design approach. It also needs to expose to application providers the right interface level such that the sustainability of their specific use case can be reflected by the underlying service implementation of the SNS services.

c) Joint activities between Partnerships

Since the initial steps of the SNS JU, it has been identified that cross-partnerships collaboration is needed to achieve the desired results. As it will be discussed in Section 5, the SNS JU has identified related HEU partnerships that are dealing with key enablers for 6G networks and services or are expected to make use of SNS JU results. The plan is to establish strong links with all these partnerships. To present the SNS JU has already created collaborations with KDT JU, soon to become the European Chips Joint Undertaking. More information can be found in Section 5.

3.2 SNS objectives and targeted impact

The following key objectives are proposed to address the challenges analysed in the previous section. It is expected that the implementation of the objectives and activities agreed in the SRIA will be reviewed and further adapted with the involved stakeholders during the lifetime of the Partnership.

Objective 1 – Full industry digitization and support of vertical industries

General Objective:

1. To provide and validate (in trials and pilots) the enablers and solutions for full digitization of the European vertical industries to improve the business operation.

[51] As referenced in the 6G book: https://www.nowpublishers.com/article/BookDetails/9781638282389

Specific Objective (by 2030):

1. Identify those vertical sectors and understand their specific needs that will benefit most from the full digitization.
2. Mobilize the multi-disciplinary stakeholders to create efficient and high-quality solutions.
3. Ensure the adoption and deployment of these solutions.

Operational Objectives:

1. Identify at least 10 vertical sectors, that can benefit from Smart Networks and Services, starting from vertical sectors that have shown promising results in Horizon 2020. An indicative first list includes: Industry 4.0, agriculture, automotive, transport and logistics, smart cities, public safety, energy, eHealth, media and entertainment and smart (air)ports.
2. Create the appropriate collaboration environments among multiple stakeholders (i.e., telecommunication manufacturers, operators, vertical industries, academics etc.) to identify real-life requirements and needs.
3. Reflect in the SNS architecture work the level of functionality exposure needed to enable vertical use cases to satisfy their requirements, both for functional and non-functional properties, and get them validated by SNS infra owners.
4. Establish MoUs with relevant international initiatives.
5. Develop and validate solutions that reduce OPEX for the selected vertical sectors.
6. Organize open calls for project proposals that will provide the design of PoCs, demos and large-scale trials and will cover the operational needs for at least 10 selected vertical sectors.
7. Analyse and understand the results produced by the large-scale trials and revisit verticals' requirements and needs.
8. Disseminate the results in a structured way to maximize the deployment and adoption of these solutions (e.g., via a close collaboration with DIHs in the Digital Europe Programme, CEF2 and relevant European Partnerships i.e., CCAM).
9. Support related standardisation and ad-hoc regulation.

Objective 2 – Societal and political aspects

General Objective:

To foster the development and adoption of technologies and solutions that will help to address societal challenges that can directly or indirectly contribute to

1. Achieve EU Green Deal's targets and relevant subset of United Nations SDGs' goals.
2. Enable Europe to reach digital autonomy and technology sovereignty.
3. Ensure that digitization of our society will be done in a secure way to retain Europe's leading position in trust and privacy.
4. Create high-skill jobs and social inclusive technologies.

Specific Objectives (by 2030):

1. Identify those verticals that will have a significant positive impact to the Green Deal objectives.

2. Design and validate specific SNS solutions that will achieve the desired levels of energy reduction for these verticals.
3. Develop end-to-end SNS architectural solutions making it possible to address energy control from an end-to-end perspective, across different business and technological domains.
4. Design and validate ICT building blocks that can be used to achieve one or more United Nations' SDGs.
5. Ensure that Europe will be self-sustained in key technological sectors, including the value chain considered for SNS[52].
6. Provide advanced end-to-end cyber security solutions considering among others, the support of highly critical services and infrastructures and the privacy of the end users.
7. Link SNS technological directions to social inclusiveness and the creation of high-skill jobs via the digitization of vertical industries and the support of emerging applications.

Operational Objectives:

1. Reduction of the subsector GHG percentage between 2020 – 2030, should be[53]:
   - Mobile network operators: 45 %
   - Fixed network operators 62 %
   - Data centre operators 53 %
2. Reduction of energy footprint of SNS platforms by increasing the energy efficiency, compared to 1990 levels, in each sector, including the ICT sector, from a level of 20 % in 2020, to a level equal or higher than 32,5 % in 2030, if operators manage to deploy the new solutions by the end the SNS JU.
3. Reduction of GHG emissions, compared to 1990 levels[54], from a level of 20 % in 2020 to a level equal or higher than 40 % in 2030, if verticals adopt the SNS solutions.
4. Follow ITU's methodology[55] to identify ICT building blocks that will be used to meet goals set by at least 5 different UN's SDGs.
5. Provide solutions that have the potential to stimulate viable technological alternatives for at least 4 sectors (e.g., microelectronics, specialized devices, data economy and cloud) where EU is currently dependent on other regions. This will also include stimulation of the presence of EU actors in open-source activities.
6. Provide solutions that reduce electromagnetic field (EMF) exposure to citizen.
7. Provide solution that will access availability to real time Cyber Threat Intelligence information (attacks/threats and vulnerabilities).
8. Develop risk analysis tools and services enabling 100 % of awareness and level-based appropriate protection counter-measure deployment.

[52] European Commission: Secure 5G deployment in the EU - Implementing the EU toolbox. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, Brussels, 29.1.2020 COM(2020) 50 final, available at: https://ec.europa.eu/digital-single-market/en/news/secure-5g-deployment-eu-implementing-eu-toolbox-communication-commission

[53] GSMA: Setting Climate Targets, available at: https://www.gsma.com/betterfuture/wp-content/uploads/2020/03/Setting_Climate_Targets_singles.pdf

[54] European Commission: Fourth Report on the State of the Energy Union. 9 April 2019, available at: https://ec.europa.eu/commission/publications/4th-state-energy-union_en

[55] ITU: SDG Digital Investment Framework - A Whole-of-Government Approach to Investing in Digital Technologies to Achieve the SDGs. ITU, 2019, available at: https://www.itu.int/dms_pub/itu-d/opb/str/D-STR-DIGITAL.02-2019-PDF-E.pdf.

9. Build a framework that will build trust in ICT infrastructure through systematic exposure of cybersecurity levels 100 % compliant with the European-legal basis (certification, Security Service Level attributes, GDPR/EU strategy for Data, etc.).
10. Address highly critical applications and essential services requirements leading to sovereign solutions able to provide 100 % availability of services for verticals.
11. Improve attack detection and response mean time of Cybersecurity incidents including zero % unprotected data leakage.
12. Provide solutions for disaster relief.
13. Create applications and services that promote social inclusiveness.

Objective 3 – Business aspects – Europe's share on the global market

General Objective:

1. To reinforce European leadership in the smart networks domain, to seize opportunities to stimulate EU ICT capabilities in domains where the EU industry is less prominent, and mobilize cross-disciplinary private sector forces to build solutions that will improve the operation of European vertical industries.

Specific Objectives (by 2030):

1. Produce high-quality results (scientific, IPRs, standards contributions, trials, etc.) that will have a global impact.
2. Mobilize the private sector to invest in key technologies and become engaged in multiple additional activities.
3. Create an environment which allows the easy setup of multi-disciplinary and cross-sectoral consortia (i.e., verticals, stakeholders from the telecom and beyond sector, academia, etc.).
4. Strengthen the participation of SMEs in R&I activities.
5. Strengthen verticals deployment perspectives in Europe.

Operational Objectives:

1. Reach more than 15 % in declared 5G and B5G patent families (granted and non-granted) by European based HQ companies.
2. Reach a patent grant rate of more than 60 % for European based HQ companies.
3. More than 1000 B5G/5G contributions in SDOs deriving from SNS work.
4. Provide more than 1000 publications in international journals and conferences.
5. Organize more than 25 workshops and more than 100 webinars.
6. Target the organization of large-scale trials where synergies among multi-disciplinary stakeholders can be achieved.
7. Ensure commitments from the partner (i.e., respective Association) to collectively mobilize additional resources to further support the objectives of the SNS JU and develop synergies with relevant national, regional and EU programmes and investments.
8. Organize additional activities that will have multiplier effects.
9. Secure commitment from the private sector on financial and/or in-kind contributions.
10. Ensure that SMEs reach an overall share of 20 % of funding in R&I projects.
11. Increase the turnover for each participating SME in R&I project.
12. Define and regularly update the Strategic Deployment Agenda (SDA) for CEF2.

13. Establish clear links with the CCAM Partnership and exchange technical information that will address topics related to connected and automated mobility potentially by open calls.

Objective 4 – B5G Systems design and support of emerging applications

General Objective:

1. To research, develop and validate the next generation of smart networks and support emerging services, while enabling networks to efficiently support any service to be provisioned under all relevant environments.

Specific Objectives (by 2030):

1. Integrate key technological enablers in future networks (i.e., IoT, AI, distributed HPC, cloud and edge computing and cybersecurity).
2. Based on the SRIA, develop a coherent long-term research framework and roadmap to identify priorities and main challenges to be addressed to build future networks' critical building blocks.
3. Evaluate and validate novel solutions and mechanism in appropriate large-scale trials.
4. Bring key developed solutions to relevant standardization fora.

Operational Objectives:

1. Identify the requirements from the emerging services and their impact on future networks
2. Design and validate network enhancements to support emerging services.
3. Identify network complexity issues that require the use and integration of key technological enablers.
4. Provide architectural solutions to accommodate those enablers and to address these issues (AI, HPC, IoT etc.).
5. Develop and implement common agendas, where appropriate, with key initiatives, notably KDT, Cybersecurity and CCAM.
6. Validate their performance through PoCs, pilots and large-scale trials.
7. Provide requirements and receive feedback and guidance from partnerships and associations focusing specifically on these enablers through workshops and Impact Assessment and Facilitation Actions (IAFAs).
8. Reduce service creation time from 90 minutes to 9 minutes.
9. Contribute significant advancements on network architectures and capabilities such as:
    - Significant improvement of the network KPIs.
    - Minimization of the necessary radiated RF power close to physical limits.
    - Provision of more efficient network management solutions without human interaction.
    - Further improvement of energy efficiency compared to 5G 3GPP Releases 16 and 17.

