6GStart

Milestone 3

Publication of a 2nd updated NetworldEurope roadmap for smart connectivity

Date: 30/04/2024

Document revision history

Version	Date	Description of change	List of contributor(s)
v0.1	04/03/2024	Initial TOC and contributions	Rui Aguiar, José Cabaça (ITAV)
v0.2	19/04/2024	Section 2 and section 3	Rui Aguiar, José Cabaça (ITAV)
v0.3	22/04/2024	Section 4	Rui Aguiar, José Cabaça (ITAV)
v1.0	30/04/2024	Document revision and update	Rui Aguiar, José Cabaça (ITAV)

Table of Contents

LIST OF ABBREVIATIONS

Abbreviation	Explanation
3GPP	3rd Generation Partnership Project
5G	5th Generation mobile network
5GPPP	5G Public Private Partnership
6G	6th Generation mobile network
6G-IA	6G Smart Networks and Services Industry Association
AI	Artificial Intelligence
DIH	Digital Innovation Hubs
CEF	Connecting Europe Facility
ECSO	European Cyber Security Organisation
EU	European Union
FNWF	Future Networks World Forum
IAFA	Impact Assessment and Facilitation Action
IEEE	Institute of Electrical and Electronics Engineers
IoT	Internet of Things
ML	Machine Learning
MWC	Mobile World Congress
NTN	Non-Terrestrial Networks
NWE	NetworldEurope
R&D	Research and Development
SDO	Standards Developing Organizations
SB	Steering Board
SNS	Smarts Networks and Services
SRIA	Strategic Research and Innovation Agenda
TB	Technical Board
VFCS	Visions for Future Communications Summit
WG	Working Groups

LIST OF FIGURES

LIST OF TABLES

1. EXECUTIVE SUMMARY

This document presents the results obtained for M3 milestone "Publication of a 2nd updated NetworldEurope roadmap for smart connectivity" as well as explaining the procedures adopted to achieve it.

2. INTRODUCTION

The M3 milestone is the reflection of the periodic NetworldEurope Strategic Research and Innovation Agenda (NWE SRIA) update. Besides the original NWE SRIA documents for the update we also considered 2 additional documents, the 5G PPP Trials and Pilots and the National Initiatives document. The reports of the multiple events organized by NWE and by 6G-IA are also included. This information is introduced at the level of coordination discussions between the editors of the SRIA update chapters in order to ensure that the results of these documents are properly considered.

3. NETWORLDEUROPE ROADMAP FOR SMART CONNECTIVITY

3.1 NetworldEurope SRIA 2024

The NWE SRIA is currently being updated and it comprises 2 components, the Technical Annex and the Whitepaper. Next a short description of each one of these documents is provided.

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

  - ➢ **System Architecture** – 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 Enablers** – this chapter will address network protocols and network services interfaces. This chapter is a novel introduction over the previous NWE SRIA 2022 document and as such the whole content is completely different from the previously published content on the SRIA.
  - ➢ **Network and Service Security** – discussing the paths on the increasingly relevant aspects of security in our infrastructure.
  - ➢ **Software Technologies for Telecommunications** – addressing the software related challenges of the ongoing network 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.

The NWE SRIA 2024 document is an update of the NWE SRIA 2022 and as such much of the content will be the same, as it is not expected that a document that aims the future in around 10 years will undergo radical changes in the space of 2 years. However, there is a general update in all technical components, and it is worth noting that there is the introduction of a new Network Enablers chapter that will encompass 2 new areas: network protocols and network service interfaces. These 2 areas were identified as relevant areas that were not adequately covered in the previous SRIA 2022 and therefore have to be introduced in this SRIA update. The introduction of these new areas also implies that the Whitepaper itself has to present a global vision of the system, which has to be somewhat distinct. Apart from these major changes, there will be updates in the different chapters, some introducing new technologies such as the introduction of Optical Wireless in the Optical Networks chapter. However, all of this is still work in progress and we expect that the document will be available by the end of July 2024.

- **The NWE SRIA Whitepaper** is a separate document relying on the SRIA Technical Annex. This document will have a different target audience being oriented towards interested stakeholders and not only technical experts. The whitepaper will provide the overall system vision for 6G, including expected performance improvements for the future. This document is expected to be available by the end of July 2024.

