6G-SANDBOX

Supporting Architectural and technological Network evolutions through an intelligent, secureD and twinning enaBled Open eXperimentation facility

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ABSTRACT

This document presents the final report of 6G-SANDBOX activities around standardization, exploitation, innovation, and intellectual property management (IPR). It includes the full list of contributions submitted to target standardization organizations (SDOs), such as:

i. the 3GPP WGs (SA2, SA3, SA6),
ii. the ITU SG12 which is related to performance, quality of service (QoS) and quality of experience (QoE).

In addition, it presents standards-related activities which have either been organized by the project, or those which the project participated in and contributed to, such as the ETSI MCX PlugFest, and the 1st ETSI SDG_OpenCAPIF Hackathon event which took place in the context of the broader SNS4SNS event. Furthermore, this deliverable presents the overall 6G-SANDBOX exploitation activities, showcasing the identified project-specific Key Exploitable Results (KERs), as well as details on the methodology followed to assess the exploitation potential of the most promising results. To this end, it summarizes the latest updates related to the imminent submission of the most promising KERs to the EU Horizon Results Platform (HRP); (M1-M36), followed by a high-level description of future partner-specific exploitation actions. Selected outcomes exhibiting high innovation potential will gradually be submitted to the EU Innovation Radar during the extended period (M36-M42) and are also subject of the current deliverable. Last but not least, the current report delineates how the anticipated impact is achieved through IPR filing.

KEYWORDS

Standardization, Exploitation, Innovation, IPR

1 INTRODUCTION

The current deliverable serves as a final report for 6G-SANDBOX activities around standardization, exploitation, innovation, and intellectual property management (IPR).

The highlights around **Standardization achievements** include numerous contributions to various 3GPP Working Groups (SA2, SA3, SA6), to the ITU SG12, as well as various events promoting standards such as the ETSI MCX PlugFest and the 1st ETSI SDG_OpenCAPIF Hackathon. More specifically, the project submitted **33 contributions to 3GPP** with an acceptance rate of **~73%**. The 3GPP contributions revolve around four main areas: i) *Multiaccess communications* which include various enhancements of the Multipath QUIC protocol, deemed essential for video streaming, online gaming, and VoIP applications, ii) *Energy Efficiency and Energy Saving* topic which is pertinent to the energy consumption measurement campaign conducted in the context of WP5 activities, iii) *CAPIF enhancements* which are related to the project activities since CAPIF is an important deployed component, and finally iv) *XRM enhancements* which are bound to the project experimentation activities in an attempt to assess and enhance XR applications encompassing AR, VR, and mixed-reality features. In addition, the consortium has submitted **34 contributions to the ITU SG12** which target enhancements related to performance, quality of service (QoS) and quality of experience (QoE). Noteworthy here is the fact that 6G-SANDBOX initiated the foundation of a new **ETSI standardization group - ETSI ISG RIS -** which sets the basis for the development of a universal methodology to be followed when conducting RIS performance assessment. Furthermore, the various standardization events such as the ETSI MCX PlugFest which took place in Malaga in October 2023, the 1st ETSI SDG_OpenCAPIF Hackathon hosted by ETSI in Sophia Antipolis back in November 2024, as well as the consistent attendance of 6G-IA Pre-Standardization working group meetings assisted in promoting the importance of standards and aligning them with the ongoing project activities.

On the **Exploitation activities**, the consortium executed their exploitation plan capitalizing on the early identification of the exploitation methodology which had been documented within the previous deliverables D6.1[1] (M3) and D6.2 (M18). During the last 18 months, the full list of the project outcomes has been finalized, the innovative outcomes will soon be submitted to the **EU Innovation Radar**, and the most promising KERs have been identified (i.e., the **6G-SANDBOX Toolkit**, the **RIS Validation**, and the **Internet of Senses** (IoSenses)); for these KERs, a *GAP analysis* has been executed, their innovative aspects have been extracted through the *Innovation Radar's questionnaire*, and a *Business Value Canvas* has been executed to directly connect the project KERs with the customer needs. Based on these exploitation assessments the consortium has identified, and hereby justifies, the high commercialization potential of the aforementioned KERs. In order to spread the word and approach the market even faster, the consortium has committed to uploading these three KERs to the **EU Horizon Results Platform** (HRP), where details of the outcomes will be provided to interested 3rd parties and potential investors. Finally, Intellectual Property Rights (IPR) management has been also

crucial for reaching the anticipated project impact and, as such, IPR actions have been executed with due diligence.

The current deliverable, is structured as follows:

- **Section** Error! Reference source not found. presents the overall standardization achievements including contributions to SDOs, the complementary standardization events, the formation of the new ETSI group focusing on RIS assessment methodology, and final remarks on the 6G-IA pre-standardization.
- **Section 3** details the exploitation activities, providing the full list of all identified outcomes during the project's course (see Table 3-1), the three main KERs as well as details of the methodology that has been executed to assess their commercialization potential, information related to the upload of the KERs to the EU HRP, a high-level view of the individual exploitation plans, and IPR-related details.
- **Section 4** provides information around the list of innovative outcomes with further details pertinent to their submission to the EU Innovation Radar.
- **Section 5** concludes the deliverable with key take aways.

2 STANDARDIZATION ACHIEVEMENTS

The vital importance of standardization activities has been considered by the 6G-SANDBOX consortium, already from the beginning of the project. Standardization has played a crucial role, both in aligning the project outcomes with the established and ongoing standards specifications, as well as in contributing novel methods identified during the project activities to the relevant standardization bodies. 6G-SANDBOX project managed not only to align with the common European standardization efforts toward global impact and technological sovereignty, but also to deliver beyond formal commitments. The project's standardization achievements are thus reflected not merely in terms of numbers, but also within their high quality which is revealed through the increased adoption rate; in 3GPP, for instance, the **6G-SANDBOX standards adoption rate** reached **~73%**. These results signify the ceaseless focus of the consortium to standardization activities throughout the entire project lifetime.

The standardization achievements are a result of careful planning from the beginning of the project. The list of standardization bodies had been early identified and documented within the first deliverable D6.1[1] (M3), and the roadmap, along with some initial contributions, was presented within D6.2 (M18). The most important standardization bodies which 6G-SANDBOX contributed to, have been **3GPP**, **ITU**, and **ETSI.** Besides the numerous contributions to 3GPP, and ITU, 6G-SANDBOX has been a cornerstone to the formation and subsequent developments of the **ETSI SDG OpenCAPIF**, whose adoption by 6G-SANDBOX testbeds serves as a paradigm on how modern beyond-5G platforms should securely publish and expose their inner APIs via this standards' compliant **C**ommon **API F**ramework.

In addition, some key events have been either organized or exploited by 6G-SANDBOX to demonstrate the ongoing activities and foster pan-European collaboration. Such technical events that took place throughout the project's lifetime, have been the **ETSI MCX PlugFest**, as well as the **1st Hackfest** which has been organized by **ETSI SDG OpenCAPIF** in the context of **ETSI's SNS4SNS** event.

Details on the contributions submitted within each one of the targeted standardization bodies, as well as on the standardization related events, are provided in the subsections that follow.

2.1 3GPP CONTRIBUTIONS

3GPP has been one of the global standardization bodies in which 6G-SANDBOX consortium achieved significant results. The fact that many consortium partners are also active 3GPP members, provided a boost to the submitted contributions, showcasing an increased number of supporting companies, thus indicating the high value of these contributions to the broader networking community. *Lenovo*, *Telefonica*, *Nokia*, *Fogus*, *University of Malaga*, *Keysight*, and *National Centre for Scientific Research "Demokritos"*, initiated and/or supported a high number of contributions to 3GPP.

The areas which 3GPP contributions targeted to, have been:

A. **Multiaccess communications** (i.e., data communications over multiple access networks): This topic is highly relevant to 6G-SANDBOX project, since the four platforms comprising the 6G-SANDBOX facility (i.e., Athens, Berlin, Malaga, Oulu) allow access to the network via a single access, or a combination of 3GPP and non-3GPP (e.g., 5G and WLAN), as well as of Terrestrial and non-Terrestrial (NTN) access networks. As detailed within deliverable D6.2 (M18), there has been a more granular classification of multiaccess communication contributions, relative to the proposed solutions and consequently, to the 3GPP Working Group to which they have been submitted. Therefore, two main sub-categories have been targeted by the consortium:

   i. *Multipath QUIC protocol enhancements* which have been submitted to 3GPP SA2 and are proposing enhancements which enable additional multi-access capabilities to existing 5G and beyond networks; such enhancements will enable beyond-5G platforms to support multi-access experiments with applications exploiting UDP transport protocol, such as **video streaming**, **online gaming**, and **VoIP calls**, where low delay is more important than reliable data transfer.

   ii. Relevant contributions have been also submitted to 3GPP SA6, proposing an *application-layer multi-access solution*, which enables end-to-end application-layer multi-access communication avoiding the requirement for additional modifications at the heart of the network, which SA2 architecture currently mandates. The implementation at the application layer would entail quick adoption by modern networking platforms.

B. **Energy Efficiency:** In addition, the 6G-SANDBOX consortium has devoted significant effort in developing and integrating all those tools that enable accurate measurements of the energy consumption of the various networking components and functions. This activity aligned well with Lenovo's Rapporteurship in 3GPP SA2 on the Rel-19 Energy Efficiency and Energy Saving topic – *"5GS Enhancement for Energy Efficiency and Energy Saving (EnergySys)"*. As a result, several contributions have been brought to 3GPP covering project-related aspects.

C. **CAPIF enhancements:** A big part of 6G-SANDBOX consortium partners constitutes also founding members of ETSI SDG OpenCAPIF (TID, FOG, UMA, Lenovo, NCSRD), thus significant effort has been devoted to developing CAPIF framework based on existing specifications. During OpenCAPIF developments, important feedback has been provided to 3GPP on gaps identified within the specs, as well as several proposals on further CAPIF enhancements and deployment examples. Besides OpenCAPIF engagement and the resulting 3GPP contributions, CAPIF is of high importance to 6G-SANDBOX project, serving as the main framework for publishing, securely exposing, and consuming both network and application-specific APIs. CAPIF related contributions have been submitted to 3GPP SA6 and SA3 Working Groups.