The scope of the SNS SRIA considers the full value chain. Figure 5 presents the Partnership Specific Impact Pathways (PSIPs) for the objectives presented above. As shown in Figure 5,

SNS has as a main target to contribute to societal challenges. This is also captured in the SRIA and related R&I Work Programmes.

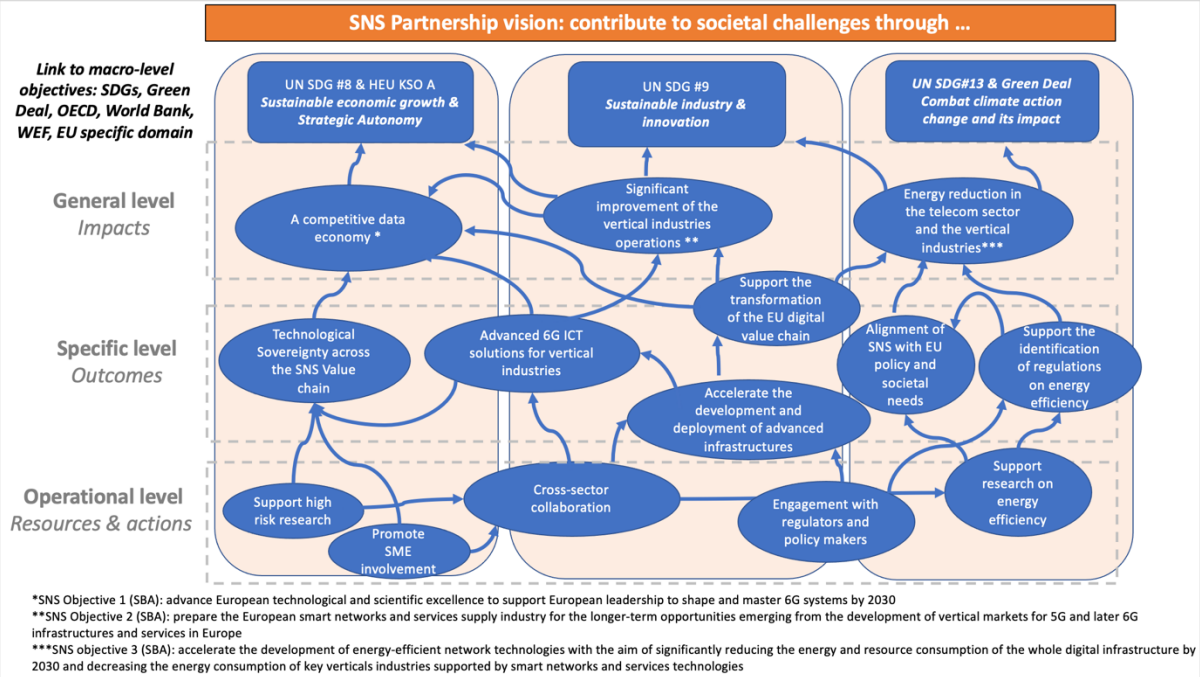

Figure 5: Partnership Specific Impact Pathways

3.3 Key areas identified in the Networld Europe SRIA

Networld Europe, the European Technology Platform for Communications and Services, is one of the institutions that aims to address the challenges brought by this increased intertwining of ICT and society. Networld Europe 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, Networld Europe has worked with the 6G Infrastructure Association (6G-IA) and has established liaisons with other European supporting associations to build a Strategic Research and Innovation Agenda (SRIA) for communications and services. Given the essential role ICT takes in all society domains, such a SRIA cannot aim at completeness: there are always aspects that will be missing for specific sectors. Hence, we rather envision an establishment of a foundational basis for communications and services, on which other sectors can rely to plan their evolution and the deep transformational aspects that ICT will bring into the society at large.

As already mentioned, part of the immediate impact of this effort is reflected in the European research Work Programme of the Smart Networks and Services Joint Undertaking , driven by the European Commission and the 6G-IA. But the content of this SRIA can impact other European Work Programmes, 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, e.g., Cluster 3 and Cluster 4 Work Programmes, or in other Joint Undertakings/Public-Private Partnerships besides SNS). As a deeply technological vision on communication and

services, the Networld Europe SRIA can be explored in different dimensions and in different technological and application domains.

This Networld Europe SRIA is divided in two large and related parts. The main body[56], consists of a simplified, higher-level vision of the technological roadmap, with an additional deep section providing simplified metrics tables that identifies reference specifications for technology at different times and expected technological features associated with those nodes. A second part, the technical annex[57], provides a deeper reaching discussion on the technologies we envisage as key for the future, under the overall scope of ICT.

3.3.1 Networld Europe's 6G vision

Future SNS is expected to focus on an integrated ICT system able to address different types of applications that are only briefly envisaged today. Although there is no consensually established ideas on those new applications, commonly referred scenarios by industry include: telepresence, including surrogate robots and holography; shared cooperative environments, with high-resolution AV and VR for both gaming and professional applications; mood mediators, with automated environment monitoring and adaptation to the user; automated machines, including domestic robots and self-driving vehicles; cobots, swarms of machines cooperating in both regular and hazardous environments; global reachability, covering the sea and skies; environment sensing and acting, covering global service intelligence provisioning with remote data collection; and body monitoring, specially to address an ageing society and internet of senses challenges. All these diverse scenarios can be looked at as ultimately addressing increasingly collaborative services, including creative industries, in increasingly larger areas, and with increasing reliability and (human verifiable) trust, providing the scope for the overall challenges that 6G systems will need to address, fulfilling the needs of the society in general.

In 6G networks more and more intelligence and computing power will be available per resource, whereas the resources of these systems will be dynamically configurable and orchestratable. Unlike 5G, 6G will be not only more flexible in both its services and in its capabilities and realization but will also exhibit much higher dynamics, in service types/loads but also in its own topology.

Using the offered large variety of novel challenging ICT services, a massive number of devices will be served by these systems generating, exchanging and treating very large quantities of data. The infrastructure that supports society (IoT, cyber-physical systems) will be integrated with the Internet, which will help improve the effectiveness and efficiency of both. Useful insights can be generated based on the automatic analysis of all that data (e.g., using machine learning methods, , and artificial intelligence, AI). Beyond the analysis, AI/ML can also be used to optimize deployment, adaptation, reconfiguration and other decisions or to create better-suited system modularizations and novel entities better suitable for the overall required processing. Moreover, 6G networks are expected to be much more resilient to failures, operational errors and security threats alike, in a world, where autonomic operations for both services and infrastructures, and in particular AI/ML techniques, will be widely used. Open standards will be required, while governments will want to impose limits and regulations on the operations on all the data required to drive these new systems. Additionally, 6G networks are targeted to be truly green using elasticity, as the capability of adjusting resources used in

[56] Networld Europe, Strategic Research and Innovation Agenda 2022, available at: https://bscw.5g-ppp.eu/pub/bscw.cgi/d516608/SRIA-2022-WP-Published.pdf

[57] Networld Europe, Strategic Research and Innovation Agenda 2022, Technical Annex available at: https://bscw.5g-ppp.eu/pub/bscw.cgi/d516614/SRIA%202022%20Technical%20Annex%20Published.pdf

service execution. This will allow to redirect requests to resources with better ecological sustainability and to limit the overall resource footprint while preserving the service throughput.

Overall, Networld Europe envisions a Smart Green Network as a programmable system based on a unifying controllability framework spanning all resources a service/tenant is authorized to control, including from previously separate and heterogeneous domains, e.g., enterprise and telecom networks, virtual and physical, data centers and routers, satellites and terrestrial nodes, etc., covering a global network of networks (including the space domain).

For reasons of completeness of the SNS JU SRIA, this information is summarized in the following sections.

3.3.2 Key Technological Areas – Networld Europe SRIA

A very detailed analysis[58] of all the considered technological topics to meet the aforementioned goals and objectives, is provided. Additionally, the annex[59] provides a discussion on ICT that, by necessity, had to be restricted to key dimensions from the point of view of the communications ecosystem. There are nine different chapters in this annex, which include:

- System Services aspects – overall system trade-offs that need to be considered for the future, posing the stage for technology development.
- System Architecture – analysing the evolution of systems towards dynamically composed, multi-stakeholder environments, with an increasing softwarization and intelligence of the whole system, and the accompanying challenges.
- Network and Service security – discussing the paths on the increasingly relevant aspects of security in our infrastructure
- Software technologies – addressing the software related challenges of the ongoing network softwarization, 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 is detailed in this chapter.
- Non-terrestrial networks and Systems – discusses the upcoming closer integration of 3D networks into the overall communication system
- Devices and Components – tackles the unavoidable challenges at the fundamental element level, which will constrain and limit all system developments.
- Future Emerging Technologies – is a final chapter 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.

