ANNEX TO DECISION No 12/2021 OF THE GOVERNING BOARD OF SMART NETWORKS AND SERVICES JOINT UNDERTAKING

Smart Networks and Services Joint Undertaking

Strategic Research and Innovation Agenda 2021 – 2027

Brussels December 2021

1. Introduction

The current document presents 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 Smart Networks and Joint undertaking is based on the Smart Networks and Services proposal [1], that was the result of joint efforts from the 6G Smart Networks and Services Industry Association (6G-IA), NetWorldEurope European Technology Platform (ETP), AIOTI, NESSI and CISPE.cloud.

The current document forms the basis for the SNS Partnership in the context of the Multiannual Financial Framework of the EU. The SNS SRIA has been developed from the collaboration of the 6G Smart Networks and Services Industry Association (6G-IA) and the NetWorldEurope 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, NetWorldEurope has formed a detailed SRIA for 2021-2027 [2]. The 6G-IA has taken the NetworldEurope's SRIA into consideration and used it as the basis for the SNS SRIA. Since 28.04.21 the two organizations have setup a collaboration framework [3] that defines exactly this process for the preparation and adoption of the SNS SRIA.

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 - [4]) 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 [5] 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 [6] to underline the importance of communication systems and networks.

Moreover, the evolving geopolitical environment has highlighted the need to develop cybersecure infrastructures and to secure European sovereignty in critical technologies and systems [7].

Consequently, the SNS Partnership has been designed to address a strong European position on critical infrastructure supply chains (e.g., connectivity, cloud, data economy components and devices).

2. Intervention Logic

The problem that the SNS Partnership is trying to address has been very clearly defined in the SNS Proposal [1] and the Impact Assessment Report [8]. The following sections present the key problems to be addressed, the SNS Partnership 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 innovation and EU deployment policies and programmes in the field of Smart Networks and Services would have a specific role to play.

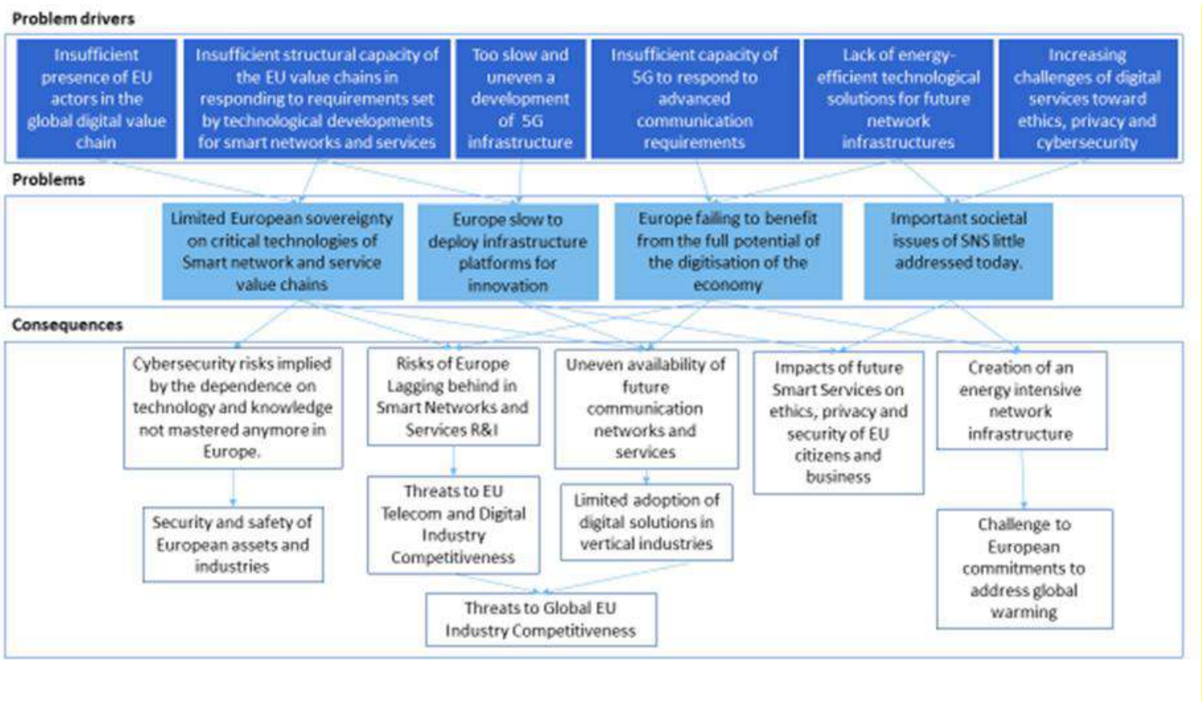

Figure 1: Problem Tree for the Smart Networks and Services Initiative, source [8]

2.1.2 Europe's lack of ability to benefit from the full potential of the digitisation 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[2]. Further estimates predict a global potential economic impact of IoT between €3.5 and €11 trillion per year by 2030 across multiple business domains[3].

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[4] 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.

The problem for Europe is hence to put in place the needed critical mass of stakeholders to support a coherent roadmap for SNS, create the needed deployment momentum, and avoid fragmentation. The Open Public Consultation confirmed that stakeholders from different technological horizons and different application and business model perspectives should be involved. It needs to go beyond the current 5G-PPP efforts in this field, as the framework policy constraints surrounding use cases in terms of security, privacy, reliability, deployment and even business models require an early involvement of public actors in the overall R&I process.

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 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[5] 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.

The problem 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-

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[2] https://cdn.ihs.com/www/pdf/IHS-Technology-5G-Economic-Impact-Study.pdf
[3] McKinsey: The Internet of Things, mapping the value beyond the hype
[4] Strengthening strategic value chains for a future ready EU industry, 6 Nov 2019.
[5] https://www.justice.gov/opa/speech/attorney-general-william-p-barr-delivers-keynote-address-department-justices-china

political approaches promoted by some of our main competitors, looking for dominance of the full SNS value chain.

2.1.4 Europe slow to deploy infrastructure platforms for innovation

In the wake of early 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 fragmented regulation, as well as uncoordinated efforts of both industrial and institutional initiatives. This problem is amplified by the limited investment capabilities of 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.

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. Energy consumption is also an area of concern, as the cloud and network energy consumption may increase by a factor of 10 by 2030, reaching unsustainable levels in the absence of significant technological and operational improvement.

2.2 What are the problem drivers?

2.2.1 Insufficient capacity of 5G to respond to advanced 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[6].
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.
- 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

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

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.

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 problem is fuelled by several factors:

- **A fragile position of European actors in the global digital ecosystem:** European leadership in 5G R&D depends on a limited number of major 5G infrastructure manufacturers (Ericsson and Nokia) 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 (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[7]. 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[8] has generated more than 60,000 industry contributions and thousands of essential patents. European vendors are at the forefront for contributions and patents[9] 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.

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 field of research beyond pure connectivity

[7] Source: Strategy& PwC, The 2018 Global Innovation 1000 study, analysis of the 1000 largest corporate R&D

[8] 3rd Generation Partnership Project, the global standard development organisation for mobile coms. ETSI is member.

[9] Estimated that out of the 4 main vendors (Nokia, Ericsson, Huawei, ZTE) EU has about 55% of the essential patents

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.

- **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 on 5G, 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 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 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 is expected to deploy hundreds of thousands of 5G base stations in the coming years. South Korea had already installed more than 90,000 5G base stations by October 2019. Ramp-up is going to be slower in Europe with only hundreds of 5G base stations installed at the same date, what may be due to limited investment capabilities of EU operators. This 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. 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.

- **A lack of coordination of regulatory approaches, in particular spectrum management:** Spectrum assignment remains a national prerogative. There is no formal coordination between EU Member States regarding spectrum assignment conditions. Early 2020, only 16% of the pioneer bands had been assigned in the EU[10]. This hinders EU wide 5G availability. A common approach to developing a single market environment for large-scale investment in particular spectrum in Europe is beyond the remits of an R&I initiative. However, early technological and business awareness at the Member States level would help to develop a European common approach to spectrum matters and limit the risk for the industry.

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

The development of digital services poses several challenges for the EU citizen 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 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, which are currently not a part of industry initiatives like the 5G-PPP.

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 problem 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 exacerbated. China, Japan, USA, Korea are all planning 6G initiatives, some (CN) with massive public budgetary support. Without a strong EU policy including R&I, European ability to compete is at risk. Market forces may not be sufficient: our main competitors are all considering SNS as a strategic industry and planning public support accordingly.

- ***Europe slow to deploy infrastructures for innovation:*** this issues 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,

[10] 5GObservatory.eu

as planned 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 telecommunication and digital 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:*** citizen concerns like security, trust, privacy, energy footprint or exposure to electromagnetic radiations will be even more exacerbated in the future. The ability to translate these essential requirements into technology will provide a clear competitive advantage to those companies and regions mastering those. Failure of 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 citizen concerns ex ante from a European perspective.

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

2.4 Smart Networks and Services Partnership Vision

5G as a network of networks is just the beginning of a new paradigm after the successful development of mobile communication systems such as GSM, UMTS, LTE and other networks in a complementary manner. Further development is absolutely crucial to address new challenges and requirements coming from many different sectors in society and industry. The smart network architecture will be software defined and provide features significantly going beyond connectivity: Multiservice and Mobile Edge Computing will allow to store and process data locally at the edges of the network to provide fast reactions and efficient use of network resources. Programmable aggregation and virtualisation functions as well as built-in security functions enabled (e.g., by the support of blockchains) will create a trusted environment for the Internet of smart things in which new applications and ideas can flourish. Future cost-effective communication systems and networks, both terrestrial and non-terrestrial, will increasingly be based on AI/ML and increased softwarisation in addition to requiring the continued development of classical communication technologies. Therefore, it is recommended to research future communication systems in close cooperation with these domains from an overall system perspective. The communication infrastructure will form the nervous system of the future Human Centric Internet and the digital transformation. It will intertwine distributed network, compute and storage resources to facilitate an agile composition of new services supporting a multitude of markets and industry sectors. From supercomputers and parallel computers to data analytics, passing through cybersecurity, the Internet of Things (IoT), cooperative robots, or autonomous vehicles, it is universally agreed that every system and application must be interconnected to its peers, as well as to other related entities and systems. The interconnection of everything will be a distinguishable flavour of a competitive advanced society. Without network innovation the digital transformation is likely to fail. Therefore, it is vital that the Smart Networks area is adequately represented in Horizon Europe.

