Implementation Advisory Annex

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Strategic Research and Innovation Agenda 2021-27

European Technology Platform NetWorld2020

"Smart Networks in the context of NGI"

Annex – Summarized advisory view for implementation

2021

For public dissemination

Overview

The NetWorld2020 European Technology Platform (ETP), an organisation representing more than 1000 entities, is 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 5G Infrastructure Association (5G-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 this reference document – the Strategic Research and Innovation Agenda (SRIA)[1].

The SRIA is a long and extensive document that defines and discusses in detail a number of crucial research problems to be addressed in the relevant technology areas. In order to provide a simplified view to help the design of the upcoming workprogramme(s), this annex provides an auxiliary addition to the SRIA, **highlighting in a tabular format some of the priorities and suggesting potential funding mechanisms to the different areas** identified in the main document. This summarized version was built by the editorial team of the SRIA, helped by representatives from 5G-IA, AIoTI and NESSI. Details and explanations to each individual topic can be found in the main SRIA document, which, in case of all doubts, should be used for clarification.

For this Annex, the key reference program considered is the upcoming initiative on Smart Networks and Services (SNS), and the key relevant sections inside SRIA for each topic in the table are identified (note that the topics identified in the table are not necessarily the only topics in the SRIA, and the single purpose of this Annex is to provide a fast insight on the technical details behind the specific summarized topic in the table). The SNS initiative has the ambition and potential to address simultaneously two different evolution tracks: an **evolutionary path**, dedicated to evolve current ideas and technologies to retain European competitiveness for the 2024-25 timeframe, in a Beyond-5G strategy; and a **ground-breaking path**, dedicated to the development of more fundamental work to capacitate Europe to perform a technology step for the 2027-30 timeframe, in a 6G strategy[2]. Furthermore, as communications become increasingly embedded in society, it becomes more multidisciplinary, and the **required research to improve communications system increasingly depends on evolutions in different areas**. This document suggests some of the dependencies (and coupled innovations) that will need to be considered across areas of relevance to future communication systems. Moreover, in general, all topics associated with specific use-cases should be implemented by harmonized efforts with program calls in other partnerships (or open calls). Some suggestions for **joint projects with other countries** (Brazil, China, Japan, Korea), in a similar context of past intercontinental calls, have also been made, after informal discussions with representatives from those blocks.

Nevertheless, this Annex is not exhaustive, as it depends on the future funding structures in Horizon Europe, and, as such, some of those potential relevant areas are simply identified in large lines, with the details on the specifics of the funding programmes to be worked out later; in case one of those areas would not have a specific funding mechanism, open calls should be considered to overcome the technological gaps, which will then appear. For several technology challenges, the selection of the programme to fund is not clear at this time (and in many cases, probably several programs should fund the research challenge, from different perspectives). **Work will be required to harmonize research efforts in different initiatives**, both with the European Commission and with other initiatives.

As soon as the funding situation for Horizon Europe becomes clearer, a second version of this document will provide more detailed information on priorities of implementation, if the overall funding envelopes per year are known. At this moment, the document already suggests some more

[1] https://bscw.5g-ppp.eu/pub/bscw.cgi/d367342/Networld2020%20SRIA%202020%20Final%20Version%202.2%20.pdf

[2] This is represented in the SNS discussion document along the lines of the so-called development Streams A and B.

immediate calls, given their very fundamental structuring nature. Given the delays in funding in Europe, it is becoming probable that new updated versions of this document will be overlapping with the expected updated versions of the main SRIA document, to be started this year. Nevertheless, the staging of topics (and of perspective in those topics) is an issue that needs to be tackled in more detail when designing the different (bi-)yearly workprogrammes, in SNS and other Cluster 4 initiatives. Networld2020 will remain available to contribute to these discussions in the future and will continue to strive to provide long-term technological consistency.

In summary, the added structural points to be considered for the design of an European R&D plan for leadership in communications are:

- The topics identified could be implemented considering one of (or both) the perspectives: evolutionary or revolutionary.
- Many topics require multidisciplinary efforts and should be aligned across different R&D funding initiatives, at both the European and national levels.
- Several topics would benefit from intercontinental cooperation, providing early alignment of ideas and directions across the world.
- Funding of several topics should be staged, but the delays at the beginning of the workprogramme will probably impair effective staging planning for its first two years.