3.2   5G PPP Trials and Pilots

The 5G Infrastructure Public Private Partnership (PPP) Programme, encompassing 93 projects, unfolded across three distinct phases: specification, development, and execution of trials and pilots (T&P). By March 2024, almost all of these PPP projects were completed, with just eight remaining in the third phase. Collectively, these projects have contributed to a comprehensive array of advanced European telecommunication solutions and have played a crucial role in propelling the momentum and dynamism for real-world trials and the ongoing evolution of 5G technologies as we transition towards 6G networks. This includes efforts supported by the 6G Smart Networks and Services (SNS) Joint Undertaking (JU).

The focus of the projects in Phases 2 and 3 was to extensively test and implement 5G technology across various sectors such as automotive, industry, media & entertainment, public safety, health, energy, smart cities, and transport & logistics. To this end, five "5G Infrastructure PPP – Trials & Pilots" brochures were published in September 2019, December 2020, August 2021, November 2023, and April 2024.

The most recent Trials & Pilots Summary Brochure serves to encapsulate the extensive work undertaken by the Phase 2 and Phase 3 projects of the 5G Infrastructure PPP. Notably, this summary brochure concentrates exclusively on large-scale trials and pilots (i.e., TRLs 5-6-7), and thus, it does not include information on the realization of proofs-of-concept, prototypes and demonstrators. Nevertheless, it offers valuable insights that are critical for updates in the Strategic Research and Innovation Agenda (SRIA).

In terms of big numbers 5G PPP Trials & Pilots covered:

- 9 verticals
- 23 countries
- 90 cities
- 322 trials & pilots

During the development of the 5G PPP programme, the following verticals and specific areas were targeted:

- **Automotive** - Connected car – V2X, Autonomous driving, Remote assisted driving,

Telematics…

- **Industry -** Manufacturing & Automation (Factory & process automation, In-factory tracking of goods and resources, Telemetry & Monitoring, Zero Defect Manufacturing (ZDM)…), Agriculture & farming technologies, Aquaculture / Aquafarming, Financial Services…

- **Media & Entertainment -** Broadcast services (B2C, B2B2C, Home production), Immersive & integrated Media and Gaming, (Mass) Media production, generation and consumption, Fixed (Home and SOHO) services, Education (MOOCs)…

- **Public Safety -** Emergency communication, Daily first response, Rapid disaster response, Public event management, Critical assets protection and surveillance, Border protection and remote area coverage…

- **Health -** Smart health, Smart pharmaceuticals, Medical emergency management, Hospital administration, Telemedicine…

- **Energy -** Residential/Industry energy management and provisioning, Energy Distribution, Energy Management, Electric vehicles smart charging, Advanced monitoring and maintenance support, Smart metering…

- **Smart Cities -** Public administration, Tourism, Assisted living, People mobility, Smart Building, I2X (traffic lights, sensors…), Education – Smart Campus…

- **Transport & Logistics -** Rail, maritime and aviation, Efficient mobility of people and goods, Mobility as a Service, Smart Ports (incl. Autonomous assets & Logistics and Safety), Smart Roads, Smart Railways Tracks, Smart Airports…

3.3   National Initiatives

This NWE SRIA update will allow us to analyze the progress that has been achieved over the last 2 years. This progress includes developments within European projects but also includes efforts that have been made in national programs. What will be done will be to identify progress in national initiatives, such as some reported and associated with the 5G PPP trials and pilots, and it will be verified which initiatives could correspond to significant changes in what is expected in terms of evolution for the future, whether of technology or timing.

In the next table a summarized set of priority topics for several countries is presented.