D. **XRM enhancements:** XR application experiments are of high importance within 6G-SANDBOX project, serving as a means to verify the technology developed within the project, and its successful integration within the four platforms (Athens, Berlin, Malaga, Oulu). Since XR applications encompassing advanced augmented-, virtual- and mixed-reality features will be one of the main 6G network resource consumers, several contributions have been submitted to 3GPP SA2 relevant to ongoing Rel-19 study on *"Extended Reality and Media service (XRM) Phase 2 (FS_XRM_Ph2)"*, and to 3GPP SA6 on *"XRApp Study on Application Enabler for XR Services"*.

Details of the **33 contributions submitted by 6G-SANDBOX consortium to 3GPP**, are provided in Table 2-1: Overall Standards Contributions submitted to 3GPP below. Contributions are classified based on the four major categories identified earlier, that is, contributions related to multi-access communications (objectives A- i, A-ii), energy efficiency domain (objective B), CAPIF contributions (objective C), and XRM enhancements (objective D).

Table 2-1: Overall Standards Contributions submitted to 3GPP

3GPP WG	Date	Contribution Identity	Objective	Summary
SA2	17-21 Apr. 2023	S2-2305017	A-i	A Change Request to specify how Access Traffic Steering, Switching and Splitting (ATSSS) can support the MPQUIC protocol. New text is added that specifies how SMF determines the ATSSS capabilities supported by a MA PDU Session when the UE supports MPQUIC.
SA2	17-21 Apr. 2023	S2-2305019	A-i	A Change Request to specify how ATSSS can support the MPQUIC protocol. It is specified that the UE sends all traffic of a QUIC connection over the QoS flow associated with this QUIC connection. This enables the UPF to determine the QoS flow associated with each QUIC connection and to select a QUIC connection for sending the downlink traffic of a QoS flow.
SA2	17-21 Apr. 2023	S2-2305021	A-i	A Change Request to specify how ATSSS can support the MPQUIC protocol. The MPQUIC steering functionality is introduced.
SA2	17-21 Apr. 2023	S2-2305429	A-i	A Change Request to specify how ATSSS can support the MPQUIC protocol. New text is added that specifies how SMF determines the ATSSS capabilities supported by a MA PDU Session when the UE supports MPQUIC.
SA2	17-21 Apr. 2023	S2-2305474	A-i	A Change Request to specify how ATSSS can support the MPQUIC protocol. It is specified that the UE sends all traffic of a QUIC connection over the QoS flow associated with this QUIC connection. This enables the UPF to determine the QoS flow associated with each QUIC connection and to select a QUIC connection for sending the downlink traffic of a QoS flow.
SA6	21-25 Aug. 2023	S6-232420	A-ii	A new Rel-19 study proposal on "Application layer support for ATSSS"

SA6	21-25 Aug. 2023	S6-232418	A-ii	A Rel-19 discussion paper providing the motivation for the proposed study on "Application layer support for ATSSS"
SA6	09-13 Oct. 2023	S6-233073	A-ii	New proposal for SEALDD work (SEALDD-ATM) to enable "Application Traffic Management in SEALDD"
SA2	13-17 Nov. 2023	S2-2313006	B	23.700-66: KI#1, Exposure of Energy Consumption related information.
SA2	13-17 Nov. 2023	S2-2313010	B	23.700-66: New KI, (based on WT#2) Enable energy consumption and energy credit control as service criteria.
SA2	13-17 Nov. 2023	S2-2313157	B	23.700-66: KI on energy-related analytics.
SA2	26 Feb. - 1 Mar. 2024	S2-2402284	B	A solution is proposed on policy control for Energy Consumption for a UE. Not handled due to lack of time.
SA2	26 Feb. - 1 Mar. 2024	S2-2402654	B	New Solution proposed on BDT Policy considering Energy Metrics Merged into S2-2403191 and agreed.
SA2	15-19 Apr. 2024	S2-2404677	A-i	New solution proposed that enables simplified 5G connectivity via Untrusted Non-3GPP access based on the QUIC protocol. Not handled due to lack of time.
SA2	19-23 Aug. 2024	S2-2408644	A-i	Normative work on TS 23.501. Proposes additional support of MPQUIC-IP and MPQUIC-Ethernet steering functionalities. Merged into S2-2409075.
SA2	14-18 Oct. 2024	S2-2410072	D	CR provides description of conveying metadata information over an N6 tunnel as per KI2 XRM study agreements Finally revised to S2-2411182 and agreed.
SA2	14-18 Oct. 2024	S2-2410509	B	This TS 23.501 CR specifies that the feature for subscription and policy control to enable network energy savings needs to be supported. Merged into S2-2410752.
SA6	14-18 Oct. 2024	S6-244198	C	This pCR proposes changes to TR 23.946 v0.6.0 on ETSI MEC deployment based on CAPIF. This contribution has been approved.
SA6	14-18 Oct. 2024	S6-244199	C	This pCR proposes changes to TR 23.946 v0.6.0 on NEF AEF profile updates. This contribution was revised to S6-244557 and has been approved.
SA6	14-18 Oct. 2024	S6-244200	C	This pCR provides an update on TR 23.946 v0.6.0 on supported features.

				This contribution was revised to S6-244558 and has been approved.
SA6	14-18 Oct. 2024	S6-244201	C	This pCR provides CAPIF Core Function APIs test Annex within TR 23.946 v0.6.0. This contribution was revised to S6-244559 and has been approved.
SA6	14-18 Oct. 2024	S6-244238	D	This contribution provides a new ADAE capability to support VAL performance analytics for tethered UEs. This contribution was revised to S6-244638 and has been agreed.
SA6	18-22 Nov. 2024	S6-245066	C	This pCR describes the use of the CAPIF vendor extensibility feature within 23.946 v0.7.0. This contribution was finally revised to S6-245665 and has been approved.
SA6	18-22 Nov. 2024	S6-245067	C	This pCR describes the MEC Platform as an API Provider within 23.946 v0.7.0. This contribution was revised to S6-245431 and has been approved.
SA2	18-22 Nov. 2024	S2-2412098	B	This TS23.502 CR proposes to update the Registration procedure to show that the PCF may modify the subscribed AM policy parameters for the UE. It further proposes to add a new Application data in the UDR which is used for the PDU Session policy creation at the PCF. This contribution has been marked as "not treated".
SA6	17-21 Feb. 2025	S6-250365	C	This contribution provides "Correction to obtaining CAPIF credentials". This contribution has been agreed.
SA2	17-21 Feb. 2025	S2-2502473	D	This contribution proposes enhancements on conclusions of XRM_Ph2 KI#5. This contribution has been agreed.
SA2	17-21 Feb. 2025	S2-2501642	D	This contribution provides details for the support of sending MMSID from CN to the RAN. This contribution has been marked as not-treated.
SA2	17-21 Feb. 2025	S2-2502165	B	This CR proposes changes to TS23.502 related to "Introducing energy savings indicator in subscription information". This contribution has been merged to S2-2501606 which was revised to S2-2502372 and has been agreed.

SA3	07-11 Apr. 2025	S3-251210	C	This Rel-19 contribution provides details related to CAPIF: "Onboarding API Invoker Residing in the UE" Revised to S3-251724 and approved.
SA3	07-11 Apr. 2025	S3-251211	C	This Rel-19 contribution provides details related to CAPIF: "Updates to Security procedure for CAPIF interconnection" This contribution has been merged.
SA3	07-11 Apr. 2025	S3-251212	C	This Rel-19 contribution provides details related to CAPIF: "Updates to resource owner authorization revocation" This contribution has been merged.
SA3	07-11 Apr. 2025	S3-251213	C	This Rel-19 contribution provides details related to CAPIF: "Updates to Draft CR for KI1.2 on Resource Owner authorization" This contribution has been merged.

2.2 ITU CONTRIBUTIONS

6G-SANDBOX also enabled studies related to Quality of Experience (QoE), i.e., *"the degree of delight or annoyance of the user of an application or service"* [ITU-T P.10/G100]. Studying and modeling QoE is essential for current 5G and future 6G networks, given that users will engage more and more with highly interactive applications. Services like high-quality video streaming, live streaming, cloud gaming, teleconferencing, and immersive experience (AR/VR) will be enhanced or even enabled by future networks.

With the experience obtained from the 6G-SANDBOX project, as well as previous related European projects, an ITU-T Work Item with the name Y.TestBed has been created in the context of ITU-T Study Group (SG) 12: *Performance, QoS & QoE*. A summary of the Work Item is included below:

"The Work Item proposes a testbed setup and a methodology to evaluate the QoE of the multiple 5G and beyond mobile use cases. A testbed, its calibration, and a testing methodology are described, able to provide consistent and repeatable results in an automated fashion. A key focus of the setup is the use of commercial devices and applications, aiming at making results more valuable by mimicking the setup of a real user."

Between 2023 and 2024, a total of 11 contributions and 3 TDs have been submitted to ITU-T Study Group 12 (SG12) meetings, plus 20 contributions to ITU-T SG12 Question 17 (Q17/12) interim meetings, listed in Table 2-2: Overall Standards Contributions submitted to ITU. Contributions have been discussed with the group's experts and served to create and fill a base text over time. The Y.TestBed work item was then submitted for consent to ITU-T SG12 during the study group meeting held in Geneva, Switzerland, on 16-25 April 2024, where it

was consented as ITU-T Recommendation G.1052. The recommendation was then finalized during the month of August, completing an editorial review.

The ITU work done to standardize QoE is highly relevant for 6G-SANDBOX and vice versa. The ITU work focuses on the following topics, all specifically related to QoS and even more to QoE evaluation:

- KPIs
- Testbed description and calibration
- Testing methodology
- Use cases and networks scenarios

6G-SANDBOX offers a trial facility to assess technologies and future services, contributing to the writing of the testbed description and calibration, as well as the testing methodology. Part of the project defines KPIs which are important for 6G while at the same time running experiments to have a feeling if these KPIs are set correctly. A few identified KPIs are covering end-to-end services, such as QoE[1] on different use cases of interest for future 6G networks. The consortium identified some shortcomings towards the availability of testbeds and guidance on how to build these testbeds specifically to measure objectively the QoE. For this reason, contributions to ITU were submitted, ultimately being collected and consented to become an ITU-T Recommendation.

