6G Pre-standardisation: Challenges, requirements and future steps.

Recommendations for researchers, SDOs and policymakers.

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Acknowledgements

We greatly acknowledge the support of the **HSbooster.eu*** and **SNS-OPS**** projects in preparing this document, released as an output of the deep-dive workshop series "IAFA events on pre-standardisation" organised between March and May 2024.

We extend our grateful appreciation to all the SNS OPS partners who helped set up this event series, **David Kennedy, Uwe Herzog, Luitgard Hauer, Audrey Bienvenu** (EURESCOM) and **Jessica Carneiro** (AUSTRALO), as well as all the **project representatives, workshop's participants and panellists** who interacted with the speakers and moderators, exchanged views, shared ideas, and replied to polls and live questions.

Disclaimer

*HSbooster.eu has received funding from the EU's Horizon Europe research and innovation programme under Grant Agreement no. 101058391. **SNS-OPS has received funding from the EU's Horizon Europe research and innovation programme under Grant Agreement no. 101095811.

Funded by the European Union

May 2024 – Version1.0

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Glossary of terms

Abbreviation / Term	Description
AI	Artificial Intelligence
API	Application Programming Interface
CEN	European Committee for Standardisation
CENELEC	European Committee for Electrotechnical Standardisation
CSA	Coordination and support action
DPU	Data Processing Unit
EC	European Commission
ETSI	European Telecommunications Standards Institute
IAFA	Impact Assessment and Facilitation Action
IEC	International Electrotechnical Commission
ISO	International Organization for Standardisation
ITU	International Telecommunication Union
MAC	Medium Access Control
MIMO	Massive multiple-input multiple-output
ML	Machine Learning
NTN	Non-Terrestrial Networks
OTT	Over the top
R&D	Research and Development
SDG	Sustainable Development Goal
SDOs	Standards Development Organizations
SME	Small and Medium Enterprise
THz	Terahertz
TN	Terrestrial Networks
WG	Working Group

1 Introduction

The purpose of this report is to provide a summary of the key findings, takeaways and recommendations from the workshop series **"IAFA events on pre-standardisation"** that took place online on the 12th March, 9th April and 14th May 2024. The workshops were organised by the SNS-OPs and HSBooster EU-funded project.

The events brought together key stakeholders from strategic 5G/6G technical and vertical domains and experts from the policy and standardisation sectors. The workshop aimed to foster collaboration among different sectors and ecosystems, exchange ideas, and drive consensus on current technological challenges and standardisation gaps.

This report and supportive guide have been designed to give thematic-oriented standardisation information on Research and Innovation projects and other parties interested in contributing to the pre-standardisation roadmap to support 6G deployment.

1.1 Purpose of the Workshop Series and Key Takeaways

The main objective of the three online workshops was to provide specific overviews and experiences in standardisation, coming from experts and project representatives of the SNS-JU community, discussing potential solutions to fostering the development of standards and the different mechanisms to accelerate this process. These discussions will support the work and next steps in 6G pre-standardisation.

In brief, the key takeaways from the workshop series, especially with reference to standardisation topics, are listed below:

- **Key message #1 – Early Engagement and Standardisation**
  Emphasise the importance of early engagement in standardisation activities to align 6G research with industry standards services such as the Horizon Standardisation Booster (HSBooster.eu) for effective collaboration.
- **Key message #2 – Advanced Native Features and AI Integration**
  Focus on the challenges of integrating advanced native features and AI into 6G architectures to enhance network efficiency and sustainability, requiring a shift in network solution development and standardisation.
- **Key message #3 – Industry-Specific Solutions and Sustainability**
  Highlight the need for 6G research to be tailored to specific industry needs, addressing the unique challenges of each sector with a strong emphasis on sustainability and energy-efficient technology development.
- **Key message #4 – Multidisciplinary Collaboration and Global Standards**
  Foster multidisciplinary collaboration across various fields, such as AI and cybersecurity, and enhance engagement with global stakeholders to harmonise standards and promote international interoperability.
- **Key message #5 – Regulatory Support and Infrastructure Development**

Advocate for comprehensive regulatory frameworks that support developing and deploying 6G technologies, ensuring safety, efficiency, and global competitiveness while encouraging innovation through supportive policies.

1.2 Purpose of the document

The following sections provide a summary of the presented topics without including too many details, as additional resources are provided to complement the understanding of the presentations (e.g., links to events' recordings and downloadable slides). The main focus of the document is on post-event analysis to suggest specific and practical actions and recommendations for key stakeholders, such as research and innovation projects, Standards Development Organisations (SDOs) and other standardisation bodies, and policymakers.

This initial publication is also intended to kick off further discussions and debates within the communities where it will be shared. Revised versions of this document will be released upon receiving relevant feedback. If you would like to contribute to further refining this publication, please contact c.demajo@trust-itservices.com and m.giuffrida@trust-itservices.com.

2 The event series

The standardisation of 5G and the advancement towards 6G technologies pose considerable challenges, particularly in meeting the diverse requirements of industry verticals ranging from automotive to public safety. Ensuring these technologies and their services align with end-user needs requires a meticulous standardisation process, accounting for the capabilities and performance characteristics vital for different applications. This necessity highlights the importance of collaboration between industry experts and standardisation communities to produce globally recognised standards that facilitate interoperability and enable the full potential of 5G and 6G applications.