Note: colours in the following table simply identify visually SNS topics which are predominantly groundwork for the future (targeting 6G systems), topics which are mainly evolutionary (focusing on 5G evolutions), and topics which will need to address both aspects typically different technological choices, at different maturity stages, for these two different technological ambitions). Areas inside other programs are kept in white.

Area of intervention	Research on:	Key funding mechanism	Complementary funding mechanisms
Human Centric Services			
Software and service engineering (3.4, 3.5)	Improve software development so that they best support SNS ecosystems, with service-based architectures in network slicing frameworks, and addressing the heterogeneous compute continuum across the distributed cloud infrastructure of SNS and its extension to include IoT devices,	SNS – groundwork SNS - evolutionary	**Software program**
Extreme Automation and Real-Time Zero-Touch Service Orchestration (3.6)	Develop technologies able to provide enhanced policy management (including huge data analytics, Artificial Intelligent and cloud-native management and serverless approach)	SNS – groundwork SNS - evolutionary	**Software/Big Data programs**
Engineering software intensive systems (3.4 and 4.3)	Create Software engineering methods able to handle situations where interconnected services are not known in advance, and able to model consequences (e.g. “digital twins”) that may have a legal or ethical dimension, including co-creation models for new software intensive technologies to enhance human-centricity and interaction capabilities of SNS based services and applications, and AI to support the evolution of DevOps methods that meet ethical, legal,social, economic and energy-efficiency requirements as they evolve in the presence of new input data.	SNS – groundwork	**Software/Big Data/AI programs**
Building digital trust into SNS infrastructure and SNS- based services (3.3 and 8.2)	Develop mechanisms to verify data authenticity and truthfulness (e.g. smart contracts, fact checking services based on AI), along with trusted digital interactions, especially in dynamically- composed service environments, including: - software engineering methodologies and tools providing trust anchors - software engineering methods to support cost-effective certification procedures in dynamically changing systems	SNS – groundwork	**Security/Software programs**
System Architecture			
System Architecture Vision: Towards Smart Green Systems (4.2, 4.5)	Develop future ICT as a holistic system that combines the problem of data communication with that of distributed computing, transforming the existing infrastructure from the best effort Internet to a sustainable, greener Intercompute system. In this endeavour, address the needs of service developers and end users (e.g., focus more on time-to-market and continuous functional improvements and the desire to collect increasing volumes of data to facilitate the use of AI), while maintaining the craftsmanship necessary to provide optimized and energy-efficient infrastructures, as well as software foundations and tools, in a design-to-cost and design-to-energy efficiency manners.	SNS – groundwork SNS - evolutionary	

Virtualised Network Control for Increased Flexibility (4.3)	Research on the general problem space of Intercomputing through an autonomic, distributed, adaptive approach to resource control, including resource pooling, service request scheduling and conflict resolution.	SNS - groundwork	
Re-Thinking the Data & Forwarding Planes Design (4.4)	Explore functional extensions of the basic transport mechanisms to overcome known limitations of the current TCP/IP model, with aspects related to guaranteed packet delivery, increased dynamics in network topologies as well as compute resources and the resulting required flexibility in routing, while also considering security and precision delivery as explicit goals.	SNS – groundwork SNS - evolutionary	**Security program** – Fast distributed security trust models **China-EU calls**
AI/ML-based System Evolution (4.6, 5.9)	Research to natively integrate AI/ML mechanisms to implement adaptive decision making at different time scales. This implies explainable and system-integrated AI, dynamic retraining on system change, and reliable self-adapting software and systems to avoid unexpected effects	SNS – groundwork SNS - evolutionary	
Proliferation of AIaaS in NetOperations (4.6)	Research on strongly distributed AI/ML instrumentation integrated at the resource layer	SNS – groundwork	
AIaaS Proliferation in Service Provisioning (3.6 and 4.6)	Development of training data, AI security and comprehensibility of ML.	SNS - groundwork (obtaining training data)	**AI/data analytics program** - comprehensibility of ML **AI/security programs** - security for AI
Deep Edge, Terminal and IoT Device Integration (4.7)	Development of system architectures able to span all types of resources, regardless of their nature (compute, networking), realization (virtual/physical) and position (remote/local), dynamically adding and removing resources as they come and go (churn). Architecture should cope with terminals and IoT domains, which are to be considered full-fledged resources, allowing to deploy services at the deepest possible "edge" and in the direct user vicinity.	SNS – groundwork	
Frictionless optimization on compute continuum (4.3, 4.7)	Develop frictionless optimisation across cloud, edge and fog platforms in order to meet application requirements (e.g. according to specific verticals requirements) for latency and performance, and to meet operators' and verticals' requirements for efficient utilisation of resources (in terms of cost, energy, CO2, etc…).	SNS -- groundwork SNS - evolutionary	
Edge Computing and Meta-data			
Computing platform technologies (5.5)	Develop efficient containers and container orchestration, with reliable software virtualization, with fast instantiations and mobility	**Software program**	SNS – groundwork, for containers in SBA