Table 2-2: Overall Standards Contributions submitted to ITU

Meeting type	Date	Contrib. ID	Contribution name
SG12 meeting	18-26 Jan. 2023	C-100	Mandatory Clauses and Document Structure
SG12 meeting	18-26 Jan. 2023	C-103	Scoring Methodology
SG12 meeting	18-26 Jan. 2023	C-104	Use Cases and Network Scenarios
SG12 meeting	18-26 Jan. 2023	C-105	Testbed Description
SG12 meeting	18-26 Jan. 2023	C-111	Scoring Methodology applied
SG12 meeting	19-28 Sep. 2023	C-158	Contributions added to base text
SG12 meeting	19-28 Sep. 2023	C-160	Use Cases and Network Scenarios
SG12 meeting	19-28 Sep. 2023	C-161	Example workflow of Y.TestBed
SG12 meeting	19-28 Sep. 2023	C-162	Updates to base text
SG12 meeting	19-28 Sep. 2023	C-178	Scenarios Parameters Settings
Q17/12 interim meeting	14 Nov. 2023	Q17-C001	Baseline draft of the Work Item
Q17/12 interim meeting	14 Nov. 2023	Q17-C002	Testing Methodology

[1] 6G-SANDBOX provides the infrastructure for this QoE work; actual experimental and research work is not funded directly by 6G-SANDBOX.

Q17/12 interim meeting	14 Nov. 2023	Q17-C003	OpenTAP Overview
Q17/12 interim meeting	14 Nov. 2023	Q17-C004	Clause 6.4 updated terminology
Q17/12 interim meeting	30 Jan. 2023	Q17-C005	Baseline draft of the Work Item
Q17/12 interim meeting	30 Jan. 2023	Q17-C006	Revision of sub-clause 6.4 "Objective/Estimated MOS"
Q17/12 interim meeting	30 Jan. 2023	Q17-C007R2	Updates to clause 11.2.5 "Core Network"
Q17/12 interim meeting	30 Jan. 2023	Q17-C008R1	Draft of clause "Testbed calibration"
Q17/12 interim meeting	13 Feb. 2023	Q17-C009	Baseline draft of the Work Item
Q17/12 interim meeting	13 Feb. 2023	Q17-C010	Draft of clause "Market Share Analysis"
Q17/12 interim meeting	13 Feb. 2023	Q17-C011R1	Updates to clause "Testbed calibration"
Q17/12 interim meeting	13 Feb. 2023	Q17-C012	Provides updated structure for the document
Q17/12 interim meeting	13 Feb. 2023	Q17-C013	Editorial changes to the document
Q17/12 interim meeting	5 Mar. 2023	Q17-C014R1	Baseline draft of the Work Item
Q17/12 interim meeting	5 Mar. 2023	Q17-C015R2	
Q17/12 interim meeting	5 Mar. 2023	Q17-C016R1	Provides updates to clause "Testbed calibration"
Q17/12 interim meeting	5 Mar. 2023	Q17-C017	The contribution adds scenario parameters settings for all scenario described in the body of the document.
Q17/12 interim meeting	5 Mar. 2023	Q17-C018R1	The contribution aligns the terminology used within the document to other ITU-T Recommendations, e.g., ITU-T Y.1540.
Q17/12 interim meeting	5 Mar. 2023	Q17-C019	The contribution includes a NOTE that the Q17/12 rapporteur asked to add to clause 6.3 "Normalized KPIs".
Q17/12 interim meeting	5 Mar. 2023	Q17-C020R1	The contribution provides editorial changes to the document
SG12 meeting	16-25 Apr. 2024	C-0188	The contribution provides editorial changes to the document
SG12 meeting	16-25 Apr. 2024	TD-0584	Draft new Recommendation ITU-T Y.Testbed: Test Bed Framework for Mobile Application QoS and QoE Evaluation.

			The Work Item was consented and will become ITU-T Recommendation G.1052.
SG12 meeting	16-25 Apr. 2024	TD-0638	LS/o on consent of draft new Recommendation ITU-T Y. xxxx (ex. Y.TestBed) "Test Bed Framework for Mobile Application QoS and QoE Evaluation". The Liaison Statement will inform relevant SDOs of the newly consented ITU-T Work Item, allowing them to provide further feedback or requesting for a review.
SG12 meeting	16-25 Apr. 2024	TD-0639	A. 5 justification information for draft new Recommendation ITU-T Y.TestBed "Test Bed Framework for Mobile Application QoS and QoE Evaluation". The document justifies why references from other SDOs other than ITU are needed for the full understanding of the newly consented Recommendation.

2.3 ETSI RIS VALIDATION

Within the newly established ETSI Industry Specification Group on Reconfigurable Intelligent Surfaces (**ISG RIS**), 6G-SANDBOX partner *Keysight* has assisted in completing the draft Group Specification DGS/RIS-008 *"Standardized Testing for Reconfigurable Intelligent Surfaces"*, which defines a **first standardized framework for RIS validation**. The document selects a core set of RIS parameters (e.g., operating frequency range, maximum operating bandwidth, radar cross section, spatial beam characteristics, total reflected/refracted power, modulated signal quality, static power consumption, and reconfiguration time) and specifies corresponding over-the-air measurement setups and methodologies (bistatic and monostatic, CATR and DFF-based) to enable comparable and repeatable performance assessment across vendors and prototypes. 6G-SANDBOX through its partner *Keysight* consolidated partner input and aligned with the evolving state of the art in time to deliver a mature draft for approval in ISG RIS, positioning this work at the heart of the emerging ETSI RIS validation ecosystem and providing a solid technical basis for future conformance testing, product datasheets, and potential 3GPP/6G alignment.

2.4 ETSI MCX PLUGFEST

UMA has contributed again to support the ETSI plugtests. ETSI, in cooperation with the European Emergency Number Association (EENA), organized a NG112 Emergency

Communications with NG eCall Plugtests event which was held in UMA from 30 September to 4 October 2024[2].

Before this NG112 event, 6G-SANDBOX Malaga platform was selected by ETSI to host the 8th MCX Plugtests event[3]. The event, organized by ETSI with the support of the European Commission and international associations like EFTA and TCCA, has been the place to test interoperability for 4G and 5G vendors in the areas of 3GPP MCS (Mission Critical Services) and FRMCS (Future Railway Mobile Communication Systems) that is based on MCX. More than 100 participants brought their solutions for applications, user equipment, radio access (RAN) and core network to progress in interoperability. The project platform in Malaga contributed to the event with the main purpose being to identify and solve interoperability issues in MCS and FRMCS with the 4G and 5G equipment and support from UMA staff that participated in the event. The final report from previous edition in Malaga gives an impression of the impact of the event[4].

2.5 ETSI SDG – OPENCAPIF

The project also contributed significantly to the formation of the ETSI Software Development Group (SDG) OpenCAPIF (OCF), advocating for the adoption of the CAPIF framework to foster innovation in experimental contexts. This initiative highlights the project's commitment to open standards and the facilitation of interoperable solutions.

The importance of the OCF CAPIF implementation to 6G-SANDBOX is manifold, primarily due to its role in enabling standardized, efficient, and secure exposure of network services to experimenters. This standardization is crucial for trial networks within the 6G-SANDBOX project, as it ensures a consistent and interoperable framework for accessing and utilizing network functionalities. By adhering to CAPIF standards, 6G-SANDBOX can provide a robust platform for testing and validating new technologies and services, fostering innovation while ensuring compliance with global telecommunication standards. This framework significantly contributes to the project's goals of advancing 6G technologies by facilitating seamless and scalable experimentation environments.

6G-SANDBOX has been the major contributor for the evolution of OpenCAPIF from Release 1 to Release 3, while project partners TID and FOGUS have been leading an OpenCAPIF tutorial session during the SNS4SNS event 2024.

2.6 6G-IA PRE-STD WG

In addition to the above-mentioned activities, the 6G-SANDBOX consortium has been regularly represented in all 6G-IA Pre-Std WG meetings via its partner *Lenovo*. Besides the

[2] https://www.etsi.org/events/2351-6th-ng112-with-ecall-plugtests

[3] https://www.etsi.org/events/2242-8th-mcx-plugtests

[4] https://portal.etsi.org/Portals/0/TBpages/CTI/Docs/7th_ETSI_MCX_Plugtests_Report_V100.pdf

typical obligations of providing the quarterly reports of the project's standards' contributions, Pre-Std WG served as a valuable bidirectional source of information shared between EU projects on how to shape ongoing standards and increase the EU global impact.

3 EXPLOITATION ACTIVITIES

The 6G-SANDBOX exploitation strategy which was thoroughly described within D6.1[1] (M3): *"Initial Dissemination and Exploitation Plan"*, served as a compass for the execution of the actual activities that took place during the main development phase of the project. While the intermediate deliverable D6.2 (M18-SEN): *"Intermediate report on Dissemination & Exploitation activities and Open Calls"* provided some coarse identification of the initial project-specific exploitable results, this final deliverable (D6.3 [M36]) describes in detail the final project-related Key Exploitable Results (KERs) and delineates the precise methodology followed to identify, classify, and assess the project outcomes with regard to their potential and their foreseen impact. In addition, an updated abstract of the partner-specific exploitation plans is also provided in the context of this section.

3.1 PROJECT OUTCOMES IDENTIFICATION AND ASSESSMENT

Part of the 6G-SANDBOX WP6 activities was the identification of all possible project-specific outcomes, the full list of which, is depicted in Table 3-1 below. The methodology which has been followed included assignment of outcomes to partners so that further details could subsequently be provided, i.e., the type of outcome, its TRL level, the project ambition each outcome satisfies, a short description of it, as well as a brief description of the competition (if any), and finally a list of the consortium partners involved in the developments of each respective outcome.