These nine chapters are supporting Networld Europe's overall 6G vision and are linked to a related timeline and expected measurable key performance indicators.
In summary the proposed technological areas for further investigation and evolution include:

[58] Networld Europe, Smart Networks in the context of NGI, 2020 available at: https://bscw.5g-ppp.eu/pub/bscw.cgi/d367342/Networld2020%20SRIA%202020%20Final%20Version%202.2%20.pdf
[59] Networld Europe, Strategic Research and Innovation Agenda 2022, available at: https://bscw.5g-ppp.eu/pub/bscw.cgi/d516608/SRIA-2022-WP-Published.pdf

- An architectural evolution to achieve a holistic smart green system including: an AI-native platform beyond the 5G SBA (Service Based Architecture), Pervasive Resilient Autonomic Resource Control, Separation of Controllability and Control, Compute-Interconnection (CIC) architectural frameworks, Runtime Compute Interconnection (resource) scheduling, Runtime Service Scheduling, CIC Operation and management (OAM) frameworks, Net zero (distributed) AI/ML, Conflict Avoidance/ Resolution, Articulation of needs and provisions from the system to the user/applications, etc.
- Further evolvement of software technologies for telecommunications to efficiently manage swarm, edge, heterogeneous and federated "clouds" and provide novel advanced services considering solutions for (indicatively): AI-powered edge cloud compute continuum, Automated and agile software engineering, Enablement of digital services, Engineering complex, software-intensive, and self-adaptive SNS systems, Software architectures, Human centricity and digital trust, Digital twins in the SNS context.
- Appropriate evolution of holistic and adaptive security, trust, resilience solutions to meet the metamorphic properties of the systems, including new architectures for end-to-end security distribution, security as a service, differentiated security, Root of Trust distribution and Black Boxes Tolerant architectures, data centric support, hardware and physical layer security, software and virtualization security, AI based operational security, etc.
- Advancements in the radio technology and signal processing including, spectrum re-farming and re-utilization, mmWave and THz communications, massive and Ultra Massive MIMO, waveform, multiple access and full duplex, Reconfigurable intelligent surfaces, cell free networks, coding and modulation, positioning, massive random access and wireless edge caching, optical wireless communications, integrated sensing and communication, machine learning empowered physical layer, etc.
- New solution in the optical domain targeting backhaul and fronthaul to ensure sustainable capacity scaling, new switching paradigms, real-time programmable optical devices in distributed architectures, disaggregated switching platforms, optical-wireless integration to achieve ultra-high energy efficiency also considering post quantum security and resilience aspects as well as future evolution of optical access technologies and architectures.
- Further evolution of satellite communications technologies, including evolved 3D network architectures, optical based satellite communications, new antennas, integrated satellite and terrestrial networks, etc.
- Device and components evolution in terms of communication systems (e.g., sub-10GHz RF), mmWave and THz communication components, ultra-low power communication systems, in-band full duplex technologies, optical components and building blocks, antennas and packages, baseband modems, CMOS scaling towards 1nm (A10) and beyond (A7, A5, ...), processors for Cloud-AI, Edge-AI and on device-AI, memories and hardware for security and IoT devices.
- Emerging technologies on various areas such as: nano- and bio things, quantum computing and networking, scalable homomorphic encryption, Human centric multimodal communication, Bio-degradable and digestible sensors, Energy harvesting, (near)-zero energy UEs etc.

From the above list, it is clear that the Networld Europe SRIA is a thorough analysis of technological trends that are expected to have a significant impact on the evolution of the future

telecommunication systems. The Networld Europe SRIA is updated on a biennial basis and used as the basis for the development of the SNS JU SRIA.

3.3.3 Considered KPIs

Networld Europe analyses[56] a number of KPIs for the system architecture and software, security, radio and NTN, optical and devices and components along with a targeted timeline that these should be achieved until 2031. Given the large scope of technologies discussed, these metrics are multiple and reflect very different essences. There are performance indicators that are typical (and very detailed), like in the case of radio, but the increasing complexity of the SNS systems require increasingly complex metrics, across a multitude of technology domains. In fact, some of the performance indicators (the metrics themselves) will evolve during the next years. It is worth noting that Networld Europe does not include information about Key Value Indicators that are considered as part of the SNS JU. This is a point where future editions of Networld Europe SRIA can also provide some insight.

3.4 Adapting Networld Europe's SRIA to the SNS JU

The Networld Europe SRIA has been used as the basis for the development of the SNS Partnerhsip SRIA. It has to be noted at this point that the Networld Europe SRIA contains a superset of topics, some of which do not fall directly into the scope of the SNS JU, but rather in other HEU related Partnerships (e.g., KDT, Photonics21, etc.). Thus, a specific methodology has been developed, involving members of the 6G-IA as well as other Associations supporting the SNS JU (i.e., AIOTI, PSCE and NESSI).

To achieve this adaptation, a dedicated list was developed to summarize the main technological topics for B5G and 6G networks, as well as cluster these as "SNS groundwork" and "SNS revolutionary" activities and also identify if the Networld Europe SRIA topics are to be covered by the SNS JU or other related HEU Partnerships.

A group of experts from the 6G-IA, Networld Europe, NESSI, PSCE and AIOTI evaluated and selected which of these topics fall under the scope and objectives of the SNS JU. A prioritized list of topics was thus, identified. This list was provided to the private side through an open consultation among the members of the 6G-IA to check if the topics were well-selected and if there were additional topics that could further populate the list. Based on their feedback the final list of topics for the SNS JU SRIA were selected. These are analyzed in the following subsections.

3.5 SNS JU key technological areas

As mentioned earlier the SNS JU SRIA is based on the Networld Europe SRIA, after evaluating and selecting those topics that closely match the objectives of the Joint Undertaking. The SNS JU SRIA will be updated on a biennial basis following the process described in Section 6. For the first phase of the SNS JU the technological topics to be investigated have been grouped into 4 main streams. More specifically:

- **Stream A:** Targets the development of smart communication components, systems, and networks following the further evolution of 5G systems. It follows an evolutionary path towards the development of 6G networks, relying on the development of an intermediate technology point. The proposed research topics are complementary and altogether support a complete system view. Note that Stream A was considered for the

Work Programme of 2022 and it decided not to be further supported as it comes too late to further influence 5G Advanced standardization

- **Stream B:** Covers research for revolutionary and evolutionary technology advancements, in preparation for 6G and revolutionary and evolutionary advancements including IoT, devices and software. This Stream targets low to medium TRL, with the objective of delivering innovative solutions towards real-life networks in a long-term period.
- **Stream C:** Focuses on SNS Enablers and Proof of Concepts (PoCs) used to further develop and consolidate experimental and federated infrastructure(s), in support of the various phases of the SNS JU. This includes experimental infrastructures also for the integration of microelectronics and photonics, developed by related partnerships, in 6G experimental infrastructures.
- **Stream D:** Targets large-scale SNS Trials and Pilots with Verticals, including the required infrastructure. The aim is to explore and demonstrate technologies and advanced applications and services for the vertical domains. During the second SNS phase, Stream D projects are expected to mostly rely on SNS Phase 1 technologies and especially the infrastructures to be developed from Stream C projects. The goal is to gradually incorporate innovative 6G functionalities. From the societal point of view, stream D will, during Phase, highlight sustainability evaluations across verticals, validating exploitation of 6G across different vertical sectors.

These Streams are expected to be active for the whole duration of the SNS JU and their topics are expected to be updated on a biennial basis.

This SNS Phase 1 builds upon the outcomes of Horizon 2020 5G-PPP projects, as well to capitalize on the results from other instruments and initiatives (e.g., undertaken in Member States, Horizon 2020, or other activities that follow open principles, as for example Open RAN, etc.). The SNS roadmap (Figure 6) illustrates the phases of the four Streams. The SNS roadmap is expected to be updated considering the SNS targets and the key achievements from projects of subsequent Phases.

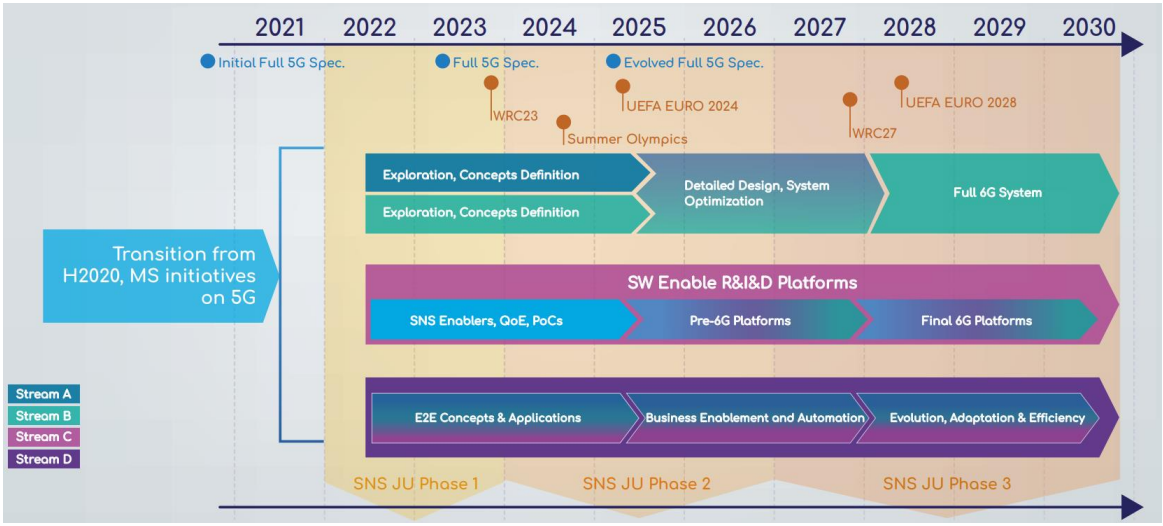

Figure 6: SNS JU Roadmap

Figure 7 illustrates the phases of the SNS JU. It also presents how the outcome of each Stream is combined with other Streams' activities and results during the following SNS phases. Thus,

it is envisioned that complementary results from the Streams may be re-used in subsequent phases.

The arrows in Figure 7[60] illustrate how the outcomes of projects in Phase 1 could be used in Phase 2, and then likewise from Phase 2 to Phase 3. More specifically,

1. Stream C Experimental Infrastructure technologies are expected to serve as the basis for the subsequent phase Stream D Vertical Pilot projects.
2. 6G solutions and potential PoCs, to be developed in Stream A and B projects, are expected to contribute to the Experimental Infrastructure projects (Stream C) and Vertical Pilot projects (Stream D) of subsequent SNS JU phases.
3. Experimental infrastructure Projects (Stream C) and especially Vertical Pilot projects (Stream D) are expected to provide new requirements (e.g., KVIs, KPIs) to Stream A and Stream B projects of subsequent SNS JU phases.
4. The further development of Stream C projects is expected to follow a spiral evolutional approach, subject to the successful delivery of selected projects.
5. The further development of Stream D projects is expected to follow a spiral evolutional approach, subject to the successful delivery of selected projects.