The Smart Networks and Services concept provides the necessary infrastructure and builds on scientific advances in the areas of ICT as well as key enabling technologies to provide a coherent framework supporting the future network designs. It is a combination of Smart Connectivity, Data Analytics (AI and ML), high performance distributed computing and Cybersecurity.

The SNS Partnership SRIA is summarising the different research domains to make the overall vision of Smart Networks happen.

Currently, there is a wide acceptance that 5G networks will have a significant impact in the worldwide economic development and revolutionize all aspects of everyday life. Even though 5G networks offer undeniable improvements over legacy networks, key findings suggest that European research activities in the communication networking sector need to continue at an increased pace. For this reason, we need to address several key challenges in a structured way so as to achievement maximum positive impact, see Figure 2.

Figure 2: Challenging areas for the SNS partnership and expected impact, source: SNS partnership proposal [1]

The common vision of the SNS Partnership envisages the integration of selected elements from new technologies such as Artificial Intelligence (AI) and Data Analytics, High Performance Distributed Computing, as well as Cybersecurity and Trust.

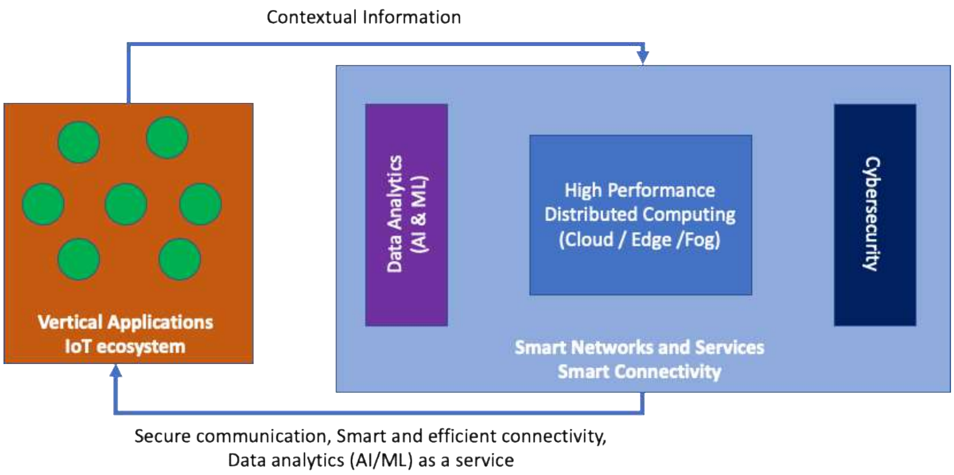

Figure 3: Integration of new technologies into the Smart Networks and Services vision [1]

Figure 3 above illustrates the interplay and integration of such new technologies whereas the rationale and main elements identified by the Partnership are described. Some of these enabling technologies are:

- **Artificial Intelligence (AI) and Data Analytics:** AI is perceived as a potential technology solution to cope with the increasing complexity of Smart Networks and Services system design and associated management, due to the extreme range of requirements for user experience, efficiency, and performance. Future **Smart Networks and Services will require robust intelligent algorithms to adapt network protocols and perform network and resource management tasks for different services in different scenarios.** For example, for network administration duties, AI will be mainly expected to make smart predictions, and to take improved decisions and actions that until now were mostly based on pre-defined rulesets obtained from experience accumulated by humans over the years. And, vice-versa, AI itself capitalises on digital technologies. For example, in their training/learning phase, AI algorithms rely on a significant amount of storage and computational resources [C1-17] so that huge amounts of training data can be fed into the algorithms. Mostly, the storage resources where data are originally residing and the computational resources where the algorithms are executed are not co-located. AI will also help telecom operators to optimise network deployment in real time according to user requirements. Accordingly, **Smart Networks and Services are needed to connect in an efficient and timely manner the data to the AI algorithms.**

- **High Performance Distributed Computing (HPC):** The computing paradigm has radically changed [C1-18]: in past decades, it was common to assemble the highest performing processors inside the same infrastructure equipment. However, the today's model is to design a data centre scale system with the entire network in mind. Thus, the trends that are most affecting High-Performance Computing (HPC) today are highly influenced by the need to have all aspects of the distributed computing infrastructure working in unison. Two of the most relevant aspects are the need for (i) a fast (and potentially massive) access to storage from anywhere in the network without disturbing the processing engines, which can only be accomplished with an intelligent network that can efficiently handle such tasks; and (ii) efficient strategies for network-wide off-loading, since nowadays CPUs are reaching their performance limits and, thus, the rest of the network must be better utilised to enable additional performance gains. Thus, current HPC architecture approaches depend heavily on offloading technologies that free the CPU from non-compute functions, and instead place those functions on the intelligent network. Thus, **Smart Networks and Services emerges as a key enabler for the transformation of the HPC domain.** Regarding the impact of HPC to Smart Networks, significant advances in components and techniques for wireless transmission are expected from continued research on quantum processing and technologies in such a way that emerging **quantum technologies are expected to provide true breakthrough advances in, e.g., computing speeds within the next decade and, by doing so, pave the way for more secure communications** through potentially unbreakable cryptography.

- Cybersecurity and Trust: Starting from the NIS directive followed by strategic positions [C1-19] GDPR or continuing efforts on the Cyber Act [C1-20] the EU has recognised the fundamental role of cybersecurity in the digital world. This leads to at least two major priorities focused on (i) the **contribution of Smart Networks and Services to secure the digital world**, which includes the provision of data and information protection (e.g., location, data on the move) in all dimensions to protect citizens, enterprises and governments against malicious or outlaw usages with diverse security levels, as well as the detection of attacks and mitigation of their risks through the various components of digital services; and (ii) **the cybersecurity threats related to the Smart Networks and Services themselves**, namely, mitigating security threats related the various sensitive (new) components coming with 5G and beyond 5G technologies (e.g., identity and access management in mobility, virtualisation, softwarisation, over-the-air updates, AI technologies, etc.) as well as the monitoring and sustaining security levels for complex Smart Networks and Services.

Currently, many governments, globally, identify that world-class communications networks are, or will become, an intrinsic component of their critical national infrastructure and essential to ensuring that citizens can take full advantage of increasingly pervasive digital services across the plethora of existing and emerging applications, use cases and verticals, see e.g., [C1-21]. In particular, this can accelerate data-driven innovation, industrial automation, AI deployment and ensuing social and economic opportunities across economies, and increasingly between economies, for example the European Union's developing Digital Single Market, or if considering how an autonomous system might operate across borders.

2.4.1 Link to Key Strategic Orientations

Smart Network and Services (SNS) Institutional partnership is part of Horizon Europe (HE) and it should support the following Key Strategic Orientations, as outlined in the 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 Institutional partnership 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.

Smart Networks and Services (SNS) Partnership 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 (SDG's while boosting the European data economy and contributing to ensure European sovereignty in this critical supply chains.

3. Key elements of the SNS SRIA

3.1 Objectives and targeted impact

The SNS partnership ambition to address the problem statements as described in the previous sections is fully aligned with key policy objectives of the strategic planning for Horizon Europe [9]. The vision is based on the socio-economic evolution of SNS platforms which are becoming critical infrastructure for the economy, on the need to retain technological leadership in Europe and on the need to address societal concerns [1]. The corresponding objectives include:

- ensuring EU competitive edge and sovereignty of the EU industry through a value chain approach covering EU technological capabilities in devices (IoT), networks and service platforms (edge computing);
- Supporting large scale digitisation of EU industry through SNS platforms covering the most demanding use cases;
- Supporting the emergence of new classes of applications, opening new economic opportunities;
- Addressing societal needs, notably as outlined in the Green Deal and SDG's;
- Supporting European access and inclusion to new high skilled jobs;
- Promoting Europe as a lead market for specific use cases (focus on automotive to leverage CEF2 activities).

General, specific and operational objectives

A key goal of the SNS Partnership 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 Partnership will also focus on the full digitization of European society including vertical industries and public administration. Thereby, the SNS Partnership targets to have a positive impact on the quality of life for European citizens and boost the European data economy.

This goal will be achieved by supporting the development and uptake of a wide range of technologies (AI, blockchain, IoT, etc.) and services (personalized access to information, services and media, everything-as-a-service, etc.) across all sectors of our society. The aim is to address important social, economic and environmental challenges with independence and technology sovereignty. Overall, the ambition is to create a more inclusive, open and participatory society centred on the citizens' needs, both as individuals and as organizations (private and public ones), minimize the digital divide and reduce inequalities.

To this purpose the SNS Partnership will:

- Create an appropriate environment for successful R&D&I activities to flourish and grow, reaching out to all key players in all Member States and Associated Countries.
- Mobilize the relevant stakeholders across the value chain.
- Stimulate operational collaborations with related initiatives.
- Define common operational roadmap across stakeholders based on SRIA cross interests, which will be available in June 2020.
- Design and verify an overall framework where novel smart network and services solutions will be combined with state-of-the-art AI mechanisms and advanced security schemes that will operate in high-performance distributed computing facilities, including tighter integration and operation of IoT devices and services.
- Support exploitation of R&I results, dissemination and downstream deployment.
- Based on the SRIA, develop a strategy, in collaboration with the EU and stakeholders of related enabling technologies, to address current European industrial and market shortcomings and to create new opportunities for European ICT and verticals industries.
- Provide and enforce a governance model, which supports the goals of openness, transparency and representativeness, while ensuring efficient management with minimized overhead.
- Support an efficient coordination and information flow between R&D&I projects by respecting the interests of all the partners regarding confidentiality and access rights.
- Ensure programme effectiveness, agility and adaptation according to research needs and an appropriate impact assessment, including societal and human factors.
- Incorporate EC policy requirements, reflecting public interest during the implementation of the Partnership.

