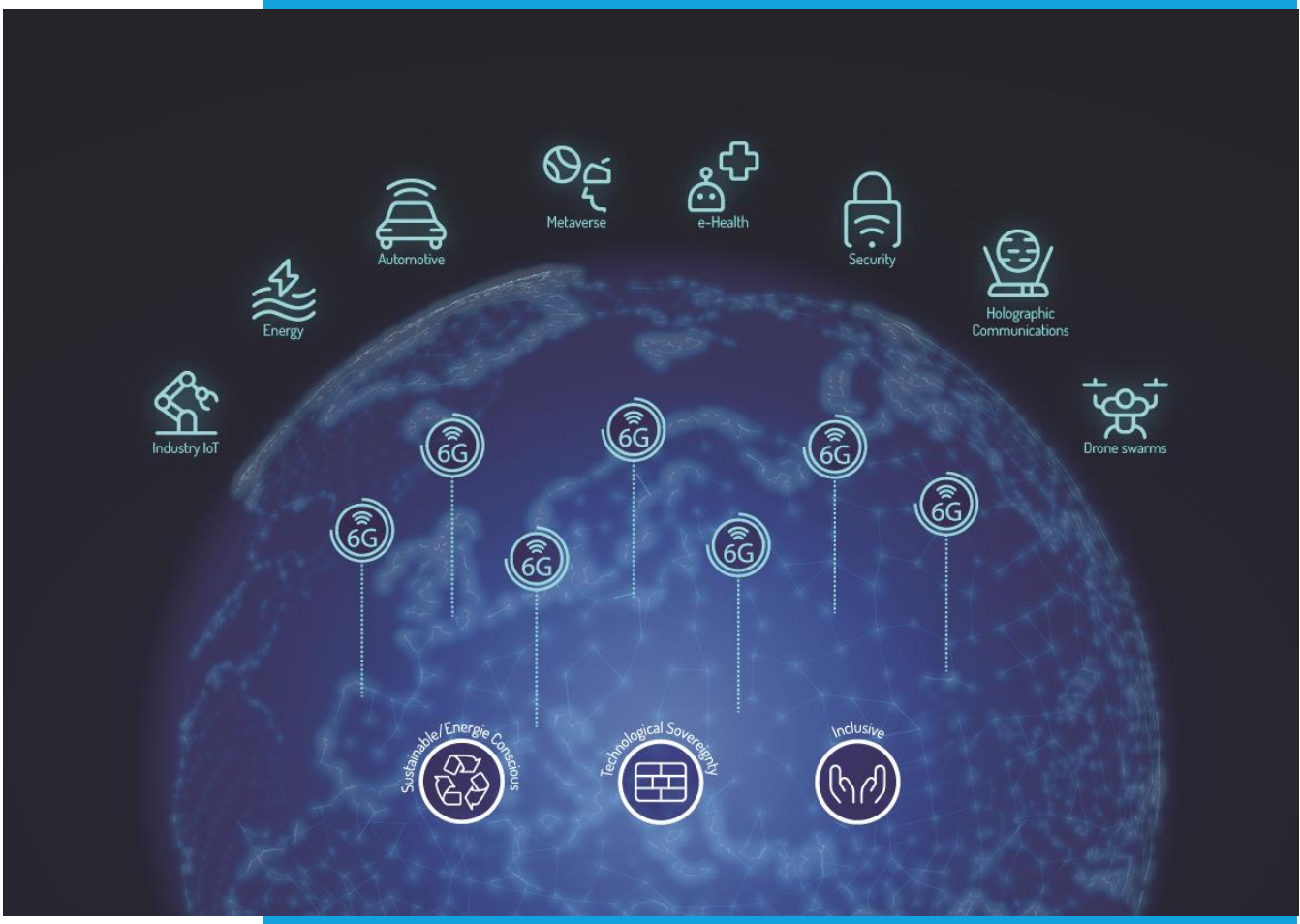
6G Smart Networks and Services Industry Association (6G-IA)



Version 1.1

April 2024

Not yet approved by the 6G-IA Board

Position paper

RESEARCH PRIORITIES ON CLOUD AND SERVICE PROVISION

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1. INTRODUCTION

Cloud solutions are becoming an integral part of future networks. The current trend in cellular networks is adopting cloud solutions further to the far edge and on-premises networks. This trend creates a cloud continuum that refers to a seamless integration of computing resources across different domains. This continuum enables efficient data processing, minimizing latency, saving bandwidth, improving security, ensuring privacy, and enhancing autonomy. This continuum is expected to introduce higher levels of flexibility for the seamless deployment, integration, composition provision, and management of services.