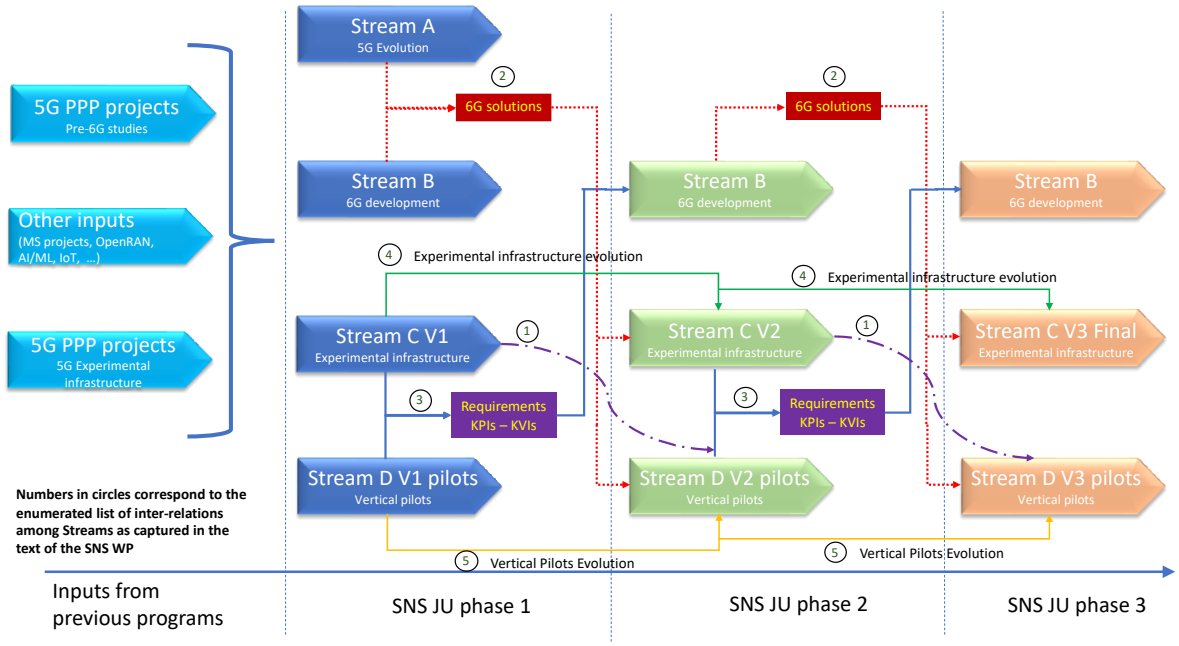

Figure 7: Interlinking of Streams into Phases

Stream A related topics

The challenge is to address emerging mid-term requirements, deriving from evolving policy objectives, societal needs, digital business operations, and new applications domains, that cannot be supported by existing connectivity and service systems.

A key goal is to prepare for new advanced user services (e.g., immersive communication, holographic telepresence & Augmented Reality / Virtual Reality etc.), as well as new vertical

[60] The numbering in the figure correspond to the points raised in the itemized list

challenges (e.g., connected mobility, environment surveillance, personalized medicine, etc.) which require significant improvements from existing connectivity and service platforms.

Another goal is to support the European vision for societal challenges such as digital inclusion and accessibility, unlocking rural economic values and opportunities, under a Green Deal overarching objective (see KVIs explained in the 'Context and Objectives' above). It requires addressing high energy efficiency solutions. It also targets at an open connectivity and service platform evolution with reduced energy consumption and lower operational and ecological costs, able to meet KPI requirements identified in the Networld Europe's SRIA for mid-term objectives.

The challenge is hence to develop the technologies supporting these mid-term functional and non-functional properties. It also requires realising seamless and cost-effective integration of multiple enablers from related domains (e.g., HPC, (cyber-)security, AI/ML, IoT) with the objective to prepare strong European industrial positions for the further mid-term evolution of 5G standards expected in upcoming 3GPP Releases and eventually moving towards the 6G era.

Stream A topics define and establish system level interfaces to be able to realize a unified vision of pre- 6G systems, with the support of the Coordination and Support Actions (CSAs) projects.

AI techniques are widely explored across Stream A activities. The data sets to be used for the training and the evaluation of the mechanisms to be developed are key for open innovation strategies. Such open data sets (e.g., date of release, its scope, and the dimension and diversity of data) will be considered for relevant projects that aim to explore AI techniques.

The topics of Stream A include:

- Green radio technology: Address basic building blocks that go beyond current 5G specifications (e.g., PHY layer topics, hardware acceleration, cell-free, software-based radio, improvements on mmWave, BC/MC architectures, EMF impact, considering enablers such AI/ML, to minimize energy consumption).
- Ubiquitous radio access: Impact on coverage, accelerate the deployment, integrated terrestrial and non-terrestrial components, highly consolidated NTN architectures.
- Sustainable capacity networks: Focus on transport networks, converged packet-optical transport network, improve network capacity, increased programmability, control latency taking into consideration energy consumption.
- Towards Smart Green Systems: Develop architectures to jointly optimize the energy consumption of all elements of the future SNS systems. Improving SBA solutions, use enablers e.g., Artificial Intelligence for programmable and energy optimized cloud and edge computing solutions.
- Evolution on Cloud/Edge Computing architectures and operational support: Open, distributed, virtualized and possibly decentralised, edge computing architectures and implementations. Consideration of new IoT device management techniques will appear, expecting to operate over distributed architectures for IoT systems. A clear technological strategy for edge integration into a cloud continuum offering opportunities for European cloud/edge technology suppliers and supporting various edge/access integration scenarios, (e.g., NTN). Create a data space to help the planning for operations in distributed and decentralized environments.
- Trustworthy and Reliable End-to -End connectivity Software platforms: Projects should evolve security of 5G towards the notion of building and maintaining Trust in deployed and interconnected 5G systems and services. The outcome should build trust and reliability, significantly advanced beyond the baseline security measures of 5G.

- Real-time zero-touch service technologies: Develop a framework for an effective service deployment and management, zero-touch software strategies pursuing the ambitions of the Green Deal, including open-source technologies operating at optimal energy performance

Stream B related topics

Stream B addresses the industrial and technological long-term challenges that need to be addressed to ensure European leadership for the introduction of 6G mobile Internet systems by 2030 including:

- **Reinforced European leadership in 6G technologies:** Smart Networks and Services including connectivity extended to devices, enabling technologies, and service infrastructures, underpinning the emerging 6G vision of intelligent inter-connectivity between the physical, digital, and human worlds, supporting massive digitisation of our economies and societies.
- **Further integration with verticals** and fine-tuning of network functionalities and interfaces to support specialized services.
- **Disruptive high-value applications** support, with performance requirements beyond those of current 5G capabilities (scalability and new KPIs), especially for highly immersive and "digital twinning" applications.
- **Green transition** contribution with significantly lower energy needs for high-rate/performance connectivity and capabilities to decrease energy needs of use cases.
- **SDGs** support and in particular connectivity and service availability (coverage), affordability (cost) and accessibility for a large number of use cases of high public value (SDGs 8, 9, 11 and 13).
- **Innovative business models** based on managed end-to-end service provision over heterogenous business and technological domains.
- **Global Single standards** for 6G, enabling interoperability, economies of scale and of scope.

Stream B consequently targets revolutionary technologies of low to medium TRL technology advancement as required for future 6G systems. It takes a holistic research approach towards the needed technology, with a value chain perspective covering an integrated ecosystem with IoT, devices and software-based solutions in unified networks. From a comprehensive system perspective, the target is a globally connected continuum platform with the convergence of networks and IT systems to enable new future digital services. This continuum must provide users with improved performance, higher level of control, increased transparency in interactions with digital services, adequate support of ethical values and conformance with societal requirements and readiness (e.g., GPDR, EMF awareness, etc.) whilst contributing to key SDG's.

In that context, the following specific objectives are considered in Stream B:

- Technologies supporting the validation and feasibility of the globally accepted set of KVI's and KPI's framing ongoing 6G developments and contributing to global interoperability.
- Availability of key technologies and open architectures with high potential for 6G standardisation.

- Further evolution of the 6G architecture investigating key topics from short-range communications up to NTN, for public and private networks, focusing on native AI solutions, advanced data transport schemes, defining new northbound interfaces, for a more efficient services-to-networks interoperation, as well as interfaces for inter-operator federation, digital twining and integrated and dependable sensing and actuation networks.
- Developing leading 6G radio access network solutions capable of meeting the strictest 6G KPIs and KVIs, considering advances on cell free and extreme MIMO, joint communication and sensing, key functionalities in RAN (e.g., modulation, coding, synchronisation, multiple access etc.), machine learning physical layer evolutions, and seamless integration of multiple frequency bands.
- Network architecture concepts for optical, terrestrial and non-terrestrial networks including the integration of wireless and optical networks.
- Energy-efficient solutions from an architectural, hardware and software implementation perspective considering various aspects from optical networks to the interoperation of IoT devices with the network elements, short range networks.
- Further advances on IoT devices that will support the demanding 6G smart services.
- End-to-end Trustworthy and energy-efficient device, network, and service infrastructures, to deliver critical services in a sustainable manner. It also includes enablers and open APIs to improve the operation of verticals and significantly reduce energy/carbon footprint of use cases making use of the 6G connectivity platform (e.g., automotive, factories, healthcare, etc).
- Dynamic end-to-end distributed security for connectivity, devices and service infrastructures extending the current set of patchy technologies for service security, trust and resilience towards a comprehensive end-to-end framework across heterogeneous environments. This security "lifecycle" should be provisioned to account for distributed systems (e.g., asset orchestration and data aggregation), operational security, security quantification, and a strategy for ongoing security threat assessment.
- Fostering European capabilities in key technologies and notably AI/ML, software and security enablers, and advanced signal processing, paving the way towards advanced fully automated systems across all network layers. It includes the availability of open data sets originating from the projects.
- Stimulation of international cooperation and international consensus on critical technologies.
- Providing tangible breakthroughs on sustainability (both for Sustainable 6G and 6G for sustainability), and consolidate the work started in the SNS Phase 1 and early Phase 2 projects on sustainability.

6G R&I requires the identification of a 6G performance evaluation framework using a well-defined set of KVI's and KPI's. As 6G is still largely undefined, a starting point is the currently contemplated set of KVIs/KPIs under authoritative industrial/research environments (e.g., Networld Europe SRIA, 5G-PPP ICT-52-2020 projects, national 6G initiatives or of other regions of the world). To progress towards a European/global consensus on these KPI's, collaborative work across projects is expected towards a European vision and consolidation of the KVIs/KPIs that will frame future 6G developments in Europe. It is worth noting that the SNS R&I WP has placed specific focus on mainstreaming environmental values within most Streams and Strands.