As mentioned above, the HEU SNS Partnership 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 digitisation of Public Administrations. 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.

Within this broader context, the SNS SRIA is expected to progress towards the technological and business realisation of the 6G vision developed notably under the 5G Infrastructure PPP ICT-52-2020 projects and targeting massive digitisation of societal and business processes through intelligent connectivity across the human, physical and digital world. This covers several related objectives, and in particular:

- Moving beyond a simple increase in speed or performance of connectivity platforms, 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 solutions, like the “Internet of Sense”, realizing a fusion between the communication and sensing environment, massively scalable immersive environments, like XR/VR, digital twins, and holographic type communication.

- Supporting key United Nations Sustainable Development Goals (SDGs), with SNS aiming to directly to align to:

    - **SDG 8**: Promote sustained, inclusive, and sustainable economic growth: achieve higher levels of economic productivity through diversification, technological upgrading, and innovation.
    - **SDG 9**: Build resilient infrastructure, promote inclusive and sustainable industrialization 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
    - **SDG13**: 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)

This alignment serves as an example to applicants. It is expected that applications will also identify any other SDG that their work will serve. 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 WP.

Supporting Key Societal Value indicators (KVI) 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 digitization, supply chain resilience, and the need to address European and global societal challenges across.

Moreover, the SNS WP targets a strong European impact at future downstream 6G standardisation stages, including a Europe wide consensus of 6G Key Performance Indicator (KPI’s) that will frame future developments. Additionally, the integration of concepts and technologies originating from the Cloud/IT environments to support massive device (IoT) connectivity and ultra-reliable communications and services on top of enhanced mobile broadband services. This is an important target towards a complete value chain to serve an IoT device-connectivity-service platform.

The stimulation of strategic alliances is a key objective, with vertical 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 universal and global smart interconnected public and private networks and services. In this WP, the industry is described in terms of vertical sectors. A strategic goal of the SNS Partnership is to empower many vertical domains further beyond current 5G capabilities. Participation and contribution of these actors to the SNS WP are considered important, both to drive the requirements and to validate the technologies in specific business contexts.

The SNS WP targets towards serving several European policies[11], and notably:

- Green Deal[12]
- Resilient Communication Privacy via Developing Proper Security Strategies [13]
- Artificial Intelligence (AI) [14] [15] [16]
- Data & Cloud Computing
- Blockchain Technology
- High Performance Computing (HPC)
- Internet of Things[17]
- Microelectronic components

To that end, the SNS Partnership will put in place appropriate mechanisms to allow the close collaboration with other relevant Partnerships, notably in the areas of HPC, micro-electronics, photonics, AI and data analytics and Connected and Automated Mobility (CAM) as appropriate. Relevant proposals in these domains are expected to support these goals.

Additional goals of the SNS WP are to:

- Develop strategies and technologies for the integration of future connectivity and service platforms into larger globally applicable infrastructures, whilst preserving European competitiveness and sovereignty.
- Define trust, security and communication privacy enhancing technologies, process and architectures that will be required for massively heterogeneous, virtualised and software platforms of the future.
- Bring new actors from, and beyond the verticals. Contributions from industry, RTO, academics and Small and Medium-sized Enterprises (SMEs) actors in the connectivity, IoT and cloud/IT domains are expected to be complemented, where applicable, by adequate participation of the micro-electronics industry from the onset of the partnership, in view of their potential impacts at downstream standardisation level.
- Provide a stable experimental framework towards minimising risk and validating core technologies.
- Provide 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 (USA, China, Republic of Korea, Japan).

11 https://digital-strategy.ec.europa.eu/en/policies

12 https://ec.europa.eu/info/sites/default/files/european-green-deal-communication_en.pdf

13 https://digital-strategy.ec.europa.eu/en/policies/cybersecurity-act

14 https://digital-strategy.ec.europa.eu/en/policies/artificial-intelligence

15 https://ec.europa.eu/newsroom/dae/document.cfm?doc_id=75787

16 https://digital-strategy.ec.europa.eu/en/policies/regulatory-framework-ai

17 https://digital-strategy.ec.europa.eu/en/policies/iot-policy

The SNS WP hence offers opportunities to European stakeholders in industry, research and academia to build innovation capabilities to achieve a leading position in the standardization process (e.g., 3GPP, ETSI, and similar organisations addressing the broader scope of Smart Systems and Networks), securing a leading position for Europe in the global ICT market, over the coming 8-10 years for 6G.

The following key objectives are proposed to address the problems 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 in order to improve the business operation.

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. Establish MoUs with relevant international initiatives.
4. Develop and validate solutions that reduce OPEX for the selected vertical sectors.
5. 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.
6. Analyse and understand the results produced by the large-scale trials and revisit verticals’ requirements and needs.
7. 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).
8. 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 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. Design and validate ICT building blocks that can be used to achieve one or more United Nations' SDGs.
4. Ensure that Europe will be self-sustained in key technological sectors, including the value chain considered for SNS [7].
5. 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.
6. 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 according to [10] be:
   - 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 Partnership.
3. Reduction of GHG emissions, compared to 1990 levels [11], 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 [12] 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., micro-electronics, 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.
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 ensure European leadership in the ICT sector 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 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. Provide contributions to more than 1000 contributions in SDOs.
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 Partnership 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 telecommunications 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 4 presents the Partnership Specific Impact Pathways for the objectives presented above.

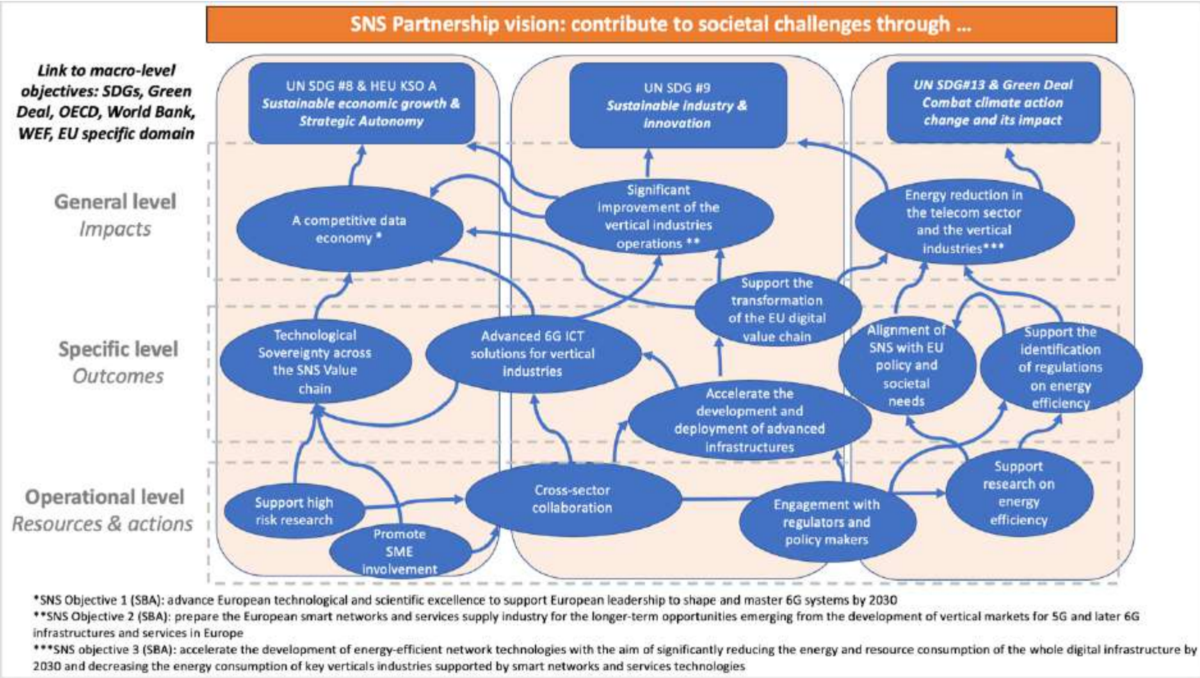

Figure 4: Partnership Specific Impact Pathways

3.2 Key areas identified in the NetWorldEurope SRIA

The NetWorldEurope European Technology Platform (ETP), organisations representing more than 1000 entities, representing 5 % of European GDP, are contributing to the definition of research areas especially in the domain of communication systems and networks. This effort has also benefited from the notable help of the 6G Smart Networks and Services Industry Association (6G-IA), and from contributions from the Alliance for Internet of Things Innovation (AIoTI) and from the Networked European Software and Services Initiative (NESSI). Other external organizations provided inputs in different stages of the development of NetworldEurope SRIA. This work forms essentially the basis for the SNS Partnership SRIA through a process that will be explained in the next section.

In this section a summary of the key areas that the European R&D Community believes relevant for the future of communications technology in Europe and in the World is presented. This analysis has been anchored in the challenges identified by the United Nations, the Sustainable Development Goals, and in the current policies inside the European Union, notably the European Green Deal and thus, is fully compatible with the SNS objectives.

3.2.1 Emerging applications and use cases

Every industry sector is undergoing profound changes in terms of digitalisation, which in turn will have positive socio-economic impact in the industries and the society. This digital transformation is acting as a strong driver for current and future developments in the area of Smart Networks and Services (SN&S). Networks become the key connectivity technology and infrastructure solution for enabling the Next Generation Internet (NGI) vision and adopting its Human Centric approach. Although Human Centric means empowering the individuals and facilitate the interaction with digital services (B2C) these principles also needs to be applied to the digital transformation of vertical industries (B2B). The Internet evolution must incorporate the EU values that represent our Society and respect the rights of EU citizens. Therefore, any technical solution must attain the necessary levels of trustworthiness, resilience, openness, transparency and dependability while inclusive and respectful with diversity [13], and assuring societal privacy concerns. Telecommunication Networks are also critical and strategic infrastructures that need to be cybersecured with suitable tools [14]. These concepts and values must be translated to technical requirements of future networks and services. Just by looking to what is happening across the different vertical sectors, it is easy to identify common digitalisation trends and emerging applications **in the short and medium term** that are demanding proper advances in the technological domains where SN&S can impact. *For illustration purposes*, five big trends and their impact in different industrial sectors and also in the citizens life, in a non-exhaustive manner, are briefly examined below.