Both the public and private sectors recognize the importance of developing European solutions for the cloud continuum, and related actions are already executed or planned. For example, in the context of the SNS JU, cloud-related and advanced service provision topics have been in all past yearly calls (starting from 2022). The selected projects work on **5G Advanced and 6G cloud and secure service provision solutions**.

Moreover, Horizon Europe cluster 4 for "Advanced computing and big data"[1] projects are working to provide advanced solutions for **modern IT computing platforms for a cognitive cloud edge computing continuum**.

Additionally, several activities of communities like GSMA (e.g. Open Gateway[2]), TIP (e.g. OpenRAN[3]), as well as open source projects (e.g., Sylva[4], Anuket[5], Open Nebula[6], CAMARA[7], ETSI hosted[8], etc.) are working to provide means and solutions that will support various aspects of the **cloud continuum for the telecommunications industry**. Very recently, 6G-IA's position paper[9] has recommended that in terms of cloudification and distributed computing, Europe should, among other things, "exploit and enhance open source solutions to contribute to 6G technological sovereignty, and develop open interfaces to enable cloud interoperability, cloud enabled telco services interoperability".

At the same time, main European stakeholders from 12 EU countries are working together under the IPCEI-CIS[10] (Important Project of Common Interest on Next Generation Cloud Infrastructure and Services) to deliver a multi-provider cloud-edge continuum, based on

[1] https://cordis.europa.eu/search/en?q=contenttype%3D%27project%27+AND+programme%2Fcode%3D%27HORIZON.2.4.7%27&srt=/project/contentUpdateDate:decreasing
[2] https://www.gsma.com/solutions-and-impact/gsma-open-gateway/
[3] https://telecominfraproject.com/openran/
[4] https://sylvaproject.org/
[5] https://anuket.io/
[6] https://opennebula.io
[7] https://camaraproject.org/
[8] https://www.etsi.org/committees
[9] https://6g-ia.eu/wp-content/uploads/2023/10/6g-ia-position-paper_2023_final.pdf?x21650
[10] https://ec.europa.eu/competition/state_aid/cases1/202412/SA_102517_707E5C8E-0000-C216-8C1C-3081176554C2_287_1.pdf

open source, standard, secure and green technologies, that will cover an important part of the requirements for a Telco Cloud.

Recognizing the importance of this technological area for Europe, the EC has recently published a white paper on "How to master Europe's digital infrastructure needs?"[11]. Under Pillar one of this white paper, the EC indicates its strong interest in large-scale pilots that will set up end-to-end integrated infrastructures and platforms for telco cloud and edge and the possibility of creating infrastructure focused IPCEI. The white paper also indicates the assignment of a coordinating role to the Smart Networks and Services Joint Undertaking. Additionally, the EC is preparing a call under Cluster 4 large scale pilots for e2e infrastructures with the following topics under consideration (there is an open consultation for this topic[12]):

- Prototyping at scale end-to-end telco edge cloud integrated infrastructures and platforms (devices, edge, cloud, and communication resources).
- Enabling new innovations and services for EU supply industry while strengthening the industrial ecosystems (e.g. mobility, smart communities, energy, health, farming, logistics and manufacturing).
- AI-based orchestration over network and computing resources, cloud-native to continuum-native software, IoT, Edge server density and placement issues, edge-as-service orchestration, lightweight and cloud-native forms for NFV and optimisation by means of acceleration, multi-cloud orchestration, multi-level federation, mobility management, etc.

Based on the above information, it is clear that the importance of cloud solutions and the seamless deployment, integration, composition provision, and management of services will be significant for the telco industry. Europe is already activated at an R&I level, but as several related activities are running or are planned to run in parallel, covering various aspects, technologies, and TRLs, a clear roadmap of synergies is needed to maximize the impact of these efforts. The purpose of the current document is to provide such a plan.

[11] https://digital-strategy.ec.europa.eu/en/library/white-paper-how-master-europes-digital-infrastructure-needs?pk_source=ec_newsroom&pk_medium=email&pk_campaign=Shaping%20Europe%27s%20Digital%20Future%20website%20updates

[12] https://research-and-innovation.ec.europa.eu/news/all-research-and-innovation-news/feedback-opportunity-horizon-europe-work-programme-2025-now-open-2024-04-15_en

2. CURRENT STATUS

This section discusses the status in terms of business and architectural aspects. In terms of use cases, the topic of cloud and service provision is horizontal for all 6G use cases. Beyond connectivity, 6G should become a platform offering new services to increase the monetization vector.