Stream B technological topics are grouped in four strands as shown in Figure 8. Notice that Strands 1 to 4 are present in all versions of the SNS Work Programmes whereas Strand 5 (International Collaboration) is present since the SNS Work Programme 2023 onwards[61] targeting tighter international collaboration with other regions that can bring extra added value to European research activities. Strand 6 (Microelectronics for 6G networks) was included in the WP 2023 to strengthen the link with the KDT JU. Moreover, the flagship Holistic System project is scheduled for the first phase of the SNS, whereas other lighthouse projects (e.g., sustainability lighthouse) or cross-Stream B topics (e.g., AI/ML for 6G networks) are scheduled based on the evolution of the technology and results of the previous SNS phases. The topics for Strand 1 to 4 are updated and selected according to the phase of the SNS JU focusing from initial concepts to PoCs that can have significant impact in standardization activities. All topics mentioned below are fully analysed in the corresponding SNS Work Programmes.[62]

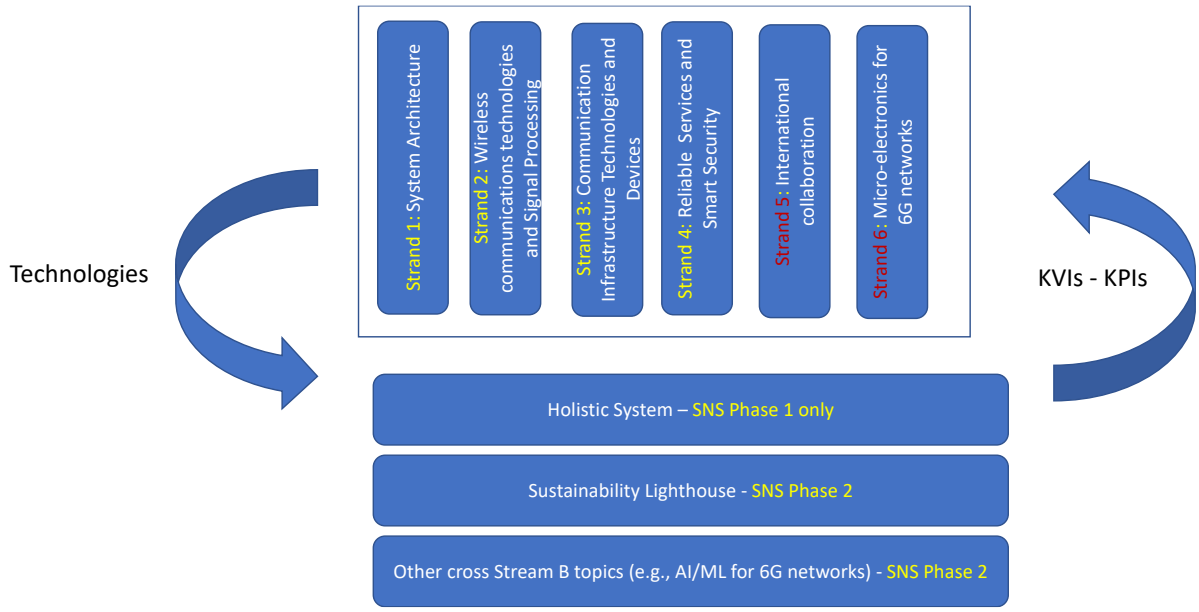

Figure 8: Stream B - organization of technological areas

More specifically, in Strand 1 (System Architecture) the following topics are included:

- Technologies for scaling Inter-computing systems
- Control and controllability separation
- Frictionless inter-domain resource management
- Native and trustworthy integration of AI for telecommunications
- AI powered edge cloud continuum
- Technologies for efficient Network and Service Resource Management in dynamic multi-tenant environments
- New Data Transfer Paradigms with deep Edge integration
- Improve data plane performance
- Deterministic Networking

[61] So far international collaboration with USA, Republic of Korea and Japan have been scheduled.
[62] https://smart-networks.europa.eu/reference-documents/ and https://smart-networks.europa.eu/previous-calls-for-proposals/

- Energy efficiency enablers
- Pervasive Resilient Autonomic Resource Control in Virtualised Systems
- Integrated and dependable sensing & actuation networks
- Digital network twinning applied in 6G
- New Communication Paradigms with enhanced intelligence
- Network exposure to vertical application developers
- New design approaches for 6G system architecture systems

In Strand 2 (Wireless Communication Technology and Signal Processing) the following topics are to be investigated:

- Terahertz Communications and Ultra-Massive MIMO
- Joint communications and sensing
- New Waveforms, Random and Multiple Access
- Enhanced Modulation and Coding
- Wireless Edge Caching
- Human-friendly Radio systems
- Spectrum Re-farming and Reutilisation
- New physical layer technologies
- Extreme exploitation of MIMO technologies up to millimeter wave range
- Human-friendly Radio systems
- Machine learning empowered physical layer evolutions
- Seamless integration of multiple frequency bands
- Optimal usage of wireless edge caching
- Cell-free and extreme exploitation of MIMO technologies potentially including reconfigurable surfaces
- Key functionalities and technologies for 6G RAN system design

In Strand 3 (Communication Infrastructure Technologies and Devices) the following topics are investigated:

- Flexible Capacity Scaling
- Ultra-high Energy Efficiency
- Integration of Optical and Wireless Technologies
- Packet optical technologies for 6G radio networks
- Ultra-high energy efficiency especially in optical networks
- 3D networking for 6G networks
- Development of low-energy communication solutions
- NTN Infrastructures
- Integrated NTN service provision
- New IoT components and devices
- Troposphere Networking
- New Physical Layers
- Nano-things networking

Finally, in Strand 4 (Secure Service Development and Smart Security) the following topics are to be investigated:

- Human-centric security and privacy technologies
- Holistic smart service development frameworks

- Secure lifecycle service management and smart operation
- Enhanced service features for fostering security
- Efficient security enablers for dynamic heterogeneous untrusted environments
- Service deployment for complex services
- Cooperative holistic end-to-end security for 6G architectures
- Zero-touch integrated security deployment
- Exploitation of (distributed) AI/ML for 6G Infrastructures
- Developments on service technologies for secure time-sensitive and computation intensive applications
- Physical layer security
- Human Centric methods
- Cooperative holistic end-to-end security and privacy solutions for 6G architectures
- Smart and trustworthy service frameworks
- Efficient security and privacy enablers
- Quantum key distribution and post-quantum cryptography support for secured 6G communications
- Timing sensitive, and time responsive software technologies for distributed, multi-stakeholder service provision
- Service frameworks

Stream C related topics

The outcome of the SNS JU should also include working platforms and experimental infrastructures so as to enable the ICT community in Europe to develop innovative and competitive solutions. The main objective of Stream C R& I activities is as follows:

- Validate and reduce the introduction risk of candidate 6G technologies, components and architectures at system or sub-system level paving the way towards their adoption at standardisation and at market level.
- Show the applicability of such technologies to efficiently support advanced application and use cases not supported by current 5G and 5G Advanced systems.
- Integrate advanced European microelectronics components into an end-to-end 6G system.
- Validate the performance and benefits of the aforementioned components in realistic usage scenarios.

Related objectives include:

- Reusability and evolvability of the experimental platforms over the lifetime of the SNS programme: The target is to follow a spiral development where platforms or specific components can be further extended to ensure a continuous integration of the most promising 6G technologies using agile methodologies. The developed platforms should be available for use from future large-scale trials.
- Accessibility and openness: Use of the platform in further phases of the SNS programme by any consortium, requires using modular implementation methodology, potentially open-source solutions with well-defined technological and business interfaces clearly documented.
- Directionality and optimisation of previous and related investments in Europe: Early 6G PoCs may be supported by existing facilities, e.g., evolved 5G Infrastructure Platforms integrating new components or facilities developed in software

engineering/cloud projects or IoT Large-Scale Pilots or other technology-oriented projects that allow the investigation of open ecosystems (e.g., Open RAN). Leveraging 6G investments by Member States is also relevant in this context.

- Disruption friendly: Experimental facilities, even if originating from earlier experimental initiatives, should be capable of hosting possible upcoming 6G disruption and hence guarantee their future-proofness.
- End-to-end: The target experimental facility should be capable of demonstrating end-to-end service capabilities and include a full value chain including IoT devices, connectivity, and service provision.

A well-designed integration of existing components (i.e., PoCs) to create an experimental platform will allow a constant improvement on services and technologies to be tested in the SNS JU. This integration will allow the test of complete systems that will become the basis of 6G networks and thus, create new knowledge and ideas.

Stream D related topics

The challenge is to prepare very early in the SNS programme future adoption and market take-up of European SNS technologies and systems. The 5G experience has shown that it takes several years to prepare the adoption of 5G systems by key vertical players. The challenge is thus to validate beyond 5G and 6G technologies in a user context to maximise downstream take up. Beyond the technological validations of Stream C, this Stream targets:

- The validation of SNS KVIs and KPIs in the context of very advanced digital use cases implemented through Large-Scale Trials and Pilots (LST&P).
- The identification of use case specific KVIs and KPIs and how they may be matched by SNS platform KVIs and KPIs.
- A structured feedback loop from vertical users towards SNS stakeholders, in view of ensuring the best match between 5G Advanced / 6G systems capabilities and users.
- An integrated validation approach, from 6G platform to use cases, leveraging existing (open) platforms (e.g., developed under Stream C).
- The evaluation, measurement and testing of ICT technologies enablement effect and impact in different ecosystems.
- Accessibility and openness: The required targeted adaptations of the Stream C infrastructures/platforms as required to support specific Stream D use cases should be available in further phases of the SNS by any consortium, which requires using modular implementation methodology, potentially open-source solutions with well-defined and clearly documented technological and business interfaces.

One of the most important factors for the success of 6G networks is the creation of ecosystems with verticals identifying real business pain points and how these can be addressed by advanced technological solutions. As this is a lengthy and difficult multidisciplinary process, Stream D started its activities from the beginning of the SNS Programme.

3.6 Deliverables and milestones

As shown inFigure 6, the SNS Programme is organized in 3 distinct phases. Every two years the SNS SRIA is expected to be updated following the process described in Section 6.