The evolution towards 5G Advanced in the shift from 5G to 6G propelled by the Smart Networks and Services Joint Undertaking (SNS JU) emphasises the strategic role of European contributions in shaping the global standardisation ecosystem, a critical factor for maintaining competitive advantage in telecommunication systems and services. The evolution towards 6G is posed to significantly influence business sectors and societal functions, emphasising the need for multi-stakeholder collaboration. In the SNS context, the 6G-IA pre-standardisation working group aims to align with key standardisation bodies to ensure European stakeholders remain influential in the rapidly developing mobile communications landscape.

This online workshop series, organised by SNS OPS as part of its Impact Assessment and Facilitation Action (IAFA) initiative in collaboration with ETSI and HSbooster.eu, tackled relevant topics linked to challenges in standardisation in the context of 5G/6G developments. The events featured the participation of experts sponsored through HSbooster.eu premium service programme and tackled topics such as SDOs' future 6G Agendas, SDOs 6G Work Items, verticals and standardisation, including the advancements and support of services enabled by 5G and 6G.

2.1 6G research and vision

The first event provided information on the initial phase of 6G technology, highlighting the latest research and the future goals for 6G while considering lessons learned from 5G deployments and service evolution. It aimed to address the challenges and opportunities in the early stages of 6G development, discussing the potential applications and innovative aspects that 6G could bring to various industry sectors. Experts shared insights into how 6G could transform communication systems and services and the importance of aligning this new technology with the specific needs of different industries.

Browse the event's agenda and download the slides

2.2 6G standardisation and requirements

The second event delved into emerging 6G standardisation requirements and identified actions intended to harmonise efforts between R&D projects and SDOs, with specific input on European SDOs. Emphasising the importance of collaborative efforts in research and development for 6G, this section aims to foster discussions on how ongoing research projects can contribute to the creation of standards, explore the landscape of standardisation work items, address emerging challenges such as integration between terrestrial and non-terrestrial networks (NTN), network automation efforts and challenges for security.

Browse the event's agenda and download the slides

2.3 6G trials & testing

This third and concluding session explored the relationship between 6G pre-standardisation and large-scale trials, already a central topic of R&D projects under the SNS JU Phase I, specifically from Stream C (SNS Experimental Infrastructure) and Stream D (Large-Scale SNS Trials and Pilots).

Browse the event's agenda and download the slides

The following chapters outline the primary topics and standardisation challenges emerging from the presentations, panel discussions, and debates during the event series. These insights provide specific practical recommendations to support projects, SDOs and policymakers involved in 6G standardisation efforts.

3 Standardisation and R&D Integration in Telecommunications

3.1 Key topics and challenges

- **Opportunities in Standardisation**: Engaging in standardisation offers numerous benefits, including the protection of intellectual property, networking opportunities, gaining early advantage and influencing global standards. These activities provide a competitive edge (both for regions and individual players) and contribute to the broader goals of technological advancement and economic growth. Furthermore, the fast-paced technological evolution would outrun the benefits of the features developed and create a dispersed technology landscape if it were not for standardisation and streamlining.
- **Education and Tools for Engagement**: Provide education about standardisation and offer tools to aid researchers and organisations in understanding how to navigate and benefit from the standardisation landscape. Experts with a multi-stakeholder role (such as one in the industry and one in an SDO or several SDOs) can play a key role in driving this aspect forward.
- **Integration of Standards into Research and Development**: Ensure that research and development outputs are captured in standards, increasing the impact and commercial viability of innovations. This aspect is two-sided: R&D work can lean on standards to be better applicable, and standards can get feeds from R&D results to go on the innovative track.
- **Fragmentation in Standardisation**: The significant fragmentation across different standardisation bodies, each addressing different aspects of network slicing and network functionality, poses a challenge. This fragmentation leads to inconsistencies and potential gaps in the standards that are developed, complicating the implementation of comprehensive, end-to-end solutions in network infrastructure. Here, the various SDOs and their members must work together to reduce fragmentation and encourage convergence of standards.
- **Complex Landscape of R&D and SDOs**: The intricate relationship and the expansive landscape of R&D community outputs with work streams and standards across various SDOs. This complexity stems from the need to synthesise diverse technological advancements and standardisation efforts, which can often be disparate and siloed. Grouping the numerous trends on both sides (SDOs and R&D) into megatrends.
- **Integration of Megatrends into Standards**: How emerging megatrends in technology, such as AI and machine learning, automation, and architectural evolution, need to be integrated effectively into the standardisation process. It is also extremely important to align these megatrends with research agendas and the ongoing work streams within SDOs to ensure that the research aligns with practical applications and standard requirements.
- **Bridging Gaps Between R&D and SDOs**: A significant challenge addressed is the need to bridge the gaps between the R&D community and SDOs. This involves increasing awareness, creating synergies and aligning goals between cutting-edge research outputs and the pragmatic frameworks of standards to enhance collaboration and drive the technological advancements necessary for 6G development.

- **Standardisation Gap**: There is a notable gap between the state-of-the-art technology and the current standards, which impacts the ability to deploy the latest technological advancements in testbeds. This gap exists because the technology available for testing often lags several releases behind the newest standards, creating a delay in utilising cutting-edge solutions in practical applications. The use of early trial and Proof of Concepts during research cycles and at an early stage of pre-standardisation was one accelerator for this.
- **Lack of Reference Implementations**: Many standards lack reference implementations, making it difficult to integrate and test the latest technologies within standard frameworks. This challenge is compounded by the fact that even where standards exist, the adoption and availability of implementations are often limited, further hindering the ability to conduct effective tests and validate new technologies.