- **Robotic automation**: advances in robotics and artificial intelligence are accelerating the adoption of interconnected and autonomous machines in numerous sectors.

    - In the farming sector, traditional machines like tractors and harvesters are evolving towards autonomous, driverless systems [15]. There is also an increasing trend in smaller autonomous robots [16], [17](both in the ground and in the air, such as UAVs), to make more efficient and safer all kind of harvesting tasks, analysis of the field parameters, application of phytosanitary products, etc.
    - In the manufacturing industry, robots are becoming both more autonomous [18] thanks to increasing cognitive capabilities, and more cooperative (CoBots) [19] thanks to enhanced human-robot interaction (HRI) capabilities by relying on smart sensing, specialised private networks and advanced AI, fulfilling at the same time strict safety requirements in unfenced environments.
    - Health and Social care is seeing an increasing interest in assistive robots for disabled and/or elder people [20]. These will be autonomous and cooperative robots designed for assisting persons in their everyday life.
    - Future smart mobility services will be enabled by autonomous connected vehicles [21](both public and private) interacting and cooperating with their environment (V2X) by means of smart sensors and powerful AI systems, which will allow optimal decision taking optimizing the whole performance of the mobility system, e.g. reducing traffic congestion.
    - From automation of inventory tasks [22] to autonomous delivery of goods [23], the adoption of autonomous machines is expected to revolutionise retail and logistics operations in the near future.
    - Maintenance operations in utilities [24] (e.g., power grids) and critical infrastructures [25] are also moving towards automated means for efficiency and safety reasons.

- Another category of relevant Industrial scenarios for Industrial IoT (IIoT) concerns connected environments, for instance, warehouses integrating Automated Guided Vehicles (AGVs) or Autonomous Mobile Robots (AMRs) and necessary sidelink communications for operating in cooperative and self-organizing way.

Full deployment of autonomous robots in the sectors and use cases described above require, among others, ultra-reliable and low latency communications, embedded AI at the edge, autonomous decisions, accurate and real-time positioning (both indoor and outdoor), etc.

- **Massive monitoring and remote management**: fine-grained, continuous monitoring of processes is becoming the basis for productivity optimisation and higher efficiency.

    - The future smart grids (energy, water, gas) will need to optimise supply and demand in real time, managing energy flows between millions of nodes, dynamic pricing and transactions, anticipating weather and behaviours of consumers, in a sustainable way with a high level of integrity, security and resilience. This will be only be possible thanks to the capture of high-quality data in real time [26]. In the case of freshwater, it is a vital resource which is becoming scarce, thus it becomes essential to optimise its consumption, detect leaks, and continuously monitor its quality [27].
    - Precision farming demands fine (both in time and space) remote monitoring of crops and animals [28] in order to optimise food production, making a more efficient use of resources and minimising the impact of pests.
    - There is an increasing interest in implementing effective remote healthcare and remote monitoring systems for patients. On one hand, this is motivated by the need monitoring long-term patients and those suffering chronic diseases, thus seeking more cost-effective health and social services, and also higher quality of life for the patients [29] On the other hand, continuous monitoring of our health, leveraging on wearable devices and AI technologies, makes possible to move towards healthcare prevention systems with early detection and diagnosis which will eventually lead to more effective and convenient healthcare [30]
    - Industrial processes will be finely monitored in real time thanks to Industrial IoT (IIoT), CyberPhysical Systems (CPS) and remote Media-aided Systems, enabling higher optimization levels and predictive maintenance, reducing costs and increasing productivity [31]

The main requirements in terms of SNS include autonomous operation (ultra-low power), massive Machine-Type Communication (MTC), and large-scale orchestration of networks.

- **Digital twin (DT):** The massive, continuous monitoring opens the door to create virtual models capturing all the details of physical goods and processes, enabling real-time digital representations that allow data-centric management. 3D models and new media technologies (i.e. mixed reality) are also relevant in this ambit to enrich the interactivity. DTs can be applied is different scenarios to improve situational awareness, and as well enable better responses for physical asset optimisation and predictive maintenance.

    - DTs for physical infrastructures/products allow that closely reflect their whole lifecycle: buildings, cities, vehicles, industrial products (e.g. engines), smart grids, etc.

- Evolving digital twins in energy sector with myriad of functionalities and purposes are paving way for open marketplaces and flexibility markets development, greater observability as well as flexibility of supply and demand.
- DTs for processes are especially relevant for manufacturing in factories, food production, logistics, and retail.

DTs open the doors to the full virtualization of the value chains and the creation of rich marketplaces. This is particularly relevant to sectors strongly structured around supply chains like manufacturing, food and retail. This dimension has gained importance due to the COVID crisis, where the disruption of the value chains is creating multiple supply problems.

- **Extreme pervasiveness of the smart mobile devices in Cities** together with the ubiquitous coverage of the mobile telecommunication systems may be employed to monitor large metropolitan areas. An interesting example is represented by the detection of critical urban anomalies, such as unexpected crowd gathering in metropolitan areas (e.g., concerts, football matches, traffic jam). This can be achieved through the collection of information that the different network elements (e.g., base stations, mobile terminals) are exchanging over time, in a totally anonymous fashion for the connected users [32]. More accurate detection and sophisticated events may be considered when including heterogeneous sources of data, e.g., from sensors in the street furniture.
  Smart cities typically combine use cases from the Consumer, Enterprise and the Industrial domains. In the future, several smart city applications will mostly be cross-domain, meaning the data generated by a given deployment can be used multiple times by several applications. Advances in public safety also call for connecting public safety ICT infrastructure with smart city IoT infrastructure to automate emergency handling and enhance the safety of the citizens. Examples of use cases include:

  - Safety and security using video analytics at the edge: Video analytics will play an important role in several smart city use cases. These include crowd monitoring, intrusion detection, traffic monitoring, surveillance, tracking in urban spaces, etc. With an increasing number of video sources, processing the data in central clouds will not scale meaning the use of high-density edge cloud capabilities will be key to provide near real time video analytics addressing requirements from a multitude of applications.
  - Autonomous driving and cooperative ITS: The Society for Automotive Engineering (SAE) defined several levels leading to fully automated driving. There's a common consensus that reaching the highest levels of automation will call for connectivity and a high degree of cooperation between vehicles on one side and a highly digitized transportation infrastructure (within smart cities), one that supports high throughput and low latency communications thanks to edge computing. Some advanced autonomous driving use cases may even require highly distributed edge computing capabilities.

- **Autonomous and Hyper-connected On-demand Urban Transportation** Millions of people move every day in big cities which are getting more and more crowded. That is why traffic congestion is becoming a critical problem in many of them, making people waste their time being behind the wheel of a car and being exposed to traffic security risks. Future cities will need to free up space for people and at the same time offer more agile on-demand mobility services in order to combat the traffic congestion and have sustainable cities.

On-demand smart mobility services can be achieved on one hand by providing a single platform for combining all mobility options and presenting them to the customers in a simple and integrated manner, that is, easy access to the most appropriate transport services being included in a bundle of flexible travel options, shifting from the provision of urban transport networks (i.e. buses, trams, trains) to what people require on-demand [33]. That will be translated in door-to-door mobility by highly automated chains of different means of transport. However, according to TMForum [34] on-demand services have not yet achieved a real-time 360-degree view of the customers. It is not only a matter of having enough data but there is the need to further leverage on intelligence in a way that not only provides actionable insights, but also complies with regulatory governance about security. If CSPs fail to build the necessary intelligence in their OSS/BSS, their networks will be unable to keep up with the speed and volume of changes required. By using AI, it is expected to unravel the complexity of travel patterns and identify how to reduce the social and environmental costs of transport systems.

On the other hand, traffic management is expected to be highly improved by means of connected vehicles interacting with their environment (V2X), in a higher degree as long as more sensors and intelligence are onboard connected smart public transportation vehicles, so it will be possible to collect more accurate real-time information, to know precisely which parts of the city are becoming congested. Each vehicle, e.g. shuttle service bus, would be acting as a smart object equipped with a powerful multi-sensor platform, computing units, IP-based connectivity, and big amount of data management capabilities [35]. Applications onboard of connected public buses will have to manage real time traffic congestion information received from the numerous sensors in the environment and plan automatically in advance alternative routes, continuously updating information based on predictive data analytics tools. Also novel and scalable cyber-security solutions will be needed to manage millions of connected objects and automotive sensors [36].
These hyper-connected autonomous vehicles will allow passengers to travel carelessly about the traffic (no need of consultation about traffic status or alternatives routes or their safety), which will have a direct impact in the increasing use of public transportation, and will contribute to the following key current societal challenges:

- decrease traffic congestion and passengers idling, which is translated into additional productivity and quality-of-life improvements.
- public vehicles will be transporting more people at a time, increasing road capacity, while providing significant energy savings.
- reduce time to reach travellers' destinations fomenting mobility which can turn in boosting social interactions and economic activities.

From the technology standpoint there is a playground that will combine advanced connectivity (beyond 5G/6G) with its capabilities and embedded intelligence, big data and AI mechanisms to enable future applications.

In the **longer term**, future emerging applications are currently being discussed in several communities. The ones that are described in this subsection are based on [39]. Some examples of such future emerging applications are:

- Holographic media applications: involve not only the local rendering of holograms but networking aspects, specifically the ability to transmit and stream holographic data from remote sites,

- Multi-Sense Networks: include emerging applications that involve not only optical (video, holograms) and acoustic (audio) senses, but as well smell and taste senses.
- Time Engineered Applications: use a communication system that can coordinate between different sources of information such that all the parties involved have synchronized view of the application.
- Critical Infrastructure support applications: support of critical infrastructures that refer to those essential assets that are considered vital to the continued smooth functioning of the society as an integrated entity.

In addition to these emerging applications, [38] and [37] summarize seven representative use cases for ITU-T Network 2030: holographic type communications (HTC); tactile Internet for remote operations (TIRO); intelligent operation network (ION); network and computing convergence (NCC); space-terrestrial integrated network (STIN); industrial IoT (IIoT) with cloudification.