Table 1 Summary of top priorities of National 6G Research Plans

	Priority 1	Priority 2	Priority 3	Priority 4	Priority 5
China	Ultra High-Speed Transmission	Massive Connectivity	Integrated Sensing Capabilities	AI-Enabled Networking	Green Communications
USA	Quantum Computing	Secure Comms	Resilient Infrastructure	AI-driven network optimisation	Edge Computing and IoT Integration
Japan	Thz Communications	Advanced AI Integration	Energy – efficient Networks	Quantum Comms Security	Shape Global Standards
South Korea	AR/VR	Holographic Comms	User-centric Technologies	Integrated Healthcare	Smart City Apps
India	Universal Connectivity	Localized Content and Services	Spectrum Management and Allocation	Cybersecurity and Data Protection	Smart Agriculture and Environmental Monitoring
Taiwan	Advanced Semiconductors	Network Slicing and Virtualisation	Mm wave Comms	AI-driven Edge Computing	Robust and Resilient Networking
Australia	Technological Innovation and Research Excellence	Digital Infrastructure and Connectivity reliability/resilience	Cybersecurity and Data Protection	Industry Collaboration and Partnerships	Digital Economy and Socioeconomic Development (entrepreneurship)
Singapore	Smart Nation Initiative	Innovation and Research Ecosystem (technology startups and incubators)	Cybersecurity and Data Privacy	Digital Transformation and Industry 4.0	International Collaboration
UK	Security and Privacy	Green and Sustainable Networks	Open and Interoperable Standards	Digital Inclusion and Accessibility	Edge Intelligence and Federated Learning (AI/ML)
Saudi Arabia	Vision 2030 (economic diversification): Innovation Ecosystem	Technological Innovation and Leadership	Smart Cities and Infrastructure	Cybersecurity and Resilience	Partnerships and collaborations with international partners
France	Cybersecurity and Resilience	AI Integration and Edge Computing	Smart Cities and IoT Integration	Next-Generation Infrastructure	Digital Innovation Ecosystem
Germany	Industrial Applications and Industry 4.0	Autonomous Vehicles and Mobility	Healthcare and Telemedicine	Energy Efficiency and Sustainability	Digital Transformation and Innovation
Finland	Ultra-Reliable Low-Latency Communications (URLLC)	Environmental Monitoring	Connectivity and Remote Sensing in harsh and remote environments	Education and Lifelong Learning	Cultural Heritage Preservation
Spain	Smart Tourism and Hospitality	Smart Cities and Urban Mobility	Healthcare and Telemedicine	Environmental Sustainability	Digital Innovation and Entrepreneurship
Italy	Cultural Heritage Preservation	Tourism and Smart Destinations	Smart Agricultural Innovation	Healthcare and Telemedicine	Creative Industries and Digital Media

In order to achieve each of these identified priorities, a set of requirements must be met. The following table identifies the main topics that must be addressed to achieve these identified priorities.

Table 2 Topics to be addressed to achieve the identified research priority.