Table 3-1: 6G-SANBOX Outcomes

#	Outcome	Class	Type	TRL	Project Ambitions	Description
1	**6G-SANDBOX Toolkit**[5]	Value (Open Source)	Software	TRL7: System prototype demonstration in operational environment	Amb#1: Ambition in Experimentation Processes and Facilities	Open source software framework to automate the creation of trial networks from components described in the 6G-Library. Users can describe and deploy their tesbeds automatically
2	6G-SANDBOX testbeds/facility	Profit (Commercially available)	Process/UC Demonstrator	TRL7: System prototype demonstration in operational environment	Amb#1: Ambition in Experimentation Processes and Facilities	4 state of the art testbed facilities that can be used by third parties to evaluate and demonstrate their key 6G candidate technologies.
3	6G Library	Value (Open Source)	Software	TRL4: Technology validated in lab	Amb#1: Ambition in Experimentation Processes and Facilities	Software repository with 6G Library objects that can be deployed as part of a Trial Network in any 6G SANDBOX facility.
4	Disaggregated and future-proof vRAN	Profit (Commercially available)	Software	TRL4: Technology validated in lab	Amb#2: Ambition in Disruptive wireless: Disaggregated and future-proof vRAN	Disaggregated and virtualized Open RAN, integrating CU, DU, RIC, and xApps, with both a) block-based and b) component-based (DU-CU-RU) deployments. This innovative vRAN surpasses traditional RAN by enhancing scalability, flexibility, and efficiency for 6G and will be a key addition to the 6G-Library toolkit. Solution that is provided matches the needs of highly disaggregated RAN that is robust against dense network deployment in future.

[5] The 6G-SANDBOX Toolkit is one of the three most important project outcomes with high exploitation potential.

5	RIS as a device	Profit (Commercially available)		TRL4: Technology validated in lab	Amb#2: Ambition in Disruptive wireless: RIS	The developed RIS is a modular and plug-and-play solution. RIS panels require only power and a data connection from the external environment, making its integration, and rescaling straightforward. Together with developed API this ensures that our RIS can adapt instantly to dynamic network conditions, providing a scalable and low-latency solution that significantly extends coverage of mmWave communications.
6	**RIS Validation**[6]	Profit (Commercially available)	Technical report	TRL4: Technology validated in lab, TRL5: Technology validated in relevant environment	Amb#2: Ambition in Disruptive wireless: RIS	The ability to answer the question whether RIS brings value to the overall 5G/6G system in FR1 and FR2.
7	Efficient implementation for multi-connectivity	Profit (Commercially available)	Software	TRL7: System prototype demonstration in operational environment	Amb#3: Ambition in fixed/RAN/NTN integration: Efficient implementation for multi-connectivity	The Multi-connection Tactile Internet Protocol (MTIP) is a multi-connectivity transport protocol for the Tactile Internet. MTIP uses application and network status information to select network paths intelligently and improve the KPIs related to these applications.
		Profit (Commercially available)	Patent	TRL3: Experimental proof of concept	Amb#3: Ambition in fixed/RAN/NTN integration: Efficient implementation for multi-connectivity	Patent on "ENABLING NON-5G CAPABLE DEVICE ACCESS TO 5G NETWORKS VIA UNTRUSTED NON-3GPP ACCESS"

[6] The RIS Validation is also included among the three main Key Exploitable Results (KERs).

8	Smart NTN with computing and storage in the sky	Value (Open Source)	Software	TRL4: Technology validated in lab	Amb#3: Ambition in fixed/RAN/NTN integration: Smart NTN with computing and storage in the sky	Emulated satellite communication systems (using the OpenSand open source), supporting both transparent and regenerative satellites for access or mesh satellite systems with SDN support for performance evaluation and network techniques validation
9	P4 language for programmable switches and UPF	Value (Open Source)	Software	TRL6: Technology demonstrated in relevant environment	Amb#4: Ambition in Deterministic networking enablers	Development of two P4 modules: (1) UPF: The UPF-P4 module in 6G-SANDBOX serves as a valuable tool in enhancing the transport network of the Malaga infrastructure, enabling the attainment of the requisites features for deterministic communications. These features consist of ensuring low latency, delivering quality of service, efficient traffic management, traffic prioritization, and reliability. There are two main implementations: UPF-P4 BMv2 SW, which is a software component built into a virtual machine; UPF-P4 Intel Tofino 2 HW, which is a hardware component integrated into the Intel Tofino 2 switch (2) Telemetry: The telemetry-P4 module plays a pivotal role in a 5G/6G network by enabling real-time monitoring and data collection from network devices and infrastructure. The P4 language enables efficient and precise data collection through programming the data plane, enabling efficient, real-time, and flexible network monitoring.
10	Standardization Contributions (3GPP, ETSI), ITU	Value (Open Source)	Standard/Specification	TRL1: Basic principles observed	Amb#3: Ambition in fixed/RAN/NTN integration: Efficient implementation for multi-connectivity	(A): 3GPP Standards contributions in the areas of: i) Multi-Connectivity (ATSSS_Ph3/Ph4: MPQUIC, App-Layer Multiaccess solutions), ii) Energy Efficiency and Energy Saving, iii) XRM (contributions that shape network architecture to facilitate

						XRM [eXtended Reality and Media services] use cases, iv) CAPIF, (B): ETSI: Formation of ETSI_SDG_OpenCAPIF, (C): ITU: contributions to ITU-T SG12 related to i) Testbed calibration, ii) Normalized KPIs terminology alignment, iii) Draft new Recommendation ITU-T Y.Testbed: Test Bed Framework for Mobile Application QoS and QoE Evaluation
11	OpenCAPIF developments	Value (Open Source)	Software	TRL4: Technology validated in lab	Amb#5: Ambition in Interaction with Network Core	3GPP SA6 CAPIF implementation liberated as Open Source in the ETSI SDG OpenCAPIF. Latest implementation supports 3GPP Release 18.
12	Twinning for validation of management and resource orchestration	Profit (Commercially available)	Software	TRL4: Technology validated in lab	Amb#9: Ambition in Digital Twins	Availability of a Digital Twin platform with calibrated environment, demonstrating how accurate the Digital twin can actually predict the network behavior.
13	**Internet of Sense applications thanks to haptic and XR services**[7]	Profit (Commercially available)	New Product/Feature	TRL4: Technology validated in lab	Amb#10: Ambition in XR-Haptics	The service offered by the immersive communication platform can be seen as an evolution of current videoconferencing applications towards a fully pervasive experience, that provides remote users with the feeling of being teleported to the place where the capture device is being operated and being able to communicate naturally with the people present there, and with other remotes participants too.

[7] The Internet of Senses application (IoSenses) concludes the list of the three project KERs.

14	B5G Security as a Service	Profit (Commercially available)	Software	TRL6: Technology demonstrated in relevant environment	Amb#7: Ambition in Security as a Service	An Encryption-as-a-Service (EaaS) solution has been developed to provide flexible and efficient security for B5G/6G networks. It enables on-demand, low-latency encryption and decryption, optimized through lightweight algorithms and hardware acceleration. The solution supports dynamic integration with RAN, core, and edge components via standard APIs, allowing intelligent orchestration of security functions. Delivered as a modular service, EaaS enhances data protection, scalability, and responsiveness, ensuring secure and adaptive operations in distributed network environments.
15	AI-based Resource Allocation	Profit (Commercially available)	Software	TRL3: Experimental proof of concept	Amb#6: Ambition in AI/ML network evolution: AI-based Resource Allocation	AI-driven network function offloading solution which optimizes placement of O-RAN workloads for the CU-UP. This solution addresses the needs of end-users who need to fit their RAN deployment into available compute resources. This innovation enhances resource efficiency, scalability, and adaptive workload distribution, ensuring intelligent and dynamic allocation of computing resources in next-generation 6G networks. The solution will be offered as xApp that provides decision support to RAN and/or cloud orchestration on when to scale the CU-UP workload for the active and future users of the network.
16	KPIs and KVIs repository linked to specific scenarios B5G					

17	6G-SANDBOX Knowledge	Value (Open Source)	Documents/Books	N/A	Amb#1: Ambition in Experimentation Processes and Facilities	The 6G-SANDBOX knowledge includes material, such as articles, standardization reports, tutorials. , such as on deploying 6G-SANDBOX compatible testbeds, with details on TNLCM, Trial Networks' operations, 6G-library components' development and integration, etc. - Knowledge diffusion via Delivered Presentations/Panel discussions/Poster sessions/Workshops/Interviews/Webinars and Special sessions.[8] - Knowledge diffusion through scientific publications (Journal/Conference papers/White papers/6G-SNS & 5GPPP White papers).[9] - Knowledge diffusion through articles published in several media (newspapers, websites, newsletters).[10] - Knowledge diffusion through the publicly available project deliverables.[11] - Knowledge diffusion through description of the repositories and the various components developed by the project (i.e., 6G-SANDBOX

[8] https://6g-sandbox.eu/dissemination/workshops-presentations-trials/

[9] https://6g-sandbox.eu/dissemination/publications/

[10] https://6g-sandbox.eu/dissemination/articles/

[11] https://6g-sandbox.eu/dissemination/deliverables/

						site, Toolkit installer, 6G-Library, TNLCM, Marketplace), as well as hands-on instructions to facilitate installation/execution/verification by any interested stakeholder (developers, platform owners, etc).[12] - Knowledge diffusion to European SMEs in the form of OpenCalls.[13] - Knowledge diffusion to the global community via the various collaborations of 6G-SANDBOX project with European and international organizations, research institutions and universities (MoU with ESA, UoMalaya, ITRI, ..) -> info within WP1 deliverables. - Knowledge exchange through established collaboration with technology and equipment providers.[14] - Knowledge diffusion through collaboration with other SNS-JU projects - Third-party experimentation guide.[15]

[12] https://6g-sandbox.github.io/docs/0.4.0/introduction

[13] https://6g-sandbox.eu/opencall/

[14] https://6g-sandbox.eu/established-collaborations/

[15] https://6g-sandbox.eu/wp-content/uploads/2024/09/6GSANDBOX-3rd-P-Eng-Guide.pdf

						- 6G-SANDBOX Toolkit Installation Guide.[16]
18	Adapters/connectors to 5G/6G dataspaces	Value (Open Source)	Software	TRL6: Technology demonstrated in relevant environment	Amb#1: Ambition in Experimentation Processes and Facilities	Development of a connector to push data collected by the ELCM and stored a local Influx DB into target environments such as Slices Metadata Registry System (SLICES MRS).