2.1. BUSINESS ASPECTS

It is widely accepted that hyperscalers are currently dominating the cloud service provision ecosystem. Although efforts have been made in the past to develop European solutions, these have not succeeded in altering the status quo. This may lead to some negative impact on the European mobile operators that could subsequently affect the vendors and the overall European telco and service provision ecosystem.

Due to the cloudification of the networks and the lack of standardized European alternatives, the operators rely on proprietary cloud solutions provided either provided by hyperscalers or based on own developments. Being forced to follow such an approach, the operators are in the conflict to either risk a lock-in situation with a hyperscaler or need to undertake a huge effort to develop and maintain an own solution and a high effort to integrate supplier workloads onto it. Thus, it is important to take cloud sovereignty into account. This includes compute, transport and storage of data that will be under domains that are controlled or conform to EU jurisdiction and legislation. There are currently concerns in Europe about the low footprint on the provision of cloud infrastructures.

As cloudification is further progressing towards the edge and the RAN, if the current situation continues, there is a strong possibility that the European telecommunication market, as we know it today, will cease to exist. On the positive side, the operators still have the "ownership" of the spectrum and a large number of sites that can be used to deploy edge-clouds that will help them offer more competitive solutions (e.g., in terms of lower latencies). If designed properly, this further disaggregation of cloud facilities may alter the existing business models. **New telco cloud solutions should be based on open source solutions and trustful standardized interfaces among services, clouds, networks, and computing resources.** This is the only viable solution to create an open market where multiple cloud service providers (including the operators) will offer their services openly and fairly. Standardized interfaces will also enable the operators to select specific services not only from hyperscalers, but also the multiple stakeholders that such an open ecosystem brings (e.g., RAN providers, transport providers, function providers, AIaaS providers), more modularly and even switch from one provider and/or hyperscaler to another when they want to. Standardized interfaces will also allow user mobility among infrastructure and cloud providers in a seamless way (e.g., mobility of users among edge cloud providers). Such an approach can guarantee that European policy priorities such as technological sovereignty, security, and privacy are safeguarded.

Until today, the operators have spent considerable amounts of money acquiring spectrum and updating their equipment from one generation of cellular networks to the next. So far,

the 5G networks have not delivered the promised increased revenues from the active engagement of verticals, and thus, the current business model is not sustainable. As the telecommunication traffic is constantly growing, the operators are forced to increase the capacity of their networks but do not receive additional income, which mainly ends up with the Over the Top businesses (OTTs). To address this point, further work is needed to **extend the functionalities offered by the (east/west and northbound) interfaces in a standardized way**. This way, the operators may a) expose part of their operation to the vertical service providers and b) offer services that only they can (e.g., AI as a service) based on the wealth of data they have.

At this point, it is essential to note that technological advances alone cannot deliver the desired results. While developing the needed novel technologies, the regulatory framework in Europe must also modernize to allow European stakeholders to compete with the other regions. The recently published white paper "How to master Europe's digital infrastructure needs" clearly points to such actions.

2.2. ARCHITECTURAL ASPECTS

Cloud infrastructure will form the basis of most parts of the network and its functions. For 6G to succeed, this foundation must be reliable, dependable, secure, operationally efficient, and energy efficient. Although the cloudification of networks and the exposure of network capabilities have started as a paradigm shift with the 5G networks, the process is progressing further to meet the requirements and characteristics of 6G networks and the services promised to be delivered.

For example, according to ITU[13], to support ubiquitous intelligence and computing, emerging trends include expanding data processing in the network infrastructure to the network cloud and devices closer to the origin of the data and supporting the proliferation of ubiquitous intelligence throughout the IMT-2030 system. Furthermore, the IMT-2030 system is expected to support AI-enabling infrastructure capable of providing services for intelligent applications. To achieve this, leveraging edge computing resources and AI capabilities is needed to deliver tactile Internet and ambient awareness. Also, 6G KPIs are being targeted for the IMT 2030 system that will further boost the performance of cellular networks (e.g., delay of 0,1 to 1 msec, guaranteed throughput and reliability for specific services and applications). These new values of the KPIs will require a further evolution of the cloud technologies and network exposure APIs to address them.