Research Priority	Topics to be addressed to achieve the identified priority
Ultra High-Speed Transmission	Advanced modulation techniques, Signal processing algorithms and Novel antenna designs to enable data rates exceeding 1 Tbps.
Terahertz Communication	Ultra-high-speed wireless communication. Signal propagation, antenna design, and spectrum management to realize terabit-per-second data rates over short-range wireless links.
Spectrum Management and Allocation	Spectrum sharing techniques, dynamic spectrum access models, and cognitive radio technologies to enable flexible and spectrum-efficient communication services.
Massive Connectivity	Efficient multiple access techniques, Dynamic spectrum allocation algorithms, and Intelligent networking protocols to support billions of IoT devices and facilitate seamless communication.
Integrated Sensing Capabilities	Enable real-time environmental monitoring, Health tracking, and Smart city applications. Advanced sensor technologies, Fusion algorithms, and Distributed computing frameworks to enable intelligent data processing at the network edge.
AI-Enabled Networking	Leverage AI to optimize network operations and enhance user experience. AI-driven resource allocation schemes, Autonomous network management algorithms, and Intelligent traffic prediction models to improve network efficiency, reliability, and security.
AI-Driven Network Optimization	Leverage AI and ML to optimize network performance, predict user behaviour, and automate network management tasks. AI-driven resource allocation algorithms, dynamic spectrum sharing mechanisms, and predictive analytics tools to improve network efficiency, adaptability, and scalability.
Advanced AI Integration	Enable intelligent resource management, context-aware networking, and personalized services. Developing AI algorithms, ML techniques, and deep neural networks optimized for real-time decision-making and adaptive network control.
Quantum Computing	Developing quantum algorithms, Error correction techniques, and Scalable quantum hardware platforms to solve complex optimization problems, Secure communications, and Simulate quantum-enhanced network protocols.
Quantum Communication Security	Developing quantum key distribution (QKD) protocols, quantum-resistant encryption schemes, and quantum secure direct communication (QSDC) protocols to protect against eavesdropping and cyber attacks.
Secure Communications	Secure communication technologies and cryptographic protocols to protect against emerging cyber threats. Quantum-resistant encryption algorithms, post-quantum cryptography standards, and blockchain-based authentication mechanisms.
Cybersecurity and Data Protection	Secure authentication protocols, intrusion detection systems, and encryption standards to protect against malicious attacks, data breaches, and unauthorized access to sensitive information in increasingly interconnected and data-driven networks.
Resilient Infrastructure	Protect against natural disasters, cyber-attacks, and infrastructure failures. Self-healing network architectures, distributed consensus algorithms, and fault-tolerant protocols to enable uninterrupted service delivery and rapid network recovery.
Edge Computing and IoT Integration	Edge computing platforms, edge analytics algorithms and IoT device management frameworks to support a wide range of latency-sensitive applications, including autonomous vehicles, augmented reality, and industrial automation.
Green Communications	Minimize environmental footprint of 6G networks. Low-power device designs, energy-aware networking protocols, and renewable energy-powered infrastructure.
Energy-Efficient Networks	Reduce power consumption in 6G networks. Developing low-power device designs, energy-aware routing protocols, and sleep mode optimization algorithms to extend battery life and minimize environmental impact.
Augmented Reality (AR) and Virtual Reality (VR)	Enable immersive multimedia experiences and interactive communication services. High-resolution displays, 3D spatial mapping techniques, and real-time rendering algorithms to deliver seamless AR/VR content over high-speed wireless links.
Holographic Communications	Realistic telepresence, holographic conferencing, and interactive collaboration. Developing holographic display devices, hologram compression algorithms, and holographic projection systems to create lifelike 3D images and dynamic holographic scenes for remote communication.
Integrated Healthcare	Remote patient monitoring, telemedicine consultations, and personalized healthcare delivery.

Solutions	Developing wearable health monitoring devices, medical-grade sensors, and AI-driven diagnostic algorithms to support preventive care, chronic disease.
User-Centric Technologies	Context-aware applications, adaptive user interfaces, and intelligent recommendation systems that leverage user behaviour data, environmental context, and social interactions to deliver tailored services and content.
Smart City Applications	Enhance urban sustainability, efficiency, and quality of life. Integrating IoT sensors, real-time data analytics, and intelligent infrastructure management systems to optimize resource allocation, traffic flow, energy consumption, and public safety.
Smart Agriculture and Environmental Monitoring	Enhance productivity, sustainability, and resilience in the face of climate change and resource constraints. Deploying IoT sensors, remote sensing technologies, and AIdriven analytics platforms to enable precision agriculture, water management, soil health monitoring, and early warning systems for natural disasters.
Universal Connectivity	6G network coverage to rural and remote areas to bridge the digital divide and promote inclusive economic development. Cost-effective deployment strategies, NTN and community network models to provide affordable broadband access.
Localized Content and Services	Content and services tailored to the cultural, linguistic, and socioeconomic diversity of its population. Supporting multilingual interfaces, vernacular content creation tools, and location-based services that cater to specific needs of users.
Global Standardization	Play a leading role in shaping global standards for 6G. Define interoperable specifications, performance metrics and regulatory frameworks that ensure compatibility and global deployment.

3.4   6GStart Promoted Events

6GStart partners promoted the relevant project work via the organisation and participation in the following events:

- *NetworldEurope SRIA webinar* (12/01/2023, Online): A webinar to present the NetworldEurope Strategic Research and Innovation Agenda (SRIA 2022), highlighting technologies indicative of the innovations being sought for upcoming Smart Networks and Services calls.

- *ETSI R&D event 202*3 (6/02/2023, Sophia-Antipolis, France): Full support to this event where most of the Phase 1 SNS JU projects presented their focus, targeted outcomes and approach to standardisation.

- *NetworldEurope/CCSA Metaverse WS @MWC 2023* (01/03/2023, Barcelona, Spain): Parallel workshop with MWC 23 entitled "More than GigaBit Broadband & Metaverse on the Move". The workshop was designed to contribute to identifying future innovation challenges that are being posed by the introduction of Metaverse in our society. The workshop featured key speakers from industry and academia, representing the views of manufacturers, operators, and application developers.