3.2 Recommendations for R&D projects

- **Engage Early with Standardisation Bodies**: Researchers should actively participate in standardisation discussions and workshops from the early stages of their projects. This early engagement allows for a better understanding of the standardisation landscape and provides an opportunity to influence the direction of standards development. It also ensures that research aligns with industry needs and compliance requirements. An alignment of objectives of R&D activities and the envisioned standards that will be produced is very helpful.
- **Document and Share Research Outcomes**: Effectively documenting and disseminating research findings can significantly influence standardisation efforts. Researchers should aim to publish their results in accessible formats and platforms, engage in community discussions, and participate in industry specification groups. This visibility not only helps in shaping standards but also in securing funding and support for further research.
- **Innovative Solutions for Operational Complexity**: There should be a concerted effort to develop innovative solutions that simplify the operational complexities associated with multi-domain environments. This includes research into automated systems that can manage and synchronise various network operations seamlessly across the different network layers.
- **Focus on Integrative Research**: 6G research projects should focus on integrative approaches that bring together different technological advancements like AI, automation, and new architectural models. These projects should prioritise cross-disciplinary and cross-sectoral collaborations to foster directly applicable and integrable innovation into standard development processes.
- **Align Research with Megatrends**: Researchers should ensure that their projects align with current megatrends identified by industry and often documented by some SDOs, such as AI and machine learning, automation, and sustainability. By doing so, research outputs are more likely to be adopted into standards and find practical applications in the industry. Megatrends bear a significant market and adoption potential; that is why aligning research objectives with those megatrends helps R&D results make it a long way, even all the way into daily life.
- **Accelerate the Adoption of New Standards**: 6G research projects should focus on developing mechanisms that allow for the faster adoption and integration of new standards into practical applications. This involves creating adaptable testbeds that can quickly implement new technological advances as soon as they are standardised, ensuring that the gap between standardisation and technology deployment is minimised. The standardisation cycle time should

be optimised and shortened in order to leverage the outcome before it becomes outdated through the next development in the same area.

- **Focus on Energy-Efficient Data Processing**: Develop technologies and methodologies that enhance data processing efficiency while minimising energy consumption. This includes the creation of algorithms and network solutions that reduce the energy required for data-intensive operations, which is crucial for powering AI applications sustainably in 6G networks.

3.3 Recommendations for SDOs

- **Enhance Multidisciplinary Collaboration**: SDOs should foster collaboration across various fields such as communications, computing, artificial intelligence, automation, and cybersecurity. This approach can drive the development of comprehensive standards that anticipate and address the complexities of advanced 5G and 6G technologies. Facilitating working groups that include experts from diverse sectors will help in creating robust and adaptable standards.
- **Accelerate Integration of Emerging Technologies into Standards**: As new technologies evolve rapidly, SDOs need to stay ahead by swiftly integrating innovations into standards. This involves proactive engagement with the research community to keep abreast of advancements in fields like quantum computing and AI. Creating flexible standardisation processes that can quickly adapt to new knowledge and technologies will be crucial.
- **Strengthen Engagement with Global Stakeholders:** To ensure the global relevance and acceptance of standards, SDOs must engage with a wide range of stakeholders, including policymakers, industry leaders, academic institutions, and other international SDOs. This broad engagement helps harmonise standards across borders, promoting interoperability and reducing technical barriers to international trade.
- **Prioritise Education and Outreach**: SDOs should actively work to demystify the standardisation process for new entrants, especially from academia and smaller enterprises. Offering workshops, seminars, and online resources about how to engage with standardisation activities and the benefits of participation can increase contributions from these sectors and enrich the standard-setting process. Grouping webinars or seminars into series and structured stories would help foster certain important but complex topics. Without a clear-cut strategy behind it, running seminars and educational sessions on scattered topics is less effective.
- **Promote Cross-SDO Collaboration**: SDOs should work together to create more cohesive and integrated standards that address the entire network stack from end to end, reducing fragmentation. This might involve setting up joint task forces or working groups that focus on creating interoperable standards covering multiple network infrastructure aspects. Stakeholders and individuals active in several SDOs on synergising topics can play a key role in enabling this collaboration.
- **Standardise Operational Procedures**: Develop standardised operational procedures and behaviours for network equipment and functionalities across domains. This includes establishing standards for how different network elements should interact, respond to network events, and manage data traffic to ensure consistent and reliable service delivery.
- **Streamline Integration Processes**: SDOs should streamline processes to integrate R&D outputs into standardisation work more efficiently. This involves setting up structured pathways for incorporating research findings into standards ensuring that the latest innovations are reflected in standard protocols and practices.

- **Adopt Flexible and Dynamic Standards**: As technology evolves rapidly, SDOs need to adopt more flexible and dynamic approaches to standards development. This could involve modular standards that can be easily updated or expanded as new technologies and requirements emerge from the R&D community.
- **Streamline Standardisation Processes**: SDOs should look to streamline their processes to accelerate the development and release of new standards (e.g. AI for standards development and support). Reducing bureaucratic hurdles and increasing the efficiency of standard development can help close the gap between technological advancements and their standardisation.
- **Enhance Transparency and Accessibility of Implementations**: SDOs should work towards making standards and their implementations more transparent and accessible. This could involve creating repositories of reference implementations and providing clear, actionable guidance on how to implement new standards in technology projects and products. Furthermore, synergies and complementarity between the various aspects tackled in various SDOs should be made simpler and easier to track and navigate through.

