

6GStart

Milestone 2

“Publication of an updated Networld Europe
roadmap for smart connectivity”

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1. Executive Summary

This document presents the results obtained for M2 milestone “Publication of an updated Networld Europe roadmap for smart connectivity” as well as explaining the procedures adopted to achieve it. Overall, the document focused only on changes over the existing documentation.

2. Introduction

The M2 milestone is the result of the mapping procedure, between the research challenges stated in the “SRIA 2022 Technical Annex” document (as well as the tables presented in the “SRIA Whitepaper”) and the objectives stated in the “SNS Work Program 2021-2022” and “SNS Work Program 2022-2023” documents. Informal information on approved projects has also been used to clarify the technical aspects on many topics.

The “SRIA 2022 Technical Annex” document discusses concepts and technologies essential for developing innovative services. The diversity of technological domains required for future communication infrastructures highlights the relevance of multiple innovation domains for European Research. In this document we have nine different domains:

- **System Services** – overall system tradeoffs that need to be considered for the future, posing the stage for technological development.
- **System Architecture** – analyzing the evolution of systems towards dynamically composed, multi-stakeholder environments, with an increasing softwarization and intelligence of the whole system, and the accompanying challenges.
- **Network and Service Security** – discussing the paths on the increasingly relevant aspects of security in our infrastructure.
- **Software Technologies for Telecommunications** – addressing the software related challenges of the ongoing network softwarization, the increasing system complexity, and the enabling of adaptive and customized services.
- **Radio Technology and Signal Processing** – where the challenges and potential solutions perceived for the future wireless (and mostly cellular) communications are discussed.
- **Optical Networks** – a critical component of the backbone (amongst other potentialities) and its perceived evolution.
- **Non-Terrestrial Networks and Systems** – discusses the upcoming closer integration of 3D networks into the overall communication system.
- **Opportunities for Devices and Components** – tackles the unavoidable challenges at the fundamental element level, which will constrain and limit all system developments.
- **Future Emerging Technologies** – discussing promising technologies that may bring structural changes across all the current communication concepts. Some of these technologies are already being researched but have not yet a clear path (if ever) to the transformational impact it is expected by their wide adoption.

For each of the previous domains there is a set of identified research challenges.

The mapping procedure stated above is the verification if each one of these research challenges exists in the SNS Work Programs. If the SRIA 2022 research challenge is found in the SNS WPs then it will be declared in M2 “SNS WP Topic” column.

The M2 “Timeline (Based on WPs)” column will be:

- Short-term 2025 - if the research challenge is in SNS WP 2021-2022,
- Short-term 2026 - if the research challenge is in SNS WP 2022-2023,
- Short-term 2025-2026 - if the research challenge is in both SNS WPs.

The M2 “Time” column is the number of years needed to fulfill the research challenge identified in the SRIA 2022 Technical Annex document. This is the real changes proposed to the WP, identifying the outcome of the technical analysis.

Next table shows a small example of the mapping procedure.

SRIA 2022 Domain	SRIA 2022 identified challenge	SRIA 2022 key expected outcomes	SNS WP topic	Timeline (Based on WPs)	Time
Optical Networks	Tuneable low phase noise (PN) generation of frequency references for clock and radio frequency. up to the THz range based on integrated photonics schemes.	Integrated photonic based solution for generation of high radio frequency with extremely high accuracy	Included in WP23-24, under STREAM-B-01-03: Communication Infrastructure Technologies and Devices in topic Packet optical technologies for 6G radio networks.	Short-term 2026	(+1 year)

3. Proposed Changes

This section analysis the proposed changes to the SRIA timings, in function of the analysis performed, and presents the proposed timechanges in the SRIA plan.

3.1 System Services

SRIA 2022 identified challenge	SRIA 2022 key expected outcomes	SNS WP topic	Timeline (Based on WPs)	Time
Scopes	Coherent approach to sensing, controlling, storing, and acting; feasible to use via microservice chains/chains of network functions.	Not Included		(+1 year)
Architectural tenets	Find minimal deployable architecture sets and means to extend them as necessary.	Not Included		(+2 year)
Forming and emerging a network	Make adaptation or reconfiguration a first-class citizen with proper interfaces	Not Included		(+2 year)
Providing access	Network architecture that does not distinguish between user vs. network.	Not Included		(+1 year)
Guarantees and flexibility	Tuneable options to select guarantees vs. levels of statistical multiplexing (e.g., at the granularity of "slices")	Not Included		(+2 year)
Negotiations	Develop negotiation and billing mechanisms for a network-of-network, extending to all types of resources and different cost types	Not Included		(+1 year)
Trust and values	Work with systems that are inherently not trust-worthy; make trade-offs and risks more explicit. Deal with incompatible value systems.	Not Included		(+1 year)
Governance	Evolve and possibly converge governance models of different networks (Internet, cellular); find compromises between different value systems.	Not Included		(+2 year)