During the workshop, the following 6G capabilities and characteristics have been identified that may require such evolution[14]. It is worth noting, there was consensus that all the following topics should be developed following the open source model as much as possible to address the points analysed in section 2.1:

- Ubiquitous connectivity, considering all types of terrestrial and non-terrestrial

[13] ITU, Recommendation ITU-R M.2160-0, 2023, available at: https://www.itu.int/dms_pubrec/itu-r/rec/m/R-REC-M.2160-0-202311-I!!PDF-E.pdf
[14] Several of these are also included in the ITU-R M.2160

networks for public and private networks that will allow the establishment of innovative business models,

- Ubiquitous computing, also considering it as a service to subscribers, where solutions for federation of resources and inter-computing beyond the inter-networking capabilities of the Internet will be available. This is expected to make the execution of services possible across multiple heterogeneous but seamlessly inter-working domains, each possibly applying different policies (e.g., in terms of security, routing, access to resources, etc.), routing mechanisms, access mode to application services, etc. including capabilities to support 3D networks. The implication to network management of such massively distributed resources must as well be considered,
- Ubiquitous intelligence for the operation and management of the networks and MLOps and AI as a service,
- Cloud continuum realization from the end (mobile) devices up to the central/public cloud,
- Integration of sensing and communication (ISAC),
- Sustainability: considering all aspects, i.e., "6G for sustainability" and "sustainability for 6G" covering environmental, societal, and business aspects,
- Digital twin and connection of the physical and virtual worlds, for real-time continuous optimization, AR/VR assisted remote maintenance, possibly leading to offering experimentation as a service for pre-deployment testing,
- Network as a platform providing different instantiations, exposure functions, allowing exposition of available resources and required/value-added service attributes (performance, security, sustainability) related to the user applications and getting semantics of the requirements from user applications explicitly or implicitly, and discovery capabilities,
- Multi-provider and multi-tenancy support of network and compute resources,
- Seamless service continuity in a multi-provider and multi-stakeholder environment, where mobility and inter-connectivity especially through inter-business domain is handled in an efficient and transparent way for the end users.
- Extension of the SBA towards a stateless and event-driven architecture, able to natively integrate not only networking but computing in operational workflows,
- Dependable, resilient, and reliable cloud with advanced security and privacy end-to-end frameworks, that is guaranteeing the desired availability, performance and local survivability for end users and services.
- Further evolution of OSS, considering cloud/computing facilities as an integral part of the network,
- Optimal deployment of the required compute elements, data plane paths and control plane elements across a set of distributed physical edge,

- Enhanced data plane frameworks that guarantee economically and technically sustainable architectures with cross-flow resource management capabilities,
- Flexible hardware platforms and/or programming abstractions (covering individual and aggregate resources) to achieve the benefits for agile, simplified yet automated composition and management of resources, possibly separated in "islands",
- Vendor-agnostic hardware offloading to improve large amounts of data traffic in the user plane,
- Holistic Smart Service frameworks with secure and trustful lifecycle management and operation cover the development, provision, deployment, orchestration, and consumption of services for a new computing continuum that spans multiple heterogeneous technological and administrative domains,
- Developments on service technologies for secure time-sensitive and computation-intensive applications providing deterministic networking solutions,
- Cloud solutions that will support the desired network KPIs e.g., throughput, delay, reliability,
- As cloud solutions will be a commodity of the network infrastructure, future networks will rely more and more on software solutions. Thus, novel cloud and network function life cycle management solutions need to be developed.

3. TOPICS FOR CONSIDERATION

All the above topics require some multi-disciplinary efforts to reach the desired goal. Also, as discussed in Section 1, various EC activities are working toward this direction, and some streamlining in terminology is needed. Thus, before presenting the topics discussed and analysed during the workshop, it was necessary to define what the term "3C network (Connected Collaborative Computing)", recently introduced by the EC[15], means. During the workshop, the following tentative definition was agreed.

3C Network: *A multi-provider and multi-technology system that hosts network functions as well as functions beyond connectivity (e.g., AI as a service, Compute as a Service, Security as a Service, ISAC as a service), integrated into the telco system or independent from the telco system, and any other application or capability as a service.*

The topics discussed during the workshop were grouped under two different pillars. The first is related to cloud solutions development, and the second is related to service provision. Both groups were discussed in a time-plan of short-term (e.g., future calls for projects that will

[15] https://digital-strategy.ec.europa.eu/en/library/white-paper-how-master-europes-digital-infrastructure-needs?pk_source=ec_newsroom&pk_medium=email&pk_campaign=Shaping%20Europe%27s%20Digital%20Future%20website%20updates

start their activities in 2026) and medium-term (e.g., future calls for projects that will start their activities in 2027) priorities. Potential synergies were also discussed in relation to other funding instruments.