3.4 Recommendations for Policymakers

- **Facilitate Collaboration Between Industry and Academia**: By fostering environments that encourage collaboration between universities, research institutions, and industry leaders, policymakers can help ensure that research outputs are aligned with market needs and standardisation efforts. This could involve creating innovation hubs or consortia focusing on specific aspects of 5G and 6G technology. This is key in helping innovations from R&D make it into the widely adopted industry standards, making standards accessible to researchers as a basis of their future research work – e.g. free standards as opposed to pay-to-play – which is barely the case today.
- **Develop and Implement Clear Regulatory Frameworks**: Policymakers need to create regulatory frameworks that support the safe and ethical development of emerging technologies. This includes addressing issues related to spectrum allocation, privacy, AI, cybersecurity, and the equitable deployment of technology. Clear regulations can help reduce uncertainties that may hinder innovation and investment in new technologies.
- **Promote International Standards Alignment**: As 5G and 6G technologies will operate on a global scale, it is crucial for policymakers to engage in international forums and standard-setting organisations to ensure that domestic and regional standards are aligned with international global ones. This alignment helps avoid fragmentation and promotes interoperability, enhancing the global competitiveness of their national industries.
- **Promote and Support Collaborative Research Initiatives**: Policymakers should actively promote and financially support collaborative research initiatives that bring together academia, industry, and government agencies. This collaboration is crucial for harnessing a wide range of expertise and resources, fostering innovation that is practical and directly applicable to the challenges of 6G development. Initiatives should encourage the development of standardised solutions that address interoperability and integration challenges highlighted in the transition from 5G to 6G.
- **Support Collaborative Standardisation Efforts**: Policymakers should encourage and possibly fund collaborative efforts among different SDOs to address the fragmentation in network standards. This could involve facilitating cross-SDO dialogues or initiatives that aim to unify

standards across different network segments. SDO collaboration should prioritise complementarity and synergies to avoid work duplication and should go to larger lengths beyond the classical inter-SDO liaisons.

- **Regulations that Foster Interoperability**: Establish regulations that mandate interoperability and common operational procedures across different network domains. This will ensure that different network providers and equipment manufacturers adhere to a standardised approach that supports comprehensive network slicing and other advanced network functionalities.
- **Foster R&D and SDO Collaboration**: Policymakers should encourage and possibly fund collaborative projects between the R&D community and SDOs. This would help ensure that technological innovations are quickly standardised and that standards reflect the latest research insights.
- **Funding for Bridging Technology Gaps**: Policymakers should continuously allocate funds to support the development and deployment of technologies that align with the latest standards. This can help mitigate the gap between the release of standards and their adoption in technology solutions, ensuring that the latest innovations are promptly available for commercial and research use. Relevant examples are the StandICT.eu and HSbooster.eu projects.
- **Support Collaborative Standard Development**: Encourage collaborations between academia, industry, and standard-setting bodies to ensure that the development of standards is closely aligned with the latest research and technological innovations. This collaborative approach can accelerate the standardisation process and make it more responsive to technological advancements.

4 Technological evolution and infrastructure development

4.1 Key topics and challenges

- **Integration and Standardization of New Architectures**: as the telecommunications industry evolves from 5G to 6G. A major challenge lies in determining which architectures to standardise and how various proposed architectures will integrate into a cohesive system. This includes aligning the diverse technological solutions that various stakeholders propose, ensuring compatibility, and facilitating seamless interoperability across different platforms and international borders.
- **Incorporating Advanced Native Features into 6G**: Unlike 5G, 6G aims to integrate native features (e.g. AI and NTN security) related to joint communication and sensing, THz communications, Reconfigurable Intelligent Surfaces, Ultra-Massive MIMO and distributed computing. These innovations present challenges in terms of design, implementation, and standardisation. Ensuring that these advanced features are inherently built into the network architecture requires a paradigm shift in how network solutions are developed and standardised. Even features like basic (AI-like) automation, resource management, and sustainability will become natively supported in 6G. This stems from the learnings in 5G and previous phases, where it became clear that many features do not work if implemented retrospectively "on top" or "over the top" (OTT).
- **Diverse Use Cases Across Industry Verticals**: The application of 5G and 6G technologies across different industry verticals introduces complexity in developing universally applicable solutions. Each sector has unique requirements and trends, making it challenging to design a one-size-fits-all network solution that meets specific needs, such as ultra-reliable, low-latency communications for industrial automation or enhanced mobile broadband for consumer services.
- **Complex Integration of AI with Telecommunication Systems**: The deployment of AI within communication systems to optimise network and infrastructure is critical. However, the integration poses challenges in terms of aligning AI capabilities with telecommunication standards to ensure efficient service delivery, operational efficiency, and cost reduction. This includes transitioning from traditional DevOps to ML Ops to manage the lifecycle and operations effectively, integrating AI at various levels of network operations in a secure environment. The types of AI (such as generative or non-generative), as well as the purpose of using it (such as assistive functions, process automation, workflow and interaction automation, monitoring, enhanced security, etc.), influence the architectural approach and the requirements and interfaces in the system that need to be built or adjusted. Additionally, the following distributed intelligence has been considered:
    - **Parallel Training**: The data are partitioned, and different portions are fed to a set of distributed nodes, which deploy the same model.
    - **Model Splitting**: Different portions of a complex ML model are executed sequentially in different processing nodes. There is a decision on data handling vs ML Deployment.
    - **Federated Learning**: The model is locally trained on its data by distributed devices, and local models are aggregated centrally.