3.2 System Architecture

SRIA 2022 identified challenge	SRIA 2022 key expected outcomes	SNS WP topic	Timeline (Based on WPs)	Time
Articulation of needs and provisions from the system to the user/applications (EXP)	<p>-Protocols, algorithms, architectures and solutions for user-to-system interface, i.e. exposing available resources and capabilities to the user applications and getting requirements from user applications explicitly or implicitly.</p> <p>Final solutions:</p> <ul style="list-style-type: none"> -Supporting legacy applications as much as possible, including solutions for support of applications that use traffic encryption; -Reusing (extending, integrating, mimicking, maintaining compatibility to) existing methods, where applicable, such as network exposure, ETSI MEC, etc. -Allow runtime negotiations with compatible, novel applications. 	Not Included		(+2 year)
AI/ML driven system updates and evolution (self-updates)	<p>Evolutionary and automatic adjustment and development of Network and Service Functions.</p> <p>Final solutions should demonstrate a creation of a novel NF type from a stub or e.g. by combining modules from an existing library by AI/ML methods based on the expected features and KPIs.</p>	Included in WP22, under STREAM-B-01-02: Wireless Communication Technologies and Signal Processing in topic Wireless Edge Caching	Short-term 2025	(+1 year)
IoT architecture	<p>A suitable architecture to be executed within the general resource pool as per Section 3.2, customized for the particular needs of IoT, providing:</p> <ul style="list-style-type: none"> -Not only individual management of millions of heterogeneous often constrained devices, balancing the needs of the respective organization (efficiency, security, governance) and concerned users/objects (privacy), but also management of collaborative services and tasks executed by the latter. -Efficient, adaptive, runtime communication environment for particular ultra-dense wireless environments with a capable, multi-modal delivery model. -Efficient, adaptive, runtime edge computing and swarm intelligence. 	Not Included		(+2 year)

3.3 Network and Service Security

SRIA 2022 identified challenge	SRIA 2022 key expected outcomes	SNS WP topic	Timeline (Based on WPs)	Time
Data Security in relation to exogeneous Impact	Assurance for systems depending on 6G systems and Services enabling smart and innovative applications. [KPI] Dependability on 6G data transport 2028: partial mapping of exogenous systems requirements onto 6G 2031: 6G systems & services commitment to most of required guarantees	Not Included		(+2 year)
Root Cause and Identification	Defense against ever growing sophistication of all types of attacks	Included in WP23-24, under STREAM-B-01-04: Reliable Services and Smart Security in topics: 1 - Cooperative holistic E2E security for 6G architectures, 2 - Physical layer security	Short-term 2026	(+1 year)
Continuous Security assessment	Trust by monitoring of security boundaries up to provable conditions	Included in WP22, under Stream D – SNS Large Scale Trials and Pilots (LST&Ps) with Verticals. Included in WP23-24, under Stream D – SNS Large Scale Trials and Pilots (LST&Ps) with Verticals	Short-term 2025-2026	(+1 year)

3.4 Software Technologies for Telecommunications

No major changes were found.

3.5 Radio Technology and Signal Processing

SRIA 2022 identified challenge	SRIA 2022 key expected outcomes	SNS WP topic	Timeline (Based on WPs)	Time
Advanced methods, and protocols	New radio access node setting up a sub-network serving local nodes: <ul style="list-style-type: none"> - Vertical use cases (e.g. inside a car or robot). - Consumer use cases (smart wearables). - Very low latency, very high reliability, extreme data rates, reduced energy consumption. 	Not Included		Update timing: now
Bespoke RIS technology for OWC	RIS to support mobility in indoor and outdoor scenarios	Not included		Update timing: now
Novel MAC protocols for THz bands	Development of new protocols that go beyond current collision based schemes	Included in WP22, under STREAM-B-01-03: Communication Infrastructure Technologies and Devices in topic Nano-Things Networking. Included in WP23-24, under SNS-2023-STREAM-B-01-03: Communication Infrastructure Technologies and Devices in topic Nano-Things Networking.	Short-term 2025-2026	(+1 year)
Enhanced NOMA	Code design, resource allocation, and receiver algorithms	Included in WP22, under STREAM-B-01-02: Wireless Communication Technologies and Signal Processing in topic New Waveforms, Random and Multiple Access. Included in WP23-24, under STREAM-B-01-02: Wireless Communication Technologies and Signal Processing in topic New physical layer technologies up to millimeter wave	Short-term 2025-2026	(+1 year)
Physical layer security	Physical layer security as well as ML based techniques to combat the increased number of potential threats and cyberattacks to secure both users and networks	Included in WP23-24, under STREAM-B-01-04: Reliable Services and Smart Security in topic Physical layer security	Short-term 2026	(+1 year)