- *ETP4HPC event* (08/03/2023, Amsterdam, The Netherlands): Presentation on the process put in place to develop the SNS JU work programs and involve other IT domains, such as HPC, in the call description.

- *Global 6G Conference* 2023 (22/03/2023, Online): Online Keynote Speech on NetworldEurope and SNS JU aspects.

- *A 6G Vision Webinar – What will 6G offer to vertical industries & Future perspectives* (20/04/2023, Online): The webinar was organised as part of the 5G/6G Vertical Users Workshops, whose aim is establishing a collaborative event for strategic dialogue between vertical industries (automotive Industrial automation, health, media industry, security, public safety, energy), SDOs and 3GPP, with a view to exchange requirements, outline issues and obstacles impeding progress, and look at upcoming future standards development.

- *5G Smart Communities launch event* (25/04/2023): This event brought together interested stakeholders from mobile network operators, alternative operators, equipment manufacturers and public authorities to share ideas and insights on ways to achieve Europe's Digital Decade targets for 2030. The event had presentations by DG CNECT and the Commission's

implementing agency HaDEA, with a focus on Europe's Digital Decade targets for 2030, as well as on how the 5G for Smart Communities action under the Connecting Europe Facility (CEF) – Digital programme can contribute to the attainment of these objectives.

- *5GPPP to SNS: Passing the Torch Event* (25/05/2023 – Online & 06/06/2023 – EuCNC'23): Event to pass the torch from the 5G PPP bodies (SB/TB/WGs) to the equivalent/relevant bodies of SNS, where the key achievements and lessons learned where discussed among key stakeholders.

- *IEEE ICC Workshop on AI/ML-driven Autonomous 6G networks* (28/05/2023, Rome, Italy): This workshop was organised by 6G-IA in an attempt to highlight AI-related developments in 5G PPP and discuss the transition to the SNS JU and the 6G era.

- *Global Digital Economy Conference* (06/07/2023, Online): Keynote speech regarding the EU 6G roadmap and strengthening of international collaborations.

- *5G Smart Communities conference* (11/10/2023, Brussels, Belgium): 6GStart partners attended the event to shape Europe's digital future.

- *IEEE 9th World Forum on IoT* (12/10/2023, Aveiro, Portugal): 6GStart partners organised this entire event, with multiple sessions, aggregating interest from multiple EU stakeholders with varied backgrounds.

- *Towards Realistic Usage of AI in 6G Networks Workshop* (06/11/2023, Lisbon, Portugal): Organised by NetworldEurope with support from 6G-START, also hosting the official 5G PPP closing event.

- *IEEE Future Networks World Forum (FNWF)* (13/11/2023, Baltimore, USA): 6GStart partners presented the current status and future calls of the SNS JU and participated in international collaboration events.