  - **Explainable AI**: It has been designed to explain AI decisions.
  - **Transfer Learning**: Transfer learning regards the sharing of knowledge among different learning algorithms where the learning rate and accuracy can be considerably improved.
  - **Distributed Reinforcement Learning**: Different portions of a complex ML model are executed sequentially in different processing nodes. A learner takes actions in a stochastic environment over a sequence of time steps to maximise the long-term cumulative rewards received from the interacting environment according to a given policy.
- **AI/ML Evolution deployment**: AI/ML evolution deployment started from independent AI/ML (Proprietary AI/ML can be deployed independently either at the network or at the device, where data collection is carried out proprietary) to coordinated AI/ML (Proprietary & standardised ML procedures can be deployed and data are collected for both training and monitoring) towards Native-AI (Autonomous ML deployment between network and devices across all layers, ML procedures to train performance and adapt to different environments and transition from DevOps to MLOps). There are a few challenges towards the AI-native transition:
  - **Managing Errors**: It refers to Imprecise Measurements with added Noise, Missing Values or Entire Records from different subcomponents, Data Anomalies and Records which are communicated with a significant delay (e.g. online measurements,
  - **Growing Demand for AI Area Networking**: It refers to massive data transfers and instantaneous processing without a bottleneck and uses DPU and AI Accelerators such as Infiniband and Ultra Ethernet)
- **Development of Advanced Infrastructure for Ubiquitous Connectivity**: The evolution towards 6G involves expanding capabilities in ultra-massive MIMO, terahertz communications, and the integration of TN and NTN. These technologies require significant advancements in infrastructure to support the envisioned ubiquitous and massive communication networks that are reliable and able to adapt to the extensive data demands of future applications.
- **Addressing Sustainability and Interoperability in Network Expansion**: As network capabilities expand to include more complex systems and widespread use cases, maintaining sustainability and interoperability becomes a challenge. The integration of new technologies must consider energy efficiency and the environmental impact. Furthermore, ensuring interoperability across diverse and evolving technological landscapes is essential to realise the seamless global connectivity envisioned for 6G.

4.2 Recommendations for R&D projects

- **Focus on Interoperable and Scalable Architectures**: research projects should prioritise the development of network architectures that are innovative and interoperable across different platforms and technologies. This entails designing solutions that can be easily integrated into existing networks while also being scalable to accommodate the evolving demands of 6G. Projects should create flexible architectures that support a seamless transition from 5G and can adapt to future technological advancements. Scalability should not be performance-impacting (in a negative way) and should be within the reach of all stakeholders in an ecosystem to ensure that end-to-end services scale and perform across the entire value chain.
- **Develop Native Integration of Advanced Features**: with 6G aiming to have advanced features such as security and quality of service natively integrated, research projects should explore the technical and practical aspects of embedding these capabilities directly into the network

infrastructure. This could involve developing new algorithms, protocols, and network components that ensure these features are inherent parts of the network from the ground up, enhancing efficiency and performance. Native-AI adoption could expose monitoring and status information about resource utilisation to authorised third parties. AI/ML operations could be used to predict changes in network conditions.

- **Tailor Research to Specific Industry Needs**: Given the diversity of use cases across different sectors, research projects should be tailored to address the specific needs of key industry verticals such as healthcare, automotive, manufacturing, and entertainment. This specialisation will help develop targeted solutions that address each sector's unique challenges and requirements, thereby increasing the applicability and impact of 6G technologies.
- **Focus on AI-Driven Network Optimisation**: Research projects should concentrate on developing AI technologies that enhance network management and optimisation for 6G, including self-organising networks that incorporate AI for self-configuration, self-optimisation, and self-healing. This research will help ensure that 6G networks can handle increased data volumes and connectivity demands efficiently. Additionally, an Intent-Based Network can facilitate network slicing requirements and manage resiliency in an integrated TN/NTN architecture.
- **Develop Solutions for AI and ML Operations Integration (ML Ops)**: Given the increasing role of AI in telecommunications, research into effective ML Ops practices is essential. Projects should explore innovative ways to integrate AI lifecycle management into telecom operations to streamline AI models' deployment, maintenance, and scaling in active network environments. There are several challenges where data noise can manipulate the accuracy of AI models and network artefacts (network delay and loss can impact both the model accuracy and inference).

4.3 Recommendations for SDOs

- **Standardise AI Integration Protocols**: SDOs should work on developing and standardising protocols and frameworks for integrating AI and ML technologies within 6G networks. These standards should address aspects such as data accuracy and pre-processing and verification, AI model training, deployment, monitoring, and retraining on the network edge, ensuring consistency and interoperability across different network vendors and operators.
- **Create Guidelines for Sustainable Network Development**: With the increasing importance of sustainability in telecommunications, SDOs should formulate guidelines that promote the development of energy-efficient and low-environmental impact technologies for 6G. This includes standards for reducing power consumption and guidelines for using sustainable materials and practices in network hardware and infrastructure development.

4.4 Recommendations for Policymakers

- **Establish Clear Regulatory Guidelines for Advanced Features**: As 6G aims to integrate advanced features natively, such as enhanced security protocols and quality of service guarantees, policymakers should work to establish clear and comprehensive regulatory guidelines that support the development and implementation of these features. These regulations should ensure that new technologies meet high safety and efficacy standards and encourage innovation by defining flexible frameworks that can adapt to technological advancements.
- **Accelerate Standardisation of Native Features**: As 6G networks aim to integrate advanced features like security and sustainability, SDOs should focus on developing and standardising these

features early in development. This requires a proactive approach to setting standards that address current technological capabilities and anticipate future developments. Policymakers should encourage SDOs to work closely with technological experts and industry stakeholders to understand the practical implications and technical requirements of these native features.