Holographic type communications (HTC)

The holographic display needs to satisfy all visual cues for the human observation of any 3D object, such that it can appear as natural as possible [40]. According to [40], holography is a method of producing a three-dimensional image of a physical object by recording, on a media photographic plate or film. In addition of being optical holograms can record the wavelength (colour) and intensity (amplitude) of light waves, as well as the phase of light waves (perception of depth). It is expected that in the next decade holographic displays will adopt the lenslet light-field 3D through the naked-eye or indeed through augmented reality (AR) and virtual reality (VR) via head-mounted display (HMD) media devices [41]. Holographic type communications (HTC) are expected to digitally deliver 3D images from one or multiple sources to one or multiple destination nodes in an interactive manner. It is foreseen that fully immersive 3D imaging will impose great challenges on future networks.

Tactile Internet for remote operations (TIRO)

Tactile Internet is enabler the real-time control of remote infrastructure, creating a plethora of opportunities and opening new areas of applications within sectors such as Industry 4.0 or tele-medicine. It is expected, that immersive video streaming applications, such as the HTC 3D image streaming, will support real-time and immersive interaction between a human operator and remote machinery. Two typical use cases are described in [38]. The first typical use case is remote industrial management that involves real-time monitoring and control of industrial infrastructure operations with augmented reality (AR) support. The second typical use case is remote robotic surgery. In this use case the surgeon gets a real-time audio-visual feed of the patient and operating room, using a human system interface (HSI), where a master console is installed.

These two use cases require the network to have very low (near zero) end-to-end network latency for real-time interaction, along with guaranteed high bandwidth to support the visual feed. They also necessitate strict synchronization between the various feeds to allow interactive control.

Intelligent operation network (ION)

This use case focuses on the need that future networks will have on intelligent operation capabilities in order to efficiently provide a variety of intelligent services and applications. Monitoring of the network for impairment (or potential impairment) is important, where the key performance indicator is 'network health'. For example, intelligent technologies such as artificial intelligence (AI) will play a key role in feature and pattern recognition [42]. It is expected, that such technologies and models would be trained based upon historical data as well as learning (for example using neural network techniques) from live network operations and other statistics, to establish a human-brain like cognition to locate network malfunctions and faults accurately.

Network and computing convergence (NCC)

The recent advent of cloud computing and network functions virtualization has resulted in the emergence of network cloudification. It is expected that future networks may require multiple distributed network edge sites to interconnect and collaborate with each other. Orchestration capabilities that are computing aware may need to be supported. Furthermore, emerging edge applications (for example, AR rendering, autonomous driving and HTC) are characterized by high mobility and other time-varying features that will require one or more data centres to provide computing resources simultaneously in a coordinated way. Such applications will require the support of intelligent load-balancing among multiple edge sites. Therefore, future networks need to support computing-aware network capabilities, with unified management, control and operation in order to guarantee differentiated service experience with much higher granularity than in current networks.

Space-terrestrial integrated network (STIN)

In this use case [37], a scenario is envisioned where a future seamlessly integrated terrestrial and non-terrestrial Internet framework is applied. The aim of this use case is to leverage the inter-connected multilayered non-terrestrial network (see Chapter 9) to build a parallel Internet network that can peer with its terrestrial counterpart. In this scenario, it is considered that one essential aspect is that future mobile devices (e.g. smart phones, tablets, etc.) will be able to directly communicate with the locally accessible NTN nodes, but without necessarily relying on traditional ground station infrastructures that are constrained by geographical distributions [43].

Industrial Internet of Things with cloudification

Industrial networks enabled by the Industrial Internet of Things (IIoT) are connecting back offices to factory floors and provide the integration from device level all the way through to enterprise business systems, resulting in the automatic operation and control of industrial processes without significant human intervention. These enterprise networks need to deliver superior performance and mandate a real-time, secure, and reliable factory-wide connectivity, as well as inter-factory connectivity at large scales in the future. At the same time, operational technologies (OTs) and IT are converging, where control functions traditionally carried out by customized hardware platforms, such as programmable logic controllers (PLC), have been slowly virtualized and moved onto the edge or into the cloud.

Representations of the network requirements

These seven representative use cases have been further evaluated in [38] according to five abstract network requirement dimensions, widely discussed in [44], namely: **Bandwidth**, **Time**, **Security**, **Artificial Intelligence (AI)**, and **ManyNets,** see Table 1.

Table 1: Abstract dimensions with relevant network requirements, from [38]

Abstracted dimensions	**Relevant network requirements**
Bandwidth	Bandwidth; capacity; QoE; QoS; flexibility; and adaptable transport
Time	Latency; synchronisation; jitter; accuracy; scheduling; coordination; and geolocation accuracy
Security	Security; privacy; reliability; trustworthiness; resilience; traceability; and lawful intercept
AI	Computation at edge; storage; modelling; collection and analytics for network programmability and management
ManyNets	Addressing; mobility; network interface; multiple RATs and heterogeneous network and computing convergence.

The relative scores for these five dimensions, ranging from 1 to 10, are shown in Figure 3-1, where all the scores are given according to the relative importance of a specific network requirement: 1 to 3 are for relatively LOW requirement; 4 to 6 are for MEDIUM requirement; 7 to 9 are for relatively HIGH requirement; and 10 means EXTREMELY demanding requirement. The detailed and absolute values of the requirements associated with each use case are provided in [38].

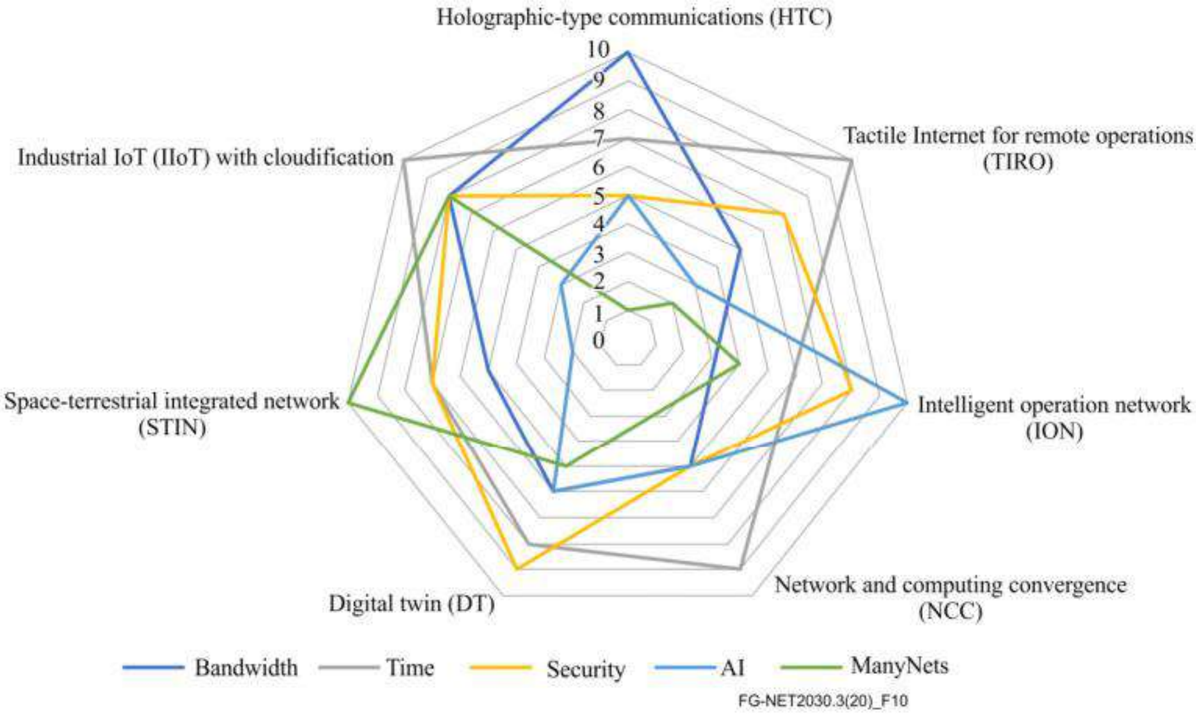

Figure 5: Relative network requirement scores for the seven representative use cases – reverse spider graph representation, copied from [38]

3.2.2 Considered KVIs and KPIs

There are several Key Performance Indicators (KPIs) that will be subject for enhancements in future Smart Network, and these span the device, the radio access, the core network, and the end-to-end system management. Examples of these KPIs include: Bandwidth, Capacity, Spectrum Efficiency, Peak Data Rate, User Data Rate, User-plane Latency, Control-plane latency, Jitter, Device Density, Area Traffic Capacity, Reliability, Availability, Energy Efficiency, EMF values, Coverage, Mobility, Positioning Accuracy, Service Deployment Time, Network Automation Metrics, Security Metrics, etc.

These technical KPIs and their targeted values in the evolution of 5G towards 6G are currently under discussion mainly in the scientific community with respect to the envisaged usage of future systems, cost implications, business cases and technical feasibility. For the time being no KPIs are formally agreed and set as requirements for research and innovation to be targeted in future wireless systems. With focus on the radio access, ITU-R WP5D has just recently (February 2020) initiated the development of a “Technology Trends Report”, which will lead to an updated vision document to agree technical KPIs on global level. In the coming years, associations in the commercial domain such as NGMN, GSMA, 5GAA, 5GACIA as well as regional associations, e.g. 5G IA and international counterparts will contribute to this discussion to achieve a global consensus. In [2] a detailed analysis of related KPIs is provided (c.f., Section 2.4). The referred KPIs will be used to form the basis of the SNS KPIs. Note that the KPIs are expected to be re-evaluated at regular intervals.