More specifically, the following topics have been identified for **cloud solutions (Table 1)** in the short-term:

- Interconnected & federated and interoperable (public and private) 3C networks and services with standardized APIs,
- Task based core network functions where the network will evolve to a service provisioning system extending the current SBA framework beyond the core network and beyond mobile connectivity provisioning,
- Enhanced CAMARA exposure capabilities,
- Improved network software lifecycle approaches such as DevOps,
- Design of stateless and event-driven principles,
- Provision of compute, function (e.g., network functions or new service-related functions) and appropriate APIs to access them,
- Novel solutions to support secure, dependable, trustful, and reliable telco clouds,
- Advanced schemes to cater for data storing/using/handling/curating so as privacy is ensured.

Moreover, solutions for sustainable telco clouds that will scale with the load, as well as, multi-provider and cross-domain telco cloud native network function orchestration and management of heterogeneous and largely distributed resources, have been identified as short-term topics. However, allocating future resources, should be re-evaluated after the proposal selection of SNS projects that have been submitted for evaluation in the 2024 call. The reason is that similar topics were included in latest call and should be addressed in the next call only if there will be no projects addressing them. If these topics will be covered by projects selected in the 2024 call, they could be further researched at a higher TRL in medium-term.

Table 1: Topics related to cloud solutions

Cloud solutions	Short- term	Medium-term	Synergies
3C cloud provision –multi provider- multi technology- (including cloud RAN, edge, far edge)		X	IPCEI-CIS
Sustainable telco cloud solutions (scale with the load)	X (after the gap analysis of call 2024)	X	
Multi-provider, cross-domain telco cloud native network function orchestration and management	X (after the gap analysis of call 2024)	X	IPCEI-CIS (workload deploy management)
Hardware offload (open-source?cl hardware) and accelerator abstraction layers			Chips JU
Native AI cloud support (handling trustability, explainability, conflict resolution, …)		X	
Improved network software lifecycle (DevOps,…)	X		
Compute, function & network as a service and API	X		
Secure, Dependable and reliable telco cloud	X		
Data storing/using/handling/curating/privacy	X		
Stateless and event driven principles	X		
Interconnected/federated and interoperable (public and private) 3C networks and with standardized APIs	X		IPCEI-CIS
Multi-stakeholder Service continuity (seamless service roaming)		X	
Large scale clusters of accelerated compute			HPC, Gen AI Initiative
Task based core network – extending the SBA	X		
Extending CAMARA edge discovery, reanchoring	X		

For the medium term the following topics have been identified (either because the technology is not yet mature, or because these topics are currently under development in by active SNS projects at lower TRL):

- Support of multi-stakeholder service continuity (6G seamless service roaming among various network and cloud providers),
- Native AI cloud support (handling trust, explainability, conflict resolution, etc.),
- 3C cloud provision –multi provider- multi technology- (including cloud-native open RAN, extreme, on-premises, near, far edges).

Additionally, the following two related topics have been identified but the consensus was that these should be considered, if possible, under other instruments (e.g., Chips JU, HPC or Gen AI) as they require further advanced on the processing capabilities. These are:

- Hardware offload and accelerator abstraction layers,
- Large scale clusters of accelerated compute.

It is worth noting the agreement that there can be clear synergies with the IPCEI-CIS as there are ongoing activities the results of which could be further re-used and adapted in future SNS calls. The community could also further investigate the possibility for reusing results

from projects operating under the HEU cluster 4 on "Advanced computing and big data" that are working for modern IT computing platforms for a cognitive cloud edge computing continuum.

Table 2: Topics related to Service provision

Service Provision	Short-term	Medium-term	Synergies
Services creation delivery and management (resources network and compute) including sustainability	X (after the gap analysis of call 2024)		
MLOps & AI aaS		X	
Exposure and ecosystem interactions	X		
Digital twin as a support of global optimisation and AI enabled operation		X	
Human centricity and digital trust, secure service distribution	X		
Service market place (catalogue of services) – standardizing a multi-stakeholder communication	X		IPCEI-CIS

The following topics have been identified for **service provision (Table 2)** in the short-term:

- Further enhancement on 3C network exposure and ecosystem interactions
- Human centricity and digital trust, secure service distribution,
- AI-driven/supported service marketplace (catalogue of services) – standardizing a multi-stakeholder communication. In this topic instantiations, exposure functions, allowing exposition of available resources and required/value-added service attributes (performance, security, sustainability) related to the user applications and getting semantics of the requirements from user applications explicitly or implicitly, and discovery capabilities are considered.