[16] https://6g-sandbox.eu/wp-content/uploads/2024/09/6G-SANDBOX-Toolkit_Installation-G-V1.0_F.pdf

3.2 KEY EXPLOITABLE RESULTS (KERS)

Based on this initial list of the project-related outcomes, the consortium selected the three showcasing the highest exploitation potential, that is:

i. the **6G-SANDBOX Toolkit**,
ii. the **RIS Validation**, and
iii. the **Internet of Senses** (IoSenses)

For these KERs, a **Gap Analysis** was initially executed in order to identify the *Strengths*, *Weaknesses*, *Opportunities*, and *Threats*. Afterwards, the innovative aspects of each KER are identified by answering a subset of the questions included within the **EU Innovation Radar questionnaire**. Finally, the **Business Value Proposition Canvas** was filled in, providing a deeper understanding of the *Product* and the target *Customer*.

3.2.1 6G-SANDBOX TOOLKIT

The 6G-SANDBOX Toolkit is a software suite, including its own all-in-one installer (the Toolkit installer). The heard of the suite is the Trial Network Lifecycle manager (TNLCM) that automates the execution of trials, providing a sandbox environment to support developers in integrating and testing 6G functionalities into their technologies. The competition could be characterized as partial regarding infrastructure automation (e.g. Terraform, JFed) but not as the full package including 6G functionality and trials execution. The customers of the Toolkit could be Infrastructure Owners, Platform Operators as well as Technology Developers (Telecom & Verticals).

Table 3-2: 6G-SANDBOX Toolkit – GAP Analysis

1. GAP Analysis		
Internal	**Strengths**	**Weaknesses**
	• It is modular, and thus expandable with new components (through the 6G Library integration). • It is based on open-source developments leveraging a big community of developers/testers. • Encapsulates the diverse expertise of the project partners (e.g. openRAN, infrastructure automation, 5G Cores etc.)	• Learning curve/effort required to create a new component in the 6G-Library. • Limited capabilities in integrating some enterprise/black box systems.
External	**Opportunities**	**Threats**
	• Turn-key solution to perform 6G experimentation. • Mature solution/no similar product in the market.	• Limited by Open-Source license changes - regarding the tools used. • SLA offered is best-effort.

Table 3-3: 6G-SANDBOX Toolkit – Innovation Radar Description

2. Innovation Radar Description				
1	Characterize the type of innovation	New product		
2	What is the level of innovation?	Obviously innovative and easily appreciated advantages to customer		
3	How will the innovation be exploited?	Introduced as new to the market (commercial exploitation)		
4	Step(s)to bring the innovation to the market	Pilot, Demonstration or Testing activities		
5	Is there a clear 'owner' of the innovation?	TID	UMA, FOG	All 6G-SANDBOX WP3 Partners
6	Indicate max 3 key organization(s) delivering it	TID	UMA	FOG
7	Indicate needs to fulfill their market potential per key organization	Business plan development	Legal advice (IPR or other)	
8	Will it be used by current or new customers?	New		
9	Market maturity	Market-creating: The market is not yet existing, but the innovation has clear potential to create a new market		
10	Market dynamics	Growing		
11	How strong is competition in the target market?	Patchy, no major players		
12	When could it be commercialized?	Between 1 and 3 years		
13	Which of the Societal Challenge(s) is/are relevant to?	Climate action, environment, resource efficiency and raw materials		
14	Which of the UN Sustainable Development Goals (SDGs) does this innovation contribute to?	SDG 9 – Industry, Innovation, and Infrastructure		

Table 3-4: 6G-SANDBOX Toolkit – BVPC (Telecoms)

3. Business Value Proposition Canvas: Telecoms: Equipment Vendor/Developers

Product/Outcome:

(Product or Service) Features

list of products, services and features targeting the value proposition to a specific customer segment.

- Comprehensive framework for 6G experimentation, integration, and testing.
- Modular and expandable through plug-and-play 6G Library components.
- Customizable via Trial Network Templates for diverse use-case instantiation.
- Open-source foundation ensuring transparency, collaboration, and extensibility.
- Supports both simulated and real-world environments for end-to-end 6G technology validation.

Gain Creators

list the ways in which these products and services can create gains for the Customer.

- Automated, fully virtualized network deployment, enabling instant access to test and integrate 6G technologies.
- Scalable sandbox environment that supports rapid prototyping and iterative experimentation.
- Streamlined integration workflow that reduces development time and operational overhead.
- Facilitates collaboration among developers, researchers, and industry partners through a shared testing environment.

Pain Relievers

the ways in which these product and services will alleviate specific Customer Pains.

Customer:

Gains

list the results customers want to achieve or concrete benefits they are seeking from their Jobs.

- Affordable and flexible mechanism to experiment with and integrate 6G technologies.
- Open, customizable, and community-driven platform supporting continuous innovation.
- Accelerated learning and innovation cycle through automated testing and pre-built templates.
- Faster go-to-market for 6G-enabled products and services.

Pains

list the risks, obstacles, problems related with the existing way (without the product) of performing the Customer Jobs.

Customer Jobs

list the existing customer jobs/processes executed by the prospect users that are relevant to each product.

- System and integration testing teams that aim to experiment with, validate, and integrate 6G technologies by setting up and managing virtualized 6G sandboxes and trial networks.

	• Provides ready-to-use 6G testing infrastructure, eliminating the need for costly physical setups. • Removes complexity of setting up and maintaining 6G environments. • Accessible and cost-effective entry point for organizations of all sizes to explore 6G capabilities. • Reduces technical and financial barriers to experimentation and innovation.	• Limited access to early 6G technology and testing infrastructure. • High complexity and steep learning curve in setting up 6G testbeds from scratch. • Resource-intensive process to maintain and adapt evolving 6G environments. • Uncertainty about interoperability and performance of 6G components before deployment.	

Table 3-5: 6G-SANDBOX Toolkit – BVPC (Verticals)

4. Business Value Proposition Canvas: Verticals: Platform Owners			
Product/Outcome:		**Customer:**	
(Product or Service) Features *list of products, services and features targeting the value proposition to a specific customer segment.* • Deployment of 6G experimental infrastructure and the execution of trials. • Unified orchestration layer for 6G testbeds. • Automated trial execution and analytics tools. • Integration of APIs for vertical and research partners.	**Gain Creators** *list the ways in which these products and services can create gains for the Customer.* • Simplifies management with automation and orchestration tools. • Increases testbed utilization through multi-tenant access. **Pain Relievers** *the ways in which these product and services will alleviate specific Customer Pains.* • Simplifies operations through automated management. • Addresses interoperability issues via standard APIs. • Improves resource efficiency and experiment reproducibility.	**Gains** *list the results customers want to achieve or concrete benefits they are seeking from their Jobs.* • Higher ROI through increased testbed demand. • Achieving easy and automated management of all test-bed components. **Pains** *list the risks, obstacles, problems related with the existing way (without the product) of performing the Customer Jobs.* • Operational Complexity and Effort required to create a new component in the 6G-Library. • Limited capabilities integrating enterprise/black box systems.	**Customer Jobs** *list the existing customer jobs/processes executed by the prospect users that are relevant to each product.* • Manage, maintain, and optimize experimental infrastructure. • Monitor usage and performance metrics. • Ensure compliance, security, and interoperability across sites. • Reduce the Total Cost of Ownership of the test-bed infrastructure.

	• Solves the complexity of manual setup by providing a turn-key solution.		

3.2.2 RIS VALIDATION

The RIS Validation is a solution that implements a standardized vendor-agnostic methodology/process to characterize RIS products (both active and passive) enabling reproduceable and comparable RIS performance assessment. In terms of competition, there is currently no relevant work reported, apart from some partial aspects which are addressed by *Anritsu* and *Rohde & Schwarz*. Prospective customers include RIS vendors as well as universities and research centers.

Table 3-6: RIS Validation – GAP Analysis

1. GAP Analysis		
Internal	**Strengths**	**Weaknesses**
	• It is easily extensible for new RIS products; solution is multi-vendor. • Builds on mature core business platform from KEY.	• Measurement environment size (anechoic chamber) must be proportional to the RIS panel size and this maybe a limitation factor for large RIS/reflector devices.
External	**Opportunities**	**Threats**
	• ETSI Standardized Method, appealing to the RIS vendors' end customer. • Frequency -agnostic method - Valid for current and future RIS designs. • Mature - Already tested with 4 different RIS products and 7 passive reflectors. • The solution is based on blocks that can be re-used to other RF research activities. • Low barrier/learning curve.	• Expensive for small/mid-scale RIS Vendors (that do not already have measurement infrastructure).