- **Facilitate Access to Testbeds and Experimental Licences**: Policymakers should facilitate access to testbeds and provide experimental licences for the trial of 6G technologies in real-world settings. This access will allow researchers and developers to test and refine their technologies under practical conditions, thereby ensuring that theoretical advancements in 6G are viable in operational environments. Such support is vital for accelerating the development cycle and ensuring that new innovations can be tested, refined, and rolled out efficiently.
- **Enhance Multidisciplinary and Cross-sector Standards Development**: Given the broad application of 6G across various industry verticals, SDOs should enhance their standards development processes to be more inclusive of different disciplines and sectors. This could involve forming specialised working groups or committees that include experts from non-traditional sectors such as healthcare, automotive, and manufacturing, which are likely to be significantly impacted by 6G technologies. These groups can provide insights into industry needs and challenges, ensuring that the standards developed are relevant and practical.
- **Promote Global Collaboration and Harmonization of Standards**: To ensure global interoperability and maximise the potential of 6G, SDOs should strengthen their efforts in international collaboration and harmonisation of standards. This involves actively participating in global forums and working with other international SDOs to align standards and regulatory practices. By promoting a unified approach to 6G standardisation, SDOs can help reduce technological fragmentation and foster a more cohesive ecosystem for 6G deployment worldwide.
- **Enhance Regulatory Frameworks for AI Integration in Telecoms**: Policymakers should develop and update regulatory frameworks to accommodate the deep integration of AI in telecommunications networks. This includes setting data privacy, security, and interoperability standards specific to AI applications within 6G environments. Ensuring that these frameworks are adaptable to technological advances is crucial for fostering innovation while maintaining user trust and safety.
- **Support Infrastructure Development for 6G:** Policymakers should facilitate and incentivise the development of advanced telecommunications infrastructure required for 6G. This could involve funding for research and development of technologies such as ultra-massive MIMO and terahertz communication systems, as well as providing subsidies or tax incentives for the deployment of sustainable and energy-efficient technologies.

5 Participation and Challenges for SMEs in Standardisation

5.1 Key topics and challenges

- **Participation of SMEs in Standards Development**: the involvement of SMEs in the creation and adaptation of standards within the telecommunications sector, focusing on their role and engagement in various standards organisations and initiatives.
- **Challenges and Opportunities for SME Involvement in Standardisation**: the barriers SMEs face in participating in standardisation efforts and exploring potential strategies to enhance their involvement, including understanding their current low engagement levels and providing targeted support and resources.

5.2 Recommendations for R&I projects

- **Inclusive Collaboration and Practical Applications**: Ensure that technological developments are both accessible and beneficial across the industry, especially for smaller enterprises. Simultaneously, research and development should be prioritised to address SMEs' specific needs and capabilities. Focus on developing scalable, cost-effective solutions that SMEs can adopt without significant resource investments. Incorporating these practical applications into standard-setting activities will help bridge the gap between SME capabilities and industry standards, ensuring that SMEs are both participants and benefactors of the evolving technological landscape. As stakeholder ecosystems are further evolving today towards open, inclusive models, the entry barrier for SMEs becomes lower. This allows best-in-class SME players to take part in the ecosystem and provide their functions and algorithms (such as Independent Software Vendors (ISVs) or AISVs). Inclusive ecosystems build on the many-to-many stakeholder relationships (e.g. multiple operators per vendor or vendors per operator) instead of classical 1-1 or 1-n ecosystems. Existing trends and efforts in the SDO and industrial community include successful examples of open ecosystems such as Open RAN (ORAN) and many others.

5.3 Recommendations for SDOs

- **Accessibility and Engagement**: Increase efforts to make the standardisation process more accessible to SMEs. This could involve simplifying participation, reducing costs, or providing targeted support for SMEs to contribute effectively. Some SDOs have started doing that, but they are a minority.
- **Feedback and Integration**: Actively seek and integrate feedback from SMEs on their needs and challenges in 6G technology. This can help ensure that standards are relevant and beneficial to a wider range of stakeholders, promoting broader adoption and adaptation. Establishing trust and promoting SME inclusion and integration in various ecosystems should also be accelerated and pushed forward.

5.4 Recommendations for Policymakers

- **Enhance Support Mechanisms**: Develop and promote policies supporting SMEs in participating in 6G research and standardisation. This could include financial incentives, information

dissemination, and simplified access to research collaborations. Besides the improved funding ratio for SME efforts (such as Horizon projects), other ways for strengthening and including SMEs as active value-adding participants should be devised and applied.

- **Formulate Regulatory Frameworks**: Create favourable regulatory environments encouraging SME innovation in 6G technologies. This can involve ensuring new regulations do not disproportionately burden SMEs and potentially stifle their innovation ability.

6 Data Management and Security

6.1 Key topics and challenges

- **Data Protection and Security in an End-to-End Service**: Ensuring data protection across the entire network service is critical. Any breach or vulnerability in a network segment can compromise the entire service, making comprehensive data protection a major challenge.
- **Regulation and Standardisation of Data Practices**: With the cross-vertical and cross-domain regulations on data, integrating and standardising data practices pose a challenge. This includes aligning various standards and regulations across different domains and ensuring that data handling practices are consistent and sustainable.