A topic for services creation delivery and management (resources network and compute) including sustainability was discussed, but this needs to be considered. after the proposal selection of SNS projects that have been submitted for evaluation in the 2024 call. The reason is that similar topics were included in latest call and should be addressed in the next call only if there will be no projects addressing them.

For the medium term the following topics have been identified (either because the technology is not yet mature, or because these topics are currently under development in by active SNS projects at lower TRL):

- MLOps & AI aaS,
- Digital twin as a support of global optimisation and AI enabled operation.

In terms of synergies, the work on IPCEI-CIS should also be considered for the service marketplace.

4. POSSIBLE WAY FORWARD

In the previous sections the overall EU R&I ecosystem in relation to the 3C networks and service provision has been presented. Also, business and architectural aspects have been discussed while a number of R&I topics have been identified and prioritized in short and mid-terms and potential synergies with other instruments have been identified.

Following the previous analysis, to plan for a way forward some key priorities must be identified. These are:

- Minimize the dependencies from the Hyperscalers for the European stakeholders,
- Rely on open source solutions to reach faster the target of European wide accepted solutions,
- Target the standardization of the results so that future solutions will abide to the European rules for security, privacy, sustainability etc.
- Identify synergies among European funding instruments to maximize the impact of their activities and shorten the delivery of well-studied and tested solutions,
- Solutions should Investigate efficient implementations of regulations (EU data act, EU AI act, CRA, etc.).

As discussed in the previous sections, apart from the SNS JU activities in this area, one needs to consider related activities in:

- the IPCEI-CIS
- the cluster 4 activities on advanced computing and big data
- the anticipated cluster 4 call on large scale-trials for e2e infrastructures

Although the IPCEI-CIS has a concrete plan to "deliver a first industrial deployment (FID) of the software components necessary to establish and operate a distributed, openly accessible and interoperable EU Multi Provider Cloud Edge Continuum" and cluster 4 activities on advanced computing and big data are working on modern IT computing platforms for a cognitive cloud edge computing continuum, future calls of the SNS JU and the anticipated cluster 4 call on large scale-trials for e2e infrastructures are under preparation. To come up with a realistic synergetic plan, one needs to consider the time-plan of the afore initiatives as shown in Figure 1.

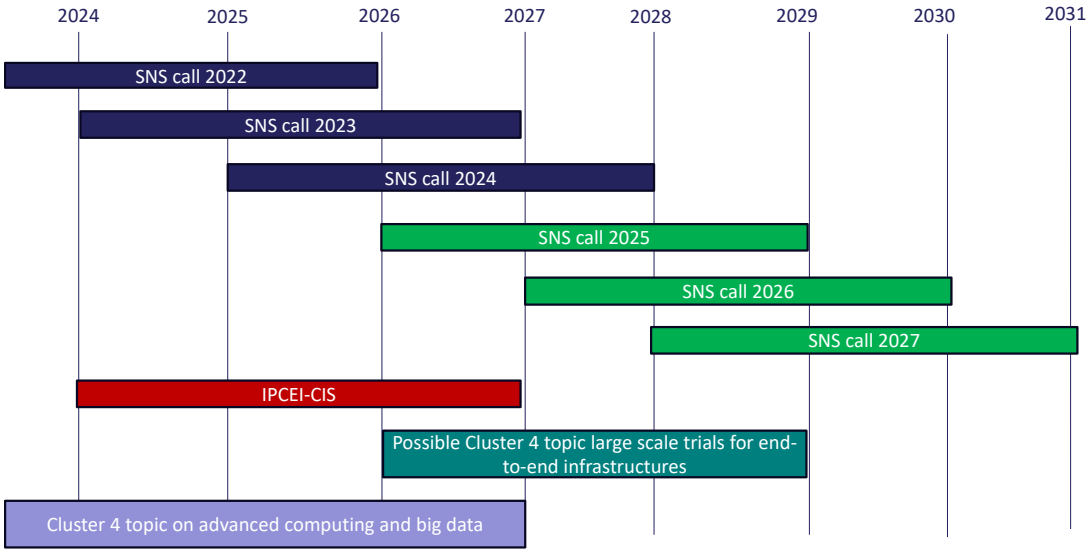

Figure 1: Timeplan for the SNS calls, IPCEI-CIS and Cluster 4 on large scale trials for end-to-end infrastructures