Moreover, as discussed in the previous sections, societal and environmental sustainability challenges and the high-level demands and requirements will be addressed through continuous research and development efforts. The variety of research and development topics that have been identified will be covered by the initial and future SRIAs. The abovementioned SNS roadmap takes these points into consideration. At the same time, it addresses how smart networks and services technology research and development must be performed in a sustainable economic and industrial context. The research, trials, deployment, adaptation, and uptake of the solutions will require deep knowledge into a) vertical industries and sectors, b) socio-technical and innovation system mechanisms and processes, including standardization, as well as c) innovations in business models and ecosystem platform development and evolution.

To ensure and facilitate for these anticipated effects, the JU will strengthen these areas into specific activities and to establish “Impact Assessment and Facilitation Actions” (IAFA) that are research-based activities and that ensure relevance and impact as well as effective processes and activities to achieve these goals. These activities will then bring in competence from industry analysis, ecosystems and innovation (e.g., platform ecosystems) and business models, regulatory and institution research and impact assessment competencies. To complement these factors and topics, research-based activities are also foreseen to address human factors, user behaviour and technology uptake and domestication. While typically, the CSAs focus on Programme internal coordination support, the IAFA activities will focus on interaction with adjacent Partnerships, initiatives and relevant Associations to ensure relevance and synergies in both directions. This includes the Partnership workshop approach described above. IAFAs will take place at a biennial basis.

Moreover, the SNS JU has defined a clear set of KPIs in terms of resources, processes and activities, Outcomes and Impacts as shown in Table 1.

Table 1: SNS JU KPIs

KPI Name	Unit of measurement	Baseline	Current status End of 2022	Target 2023	Target 2025	Target 2027	Ambition >2027	Risk and action plan (if relevant)	Comments
Resources (input), processes and activities									
SME innovation & participation	**% of SMEs participation**	**N/A**	**~18%**	**20%**	**20%**	**20%**	**20%**	For the SNS R&I WP 2023-2024 a similar approach has been followed as in 2022. Although the SNS R&I WP provides explicit hints for the participation of SMEs in various Streams, dedicated webinars for SMEs (e.g., through NetworldEurope's SME WG, or open Information days) will be used to mobilize European SMEs.	Current analysis from the first call indicates that SMEs from selected projects will receive 18% of the funding budget without taking into consideration that 7 projects will operate cascade funding (FSTP). In terms of actual participation, Phase 1 projects include 84 SMEs which means 33% out of all stakeholders (considering 253 stakeholders where affiliated entities are not counted). In case of counting affiliated entities then the number of participants in 288 which means that 29% are SMEs. This does not consider

									ongoing open calls and Financing to Third Parties (FSTP) which will increase SMEs and start-ups participation.
Rapid diffusion	**#of end-user workshops & webinars [cumulative]**	**0**	**0**	**25**	**60**	**90**	**125**		The first set of projects started in 2023. These values will be updated by the end of 2023.
High-risk research funding	**% of total funding**	**0**	**~68%**	**50%**	**50%**	**30%**	**N/A**	The risk for not meeting this objective in 2023 is minimum as low TRL activities are planned for B projects in the call of 2023 that constitute ~70% of the overall funding.	
Standardization contributions	**# of Standards Development Organizations [cumulative]**	**0**	**0**	**50**	**350**	**750**	**1000**		The first set of projects started in 2023. These values will be updated by the end of 2023.
Share on family patents	**% of patent families**	**0**	**0**	**15%**	**15%**	**15%**	**15%**		The first set of projects started in 2023. These values will be updated by the end of 2023.
	Patent grant rate	**0**	**0**	**60%**	**60%**	**60%**	**60%**		
Scientific excellence	**# of publications [cumulative]**	**0**	**0**	**100**	**400**	**700**	**1000**		The first set of projects started in 2023. These values will be updated by the end of 2023.
Collaboration and synergies with other Partnerships	**# collaborations [cumulative]**	**0**	**2**	**2**	**5**	**6**	**6**	6G-IA has proactively engaged in discussions with SNS related topics. This	In 2022 a strong collaboration with KDT and Photonics 21 has been

								activity will be further strengthened via the SNS office and 6G-IA and through the SNS CSA projects.	established. These ties will be further strengthened during the following years. Also, during 2022 links to national initiatives like Germany and Finland have been established.
Outcomes (SO)									
Development of energy efficient networks	**White papers [cumulative]**	**GeSI report on Energy consumption by 2030**	**GeSI report on Energy consumption by 2030**	**1**	**2**	**3**	**>3**		The first set of projects started in 2023. These values will be updated by the end of 2023. The SNS WGs will be operational after September 2023.
Technological solutions consensus building	**White papers [cumulative]**	**0**	**0**	**1**	**2**	**3**	**N/A**	Working towards this direction, activities are planned for an updated version of the 6G-IA Vision White paper.	The first set of projects started in 2023. These values will be updated by the end of 2023. The SNS WGs will be operational after September 2023.
Advanced 6G solutions for verticals	**# of different vertical types engaged [cumulative]**	**0**	**10**	**3**	**6**	**10**	**10**	In the second phase of the Partnership the key engagement of verticals will be again in Stream Stream D where it is expected that 4 large-scale trials will be implemented. Even if the same vertical	The gap analysis of Phase selected projects has identified around 10 verticals areas will be addressed by the flagship project, Stream C projects and Stream D projects. Of course, not all verticals will

								sectors are selected in Stream D, vertical industries are expected to be engaged in other SNS R&I WP Stream projects that will demonstrate the results of B5G and 6G solutions.	be covered at the same level, but the first step to create related ecosystems will be initiated. Note that for 2023 and 2024 special attention is being given to core areas that are covered but at smaller extent in 2022 selected projects (e.g., automotive and transportation, e-health, etc.)
Impacts (GO)									
A competitive data economy	**% Market share for the communication network**	**40%**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**		The first set of projects started in 2023. These values will be updated by the end of 2023.
Programme level consensus on 6G KPIs	**white papers [cumulative]**	**NetworldEurope SRIA**	**0**	**1**	**2**	**3**	**N/A**	Working towards this direction, activities are planned for 2022 and 2023 to compile results from 5G-PPP projects as well as supporting organizations (e.g., NetworldEurope) and 6G-IA WGs.	A first set of KPIs has been made public in the context of 6Gstart.

Uptake of digital solutions within verticals	**# of large-scale trials [cumulative]**	**0**	**0**	**3**	**6**	**10**	**>10**		The first set of projects started in 2023. These values will be updated by the end of 2023
Energy efficiency of telecommunication networks	**% increase**	**Legacy cellular systems (4G)**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**		The first set of projects started in 2023. These values will be updated by the end of 2023. The SNS WGs will be operational after September 2023.

4. Monitoring Framework

Table 2:SNS JU Monitoring Framework

European Partnership Smart Networks and Services		**Monitoring and evaluation framework**			
Overall vision: The goal is to ensure technological sovereignty as regards smart networks and services value chains. In this context, the aim is to enable European players to develop the R&I capacities for 6G technologies as a basis for future digital services in the period to 2030. The initiative also aims to foster the development of lead markets for 5G infrastructure and services in Europe. Both set of activities (for 5G infrastructure deployment and 6G R&I) will foster the alignment of future smart networks and services with EU policy and societal needs, including energy efficiency, privacy, ethics and cybersecurity.					
Objectives		**What is a measure of success?** Please use quantitative (Key Performance) and qualitative indicators, and link them to a point in time	**Which is the data source and methodology used** [project data, study, ….]	**Who is responsible for monitoring and providing the data / information** **When will it be collected?**	**Baseline and target**
General objectives (linked to impact indicators)	**GO1** Contribute to European technological sovereignty across the future smart networks and services value chain, including IoT, edge clouds and microelectronics components.	40% of market share of networks vendors in 2028.	Market studies (e.g., GSA, Dell' Oro).	EC, SNS JU and Association in the JU for reviewing data.	Baseline 40%, target 40% for the communication network Relevant target values for market share in sectors such as • Cloud and • IoT will be delivered by end of 2023.
	GO2 Advancing European technological and scientific excellence	- Industry and R&I actors shared European visions on 6G,	Industrial actors engaged in 6G.	JU, WGs, updated every 2 years.	Baseline, no global 6G vision.

	to support European leadership to shape and master 6G systems by 2030.	- Support to a global standards ecosystem to avoid regional standards.	Cooperation with ongoing activities, which may be on global level. In this context the following background information should be considered: • ITU-R tentative date for vision delivery is Q3 2023. • ITU-T has a similar activity. • Other stakeholder groups such as NGMN are engaged now, GSMA may start later. • Activities in the Networld2020 European Technology Platform will contribute (e.g. Vertical Working Group) and the SRIA development and work program contributions that will pursue some of these objectives. It is essential to maintain a global standards ecosystem and to avoid regional standards.		• Create a European vision in SNS working groups based on current global activities and contribute to such groups /e.g. ITU-R, ITU-T, industry associations). • First EU basis with targeted 5G-IA 6G Vision Paper in June 2021 and further updated versions. The following contributions are expected: • > 1000 contributions to SDOs • more than 1000 publications in international journals and conferences organization of more than 25 workshops and more than 100 webinars.