3.6 Optical Networks

SRIA 2022 identified challenge	SRIA 2022 key expected outcomes	SNS WP topic	Timeline (Based on WPs)	Time
1 Petabit/s over 1000 km in a long haul cable Overcome next major milestone of system capacity	*Provide mix of technologies to meet the goal, and design rules, including compensation of impairments. *Achieve 2Tbit/s per lambda in 5y	Included in WP22, under STREAM-B-01-03 as a topic titled Flexible Capacity Scaling.	Short-term 2025	(+1 year)
Switching architectures with optimized mix between optics and electronics for energy-efficient networks		Included in WP22, under STREAM-B-01-03: Communication Infrastructure Technologies and Devices, in topics: 1 - Flexible Capacity Scaling, 2 - Ultra-high Energy Efficiency. Also included in WP23-24, STREAM-B-01-03: Communication Infrastructure Technologies and Devices in topic Packet optical technologies for 6G radio networks.	Short-term 2025-2026	(+1 year)
Tuneable low phase noise (PN) generation of frequency references for clock and radio frequency. up to the THz range based on integrated photonics schemes.	Integrated photonic based solution for generation of high radio frequency with extremely high accuracy	Included in WP23-24, under STREAM-B-01-03: Communication Infrastructure Technologies and Devices in topic Packet optical technologies for 6G radio networks.	Short-term 2026	(+1 year)
High-bandwidth density solutions for the distribution of optical signals inside an antenna system	Solutions for the distribution of optical signals in an antenna system based on the co-packaging of heterogeneous technologies (RFIC, TIA, PD, optical waveguides, etc.) in the same device	Included in WP22, under STREAM-B-01-03: Communication Infrastructure Technologies and Devices in topic Integration of Optical and Wireless Technologies. Also included in WP23-24, under STREAM-B-01-03: Communication Infrastructure Technologies and Devices in topic	Short-term 2025-2026	(+1 year)

		Integration of Optical and Wireless Technologies		
MIMO systems based on low noise optical amplification	Integrated optical amplification to provide high Tx or Rx in antenna systems based on optical generation and distribution of radio signals	Not Included		(+3 year)
Agile operation Application of DevOps principles and IT practices for network management. This includes cloudification of OSS/BSS, adoption of open-source projects and frameworks, application of Continuous Delivery/Continuous Integration, Improved workflow automation, network optimization and development of an ecosystem of suitable automation applications. Unified short-term provisioning and long-term network-planning, with closed loops at different timescales	Novel network automation application ecosystem. Common software frameworks for unified short-term provisioning and long-term planning and dimensioning. Open interfaces for 1st party and 3rd party applications (e.g., resource allocation and function placement)	Not Included		(+2 year)
Network Domain Automation via i) AI/ML assisted decision-making processes and issuing recommendations and ii) improved resource allocation and function placement algorithms. Network Domain Automation via AI/ML with Direct Control, truly autonomous networks Network Automation via AI/ML in Cross-domain settings addressing challenges related to trust, security and optimality. Predict and/or replicate network behaviour based on potential events and actuations	Recommendation based / Direct Control Closed-Loop network automation. Digital Twin Implementations for Optical Networks and Systems with different levels of abstraction, modularity, and reusability. KPI: Increased resource efficiency, reduced blocking probability or improved energy efficiency; >25% of OpEx savings compared to manual operation; Reduced time to deploy services in cross-domain scenarios over an order of magnitude shorter than current static practices. Improved prediction of network outages and service impact; Reduced rate of	Not Included		((+2 year)

	reconfiguration errors; More efficient network planning and capacity upgrades			
<p>Flexible E2E optical networks</p> <p>Current optical networks are divided into too many domains that require the usage of different OEO conversion stages.</p> <p>Programmable Integrated Photonic Processing hardware</p> <p>Introduce new Optical Node and Transceivers</p> <p>Architectures that are fully dynamic and configurable to support intelligent on demand processing of traffic in an optimized manner.</p>	<p>An ecosystem of devices and components to create E2E flexible optical networks.</p> <p>Highly scalable and flexible, same E2E technology.</p> <p>KPIs: (I) reduction of 50% of the transceivers</p>	Not Included		(+3 year)
<p>Zero-electronic waste and scalable optical networks</p> <p>Current optical networks are not multi-generational.</p> <p>When a new generation is introduced, old and low-speed transceivers cannot talk to newer and higher-speed ones.</p> <p>Need to introduce network architectures and device technologies that are scalable and configurable for that to allow network upgradability.</p> <p>Basic building-blocks of past high-capacity backbone networks/systems may be reutilized in the future in lower performance access/short reach infrastructures (in line with the concept of Cyclic-Economy).</p>	<p>A comprehensive strategy to realize fully scalable optical networks.</p> <p>KPIs: (I) 0.15 W/Gbps, a 90% reduction respect to 100G / wavelength platforms in data centers and their interconnect.</p>	Not Included		(+2 year)
<p>Integration of optical interconnects between electrical processing modules on a chip</p>	<p>Optical interconnections on a chip using multiple material systems including on-chip mode matching / spot size converters</p> <p>Electro-optical interconnection on the same chip allowing monolithic co-</p>	<p>Included in WP23-24, under STREAM-B-01-03: Communication Infrastructure Technologies and Devices in topic Integration of Optical</p>	Short-term 2026	(+1 year)