In the above figure one can identify that IPCEI-CIS results could be used for further extensions towards 6G 3C networks and services from the SNS calls on 2025 onwards, combined with the SNS results from previous calls (i.e., call 2022 and call 2023). As similar activities are considered for the anticipated cluster 4 call on LST on end-to-end infrastructures some differentiation is needed compared to the 6G activities. This differentiation factor could be that this call could focus on how to support cloud principles and enhance service provision considering existing 5G and 5G advanced networks. This call could also take into consideration early SNS JU results from calls 2022 (e.g., on Stream A) and 2023 to test them in trials. Figure 2 illustrates the above possible interactions. As shown in this figure, the results from all the above instruments could be further used in the possible future IPCEI on infrastructure. It is worth noting that one of the key results from the SNS JU projects is the standardization of the developed solutions in the context of 6G standardization activities.

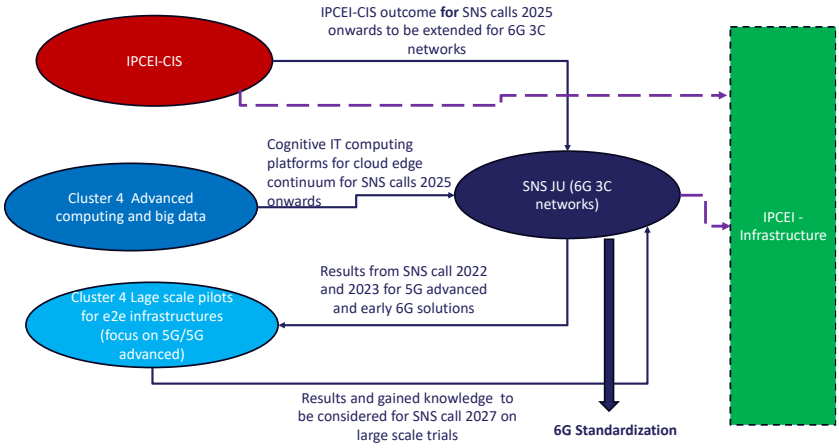

Figure 2: Potential synergies among funding instruments

5. ANNEX 1: COMPLETE LIST OF TOPICS

FOR 3C NETWORKS AND SERVICE PROVISIONING AS PRODUCED DURING THE F2F WORKSHOP

1. 3C cloud provision –multi provider- multi technology- (including cloud RAN, edge, far edge),
2. Sustainable telco cloud solutions (scale with the load),
3. Multi-provider, cross-domain telco cloud native network function orchestration and management,
4. Hardware offload and accelerator abstraction layers,
5. Native AI cloud support (handling trustability, explainability, conflict resolution, …),
6. Improved network software lifecycle (DevOps,…),
7. Compute, function & network as a service and API,
8. Secure, Dependable and reliable telco cloud,
9. Data storing/using/handling/curating/privacy,
10. Stateless and event driven principles,
11. Interconnected/federated and interoperable (public and private) 3C networks and services and with standardized APIs,
12. Multi-stakeholder Service continuity (service roaming),
13. Large scale clusters of accelerated compute capabilities,
14. Task based core network (cognitive cloud continuum) and extending the SBA model,
15. Extending CAMARA edge, discovery, re-anchoring
16. Services creation delivery and management (resources network and compute), including sustainability,
17. MLOps & AI aaS,
18. Exposure and ecosystem interactions,
19. Digital twin as a support of global optimisation and AI enabled operation,
20. Human centricity and digital trust, secure service distribution,
21. Service marketplace (catalogue of services) – standardizing a multi-stakeholder communication,

6. ANNEX 2: LIST OF PARTICIPANTS TO THE WORKSHOP ON 16.04.24

Surname	*Name*	*Company / Institute / University*
Barani	Bernard	6G-IA
Boldi	Mauro	TIM
Camps Mur	Daniel	I2CAT
Carli	Anna-Caterina	DG-CNECT
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Demay	Jerome	Orange
Demestichas	Panagiotis	Wings ICT Solutions / University of Piraeus
Diaz-Pinez	Agustin	DG-CNECT
Dotaro	Emmanuel	Thales
Duman	Selcuk	Vodafone
Fitori	Erzsebet	SNS JU Office
Garcia	Juan Carlos	EU Cloud Alliance
Hecker	Artur	Huawei MRC
John	Wolfgang	Ericsson
Juan Ferrer	An	DG-CNECT
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Llorente	Ignacio	Open Nebula
Lonsethgen	Hakon	Telenor
Lund	David	PSCE
Mangues-Bafalluy	Josep	CTTC
Mazzone	Chiara	SNS JU Office
Nicolicchia	Riccardo	Telefonica
Norp	Toon	TNO
Pyrovolakis	Odysseas	SNS JU Office
Steuernagel	Kai	DT
Urban	Josef	NOKIA