In addition to the KPIs discussed NetWorldEurope has acknowledged that the success of the future smart networks will increasingly be measured with indicators that assess how well the networks contribute to solving of the major societal challenges. These indicators are more related to value provided by the use of the networks than to the performance of the networks themselves. Several value dimensions need to be addressed including societal and sustainability related challenges, business aspects, ethics, trust, privacy and security, EMF awareness, and efficiency, among others. Proper indicators need to be defined for the value dimensions resulting in value related indicators for the future smart networks. Societal Challenges will encompass broad and complex missions for technology-oriented research and innovation. They are characterized by open-endedness and undefined final outcome. Progress towards solving Societal Challenges with conventional metrics and indicators can turn to be a difficult task. It will be necessary to reflect on a new impact assessment paradigm, focused on value creation and sustained long-term benefits and effects, around identified domains. At the time of the preparation of [2] it was acknowledged that it was too early to define the key value indicators and further work was required.

3.2.2 Key Technological Areas – NetworldEurope SRIA

In [2] a very detailed analysis of all the considered technological topics to meet the aforementioned goals and objectives, is provided. In summary the proposed technological areas for further investigation and evolution include:

- An architectural evolution to achieve a holistic smart green system
- Increased network flexibility through improved virtualized control
- Improve the performance of Data and Forwarding planes
- Creation of elastic networks (in terms of resources) keeping also energy efficiency as a main target
- Native support of AI/ML solution by the future telecommunication networks
- Provision of edge computing solutions, through a cloud continuum, that will assist in meeting the strictest requirements set by future advanced services.
- 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, coding and modulation, positioning and sensing, massive random access and wireless edge caching)
- New solution in the optical domain targeting backhaul and fronthaul to ensure sustainable capacity scaling, new switching paradigms, and optical-wireless integration to achieve ultra-high energy efficiency. The topics also include optical wireless communications
- A bundle of security topics for beyond 5G and 6G networks including topics such as: security as a service, green security, security orchestration, distributed ledger technologies, AI/ML based security mechanisms and human-centric privacy
- Further evolution of satellite communications technologies, including evolved 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, antennas and packages, baseband modems, processors for Cloud-AI, Edge-AI and on device-AI, memories and hardware for security
- Emerging technologies on various areas such as: nano- and bio things, quantum networking, AI/ML solutions for the physical networks etc.

From the above list, it is clear the NetWorldEurope 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 NetworldEurope SRIA is updated on a biennial basis and used as the basis for the development of the SNS Partnership SRIA.

The progress in the SNS Partnerhsip will be also evaluated against a well-defined set of 6G KPIs (considering as the baseline the abovementioned NewWorldEurope's SRIA KPIs, 6G KPIs produced by 5G PPP projects, etc.). In addition, KVIs will show how the SNS projects will provide societal impact to vertical sector applications and to European industrial competitiveness. The indicative list of KVIs illustrated below have been drawn from previous EU projects (e.g., in 5G PPP ICT-52-2020 projects) and is to be adapted to the goals of the SNS projects[18]:

Democracy	Ecosystem	Innovation
Privacy	Sustainability	Safety
Fairness	Business value	Security
Digital inclusion	Economic growth	Regulation
Trust	Open collaboration	Responsibility
	New value chain	Energy consumption

KVIs may be new to some applicants and should be used alongside KPIs to illustrate project benefits. To demonstrate "security" for example, a project may collect network traffic data (KPIs) and interview vertical sector use case actors, providing metrics and validating the solution in place.

3.3 Adapting NetworldEurope's SRIA to the SNS Partnership

The NetworldEurope 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 NetWorldEurope SRIA contains a superset of topics, some of which do not fall directly into the scope of the SNS Partnership, 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 Partnership (i.e., AIOTI, CISPE.cloud and NESSI).

To achieve this adaptation, a dedicated Annex has been developed [45] 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 NEtworldEurope SRIA topics are to be covered by the SNS Partnership or other related HEU Partnership.

A group of experts from the 6G-IA, NetworldEurope, NESSI, CISPE.cloud and AIOTI evaluated and selected which of these topics fall under the scope and objectives of the SNS Partnership. 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 Partnership SRIA were selected. These are analyzed in the following subsections.

18 https://www.isitethical.org/key-terms/, and work of Hexa-X, Ziegler & Yrjola - 2020

3.4 SNS Partnership Key technological Areas

As mentioned earlier the SNS Partnership SRIA is based on the NetWorldEurope SRIA, after evaluating and selecting those topics that closely match the objectives of the Partnership. The SNS Partnership SRIA will be updated in a biennial basis following the process described in Section 6. For the first phase of the SNS Partnership 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.
- **Stream B:** Covers research for revolutionary technology advancements, in preparation for 6G and revolutionary advancements of IoT, devices and software. This Stream targets Low Technology Readiness Level (TRL) technologies that are expected to deliver innovative solutions towards real life networks in a long-term time-period.
- **Stream C:** Focuses on SNS Enablers and Proof of Concepts (PoCs) used to develop experimental infrastructure(s), ideally aiming to be used during later phases of the SNS.
- **Stream D:** Targets towards 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 in the vertical domains. Phase 1 Stream D projects should incorporate as possible technologies that currently appear as key enablers for 6G networks, e.g., AI/ML, cybersecurity, high performance computing, advanced IoT solutions, etc. During the subsequent SNS phases, Stream D infrastructures will 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.

These Streams are expected to be active for the whle duration of the SNS Partnership and their topics are expected to be updated in a biennial basis.

This SNS Phase 1 is expected to build 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 further updated considering the SNS targets and the key achievements from phase 1 projects.

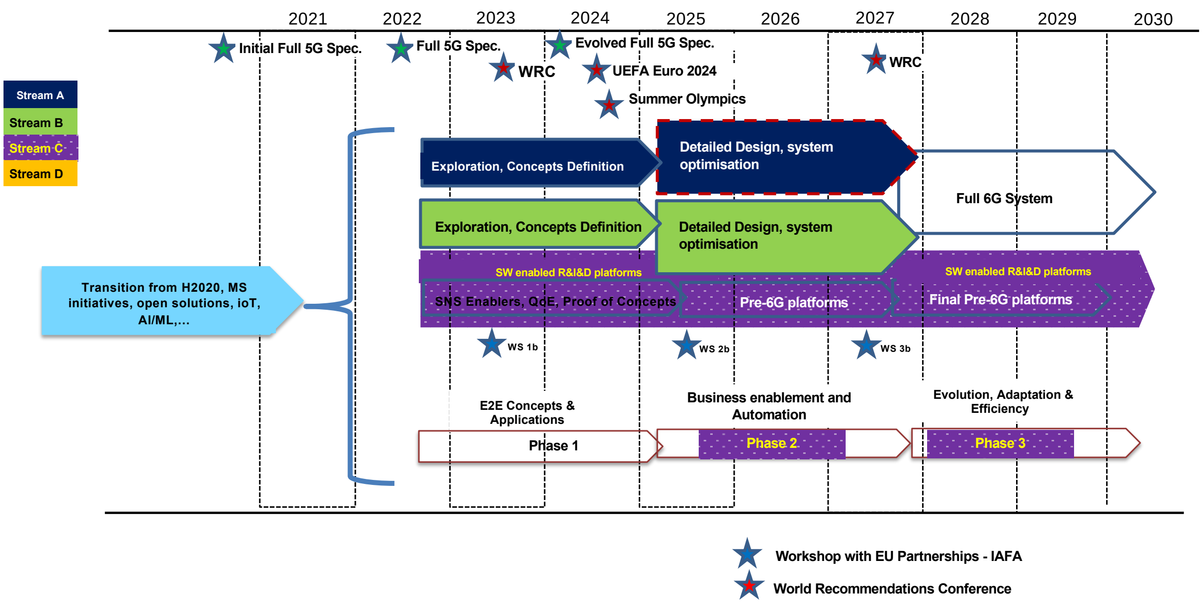

Figure 6: SNS Partnership Roadmap

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[19] 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.

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

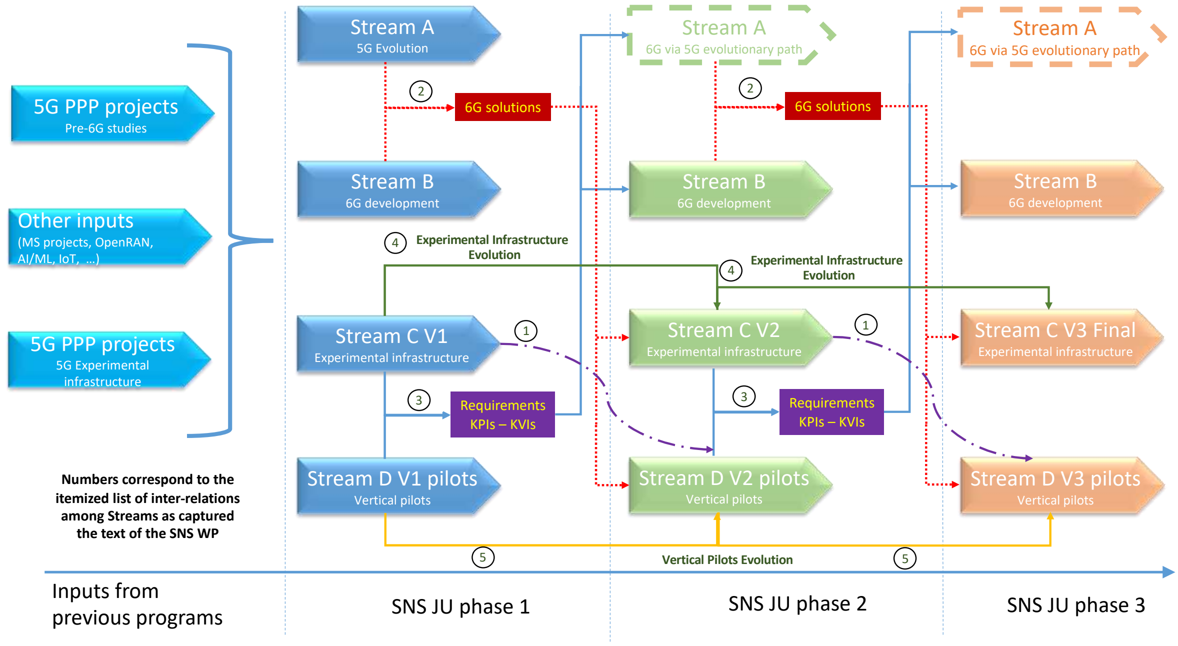

Figure 7: Interlinking of Streams into Phases

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 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 NetWorldEurope's SRIA[20] 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.