	GO3 Contribute to the uptake of digital solutions in the European markets and of digitisation of key vertical industrial sectors	5G coverage and use in industry and new services.	CEF2 projects, studies JU projects and support action surveys EU 5G Observatory monitoring provides information on the 5G EU development and deployment.	EC, JU only for the development of the Strategic Deployment Agenda JU, every 2 years	- 5G Deployment: 6 cross-border corridor projects in 2020. - Objective: Adoption and implementation of a Strategic Deployment Agenda for CEF2 aiming at 6000 km covered by 2027. - Verticals in 6G: 176 5G trials under the umbrella of 5G-PPP (until 15.10.21)➔ 20 6G Proof of concepts in 2024➔ 50 6G trials/pilots in 2027 with active vertical participation • NB: Trials and pilots outside the SNS JU are regarded as additional activities. Around 10 vertical sectors should be considered.
	GO4 Contribute to the development of digital innovations responding to a 6G EU shared vision, answering European needs and ensuring EU industry competitiveness across the value chain	Technology performances from EU actors in R&I for 6G: latency, massive connectivity, throughput, energy efficiency KPIs. • Baseline are internationally agreed KPIs.	R&I projects, JU Working Groups encharged of collecting " Key Achievements" data	JU, through SNS WGs and projects and JU support action • Establishment of one or more WGs in the SNS JU on Performance KPIs. Cooperation with other JUs. The increased cross-	5G KPI's addressed through standardised solutions➔ Solutions for 6G KPI's at standardisation level in 2027. • References are globally discussed and finally agreed

		With respect to the ongoing global discussion the JU should be prepared for new KPIs to appear in the next years.		functional work between different horizontal and vertical sectors requires this cooperation on KPIs.	KPIs in international bodies where SNS will contribute.
	GO5 Ensure the alignment of future smart networks and services with EU policy and societal needs, contribute to societal objectives and SDG's	Reduction of networks GHG emission by about: • Mobile network operators: 45 % • Fixed network operators: 62 % • Data centre operators: 53 % Reduction of GHG emission in key vertical sectors by about 20%; however, this depends on the adoption of proposed SNS technologies by respective vertical sectors, outside of SNS perimeter. Availability of technologies limiting exposure to EMF; solutions for end-to-end security. by considering trade-offs between radiation limits of EIRP and associated range, receiver performance and other transmission technologies with higher radiation limits (e.g. visible light) or more	Studies, projects, industry and user working groups	EC, JU, SNS WGs. Every 2 years • Necessary regulations for the adoption of SNS technologies for GHG reductions in vertical sectors may be considered at EC level on the basis of feasibility analysis by sector actors • Establishment of an SNS WG on Energy Efficiency / Energy Consumption issues. EMF should also be addressed in one of the SNS WGs.	Baseline: energy consumption of networks available across 2, 3, 4, 5G frequency bands ➔ reduction including the consideration of new 6G spectrum; GhG emission by vertical sectors as per GeSI report 2015 • GHG reductions targets are for the 2, 3, 4 and 5G frequency bands with respect to provided percentage values. • GHG reductions for new 6G frequency bands in the sub-Terahertz and Tera-Hertz domain. Tech solutions to keep GHG relative emissions of vertical sector at GeSI 2015 level

		dense deployment concept and associated network architectures would be needed.			
Specific objectives* (linked to outcome/result indicators)	**SO1** Facilitate a European approach towards the development of technologies able to meet advanced communication requirements and the identification of their deployment conditions.	Production and maintenance of Europe wide SRIA and SDA.	Industry and R&I/stakeholders regular consultations.	JU, ETP's, every 2 years, in view of a new Work Programme.	Networld2020 SRIA and 5G-PPP SDA existing➔ new version every 2 years for Networld Europe and SDA.
	SO2 Promote EU wide approaches to accelerate the development of energy-efficient network technologies.	Development of widely agreed industrial roadmaps for energy reduction for technology domains in the scope of the SNS JU. Estimate the saving potential in vertical sectors. However, the commercial adoption of SNS solutions in such sectors is beyond the SNS JU perimeter of activities.	Industry and research centre stakeholders, production of White Papers.	JU working groups, support action, every 2 years.	Baseline, GeSI paper on energy reduction potential by 2030. White papers to be developed • Energy efficiency targets in SNS technology domains (GO5). Energy-efficiency improvements and GHG reductions in vertical sectors by means of SNS technologies are only monitored by SNS.
	SO3 Accelerate the development and widespread deployment of 5G and later 6G infrastructure in Europe.	- Deployment of 5G solutions across pan-European Corridors, as follow up to the 5G-PPP /H2020 pilots. - Mobilisation of vertical industry stakeholders towards deployment of 6G.	Implementation of JU projects and relevant collective gap analysis. DESI (The Digital Economy and Society Index) reports or similar reports could be the basis.	Projects, support action. Proof of concept, from 2024 onwards; Pilots, from 2026 onwards. EC for launching respective CEF2 projects	Baseline: no 6G solution. Target, at least 20 PoC's and then 20 Pilots proof of concepts (including 10 for verticals, Operational Objective 3) and then 6 pilots across multiple Member States

				based on the SNS SDA managed by a different budget and Agency. Direct involvement of vertical sectors for PoCs and pilots.	• The progress of deployment across pan-European corridors is analysed by the SNS JU. However, this deployment is organised by CEF2 projects. The different TRL-levels for pilots and trials are considered, where more trials than pilots are expected.
	SO4 Support the transformation of the European value chains.	Emergence of European actors in a diversified supply chain of an open ecosystem towards 6G.	Europe wide projects study including analysis of JU projects and maturity level towards the objective.	Market research companies, JU for monitoring. Investors community: 2025 for 5G evolution and beyond 2027 for the 6G open ecosystem (date envisaged for the emergence of actors in this field).	No high maturity in Europe in the field of an open ecosystem and a few partial European players. ➔ Availability of open ecosystem solution for 5G evolution and investigation for appropriate 6G open ecosystem, demonstrated by projects PoCs and Trials.
	SO5 Strengthen the positioning of EU industry in the global digital value chain.	Active presence of IoT and edge cloud actors in SNS end-to-end R&I actions, including microelectronics actors. Number of Stakeholders in the SNS JU (Beneficiaries in projects	JU calls and cooperation with other JU's, e.g. KDT (Key Digital Technologies JU). Cross domain cooperation roadmaps.	JU support actions, Working Groups, every 2 years.	5G-PPP presence of IoT and clouds through pilots, only for 5G. ➔ End-to-end pilots (at least 20) with end-to-end value chain.

		and Association Members) by keeping a clear focus on SNS objectives.			
	SO6 Ensure alignment with ethical and security requirements.	Number of scientific publications, white papers and standard contributions achieved by the partnership on Cybersecurity and privacy in smart networks and services.	JU projects.	JU support actions, Working Groups, every 2 years.	More than 50 publications in international journals and conferences. More than 7 white papers that will cover key SNS project contributions in these areas. More than 50 contributions to SDOs.
Operational objectives* (linked to output indicators)	**OO1** Support high risk research framework in smart networks and services towards 6G.	Percentage of implemented research activities in the JU on high-risk topics and projects related to Stream B of the WP (50% of budget). Implementation of Additional activities of research activities outside the JU.	JU and SNS projects. Studies. Companies, data on additional activities.	JU support actions, every 2 years.	About 50 % of JU funding budget for high-risk research. Baseline: Leverage factor of 7 for additional activities beyond the financial and/or in-kind contributions. Target: Additional in-kind activities at least equal to the EC funding.
	OO2 A strong presence of European actors in 6G related standardization.	Contribution to standardisation and essential patent ownership.	JU projects, pre standardisation Working Group, studies.	JU support actions and a dedicated standardization working group for collecting information from JU projects and monitoring, from 2025 onwards (6G standardisation not expected to start before).	- Reach more than 15 % in declared 5G and B5G patent families (granted and non-granted) by European based HQ companies. - Reach a patent grant rate of more than 60 % for European based HQ companies.

					- Provide contributions to more than 1000 contributions in SDOs.
	OO3: promote SME involvement in 6G.	Participation of SME's.	JU Office and SNS projects. Studies. Support by Networld2020 SME Working Group.	JU.	20% baseline, target 20% funding to SMEs.
	OO4 Implement trials/pilots across the value chain with innovation across device, connectivity, and service levels in core vertical domains.	Implementation of pilots across at least 10 vertical use cases.	SNS JU projects, Studies.	JU support actions, every 2 years. Dedicated SNS working group.	Baseline; connectivity as EU stronghold and 176 EU vertical 5G trials under the umbrella of 5G-PPP (until 15.02.21). Target: 6G Pilots implemented for at least 10 verticals. • Trials and pilots outside the SNS JU are regarded as additional activities and counted as financial and/or in-kind contributions. The 5G Observatory and later on 6G Observatory (EC studies) shall be used for the referencing / quantification of such trials and pilots.
	OO5 Large-scale deployment pilots.	Number of relevant large-scale pilot for an EU cross-border corridors	JU projects steered CEF projects.	EC for implementation (CEF 2 budget).	Target: Adoption of the Strategic Deployment Agenda aiming at 6000

		based on the SNS JU SDA.		JU for monitoring.	km of cross border corridors covered by 5G CEF 2 projects.
	OO6 Implementation of long-term research activities relevant to 6G European know how.	Coverage of key 6G characteristic as identified by the SRIA.	JU projects based on independently selected proposals.	JU JU Governing Board to define means to ensure a good coverage of the call and SRIA objectives such as the pre-structuring model as input for the independent evaluation process for an efficient implementation of the research roadmap.	Tentative targets beyond todays 5G baseline (status 2021) include data rates beyond 100 Gb/s, ultra-low sub millisecond latency, sub centimetre positioning accuracy, ultra-high reliability beyond 99,999%, wide area coverage, support of more than 10 million devices per km² for smart city scenario, integrated device to service security, zero touch AI based control.
	OO7 Support research on energy efficiency in smart networks and services	Energy reduction factor Reduction of GHG emissions.	Studies.	JU support actions, every 3 years.	Energy reduction factor for SNS platforms is following the reduction of GHG emissions, compared to 1990 levels[63], from an overall level of 20 % in 2020 to a level equal or higher than in 2030: • mobile network operators 45 % • fixed network operators 62 %

[63] 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

					• data centre operators 53 % based on the different saving potential in different sectors. Energy reduction of at least 30% in key use cases like factories, automotive, Energy efficiency is a target for the SNS JU but these savings depend on the adoption of SNS solutions by the vertical industries.
	OO8 Support research on ethical and secure future digital services.	Number of publications, white papers and standard contributions achieved by the partnership on Cybersecurity and privacy in smart networks and services. All research activities follow ethics and legal requirements with respect to privacy, data processing and experiments as a general pre-condition.	JU projects.	JU support actions, every 2 years.	Framework building trust in ICT infrastructure through systematic exposure of cybersecurity levels Improve attack detection and response mean time. Provide solutions for disaster relief. Create applications and services promoting social inclusiveness. More than 50 publications in international journals and conferences More than 7 white papers that will cover key SNS project contributions in these areas More than 50 contributions to SDOs