6.2 Recommendations for R&I projects

- **Develop Open Reference Implementations**: Encourage the creation of open reference implementations for new technologies. This will not only aid in practically testing these technologies in various environments but also facilitate broader adoption and understanding across the industry.
- **Advanced Security Protocols**: Prioritise the development of advanced security protocols that ensure data protection across all network segments. This is essential to maintain the integrity and safety of data in an end-to-end service, especially as networks become more complex and susceptible to new types of cyber threats.

6.3 Recommendations for SDOs

- **Standardise Data Sharing and Protection Practices**: Work towards creating and standardising robust data sharing and protection protocols that ensure data privacy and security across various platforms and technologies in 6G. This includes the development of frameworks that manage the exchange and storage of massive data sets used by AI applications. Data is a key dimension that has the leverage to empower new use cases and unleash significant monetisation potential, and the best way to leverage that is through standardisation and SDO collaboration on this topic.
- **Promote Cross-Sector Standards for Data Efficiency**: Encourage the development of standards that enhance data efficiency across different sectors. These standards should facilitate the effective use of data, minimise redundant data processing, and promote data-sharing practices that can reduce overall energy usage.

6.4 Recommendations for Policymakers

- **Regulatory Frameworks for Data Sustainability**: Establish comprehensive regulatory frameworks that encourage developing and implementing sustainable data practices in 6G. This includes policies that promote the reduction of energy consumption in data centres and throughout the network, incentivising innovations that contribute to energy efficiency. A balanced approach between the increased data capabilities and rates of 6G and being more sustainable as aligned to directives and outperforming the predecessor (5G) benchmark.
- **Support for Cross-Domain Standards Integration**: Facilitate the integration of standards across different domains to ensure a harmonious regulatory environment for 6G technologies. This could

involve creating collaborative platforms where stakeholders from various sectors can align their data protection, sustainability practices, and standards.

7 Network Challenges and Integrations

7.1 Key topics and challenges

- **Multi-Domain Integration**: The challenge of integrating deterministic networking across multiple administrative and technological domains is significant. Initially, deterministic networks (DetNet) were considered within single domains, but practical deployment requires coordination across various domains to achieve end-to-end deterministic communications. This involves interoperating and coordinating control entities across different domains to ensure seamless, deterministic service delivery.
- **Mobility in Deterministic Networks**: Addressing mobility in deterministic networks is another major challenge. Current considerations and designs for deterministic networks often assume static scenarios where both nodes and network elements do not move. However, real-world applications involve mobile nodes and network elements, particularly in wireless contexts. This mobility necessitates advanced coordination between control entities to predict and prepare for potential handovers, ensuring that deterministic quality of service is maintained even in dynamic environments.
- **Operational Complexity in Multi-Domain Environments**: Managing the operational aspects across various domains of the network, from the radio access to the transport and core networks, is complex. This complexity is compounded by the need to ensure that different implementations and solutions behave consistently and deliver expected functionalities across different parts of the network. This requires a coordinated approach to standardisation that is often difficult to achieve given the varied responsibilities and focuses of different standard bodies.
- **AI Integration in Network Architecture and Operations**: AI is expected to play a role in telecommunication networks' architecture and operational aspects. This includes its application across various segments, from wireless access networks to core networks and specialised infrastructures envisioned for 5G and beyond. The challenge here revolves around seamlessly integrating AI to enhance strategic planning, operation, monitoring, maintenance, and network testing.
- **Self-organisation and Intent-Based Networking (IBN)**: developing networks that not only automate routine tasks (self-organisation) but also align network operations with high-level business intentions (IBN). These capabilities are pivotal for achieving efficient autonomous network operations that dynamically adapt to changing business needs and technological conditions.

7.2 Recommendations for R&I projects

Network Challenges and Integration

- **Enhance Multi-Domain Coordination**: Research projects should focus on developing technologies and methodologies that facilitate seamless integration across multiple administrative and technological domains. This includes creating more sophisticated algorithms and frameworks that can efficiently manage deterministic networking requirements in a multi-domain context.
- **Incorporate Mobility Management**: Develop solutions that explicitly address the challenges of mobility within deterministic networks. This involves researching and integrating advanced

predictive algorithms and dynamic resource allocation techniques to handle network changes and movement predictably and smoothly.

- **Development of Unified Frameworks**: Research projects should focus on creating unified frameworks that can handle the fragmentation in standardisation. These frameworks would help bridge the gaps between different standards and facilitate the integration of network slicing across various network domains.
- **Enhance Predictive Capabilities**: Develop advanced predictive analytics within AI research to better anticipate network failures, resource bottlenecks, and security threats. This forward-looking research will be crucial for 6G networks that demand higher reliability, efficiency, and security.
- **Development of AI-Driven Network Management Tools**: Research projects should focus on developing advanced AI tools for network management that include capabilities for self-organisation and intent-based networking. This will enable networks to autonomously manage complex tasks like configuration, optimisation, and healing, aligning them with business intentions and improving operational efficiencies.
- **Research on AI Integration Across Network Layers**: Projects should investigate holistic approaches to integrating AI across different network layers – from the physical layer, which involves channel estimation and precoding design, to the MAC layer, which involves spectrum sharing and access management. This comprehensive integration will ensure that AI's potential is maximised across all aspects of network operations.