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20 https://bscw.5g-ppp.eu/pub/bscw.cgi/d367342/Networld2020%20SRIA%202020%20Final%20Version%202.2%20.pdf, collected in chapter 2.

It is anticipated that Stream A topics will 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 expected to be 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 as part of the impact evaluation criteria for relevant projects that aim to explore AI techniques.

The topics of Stream A include:

1. 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)
2. Ubiquitous radio access: Impact on coverage, accelerate the deployment, integrated terrestrial and non-terrestrial components, highly consolidated NTN architectures
3. Sustainable capacity networks: focus on transport networks, converged packet-optical transport network, improve network capacity, increased programmability, control latency taking into consideration energy consumption.
4. 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.
5. 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.
6. 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.
7. 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:

- A reinforced European leadership in connectivity extended to devices, and service infrastructures, with competitive offers to overcome the current challenges of deploying, managing, and exploiting large, distributed sets of consumer- and business-oriented devices, needed to realise the 6G vision of intelligent inter-connectivity between the physical, digital, and human worlds, supporting massive digitisation of our economies and societies.
- The successful digital and green transitions towards low energy and carbon footprint of conventional (vertical) industries, by managing service delivery in a massive number of connected devices and objects.
- Solutions to address SDGs and in particular connectivity and service availability (coverage), affordability (cost) and accessibility for many use cases of high public value (e.g., healthcare, agriculture, education, public safety, etc.).
- Efficient support of upcoming innovative applications with performance requirements beyond current technological capabilities, such as the Internet of senses, holographic communications, massive digital twinning, and XR, full autonomous driving, flying networks, digital participation with service infrastructures integrating networking and computational platforms for easy deployment and management.
- Extend the current set of patchy technologies for security and trust towards a comprehensive end-to-end framework, covering virtualized and software based heterogeneous networking environment (e.g., virtualisation of key security functions for protection, detection, and remediation). This pertains to service developers, service providers, and end users, offering the necessary levels of resilience, openness, transparency, and dependability. Such end-to-end security frameworks must be “dynamic”, integrating the different ICT involved, establishing monitoring and evaluation provisions, and identifying those responsible for ownership and successful implementation.

Stream B consequently targets revolutionary technologies of low TRL (2-4) 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:

- Significant contributions to the establishment of a globally accepted set of KVI’s and KPI’s framing future 6G developments
- Dynamic end-to-end distributed security for connectivity, devices and service infrastructures. This security “lifecycle” should be provisioned to account for distributed systems (e.g., asset orchestration and data aggregation), operational security (e.g., a dedicated SOC), security quantification, and a strategy for ongoing security threat assessment.

- A comprehensive zero-touch open end-to-end resource management system with drastic OPEX reduction and innovation support.
- Trustworthy and energy-efficient device, network, and service infrastructures, delivering critical services as well as a dynamic multi-vendor supply market, through new open network and service paradigms.
- Increased spectrum efficiency and dynamic spectrum sharing across multiple (and potentially new) frequency bands (potentially above 100GHz), covering technologies and architectures enabling optimized co-existence with the most difficult spectrum environments, enabling long-term opening of new frequency bands for mobile communication usage with better energy consumption performance, innovative sharing concepts, spectrum re-farming capabilities, and also addressing citizen concerns like low EMF exposure.
- Foster European capabilities in key technologies and notably AI/ML, advanced signal processing and microelectronics, paving the way towards advanced systems realizing visual vanishing (e.g., making the infrastructure imperceptible to the end-users) by fusion with physical environment. Insofar as AI techniques are concerned, the data sets to be used for the training and the evaluation of the mechanisms are expected to be open results from projects. Aspects of provision of such open data sets (e.g., date of release, its scope, and the dimension and diversity of data) will be considered as one of the projects' valuable output for projects with core focus on AI techniques.
- Provide a set of technologies and architectures to reinforce the European industry position during the 6G standardisation phase expected to start around 2025.

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, proposals may consider in the first place KPI's currently contemplated under authoritative industrial/research environments (e.g., NetWorldEurope 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 of this call is expected towards a European vision and consolidation of the KVI's/KPI's that will frame future 6G developments in Europe.

Considering the specific role of micro-electronic components for future 6G platforms, notably for IoT devices and virtualised "disaggregated" network implementations, proposals addressing such micro-electronic issues are expected to support a collaborative framework enabling to direct specific 6G component requirements towards KDT, in view of maximising the opportunities for the European micro electronic industry to successfully contribute to the mid-term 6G standardisation discussion.

Considering the raising role of IT and cloud technologies for the implementation of IoT and connectivity systems, proposals addressing the cloud and edge cloud technologies and software implementation of network/device control functions are expected to provide a clear strategy in relation to EU supply capabilities and opportunities in the context of a future cloud continuum that may involve interoperation with non-EU systems such as the hyperscalers.

Stream B technological topics are grouped in four strands as shown in Figure 8.

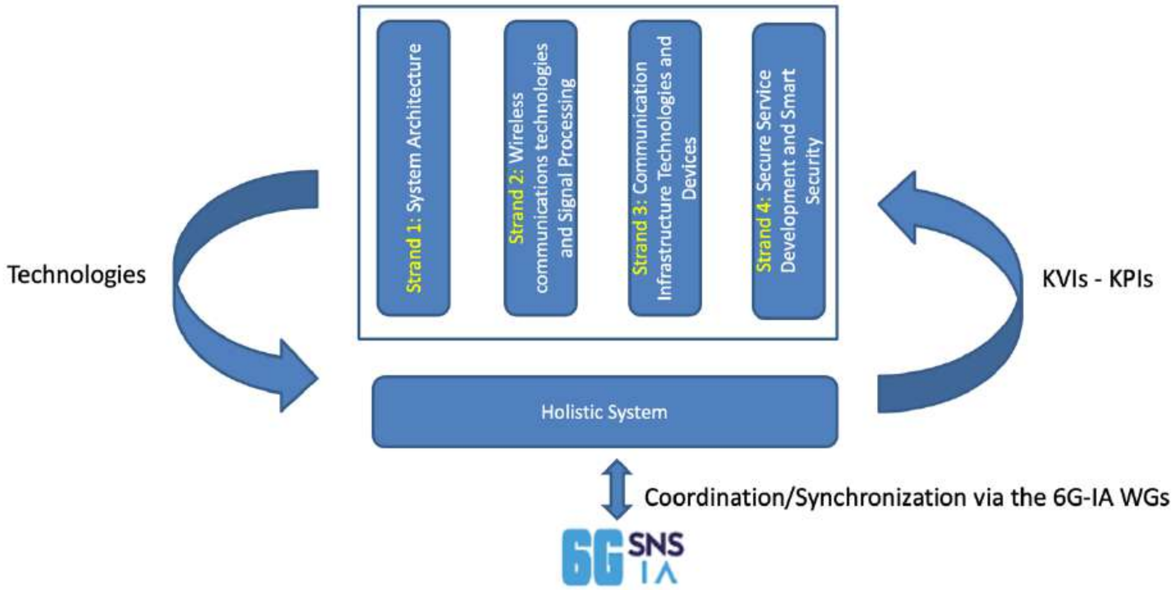

Figure 8: Stream B - organization of technological areas

More specifically, in Strand 1 (System Architecture) the following topics are to be investigated:

- Technologies for scaling Inter-computing systems
- Control and controllability separation
- Frictionless inter-domain resource management
- Native integration of AI for telecommunications
- New Data Transfer Paradigms with deep Edge integration
- Improve data plane performance
- Deterministic Networking

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

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

- Flexible Capacity Scaling
- Ultra-high Energy Efficiency
- Integration of Optical and Wireless Technologies
- 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

A key idea for the SNS Partnership is that the abovementioned topics will be also investigated also in a holistic framework so as to evaluate their performance as a complete system. This effort should take into consideration both the societal and technical aspects that creating a clear European solution for 6G networks.

Stream C related topics

The final outcome of the SNS Partnership 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 twofold:

- To develop EU wide experimentation platforms that can incorporate candidate 6G technologies for their further validation.
- To make such an experimentation platform capable of hosting advanced pilot "6G" use cases as targeted under Stream D during the second SNS implementation phase.

Related objectives include:

a) <u>Reusability and evolvability of the experimental platforms over the lifetime of the SNS programme</u>: 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.

b) <u>Accessibility and openness</u>: use of the platform in further phases of the SNS by any consortium, requires using modular implementation methodology, potentially open-source solutions with well-defined technological and business interfaces clearly documented.

c) <u>Directionality and optimisation of previous and related investments in Europe</u>: 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.

d) 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.

e) End-to-end: the target experimental facility should be capable of demonstrating E2E 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 Partnership. 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 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 KVI and KPI's and in the context of very advanced digital use cases implemented through Large-Scale Trials and Pilots (LST&P)
- The identification of use case specific KVI and KPI's and how they may be matched by SNS platform KVI and KPI's
- A structured feedback loop from vertical users towards SNS stakeholders, in view of ensuring the best match between beyond 5G/ 6G systems capabilities and users.
- Accessibility and openness: use of the infrastructures/platforms in further phases of the SNS by any consortium, requires using modular implementation methodology, potentially open-source solutions with well-defined technological and business interfaces clearly documented.

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 is planned to start from the beginning of the SNS Programme.

3.5 Deliverables and milestones

As shown in Figure 6, the SNS Partnership 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 Partnership 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 goals21. 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 and illustrated in Figure 6. These activities will take place at a biennial basis.

Moreover, the SNS Partnerhsip has defined a clear set of KPIs in terms of resources, processes and activities, Outcomes and Impacts as shown in the following table.

Table 2: SNS Partnership KPIs

[21] These activities proposed by the SNS Partnerships could be implemented inside specific Coordination and Support Actions (CSA).