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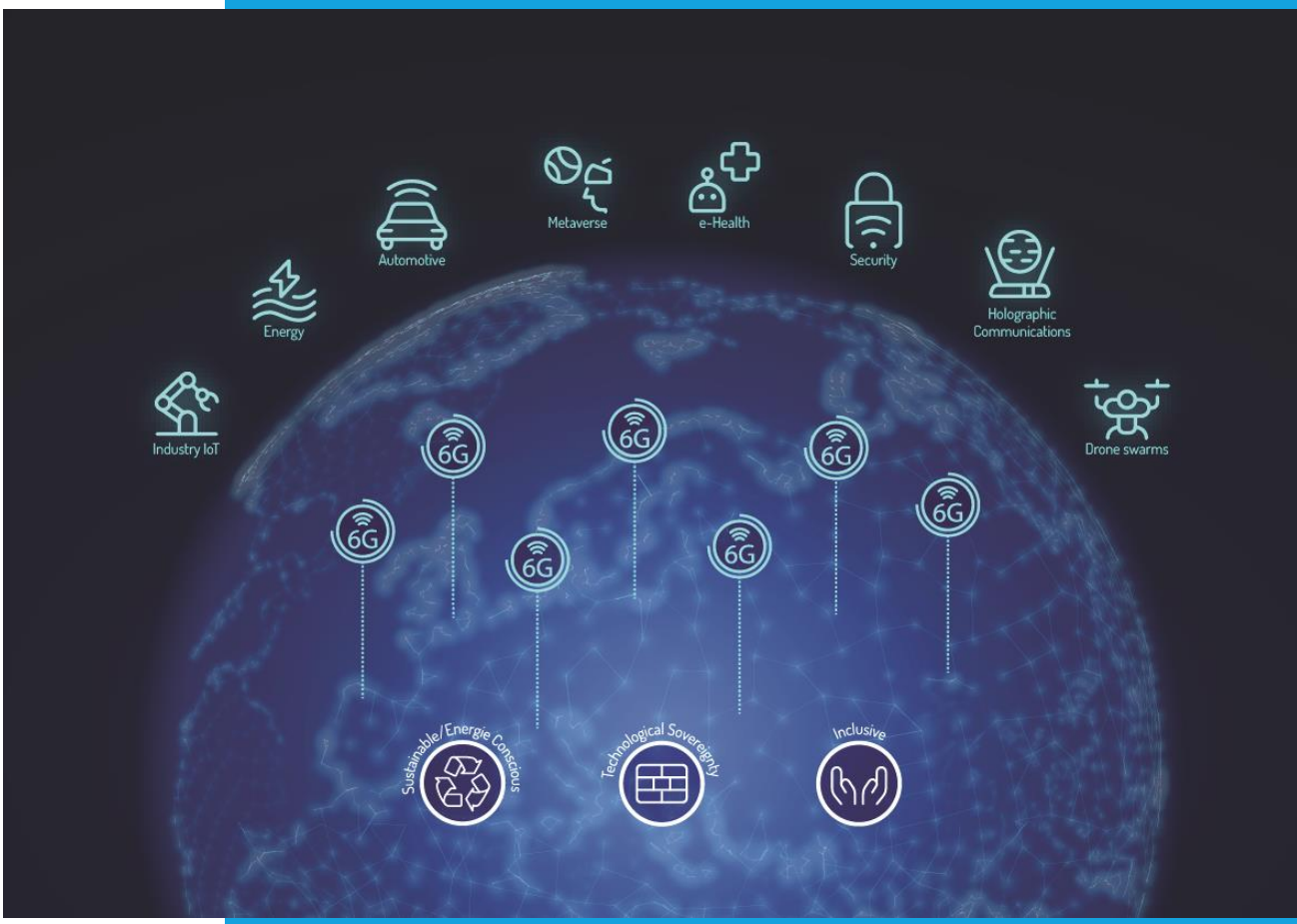

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