SNS Groundwork (later reach into market) (earlier reach into market) SNS Evolutionary

Edge AI (5.9)	Research on distributed edge AI solutions, covering consensus convergence, resource limitations, and localized data management.	SNS - groundwork	**AI program**
Distributed services (5.7)	Open distributed edge computing architectures and implementations for IoT and integrated IoT distributed architectures for IT/OT integration, heterogeneous wireless communication and networking in edge computing for IoT, and orchestration techniques for providing compute resources in separate islands	SNS -- groundwork SNS - evolutionary	**Specific calls in vertical domains** (energy grid, transportation, …)
NFV/SDN orchestration (4.5 and 5.7)	Develop orchestration architectures going beyond virtualization, using a range of programming abstractions (covering individual and aggregate resources) to achieve the benefits for agile, automated composition and management of resources, including models for devices interacting with the physical world (sensors and actuators) and quantum information processing	SNS - evolutionary	**Korea-EU calls**
Radio Technology and Signal Processing			
Terahertz Communication (6.4)	Develop Terahertz communications in a staged manner. The relevant channel measurements and models should be considered first, followed by the transmission technologies (waveform, modulation, massive MIMO), and then by higher layer networking protocol design	SNS - groundwork	**Materials/electronic programs** **Open calls** (immediate) **Korea-EU calls**
Radio Building Blocks (most of chapter 6)	Perform fundamental work in multiple technology building blocks, both for cellular and short range communications: - Spectrum Re-farming and Reutilisation - Massive and Ultra-Massive MIMO - Waveform, Multiple Access and Full-Duplex - Massive Random Access - Coding and Modulation - Full wireless (Millimetre Wave) Systems	SNS – groundwork (Terahertz) SNS – evolutionary (lower bands and short range))	**China-EU calls** (short range)
Positioning and Sensing (6.8)	Develop communication systems with the ability to map the environment, able to realize novel IoT applications	SNS - groundwork	**Open calls** (immediate)
Optical Wireless Communication (6.3)	Develop future terrestrial wireless systems that consider/integrate the infrared and visible light spectrum	SNS - evolutionary	**Photonics/materials programs**
Wireless Edge Caching (6.10)	Develop technologies that fully explores the advantages of edge caching in areas as Coding (e.g., combining edge caching with modern multiuser MIMO physical layer schemes), Protocol architectures (e.g., combining edge caching with schemes for video quality adaptation); and AI/ML based content popularity estimation and prediction, to efficiently update the cached content. Link with vertical-specific applications	SNS - groundwork	**Specific calls in vertical domains** (energy grid, multimedia entertainment, …)

SNS Groundwork (later reach into market) (earlier reach into market) SNS Evolutionary