KPI Name	Unit of measurement	Baseline	Target 2023	Target 2025	Target 2027	Ambition >2027
Resources (input), processes and activities						
R1. SME innovation & participation	% of SMEs participation	0	20%	20%	20%	20%
R2. Rapid diffusion	#of end-user workshops & webinars [cumulative]	0	25	60	90	125
R3. High risk research funding	% of total funding	0	50%	40%	30%	N/A
R4. Standardization contributions	Contributions to SDOs [cumulative]	0	50	350	750	1000
R5. Share on family patents	% of patent families Patent grant rate	0 0	15% 60%	15% 60%	15% 60%	15% 60%
R6. Scientific excellence	# of publications [cumulative]	0	100	400	700	1000
R7. Reach an appropriate balance between research, innovation, and deployment	% RIA % IA %CSA	N/A	78% RIA 20% IA 2% CSA	N/A	N/A	N/A
R.8 Accelerate the development of energy efficient networks	# of related projects investigating to a significant extent energy efficiency topics: >=3	0	>=3	N/A	N/A	N/A
R.9 Ensure research on secure future digital services	# of related projects:	0	>=3	N/A	N/A	N/A
R.10 Collaboration and synergies with other Partnerships	# collaborations	0	2	5	6	6
Outcomes (SO)						
O.1 Development of energy efficient networks	White papers [cumulative]	GeSI report on Energy consumption by 2030	1	2	3	>3
O.2 Technological	White papers [cumulative]	0	1	2	3	N/A

solutions consensus building						
O.3 Advanced 6G solutions for verticals	#of different vertical types engaged [cumulative]	0	3	6	10	10
O.4 Foster emergence of new actors in the 6G supply chain	KPI7: # of related projects or cross-projects WGs dealing with the investigation and potential adoption of open ecosystem principles in B5G and 6G networks	0	>=2	N/A	N/A	N/A
Impacts (GO)						
I.1 A competitive data economy	% Market share for the communication network	40%	N/A	N/A	N/A	N/A
I.2 Reach Programme level consensus on 6G KPIs	white papers [cumulative]	NetworldEurope SRIA	1	2	3	N/A
I.3 Uptake of digital solutions within verticals	Number of large-scale trials [cumulative]	0	3	6	10	>10
I.4 Energy efficiency of telecommunication networks	% increase of energy efficiency of cellular communications	Legacy cellular systems (4G)	N/A	N/A	N/A	N/A

4. Monitoring Framework

This section contains detailed information about the planned monitoring framework

<table>
<tr><td colspan="3">European Partnership Smart Networks and Services</td><td colspan="3">Monitoring and evaluation framework, draft 1, 01 March 2021</td></tr>
<tr><td colspan="6">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.</td></tr>
<tr><td colspan="2">Objectives</td><td>What is a measure of success?
Please use quantitative (Key Performance) and qualitative indicators, and link them to a point in time</td><td>Which is the data source and methodology used
[project data, study, ….]</td><td>Who is responsible for monitoring and providing the data / information
When will it be collected?</td><td>Baseline and target</td></tr>
<tr><td rowspan="2">General objectives (linked to impact indicators)</td><td>GO1 Contribute to European technological sovereignty across the future smart networks and services value chain, including IoT, edge clouds and microelectronics components</td><td>40% of market share of networks vendors in 2028</td><td>Market studies (e.g. GSA, Dell‘ Oro)</td><td>EC, SNS JU and Association in the JU for reviewing data</td><td>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</td></tr>
<tr><td>GO 2 Advancing European technological and scientific excellence to support European leadership to shape</td><td>- Industry and R&I actors shared European visions on 6G,
- Support to a global standards ecosystem to avoid regional standards</td><td>Industrial actors engaged in 6G

Cooperation with ongoing activities,</td><td>JU, 2022, updated every 2 years</td><td>Baseline, no global 6G vision

• Create a European</td></tr>
</table>

	and master 6G systems by 2030		which may be on global level. In this context the following background information should be considered: • ITU-R tentative date for vision delivery is Q2 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		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

			will pursue some of these objectives. It is essential to maintain a global standards ecosystem and to avoid regional standards		journals and conferences • organization of more than 25 workshops and more than 100 webinars.
	GO 3 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. • With respect to the ongoing global discussion the JU should be prepared for new KPIs to appear in the next years.	R&I projects, JU Working Groups encharged of collecting " Key Achievements" data	JU, through 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-functional work between different horizontal and vertical sectors requires this cooperation on KPIs.	5G KPI's addressed through standardised solutions➔ Solutions for 6G KPI's at standardisation level in2027. • Reference are globally discussed and finally agreed 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 dense	Studies, projects, industry and user working groups	EC, JU, support action. 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.

		deployment concept and associated network architectures would be needed.			• 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
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 Workprogramme	NetWorld2020 SRIA and 5G PPP SDA existing➔ new version every 2 years
	SO2 Promote EU wide approaches to accelerate the development of	Development of widely agreed industrial roadmaps for energy reduction for technology domains in the scope of the SNS JU.	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.

	energy-efficient network technologies	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			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 CEF 2 projects based on the SNS SDA managed by a different budget and agency.	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

				Direct involvement of vertical sectors for PoCs and pilots.	across multiple Member States • 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	No high maturity in Europe in the field of an open ecosystem and a few partial European players. ➔ Availability of open ecosystem

				envisaged for the emergence of actors in this field).	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 and Association Members) by keeping a clear focus on SNS objectives.	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.
	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 an 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 SME's.
	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 based on the SNS JU SDA	JU projects steered CEF projects	EC for implementation (CEF 2 budget) JU for monitoring	Target: Adoption of the Strategic Deployment Agenda aiming at 6000 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 SRIA and international roadmapshowever, due to the independent evaluation process the JU has no influence on the selection of projects.	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 [14], 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 % • 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 is monitored by the SNS JU, because the adoption of

					SNS solutions is in the responsibility or such vertical sectors.
	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 allocation and 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: adoption of 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. Contributions by JU projects to the related definition of the assignment methods to be used in licensing process by Member States
	OO11 Support the identification of regulations on energy efficiency	Contributions by SNS projects and the JU of technical information, public consultations and position papers to support the preparation and adoption of regulation	EC, JU as technical contributor	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: complement R&I on energy efficiency with specification of an SNS label of energy efficiency 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 Partnership and the other relevant initiatives of Horizon Europe, including other relevant European Partnerships and EU actions / initiatives beyond Horizon Europe.

The SNS Partnership will target 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 Partnership included in the Digital, Industry and Space Cluster is targeting specific interactions with several Partnerships.

The SNS Partnership will target 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 Partnership 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).

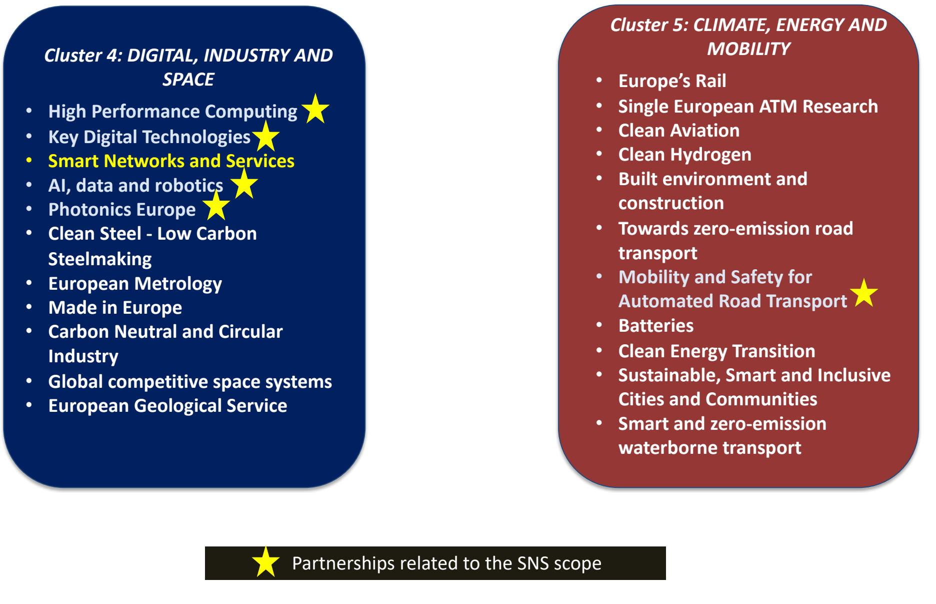

Figure 9: Partnerships related to the SNS scope

Note that in 2021 the 6G-IA has collaborated with AENEAS, (KDT Partnership) and under the context of the COREnect project. The target was to identify potential opportunities in the SNS WP orientations for the micro-electronics community in view of maximising the opportunities for the European micro electronic industry to successfully contribute to the mid-term 6G standardisation discussion. The SNS community has contributed with input in the ECS SRIA and presented potential topics in the Visions of ECS beyond 2023 workshop. Moreover, 6G-IA is currently working on identifying how these topics can be mapped in envisioned 6G architecture as developed by the 5G PPP Hexa-X project.

In 2020 6G-IA and the CCAM partnership collaborated to clarify the activities of the two Partnership and the scope of their activities. 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 will additionally explore 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 sector 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 scope for functional requirements and technology validation for beyond 5G.

6. Plans for updating the SRIA

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

Future releases of the SNS will rely again on the NetWorldEurope SRIA. This is because, the NetWorldEurope has a significant basis of industrial, research and academic and SMEs members, thus reaching out to significant part of the European ICT community. Also, its scope constitutes a superset of topics compared to the scope of the SNS Partnership. NetworldEurope is updating its SRIA every two years.

As described in the MoU between the 6G-IA and NetworldEurope [3], this SRIA will be used as the basis for the SNS SRIA. The plan for doing this adaptation contains the following steps:

1. Consultation with the 6G-IA members to select the most relevant topics from NEtworldEurope SRIA to populate the SNS SRIA
2. Formation of a group of experts from the 6G-IA, Networld Europe, AIOTI, NESSI, CISPE.cloud and the public side to select and prioritize the most promising topics for the future of telecommunications in Europe. This will constitute a first complete version of the SNS SRIA
3. Dissemination of the SNS SRIA in dedicated workshops/webinars and organization of an open consultation process, so as to receive comments from all involved public and private European Stakeholders
4. Finalization of the SRIA based on the outcome of the open consultation

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

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