	OO9 Foster emergence of new actors in the supply chain in line with the cybersecurity Communication.	Demonstrated disaggregated solutions (open ecosystem) by European actors • Further disaggregation of RAN/Core in evolved 5G networks Investigation and potential adoption of open ecosystem principles in 6G networks.	Studies, projects.	JU support actions, every 3 years.	Baseline: partial EU non mature solutions for an open ecosystem. Targets: Projects demonstrating solutions for scalable implementation of open solutions for 5G evolution and for the 6G open ecosystem on par with international competitors and addressing current limitations of open systems, in particular security energy efficiency, interoperability.
	OO10 Promote efforts toward harmonization of regulations and processes around spectrum usage.	Technical contributions in relations to new bands, contribution to ITU by technical contribution to WRC preparatory process e.g., in ECC PT1 and ITU-R WP5D.	JU projects	JU support actions, every 3 two years for monitoring of contributions. SNS JU projects for technical contributions. Forthcoming SNS Spectrum WG under the umbrella of respective JU projects for the coordination of technical contributions.	Target: input to technical contributions by ECC PT1, EU RSPG, national administrations and ITU-R WP5D preparatory process for forthcoming WRCs towards the identification of 6G spectrum above 90 GHz.
	OO11 Support the identification of regulations on energy efficiency.	Contributions by SNS projects and the JU of technical information, public consultations and	EC, JU as technical contributor.	Depending on type of Regulation responsible. for the development and adoption	Target: complement R&I on energy efficiency with specification of an SNS label of energy efficiency

		position papers to support the preparation and adoption of regulation.		• EC and Member States • EC, EU Parliament and Member States Mid-term review, final review.	and corresponding contributions to standards to be used if accepted for the development of respective regulations.
	OO12 Support possible future regulations on cybersecurity and ethical ICT.	Contribution by SNS projects and the JU of technical information, public consultations and position papers to support the preparation and adoption of regulation as appropriate.	EC, JU as technical contributor, e.g. to ECC, NCC, ENISA….	Depending on type of Regulation responsible for the development and adoption • EC and Member States • EC, EU Parliament and Member States Mid-term review, final review.	Target: label and contributions to standards related to ethics and privacy. compliance with the certification tool put in place in the context of the cybersecurity toolbox as technical contribution for the development of respective regulations.

5. Links to other related European Partnerships

This section details the key targeted interactions and related mechanisms, between the SNS JU and the other relevant initiatives of Horizon Europe, including other relevant European Partnerships and EU actions / initiatives beyond Horizon Europe.

The SNS JU targets strong synergies with other EU Partnerships to be implemented in Horizon Europe and with the specific actions to be implemented in the Digital Europe Programme as detailed below.

Smart Networks and Services are core enablers for a variety of forward-looking scenarios and applications in need of agile, robust and ubiquitous connectivity, upon which the development of our society relies. The Horizon Europe vision is indeed centred around the capability to strengthen science and technology, so as to foster industrial competitiveness, and implement the UN SDGs. The current draft list of EC Horizon Europe targeted Partnerships is captured in Figure 9. The SNS JU included in the Digital, Industry and Space Cluster is targeting specific interactions with several other EU Partnerships.

The SNS JU targets very tight interactions within the Digital, Industry and Space Cluster with the High-Performance Computing (HPC), Key Digital Technologies (KDT), AI, Data and Robotics and Photonics Europe Partnerships. In addition, the SNS JU will also target specific information sharing and potential specific dedicated actions with some of the Partnerships with Verticals ecosystem focus (e.g., Towards zero-emission road transport, CCAM, Integrated Air Traffic Management, Accelerating Farming System Transition, etc.). Specific Memoranda of Understanding (MoUs) will be developed with different Partnerships and include (among others) the organization of joint activities (e.g., joint workshops).

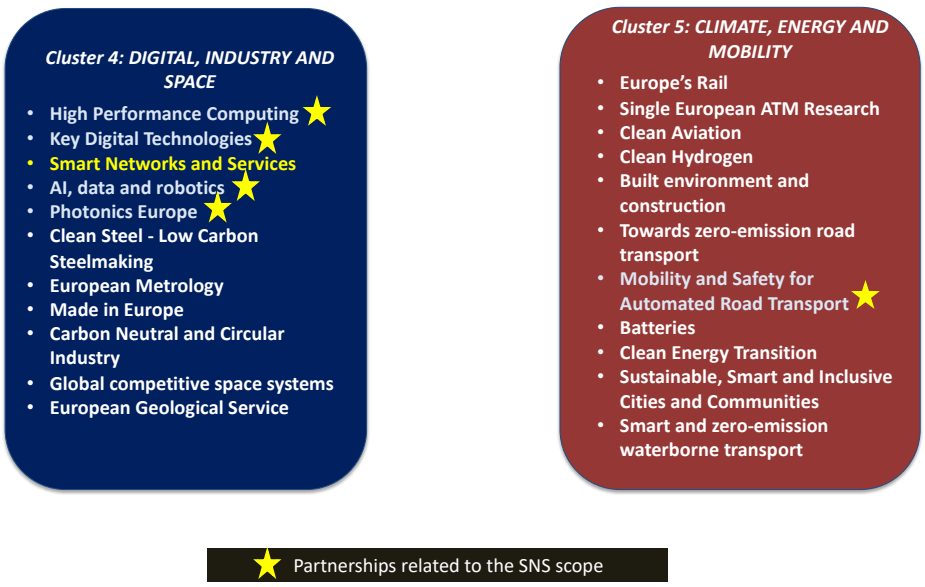

Figure 9: Partnerships related to the SNS scope.

Note that in 2022 the 6G-IA established an MoU with AENEAS, one of the three industry associations of the KDT JU. The target was to identify potential opportunities in the SNS WP orientations for the microelectronics community in view of maximising the opportunities for the European microelectronic industry to successfully contribute to the mid-term 6G standardisation discussion. The SNS community has contributed with input in the ECS SRIA in two editions and presented potential topics in the Visions of ECS beyond 2023 workshop. More importantly, DG-CNECT together with 6G-IA and in collaboration with SNS JU Office and KDT Office have identified topics of joint interest that have been included in the Work Programmes of SNS JU and KDT/Chips JU.

The European Chips Act, adopted by the Commission early 2022 aims to enhance Europe's competitiveness and resilience in microelectronics technologies and applications, and help achieve

both the digital and green transition. One of its objectives is to help Europe reach leadership in chips for digital connectivity infrastructures. Europe has a leading position in the global connectivity infrastructure market, while at the same time has strong dependencies on chipset vendors from outside the European Union.
In the above context and with the aim of reinforcing European strengths in microelectronics and connectivity, the KDT and SNS JUs have both launched focus topics as joint and complementary activities in their respective Work Programmes with both constituencies encouraged to participate in the relevant projects funded.
In WP2024, in particular the SNS strand "SNS-2024-STREAM-C-01-01: SNS Microelectronics Lighthouse" aims to develop an experimental platform where solutions from the microelectronics domain developed either in the context of Phase 1 SNS WP, or Horizon Europe Cluster 4, and solutions developed under the KDT JU will be validated in terms of performance and applicability for 6G networks. Potentially, this will also be extended to photonics components and systems. Therefore, solutions developed in projects funded under the KDT JU and the European Partnership for Photonics64 projects could find their way into the afore-mentioned SNS topic.
In 2020 6G-IA and the CCAM partnership collaborated to clarify the respective activities and their scope of interaction. In 2021 the communication link between the two partnerships has been re-established to coordinate on activities of common interest (e.g., SDA for CEF2). SNS is additionally exploring future synergies with: Photonics21, HPC and Data and AI, Data and Robotics. The SNS proposal indicated that biennial workshops will be organized with the related partnerships to exchange information about key findings, opportunities, etc. Moreover, collaboration with these Partnerships is expected to take place for the preparation of future SRIAs and WPs.
SNS plans to explore future synergies with key vertical sectors leveraging existing partnership agreements with industry fora in domains such as Automotive, Transportation, Media, Manufacturing, Public Safety, Cybersecurity and Satellites. Partnership agreements are intended to be extended to further sectors such as Health and Utilities. Partnership agreements allow to reach economies of scale for functional requirements and technology validation for beyond 5G.

6. EU and International cooperation

The SNS JU targets for collaboration with the EU national initiatives on 6G networks. In the context of its governance, the SNS JU is discussing synergies opportunities with national initiatives through its State Representative Group (SRG). Also, the SNS ICE CSA project is working together with the Member States to establish bi-directional communication links so that all European activities are fully transparent to European Stakeholders. Moreover, the SNS is constantly supporting the inclusion of results/platforms/solutions developed in the context of national initiatives to be re-used and further extended, if possible, in the context of the SNS WPs. On top of this, note that 6G-IA has already signed a MoU with the 6G Platform in Germany, has organized dissemination events at EuCNC and will further strengthen its efforts for closer collaboration between the SNS JU and the national initiatives.
In relation to the international collaboration, the SNS has planned, after consultation, to allocate some resources to collaborate with key regions (i.e., US, Japan, Korea) in order to achieve a better understanding between regions, work for pre-standardization consensus, and investigate areas where these regions may have a joint lead.

At the same time, it is worth noting that 6G-IA is very active in international collaboration with all global regions to facilitate discussions that will eventually lead to globally accepted standardization.

[64] Co-programmed European Partnerships for Photonics in Horizon Europe: https://www.photonics21.org/

7. Plans for updating the SRIA

In this section, the process for future updates of the SNS SRIA is described.

Future releases of the SNS SRIA will rely again on the Networld Europe SRIA. This is because the Networld Europe 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. Networld Europe is updating its SRIA every two years. The SNS JU is attentive to share as widely as possible, for consultation, its SNS SRIA, so to be able to include a variety of possible contributions across different Member States and stakeholders.

As described in the MoU between the 6G-IA and Networld Europe[65], this SRIA will be used as the basis for the SNS 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 Networld Europe SRIA to populate the SNS SRIA.
2. Formation of a group of experts from the 6G-IA, Networld Europe, 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 SRIA.
3. Dissemination of the SNS 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 SRIA based on the outcome of the stakeholder consultation.

This process for updating the SNS SRIA will take place every two years.

[65] 5G-IA & Networld Europe ETP joint press release available at: https://5g-ppp.eu/the-5g-ia-and-networldeurope-etp-sign-collaboration-agreement/