Optical networks			
Sustainable capacity scaling (7.1)	Expand network capacity beyond the Shannon's and Moore's limits, explore all possibilities in the space and frequency domain, economically and environmentally sustainable.	SNS - evolutionary	**Photonics/materials programs**
New switching paradigms (7.2)	Develop novel switching architectures and new routing protocols, and design new semantic description and information models allowing the control of new devices by SDN control.	SNS - groundwork	**Japan-EU calls**
Deterministic networking (7.3)	Achieve deterministic QoS targets while using function chaining over shared compute and network resources needs to be addressed. Includes hybrid use of electronic and optical switching as well as scalability of guaranteeing deterministic QoS for large number of flows/applications.	SNS evolutionary	**Photonics/electronic programs.** **Open calls**
Optical wireless integration (7.4)	Progress on tighter integration between optical and wireless technologies and a converged network infrastructure using common transmission and switching functions.	SNS evolutionary	
Optical network automation (7.5)	Develop advances in network control, automation, and autonomicity en-route to truly self-driving networks, able to cope with technological advances in optical networks, including increased programmability and remote configurability at the device level.	SNS evolutionary	
Security for mission critical services (7.6)	Address techniques for safeguard network infrastructure against data leakage and unexpected service outages.	SNS - groundwork	**Security programs** **Open calls**
Ultra-high energy efficiency (7.7)	Develop optical technologies in the IT and communications industries to limit the increasing ICT energy consumption.	**Open calls** (immediate)	**Photonics**
Optical integration 2.0 (7.8)	Create new IT and networking devices in which optical, RF and digital electronic functions can be combined, e.g. in multi-chip modules (MCM) comprising highly integrated CMOS dies and high-speed optical engine chiplets on the same package substrate	**Photonics/electronic programs.**	SNS - groundwork
Network and Service Security			
Disruptive Technologies integration (8.1)	Develop new security approaches that cope with: - Virtualization, from basic functions to End-to-End virtual perimeters using slices - Softwarization, making smart usage of flexibility and programmability of orchestrated security closely integrated with orchestrated systems and services, including new cybersecurity strategies such as deception or Moving Target Defense. - Cloudification, "everything as a service", able to define and operate service attributes for security services.	SNS –evolutionary	**Security program** for security fundamentals **Software program** for reliability

SNS Groundwork (later reach into market) (earlier reach into market) SNS Evolutionary

Data centric issues (8.2)	Address data centric specific issues related to the threats raised by the transport of payload flows but also sensitivity of control and management data. Applicability and scalability of data centric technologies such as Full Homomorphic Encryption (FHE), Multi Party Computation (MPC), Zero Knowledge Proof (ZKP), Anonymisation/pseudonymization, data integrity of AI-based process constitute a set of relevant topics	**Security program**	SNS -evolutionary
Operational Security Research directions for System & Services (8.3)	Address the programmability of security and secured programmability, encompassing safe and secured workflows (protocols, API,…), AI life cycle (data integrity, xAI,..), privacy protection, smart orchestration of protection functions, smart orchestration/distribution of attack detection from EDR to the cloud.	SNS –groundwork, to address slicing, autonomous systems, edge and IoT	**Security program** for security fundamentals **Brazil-EU calls**
Lifecycle of smart networks and services (8.3 and 3.7)	Research on holistic approaches to security, spanning the lifecycle of smart networks and services (including vertical support), jointly using secure software engineering and operational procedures to manage risks; develop better tools for 'security by design' and for creation of "safer" code, collaborative methods and run-time tools to manage risks in the face of dynamically evolving requirements and threats, and measures to cope with new developments in areas such as AI and quantum computing.	SNS -- groundwork SNS - evolutionary	**Security program** for security fundamentals **Other (vertical-oriented) programs**, for applied cybersecurity
Security quantification (8.3.1)	Improve methods for quantification of security for communications, to make the users aware of the systems and services used and associated costs.	**Security program** for overall methodologies	SNS –evolutionary, for communications aspects
Green Security (8.3.2)	Advance smart distribution, smart orchestration and frugal usage of security functions to perform energy savings in a landscape where speed of development has been often equal to greedy approaches	SNS - groundwork	
Security as a Service (8.3.3)	Develop security-as-a-service integrated in service-based architecture able to reach the scale required by massive usage of digital services.	SNS -evolutionary	
Disruptive Security Strategies (8.3.5)	Improve Quantum technologies, beyond Quantum Key Distribution towards true Quantum Communication Infrastructure	**Photonics/Security programs**	SNS - groundwork
Distributed Ledger Technologies (8.3.6)	Explore Distributed Ledger Technologies to physical layer (radio, optical, Hardware) applications, and to improve trust in networking components	SNS - groundwork	
Artificial Intelligence (8.3.7)	Explore security techniques using Artificial Intelligence, rule-based, statistical, contextual with reasoning, AI-based disruptive strategies, encompassing at least Deception and Moving Target Defense	SNS – groundwork SNS -evolutionary	**Other (vertical-oriented) programs**, for applied cybersecurity
Human-centric privacy (8.3.8)	Develop Human Centric methods that mitigate the increasing digital society risks, give the control to the user in particular facing potential biased usage of AI, guaranteeing privacy and confidentiality.	SNS - groundwork	**Security program** for security fundamentals