7.3 Recommendations for SDOs

- **Standardisation of Multi-Domain Operations**: SDOs should work towards the standardisation of protocols and interfaces that allow for efficient multi-domain operations. This includes defining clear standards for how different network domains interact and manage data flows to ensure deterministic behaviour across boundaries.
- **Mobility Protocols and Standards**: Develop and refine standards that address the specifics of mobility in network environments, particularly for deterministic networks. This would involve setting standards for handover processes, dynamic configuration, and real-time adjustments to network conditions to support seamless mobility.
- **Standardisation of AI Applications in Networks**: SDOs should work towards creating standards that guide the integration of AI technologies in telecommunications networks. These standards should cover aspects such as the deployment of AI for network management, orchestration, and the operational use of AI in predicting network behaviours.
- **Frameworks for Distributed AI in Telecommunications**: Develop standards for the use of distributed AI techniques, such as model splitting and parallel training. These standards would help ensure that AI technologies are effectively implemented across various nodes in the network, enhancing the performance and scalability of AI applications.

7.4 Recommendations for Policymakers

- **Support for Cross-Domain Frameworks**: Policymakers should encourage and facilitate the development of policies and regulations that support the interoperability and integration of networks across different domains. This could include funding programs aimed at research and development of cross-domain deterministic networking solutions.

- **Regulatory Frameworks for Mobility**: Develop and adapt regulatory frameworks that accommodate the unique challenges of mobile deterministic networks. These frameworks should support innovations in mobile network handling and ensure that mobility is considered in the planning and deployment of new network technologies.
- **Regulatory Support for Emerging Technologies**: Implement regulatory frameworks that support the deployment and scaling of emerging technologies integral to 6G, such as advanced AI and machine learning applications, to ensure that these technologies can be tested and adopted within safe and regulated environments.
- **Support for AI Research in Telecommunications**: Policymakers should provide targeted funding and support for research initiatives exploring AI's use in telecommunications, particularly for projects that aim to solve complex problems like network slicing in multi-domain environments and predictive network behaviours.
- **Regulations Promoting AI Safety and Ethics in Networks**: Implement regulations that ensure the ethical use of AI in telecommunications, focusing on transparency, data privacy, and security. These regulations should encourage the development of explainable AI systems that make network decisions understandable and accountable.

8 Sustainability and Energy Management

8.1 Key topics and challenges

- **6G Sustainable Solutions**: 6G is expected to optimise the energy consumed in communication and computing subsystems and facilitate energy efficiency in different systems and services. As an effect, 6G is expected to minimise the negative impact on sustainability, meeting the UN SDG expectations in the areas of societal, economic and environmental goals.
- **Data and AI Sustainability Paradox**: There is a paradox where the increasing demand for data, which fuels AI and computational processes, also leads to increased energy consumption. Managing this rising demand for data while striving to maintain or improve sustainability in 6G networks presents a significant challenge.
- **Integration of AI with Network Sustainability**: The challenge lies in harmonising AI-native architectures within the network to support workload management and analytics across various network areas, enhancing both efficiency and sustainability. The focus is on effectively collecting and utilising data to refine AI models, which in turn positively impacts network operations and sustainability.
- **Balancing Data Demand with Sustainability**: As data demands increase to fuel AI and other computational processes, managing this growth sustainably becomes challenging. The presentation discussed the need to regulate and manage massive data volumes without compromising on the network's energy efficiency and sustainability goals.
- **Energy Consumption and Efficiency**: A significant challenge is managing the energy consumption within the network, particularly with the transition from 5G to 6G, where the network's transformation into a data-centre-like infrastructure increases energy demands. The emphasis is on redesigning the network to optimise energy usage, which includes managing battery requirements and overall carbon footprint.

8.2 Recommendations for R&I projects

- **Develop Energy-Efficient AI Technologies**: 6G research projects should prioritise the development of AI technologies that are inherently energy-efficient. This involves creating AI models and systems that consume less energy while maintaining high-performance levels, particularly in data processing and network management tasks.
- **Innovations in Green Network Technologies**: Research should focus on innovations that enhance network energy efficiency, such as advanced battery technologies, energy-saving network components, and novel materials for network infrastructure that reduce environmental impact.

8.3 Recommendations for SDOs

- **Promote Sustainability in Data Practices**: Develop and advocate for standards that emphasise sustainability in data operations. These standards should aim to reduce the carbon footprint of data processing and network operations, supporting the global push towards greener technology solutions in the telecom sector.
- **Standardise Sustainable Network Practices**: SDOs should work to establish and promote standards that encourage sustainability in network design and operation. This includes creating

benchmarks for energy consumption, guidelines for recyclable materials in hardware, and standards for renewable energy sources in network operations.

8.4 Recommendations for Policymakers

- **Create Incentives for Sustainable Practices**: Policymakers should develop incentives for the adoption of sustainable technologies in telecommunications. This could include tax benefits, grants, or subsidies for companies investing in energy-efficient infrastructure or pioneering new technologies reducing the environmental footprint of 6G networks.
- **Regulate Data and Energy Consumption**: Implement regulations that set data and energy consumption standards in 6G networks. Such regulations would ensure that as networks grow in capacity and capability, they do so within sustainable parameters that align with broader environmental goals.

9 Appendix I: Bibliography and Reference documents

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10 Appendix II: Online Resources

HSbooster.eu, Training Academy. Available at https://hsbooster.eu/training-academy.

StandICT.eu, Landscape Analysis Reports. Available at https://www.standict.eu/landscape-analysis-reports.