	integration of RF electronics and photonics KPI: Energy consumption < 10 ⁵ eV / bit Interconnect loss <0.5 dB/facet	and Wireless Technologies.		
Optical layer multi-tenancy in access networks	Elaboration of technical additions and design guidelines for enabling optical layer multi-tenancy in fiber access networks, and related business models SotA : N/A	Not Included		(+2 year)

3.7 Non-Terrestrial Networks and Systems

No major changes were found.

3.8 Opportunities for Devices and Components

SRIA 2022 identified challenge	SRIA 2022 key expected outcomes	SNS WP topic	Timeline (Based on WPs)	Time
Faster (>>1Gsps) and higher resolution converters (DACs and ADCs) at low power	Mix of solutions: architectures, circuits, silicon technology node	Included in WP23-24, under STREAM-B-01-05: Microelectronics-based Solutions for 6G Networks	Short-term 2026	??
Semiconductor technologies CMOS, BiCMOS, III-V	Affordable semiconductor technologies for different market volumes	Not Included		(+2 year)
Architecture and processor trade-offs (TPU, GPU, CPU, DSP, ASIC, FPGAs, ASIPs,...)	Powerful and Efficient DSP implementation solutions adapted to a broad range of use cases, from simple IoT device to complex base station	Not Included		(+2 year)
Semiconductor technologies (CMOS scaling towards 1nm and beyond)	New technologies such as GAA nanosheet, GAA forksheet and complementary FET to extend Moore's law beyond 1nm	Not Included		(+3 year)
Processors for Cloud-AI, Edge-AI and on-device-AI	Powerful and Efficient AI processors and memories fitting the energy budget at cloud, edge or device. Innovative architectures such as in-memory compute and spiking neural networks	Not Included		(+2 year)

Memory technologies towards the yottabyte area	Technologies with increasing densities for all levels of the memory hierarchy (registers, L1 to L4 cache, DRAM, NAND, storage and cold storage)	Not Included		(+3 year)
Technologies for In-memory computing	More efficient AI	Not Included		(+2 year)
Long-term security	Long-term Security Maintenance, Fail-Security + Survivability under Major Attacks, HW Security Roadmap towards Post-Quantum Secure Systems	Not Included		(+2 year)

3.9 Future Emerging Technologies

SRIA 2022 identified challenge	SRIA 2022 key expected outcomes	SNS WP topic	Timeline (Based on WPs)	Time
Enabling human centric multimodal communications and services (eXtended Reality and holographic telepresence) and the respective multimodal traffic requirements particularly for teleoperation demands high-rate for XR traffic and low-latency robust link for the haptic feedback control.		Included in WP22 under STREAM-B-01-04: Secure Service development and Smart Security in topic Human Centric methods ; STREAM-A-01-05: Edge Computing Evolution ; SNS-Stream B - Research for Revolutionary 6G Technology and systems ; STREAM-C-01-01: SNS experimental Infrastructure ; Stream D – SNS Large Scale Trials and Pilots (LST&Ps) with Verticals. Included in WP23-24 under SNS-2023-STREAM-C-01-01: Complementary SNS experimental Pan-EU federated Infrastructure (RIA) and SNS-2023-STREAM-D-01-01: SNS Large Scale Trials and Pilots (LST&Ps) with Verticals	Short-term 2025-2026	(+1 year)
Developing a theory of semantic and effectiveness communications and fully realize in all layers of the communication system	Major increase in communication efficiency	Included in WP23-24 under STREAM-B-01-01: System Architecture in topic New Communication Paradigms with enhanced intelligence.	Short-term 2026	(+1 year)

4. Conclusions

Networkworld Europe will restart the update of the Strategic Research and Innovation Agenda this year. Meanwhile, several actions have led to changes on the existing expectations associated with innovation, which have been required some updates on the existing views. Several topics have to be considered delayed, since they have not been covered during these two days.