Satellite Communications Technologies			
New multi-dimensional and multi-layered architectures (9.2, 9.3, 9.4)	Develop new multi-dimensional and multi-layered architectures, encompassing space-borne and air-borne flying nodes as well as inter-node communication links, able to provide seamless integration in future communication systems as well as service ubiquity, flexibility, scalability and cost-efficiency. Include concepts of hierarchical constellations, user centric coverage, as well as smart satellites/flying nodes as Edge nodes with storage and computational capabilities to pre-process large sets of information.	SNS - groundwork SNS - evolutionary	**ESA/Space programs**
Smart and software defined Non-terrestrial Networks (9.5, 9.12 and 9.14)	Develop software-based non-terrestrial networks allowing a better orchestration of the architecture resources, resulting in a more flexible and dynamic system with overall better performance and efficiency. Include the concepts of softwarization, disaggregation, and, virtualization at all network levels, including the non-terrestrial segment. Networks architecture configuration, coverage, frequencies and power should be dynamically changeable over time. Implement security mechanisms.	SNS - groundwork SNS - evolutionary	**ESA/Space programs**
New antenna systems (9.9)	Research new antenna designs for seamless integration of satellites in existing and future wireless networks, including low cost flexible beam steering for NGSO satellite constellations as well as federated beamforming based on satellite swarms.	SNS - groundwork	**ESA/Space programs**
Non-terrestrial Networks Radio technologies (9.6, 9.8, 9.10)	Develop a unified air-interface that can provide connectivity in a heterogeneous environment, where users may access the network through terrestrial and non-terrestrial links, and a reconfigurable radio access network that can be dynamically adjusted to changing conditions and requirements and ease the co-existence of different services. Going beyond geographical coverage towards user-centric communications. Include optical communications, new frequency bands, and new spectrum usage paradigms	SNS - groundwork	**ESA/Space programs**
AI for non-terrestrial networks (9.11)	Design of autonomous and intelligent operations at all system levels, taking into account the predictable dynamic of the NT segment, towards zero delay infrastructure reconfiguration, optimum orchestration of the architecture/service resources, network management, beamforming and physical layer optimization.	SNS - groundwork SNS - evolutionary	**ESA/Space programs**
Opportunities for Devices and Components			
Solid-state technologies for Communications (10.1, 10.2))	Research to increase bandwidths with or without carrier aggregation, larger dimension MIMO, cell-free MIMO, extremely programmable radio transceivers, transceivers with strong digital content, full duplex, low phase noise and high linearity. Cover Sub-10GHz RF, Millimetre-wave and TeraHertz	**Electronics program** **Open calls** (immediate)	SNS - groundwork SNS - evolutionary