Table 3-7: RIS Validation – Innovation Radar Description

2. Innovation Radar Description				
1	Characterize the type of innovation	New product		
2	What is the level of innovation?	Obviously innovative and easily appreciated advantages to customer		
3	How will the innovation be exploited?	Introduced as new to the market (commercial exploitation)		
4	Step(s)to bring the innovation to the market	Business Plan		
5	Is there a clear 'owner' of the innovation?	Yes: Keysight		

6	Indicate max 3 key organization(s) delivering it	Org1: KEY		
7	Indicate needs to fulfill their market potential per key organization	Business plan development		
8	Will it be used by current or new customers?	Existing		
9	Market maturity	Market-creating: The market is not yet existing, but the innovation has clear potential to create a new market		
10	Market dynamics	Growing		
11	How strong is competition in the target market?	Established competition but none with a proposition like the one under investigation		
12	When could it be commercialized?	Between 1 and 3 years		
13	Which of the Societal Challenge(s) is/are relevant to?	Climate action, environment, resource efficiency and raw materials	*How does it tackle the respective societal challenge?* Instead of adding more BS, we use RIS.	
14	Which of the UN Sustainable Development Goals (SDGs) does this innovation contribute to?	SDG 9 – Industry, Innovation, and Infrastructure		

Table 3-8: RIS Validation - BVPC

3. Business Value Proposition Canvas			
Product/Outcome:		**Customer:**	
(Product or Service) Features *list of products, services and features targeting the value proposition to a specific customer segment.* • Mature and standardized solution. • Easily extensible to new RIS products. • Allows for comparison between various RIS products.	**Gain Creators** *list the ways in which these products and services can create gains for the Customer.* • Attract more customers. • Demonstrate the RIS products capabilities in a comparable manner and prove themselves. **Pain Relievers** *the ways in which these product and services will alleviate specific Customer Pains.* • Reduce learning curve/time necessary to deliver own solutions.	**Gains** *list the results customers want to achieve or concrete benefits they are seeking from their Jobs.* • Ability to compare their RIS Product performance against competition in a standard-approved manner. **Pains** *list the risks, obstacles, problems related with the existing way (without the product) of performing the Customer Jobs.* • Difficulty to perform RIS Validation in a standardised manner.	**Customer Jobs** *list the existing customer jobs/processes executed by the prospect users that are relevant to each product.* • Reduce the effort necessary for due diligence / less work for performance measurement/evaluation teams.

3.2.3 IoSenses

In this project 6G-SANDBOX partner *NOKIA* has integrated into the 6G testbed an innovative use case that implements an Internet of Senses application. To contribute to the project goals, they have developed a control layer that, running within the network, enables the assignment of guaranteed resources to the application when needed. This guarantee is provided at application level using the Network as Code paradigm, and its implementation is done through a new network component (XR extension).

The resulting scenario is a practical demonstration of the capabilities that future applications will require from last generation networks. Its integration in the testbed has been a useful first example of how such new applications will get integrated. But beyond this functional new network feature, they have come up with an end-to-end immersive communications platform with haptics functionality that demonstrates the potential of Internet of Senses. And this platform shows a clear opportunity for commercialization. The current subsection describes the concept of a product based on it , the intended target users, and the path to get this commercialization done.

Concept

Immersive communication can be considered as the flagship application of the Internet of Senses: a communications platform encompassing video, audio and haptics into a multi-peer, real-time, bidirectional experience:

- 360 video is captured and delivered over the network, providing a complete immersion of users in a remote scenario.
- Bidirectional audio enables a natural communication path between peers in the captured location and peers in remote locations using VR goggles.
- The delivery of sensations over the same communication path and its control by the same session signaling, provides a seamless integration of haptics into the full sensorial experience of the application.
- State of the art devices are leveraged: VR goggles (optimally with video pass-through), 360 video and haptic vests.

Impact

This service can be seen as an evolution of current videoconferencing applications towards a fully pervasive experience, that provides remote users with the feeling of being teleported to the place where the capture device is being operated and being able to communicate naturally with the people present there, and with other remote participants too.

The application scope of this concept is essentially a greenfield, so the potential demand is difficult to predict. However, given the expansion of current videoconferencing applications to virtually all fields of personal and professional communications with an ever-increasing

demand, it is expected that this immersive extension will have a similar or, in some cases, even higher demand.

The impact of the expansion in the usage of the immersive communication platform will have multiple dimensions:

- **Cost saving** in many of the use cases enabled by the application. For instance, the remote expert case may dramatically reduce the high cost associated with sending experts (a scarce and expensive resource) to remote places. Instead of leveraging only a fraction of their time, doing the work remotely multiplies the number of places that can be addressed, removing also the whole cost of travel and lodging.
- **Travel** costs saving in general is a common advantage provided by this application to most professional use cases.
- It can make **teleworking much more efficient**, because it makes it closer to the real presence in the office. Same for remote education and training, with the additional advantage of preventing distractions (compared to e.g. a simple videoconference training course).
- **New business models**, enabled by the possibility of bringing people from remote places to a physical venue (an office, a factory, a fair or simply a city for tourism).
- The savings associated to travel avoidance are not only economic, but also beneficial for the **environment**.
- Healthcare and personal communication scenarios provide a high **value service to society**.
- The possibility of adding tools (including AI) to the platform makes it more **accessible** for any social sector, including people with disabilities or with social isolation problems.

Target commercial application

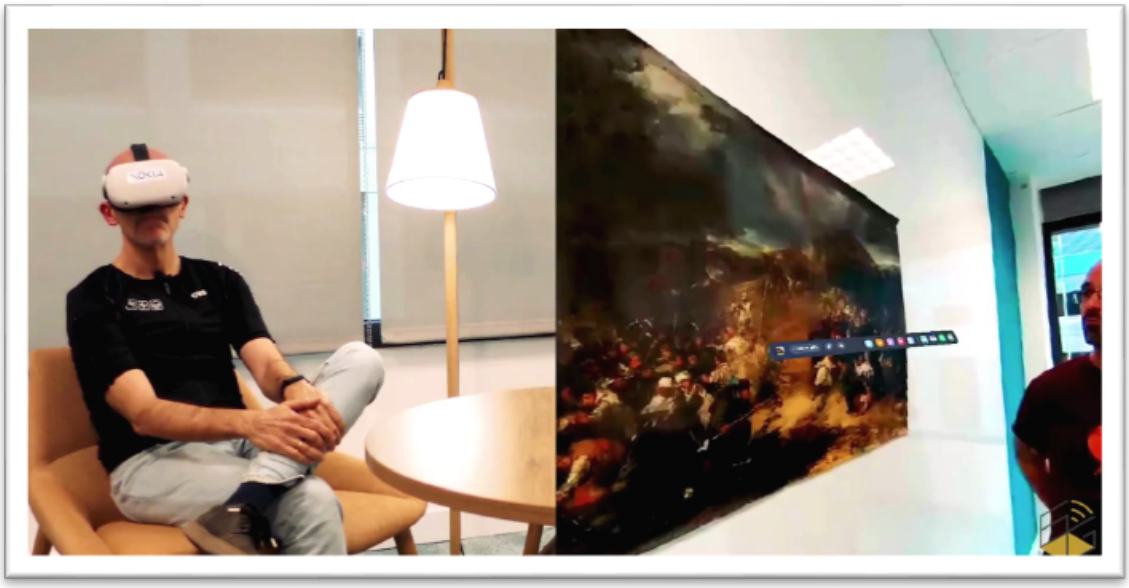
The application scope that the 6G-SANDBOX consortium through its partner *NOKIA* is targeting in this exploitation plan, is associated to entertainment which is also the use case that has been demonstrated during the project. In particular:

- **Guided visit** to museums or other touristic attractions: while the local guide provides descriptions and background information to the local attendance (real people present in the venue) the capture device enables that other people from any location worldwide feel also present immersively in the venue, listen to the descriptions and can ask questions or keep conversations with the other participants (locals or remote).

To provide an extended experience, the application includes the haptic dimension: both local and remote participants may wear haptic vests, capable of providing sensations. At specific spots during the visit a recorded audio description is triggered by the guide. While audio is playing the system triggers also synchronized sensations for the bodies of participants wearing vests. Those sensations are related with what the participants are seeing and are accurately synchronized with the description audio.

This service can be offered as a premium experience for local visitors, and the whole immersive and haptics blend can be offered as a remote visit to the venue to a wider

audience from anywhere in the world. This way **Internet of Senses** opens a very interesting commercial opportunity.



- **Enhanced theater**: Internet of Senses can enhance the experience of many types of art, and theater is an excellent use case.
    - Placing a capture device in the audience (on an empty seat) lets any number of remote people feel present at that seat and have the full sensation of being present at the theater and enjoy the play. Whispering with neighbors in the audience and with other remote attendees can also happen naturally. This extends the reach of a good theater play to a much wider audience.

- With selected plays, a haptic dimension can be added: when something happens in the stage, the participants (local in the audience or remote attendees) who wear haptic vests can feel sensations in real time which mimic what the actors are experiencing.

- With a suitable play adaptation and an additional capture device placed on the stage, remote attendees can get a completely new theater experience, feeling part of the plot. The haptic sensations that are generated in real time make the experience even more intense. This opens fully unexplored paths for dramatic art.

Productization Plan

At the end of the project, *NOKIA* expects to have a version of the immersive communications prototype tested and ready for being used in trials with the appropriate network support. Of course, turning it into a commercial product will require a significant additional effort beyond the scope of this project, such as:

- Design and production of a final device for the capture, based on the experience gathered during the pilots.
- Evolution, optimization, stabilization, and deep testing of the platform software at the capture device, the backend in the network, and the end devices (VR goggles).
- Optimization of the User Interface, done by experts.
- Hardening of the solution from security perspective.
- Integration with different network and hardware vendors. Agreements with third parties (cloud, VR goggles, network providers, etc.).
- Definition of a roadmap and a release plan, and a robust version control.

- Hiring of developers, architects, and a full team of test engineers.
- Selection of a first target use case, and definition of a complete business plan.
- Generation of documentation.
- Selection of a cloud platform for the Backoffice.
- Commercial plan, including a definition of a sales model, and a pricing list.
- Hiring of a sales force and definition of a marketing strategy, commercialization and distribution strategy. Feedback gathering should be foreseen.
- Field support plan and associated staffing.
- Compliance checks.

Go to Market

The timing for getting a product has a strong dependence on the intensity of the investment in the productization. Given the maturity of the prototype, with the appropriate funding the expected availability time of a first version of the product is expected to be below 12 months.

The product is expected to be offered to customers under the "As a Service" model. For that reason, the most appropriate path for selling it will be the available commercial channels in existing customers for other products and services. For instance, a telco may include within its offering to end customers this kind of new communication service. Or a network provider offering equipment in private networks with a set of third-party applications running on them may offer the immersive communication platform as an additional service on top of it.

The main expected barrier for a successful commercialization of the product may be the novelty of the concept, which requires a careful marketing and educational exercise.

Further Exploitation

Apart from a direct commercialization of the immersive communication platform or the service on top of it, several other exploitation options are possible:

- Licenses: parts of the platform can be delegated to third parties, who would license the technology.
- Patents: the IPR of new ideas that come up during the development and deployment can generate additional monetization.
- New funded innovation projects based on it.