4. PUBLICATION PROCESS FOR THE NETWORLDEUROPE ROADMAP FOR SMART CONNECTIVITY

4.1   NetworldEurope SRIA 2024 roadmap publication

In figure 1 we present the documents that are being produced/updated, namely the NWE SRIA Technical Annex and the Whitepaper. We also present the expected dates for the completion of each of these documents. As we can see from figure 1 the Visions for Future Communications Summit (VFCS 2023) held in Lisbon on the 07th and 08th November 2023 was the trigger for the new NWE SRIA update. This led to triggering the formal process of the NWE SRIA update, where the several editors start to write/update their chapters, and we expect to have the NWE SRIA version nº1 available by end May 2024. The next step is to have stakeholder feedback to revise and enhance the 1st draft version, and this will lead to the final version of the NWE SRIA Technical Annex, which will be ready by end July 2024. The NWE SRIA Technical Annex draft versions will also trigger the NWE SRIA Whitepaper's development, which is expected to be available as well by the end of July 2024.
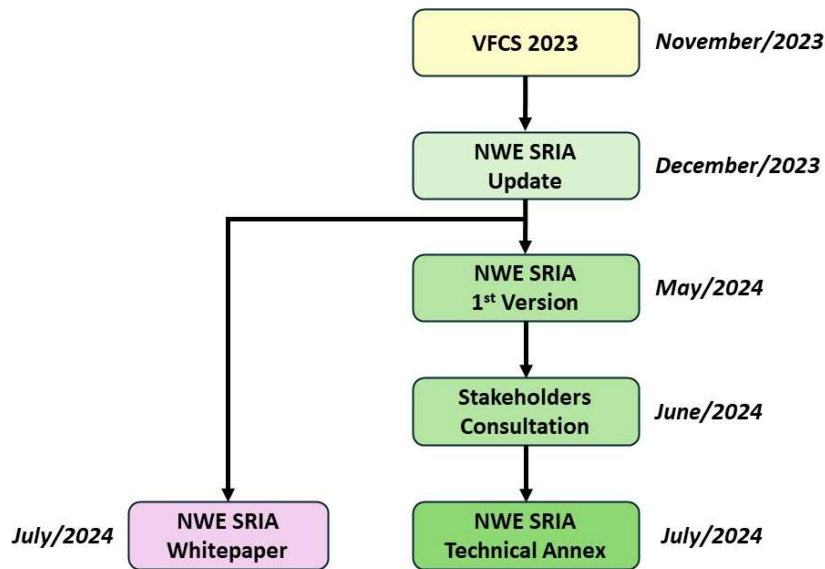
Figure 1 - NetworldEurope SRIA 2024 documents being developed.

4.2 NetworldEurope SRIA 2024 timeline process evolution

In figure 2 we present a timeline with the process evolution in producing the documents and the parallel activities that contribute to them.
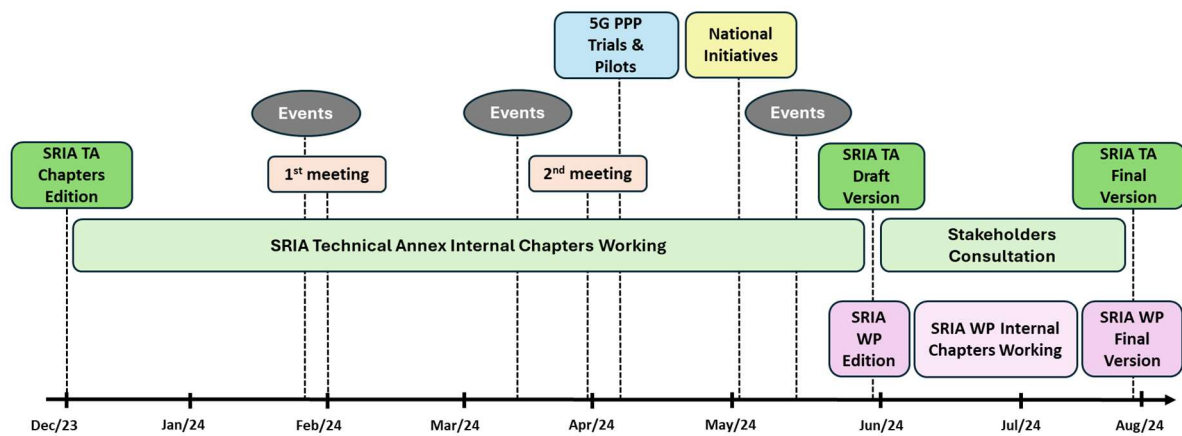

Figure 2 – Timeline process evolution for the NetworldEurope roadmap for smart connectivity

As we can see from the figure 2, and as previously described, the beginning of the process for updating the NWE SRIA 2024 began in December 2023. This was followed by the editing of the various chapters by the respective editors and in May 2024 we hope to have the first version of the NWE SRIA 2024 Technical Annex. A consultation with the various stakeholders will take place and the final document is expected to be ready at the end of July 2024. Upon completion of the first version of the NWE SRIA 2024 Technical Annex, editing of the NWE SRIA 2024 Whitepaper will begin, which will also have an internal edition of the several chapters with the final version expected by the end of July 2024. As we can see, there are also a set of activities running in parallel that contribute to the development of the NWE SRIA 2024 Technical Annex and the Whitepaper. These activities have already been described previously in this document and are the various Events that took place, as well as the documents on 5G PPP Trials and Pilots and National Initiatives.