Active and passive mm-wave and THz radar imaging (10.2 and 6.8)	Research in the field of Location and sensing capabilities, including joint radar and communications, with techniques as agile and wideband beamforming, spatial multiplexing, transceivers for higher spectral efficiencies, better power efficiency, faster data converters, high density digital logic, chip-package-antenna co-design, combination of silicon technologies with III-V technologies	SNS - groundwork	**Electronics and materials programs**
Ultra-low Power Wireless, IoT components and devices (10.3 and 10.10)	Develop devices able to be degradable, battery-free and with spatial awareness. For long autonomy applications, ultra-low power transceivers will be needed, and low eco-footprint will be needed for massive deployment.	**Electronics program** **Open calls**	**Materials program** **Open calls** (immediate)
Antennas and Packages (10.4)	Research in the following areas: antenna and packages at mm-wave and THz, on-chip antennas, metamaterials for antennas, meta-materials for intelligent reflective surfaces and meta-surfaces, cost-quality trade-offs, innovative manufacturing processes (e.g. 3D printing, nano-scale technologies, and other), holographic beamforming.	**Electronics and materials programs**	SNS – groundwork
High-speed Transceivers, Wireline and Optical (10.5, 10.6)	Research in devices for: Radio-over-fibre communication (analog, digital, mixed-signal), multi-Terabaud capable opto-electronic transceivers; optically assisted analogue-to-digital and digital-to-analogue conversion; Ultra low-cost and low-power coherent "lite" transceivers, supporting high spectral efficiency complex modulation, for short distances; Integrated low linewidth laser sources; Integrated optical phase locked loops; Novel equalization approaches relying on co-developed opto-electronics; Optically assisted wireless subsystems; Surface Wave Transmission Line Communication System, ultra-broadband optical modulators and demodulators, Monolithically integrated optics and electronics	**Photonics/electronics programs**	SNS evolutionary
Processors for Cloud-AI (10.7)	Develop processors capable of handling very complex learning algorithms for convergence; Low latency, efficient accelerators for small batches.	**AI/HPC programs**	**Electronics Program**
Processors for AI and on-device-AI (10.7)	Address processors able to handle: Extreme quantization, In-Memory Compute; Lifelong learning abilities; Unsupervised learning; Processor/sensor integration and distributed learning., neuro-morphic computing, spiking neural networks with power savings.	**Electronics Program**	**AI/HPC programs**
Hardware for Security (10.9)	Key research areas are as follows: - new HW mechanisms with graceful degradation under attacks, automated recovery of security, guarantee of critical services. - insure security against future quantum-based attacks. - security in long life-time systems, security for 20+ years with minimal maintenance cost. - AI HW with security and privacy support; decentralized/federated AI training systems with strong privacy guarantees for the decentralized data.	**Security and electronics programs**	SNS – groundwork **Photonics program (post-quantum)**

SNS Groundwork (later reach into market) (earlier reach into market) SNS Evolutionary

Memories (10.8)	Realize efficient memories for processing across the whole memory hierarchy of a processor, storage and low-power embedded. Key research areas include compute-in-Memory, different semiconductor technologies including DRAM, SRAM, MRAM ,etc... leveraging technology scaling, 3D integration, materials/technology, circuit/architecture, tools/compilers. New concepts are emerging and need further research such as DNA storage	**Electronics and materials programs**	
Emerging Technologies and Challenging Trends			
Nano- and Bio-Nano Things (11.1.1)	Explore radical new mechanisms for short range networks, in different contexts	**Open calls** SNS - groundwork	**Electronics/materials programs**
Quantum Networking (11.1.2)	Investigate new quantum networking technologies, leading to effective usage of quantum communications into networking.	SNS - groundwork (system level)	**Photonics/Security programs** (key distribution, devices)
AI/ML for the Physical Layer (11.1.3)	Develop new AI/ML mechanisms for the optimization of the physical layer, using both online and offline strategies	SNS – groundwork SNS – evolutionary	
DSL (11.1.4)	Investigate technologies that expand the current limitations of cabled media.	SNS – groundwork SNS – evolutionary	
Air Mobility Network (11.1.5)	Develop systems able to provide reliable communications to the Air Mobility Network, a new network serving all the “things” between the ground and 20 Km height.	SNS - groundwork	**Open calls**
Impact of IoT on the Network (11.2.2)	Develop seamless integration of existing platforms with multiparty IoT resources, in particular aspects that reflect on citizens’ quality of life.	SNS – groundwork SNS – evolutionary	**Specific calls in vertical domains** (energy grid, transportation, …) **Brazil-EU calls**
Impact of Blockchain on the Network (11.2.3)	Investigate the integration of DLT (specially permissioned blockchains) as Internet extensions	**Security program**	SNS - groundwork
Evolution of Protocols (11.2.4 and 11.3.1)	Research new protocols for radical Internet redesign, for new scenarios and requirements (ultra-low latency, extreme mobility, integration of end-terminals, controlled security)	SNS - groundwork	
Smart Living Environments (11.2.5 and 11.3.3)	Develop local/global architectures able to perform the integration of new localized environments in a intelligent ICT infrastructure	SNS – groundwork SNS – evolutionary	**Electronics program**