Table 3-9: IoSenses – GAP Analysis

1. GAP Analysis		
Internal	**Strengths**	**Weaknesses**
	• Technical expertise of the team. • Prototype available. • Field tests done. • Network support.	• Internal processes for product creation. • Resistance to enter new markets. • Limited budget for new products.
External	**Opportunities**	**Threats**
	• New service with great potential. • Greenfield market. • Existing need that can be fulfilled.	• Entrance barrier in classic entertainment. • Multi-disciplinary team requirement. • Business model still to be defined.

Table 3-10: IoSenses – Innovation Radar Description

2. Innovation Radar Description				
1	Characterize the type of innovation	Significantly improved service (except consulting services)		
2	What is the level of innovation?	Obviously innovative and easily appreciated advantages to customer		
3	How will the innovation be exploited?	Introduced as new to the market (commercial exploitation)		
4	Step(s)to bring the innovation to the market	Internal or external product creation		
5	Is there a clear 'owner' of the innovation?	Yes: NOKIA		
6	Indicate max 3 key organization(s) delivering it	Org1: NOKIA	Org2: OWO	
7	Indicate needs to fulfill their market potential per key organization	Business Plan development		
8	Will it be used by current or new customers?	New customers		
9	Market maturity	Market-creating: The market is not yet existing, but the innovation has clear potential to create a new market		

10	Market dynamics	Growing		
11	How strong is competition in the target market?	Patchy, no major players		
12	When could it be commercialized?	Between 1 and 3 years		
13	Which of the Societal Challenge(s) is/are relevant to?	Europe in a changing world - inclusive, innovative and reflective societies		
14	Which of the UN Sustainable Development Goals (SDGs) does this innovation contribute to?	SDG 9 – Industry, Innovation, and Infrastructure		

Table 3-11: IoSenses - BVPC

3. Business Value Proposition Canvas			
Product/Outcome:		**Customer:**	
(Product or Service) Features *list of products, services and features targeting the value proposition to a specific customer segment.* • Haptics-enhanced entertainment experiences. • Multi-peer immersive communication service.	**Gain Creators** *list the ways in which these products and services can create gains for the Customer.* • Open new ways of enhancing entertainment, enabling new markets and improving the experience of existing ones. **Pain Relievers** *the ways in which these product and services will alleviate specific Customer Pains.* • Overcome limitations in entertainment offer that depend on physical location.	**Gains** *list the results customers want to achieve or concrete benefits they are seeking from their Jobs.* • Entertainment offer is limited by the physical space (audience) and the location of the venue. Only getting there in person makes the experience possible. With this service this barrier can be broken. **Pains** *list the risks, obstacles, problems related with the existing way (without the product) of performing the Customer Jobs.* • Entertainment providers would like to extend the reach of their shows and visits to a wider audience.	**Customer Jobs** *list the existing customer jobs/processes executed by the prospect users that are relevant to each product.* • Guided visits to museums, buildings and in general any touristic attractions. • Theater shows based on real actors.

3.3 6G-SANDBOX PLATFORMS EXPLOITATION

3.3.1 ATHENS

The Athens platform, operated by NCSRD & OTE was enhanced within 6G-SANDBOX in various ways as analytically described in D4.1 [2] and D4.2 [3]. From the mobile network technology perspective, the platform is enhanced with new N78 and N258 base stations for FR1 and FR2 experimentation with the application of MOCN (Multi-Operator Core Network) that can allow the simultaneous testing with various network deployment modes (e.g. HPE Core & Ericsson RAN or Open5GS Core and Amarisoft RAN). Furthermore, implementing a direct physical interconnection between the two sites that are part of the platform (NCSRD & OTE) and deploying a single-domain OpenNebula virtualization, a powerful, cross-site, highly available computational infrastructure becomes available capable to host any kind of experiment, including computationally demanding AI applications and use cases. On top of these developments, the experimentation layer has been further extended to incorporate capabilities for TN/NTN integration, including both access and backhauling aspects, realized through a combination of simulated satellite environments and real satellite links. In this respect, and furnished with the automated experimentation layer of 6G-SANDBOX, the Athens platform is becoming a unique testbed paving the way for developing, testing and demonstrating advanced 6G use cases.

Already the Athens platform has supported many open call projects as well as Horizon and SNS projects (e.g. ENVELOPE, 6G-VERSUS) and both NCSRD and OTE are committed to maintaining and further expanding the Athens platform. Currently we are in the process of signing a Memorandum of Understanding (MoU) and preparing the platform's official website and social media presence to enhance visibility and engagement beyond the 6G-SANDBOX end. Through this arrangement, the Athens platform is expected to serve as a leading experimentation hub for the research community and Greek SMEs of the 6G ecosystem.

Towards this, NCSRD has a memorandum of partnership with the 5G Ventures S.A., as part of the strategy for the development of an ecosystem that will support the development of new generation digital services in Greece. 5G Ventures Société Anonyme ("5G Ventures SA") has been established pursuant to Article 93 of Law n. 4727/2020 (Government Gazette A' 184) and is a direct subsidiary of the Hellenic Corporation of Assets and Participations (HCAP SA). The objective of the Phaistos Investment Fund is the public investment in businesses that are actively involved in 5G/6G-related research and/or development of products and/or services in Greece, in sectors such as transport and logistics, manufacturing, public goods and utilities, health, tourism, information and media. As a result, the Athens Platform through this collaboration will be able to support the development of services and products for the 6G ecosystem.

3.3.2 BERLIN

The Berlin platform, hosted at the Fraunhofer FOKUS premises in Berlin, has been developed on top of the existing 5G testbed infrastructure. The computing resources have been

upgraded with additional servers to host the virtualization platform of the 6G-SANDBOX toolkit, which is based on the EU-developed OpenNebula virtualization solution. Within the project, extensions have been implemented to enable fine-grained energy consumption measurements across the platform, contributing to the collection of Key Performance Indicators (KPIs) related to energy efficiency.

From a mobile network technology perspective, the platform has been equipped with new O-RAN-based components from Benetel, Liteon, srsRAN, BubbleRAN, and Accelleran, which are co-financed and shared with other projects. The extensions implemented within the 6G-SANDBOX project are described in Deliverables D4.1 [2] and D4.2 [3]. The platform is already being used by various Horizon Europe and SNS projects and activities (e.g. 6G-Path, 5G-STARDUST, 6G-Takeoff), which benefit from the developments carried out in 6G-SANDBOX. In the context of upcoming measurement campaigns on Non-Terrestrial Networks (NTN), conducted in collaboration with the European Space Agency (ESA) as part of the project extension, the platform will be further enhanced with equipment required for Low Earth Orbit (LEO) satellite communications.

The tools developed and the expertise gained will be exploited in future EU and national research projects. The platform is open for experimentation to SMEs, other research projects, and industrial customers on a per-project basis. Furthermore, Fraunhofer FOKUS will leverage the acquired knowledge and tools for the further development and enhancement of its 5G and 6G toolkits, such as Open6Gcore, Open5GCore, and the OMNT measurement tool.

3.3.3 MALAGA

The Malaga platform hosted by University of Malaga has extended initial testbed by UMA. 6G-SANDBOX project has been working together with other SNS JU projects and national projects (5G+TACTILE) to cover four areas: University Campus, Malaga Tech Park, La Mayora experimental farm, and Malaga City centre. The whole infrastructure is now called Victoria Network[17].

The main contributions from 6G-SANBDOX are those in Malaga University campus: ORAN deployments, new RUs, satellite links as backhaul, all the software from the project (mainly the 6G-SANDBOX toolkit) and the whole 6G Research Lab from the agreement UMA-Keysight Technologies. In the context of the projects, MoUS were signed with several entities to integrate some of their resources in the platform: European Space Agency (access to their LEO satellites), ITRI (RIS and JCAS), TrendMicro/CTONE (cybersecurity solutions), Vicinity (all in one 5G cells)

Thanks to all the additions, Malaga platform will host large scale experimentation in 2026 in the four main topics: RIS, Deterministic Networking, NTN 5G and JCAS.

3.3.4 OULU

[17] www.victoria-network.eu

The long-term target of the University of Oulu is to evolve the current 5GTN to become the world's first 6G Test Network (6GTN). To this end, the roadmap for developing 5GTN towards 6GTN has been defined while development has begun with full speed thanks to public infrastructure funding and collaboration with leading industry. 6G-Sandbox has played an important role in implementing this roadmap.

University of Oulu has implemented the reference environment defined in the 6G-SANDBOX as integral part of the 5GTN and used in the performance measurements. 6G-Toolkit has been installed and integrated as part of the 5GTN platform offering. Several Open Call projects utilizing the 5GTN and 6G-SANDBOX platforms have already been supported.

6G-SANDBOX platform implemented as part of the 5GTN will be exploited by future nationally and EU funded projects. In fact, co-operation for example with 6G-VERSUS project has already been established and the 6G-Toolkit is offered as part of the 5GTN platform also in the 6G-VERSUS project.

In the large-scale trials planned for the 1H 2026 University of Oulu is leading the FR3 test planning. FR3 system has been ordered and will be integrated into the 5GTN. This FR3 system is then offered as a test platform for large scale trials. University of Oulu is also co-leading the definition of the platform and is planning the Deterministic Networking together with UMA.

3.4 Horizon Results Platform

Going beyond the identification and internal assessment of the three main project Key Exploitable Results (KERs), the consortium has committed to publishing them in the **Horizon Results Platform (HRP)** portal, seeking not only to highlight the project's resulting impact, but primarily to attract broader attention and even potential synergies or funding which would allow for further developments toward high TRL levels and tangible adoption in the form of commercialization or other open-source initiatives. The three KERs will be available to the HRP by the end of January 2026.

3.5 Abstract Individual Exploitation Plans

3.5.1 KEYB/KEYD

As part of the activities carried out within 6G-SANDBOX, KEYD developed innovative methodologies and technologies to enable comprehensive measurement of all KPIs defined in the project, and to design, calibrate and validate digital twin solutions. Outcomes in both areas will be leveraged by both KEYD and KEYB in future developments.

In terms of technologies, the main work performed by KEYD was the development of their OpenTAP based test automation. The requirements of 6G-SANDBOX acted as a push to enhance the capabilities of the OpenTAP system. This involved the development of plugins allowing the test automation system to talk to more tools and use more features, the writing of new potential test steps to make use of the new tools and features, and general improvements to the automation system which make it better suited towards implementation in large testing scenarios such as those seen within 6G-SANDBOX. KEYB/KEYD intend to use this now enhanced system to improve their capability to coordinate extremely large-scale testing in both other future and current EU projects as well as in their commercial ventures.

In terms of methodologies, the exploitable outcomes are twofold. The first result that will be capitalized upon is KEYD's work on the Adaptive Calibration Methodology which was used to perform benchmarking tests on the 6G-SANDBOX platform. The methodology and the methods and details of its execution allowed for a level of insight on the underlying performance of Software Based Networking that is novel, especially at this scale. KEYD and KEYB intend to take the developments in this methodology and develop it further, increasing its capabilities and scope, as well as eventually turning it into a potentially viable and sellable product for the company. The results and experiences within 6G-SANDBOX will be used as examples, case studies and jumping off points in service to this goal.

In parallel, KEYD/KEYB will take advantage of the methodology developed to create, calibrate, and validate digital replicas of 5/6G deployments in the form of Network Digital Twins. The

framework, which in the context of 6G-SANDBOX has been used to develop DTs of the Malaga and Athens' experimental facilities, will be enhanced to further increase the fidelity of the digital replicas. Such a goal will be achieved by calibrating aspects ranging from the physical propagation properties of the scenario to the specific configurations of the end devices and their 5/6G protocol stacks, building upon the expertise acquired throughout 6G-SANDBOX. The refined methodology will potentially be turned into a commercial product, enhancing KEYB/KEYD's Digital Twins portfolio.

3.5.2 UMA

UMA is one of the main contributors to the 6G-SANDBOX toolkit and will use this software framework as one of the main input points to support internal experimentation and collaboration with other entities.

The upgraded platform *Victoria Network* will be a main asset in Spain to support experimentation in 5G/6G, and UMA will define a number of collaboration approaches to attract both companies and research institutions to run their experiments for both terrestrial 5G and NTN 6G networks. Such exploitation will include additional SNS JU projects.

As a public university, UMA will also integrate the platform as part of the different teaching programs to support practical aspects of the courses as well as Master and PhD thesis.

UMA has a long record of successful collaborations and will report new cases at the Victoria Network website[18].

3.5.3 FOG

FOG's exploitation plan which was devised during the early stage of the project focused on enhancing the company's software tools and portable testbeds and, in the long term, its technological capabilities to achieve TRL 6. Hosting within its own platform the 6G-SANDBOX tools and libraries, especially those developed around the Trial Network Lifecycle Manager (TNLCM), has provided FOG with practical experience in installing, integrating, and operating advanced technologies within its own facilities. Approaching the end of the project lifetime, it is now evident that working directly with these new tools is highly beneficial, since it enhances the competitiveness of FOG in both hardware and software and enables further growth in the fields of telecommunications and networking. With the strong emphasis of FOG on R&D activities on network architecture and performance evaluation, the enhanced toolsets and testbeds will facilitate effective experimentation, benchmarking, and, moreover, innovation in areas such as openness and virtualization of mobile networks. Apart from the technical outcome, the knowledge gained fosters FOG's training and consulting services by developing new courses and material. Overall, the project allows for enhancing FOG's

[18] https://www.victoria-network.eu/index.php/casos-de-exito/

research capabilities, competitiveness, and long-term position within the 6G research ecosystem.

3.5.4 INF

INFOLYSIS will capitalize on 6G-SANDBOX results by increasing INFOLYSIS' presence and penetration in the respective areas of NTN emulated services and 6G overall research through its participation in the Athens platform, as well as by facilitating processes to ensure the project's maximum visibility and impact within the business and scientific communities, including the chatbot apps commercial market, in order to ensure quick adoption of project outputs and easier commercialization of its chatbot-based services.

INFOLYSiS participation in the 6G-SANDBOX project, in particular through INFOLYSIS' provision of NTN emulated services to 6G-SANDBOX Athens platform/use cases, and in conjunction with the participation and outcomes of relevant B5G/6G/IoT related projects (6G-VERSUS, SAFE-6G, SUNRISE-6G, aerOS, 6G-SANDBOX, 5GENESIS and 5G!Drones) will further:

- Leverage B5G/6G for NTN emulated services.
- Plan the development of additional NTN related services/scenarios that improve 6G applicability.
- Enrich its chatbot AI enabled services and products.
- Offer new chatbot based services in the new 6G-enabled communication landscape.
- Encourage the development of additional chatbot and AI based applications using the B5G/6G network capabilities and new services.
- Targeting new markets and sectors by offering friendlier, more cost efficient and environmentally friendly business solutions.
- Enrich the know-how and the research expertise of the company in these fields.

In parallel, INFOLYSIS will take advantage of its role as Communication and Dissemination leader and use its expertise to gain full exposure and influence within the business, scientific, SNS activities and 6G communities to ensure that the project's outputs are easily and quickly adopted even after the project's end through impact creation, exploitable outcomes and innovation initiatives.

Within these communities, INFOLYSIS through its corporate communication channels and participation to events, will communicate project outcomes and opportunities, explore future expansion and exploitation in current markets, products, and services, enrich its collaboration with IT-related SMEs and industries. Post-project activities will focus on relevant markets and industries in order to fully leverage the novel business opportunities generated by 6G-SANDBOX, related activities and business processes.

In specific, INFOLYSIS plans to:

- Exploit its 6G-SANDBOX results within scientific communities and chatbot apps markets.
- Enhance its participation in the evolving SMEs ecosystem, AI and chatbot apps markets.
- Contribute to the newly formulated B5G/6G, chatbots market landscape and societal impact.
- Participate in new SME accelerator communities and incubator programs through which INF will further disseminate 6G-SANDBOX developments, results and experimentation opportunities.
- Use expertise gained in the research activities of ongoing related projects in which INFOLYSiS participates for further enriching and promoting 6G-SANDBOX project's outcomes.
- Target new research opportunities for further enriching INFOLYSIS portfolio with new innovative services.

3.5.5 OWO

OWO devices have already arrived on the market, marking a significant milestone in the haptic technology industry. The anticipated outcomes of this project promise substantial benefits, providing a safer and more versatile platform for experimentation and harnessing the incredible speeds of 6G to facilitate a true real-time sensory experience. Such advancements are crucial, as they aim to enhance the quality of haptic technology by reducing latency to below 10 milliseconds for instantaneous feedback and minimizing power consumption to improve usability and extend battery life. These improvements will collectively lead to lower costs and a superior user experience.

To support this cutting-edge infrastructure, OWO is undertaking a comprehensive redesign of its device, focusing on significant upgrades, specially within the communications subsystem. Both the hardware and software of the device are undergoing meticulous redesign, testing, and implementation by OWO's team. These enhancements are expected to reach the market soon.

Although OWO's primary focus lies within the gaming industry, the vast potential applications of the Internet of Sense and haptic technologies present an exciting opportunity for the company to expand into various other sectors. The versatility of these technologies means they can be adapted to numerous verticals, and OWO plans to explore these possibilities through testing and validation processes that occur as part of the project. These processes often take place at industry fairs and commercial conferences, providing a valuable platform for showcasing advancements and receiving feedback.

3.5.6 TEL

Telefónica wants to leverage the research results of the 6G-SANDBOX project within the business units, promoting advancements and integrating findings into the strategic roadmap of Telefónica's business units globally. Exploitation activities within Telefónica are:

1. Internal Integration and Commercial Exploitation:
   - Promotion within Telefónica Units: Disseminate and promote 6G-SANDBOX results within Telefónica Group units focused on network evolution and management automation, particularly within the Global Chief Technology and Information Office (GCTIO).
   - Internal Proofs of Concept and Training: Conduct internal proofs of concept and training sessions to ensure these units incorporate the findings and learnings into their technology stacks.
   - Commercialization: Work towards the commercial exploitation of the project results by developing scalable and technically feasible products in collaboration with industrial partners in the 5G/6G community.
2. Internal Evangelization:
   - Company-wide Dissemination: Share the main project results across Telefónica using internal communication channels such as Telefónica Excellence School, workplace, ThinkBig blog, Telefónica Design Councils, and TID demonstration rooms.
   - Engagement with Entrepreneurship Initiatives: Present key innovations from the project to Telefónica's entrepreneurship initiatives (Wayra and Telefónica Open Future) to facilitate their application by start-ups nurtured by these initiatives.
3. Contributions to Standardization and External Initiatives:
   - Standardization Bodies: Contribute to standardization bodies such as ETSI, IETF and 3GPP, ensuring that the project's innovations influence emerging 6G standards.
   - European Commission Initiatives: Engage with EC initiatives like Horizon Europe, 6G-AI and Cybersecurity PPPs to align with broader technological and regulatory frameworks.
4. Intellectual Property and Innovation Protection:
   - Patents: Explore potential patents for the services and system components derived from the 6G-SANDBOX project to protect technological innovations and ensure competitive advantage.
5. Ecosystem and Stakeholder Engagement:
   - Industrial Collaboration: Involve industrial partners in the design and development of scalable commercial products based on 6G-SANDBOX concepts, facilitating the transfer of innovations to the industry.
   - Experimentation and Trial Networks: Utilize the 6G-SANDBOX facilities to perform trials and validate use cases (from Stream D projects), ensuring that the project supports the next generation of 6G technologies through dynamic and comprehensive testing environments.
6. Socioeconomic Impact and Long-term Sustainability:
   - Ecosystem Development: Create a sustainable ecosystem under the Smart Networks and Services Joint Undertaking (SNS JU) umbrella, enabling the adoption of innovative components and hosting of 6G use cases through open calls.

- Impact Assessment: Maximize the technological and business potential through targeted communication, dissemination, and standardization initiatives, ensuring the project's outcomes create tangible socioeconomic benefits.

This comprehensive plan aligns with the key objectives and strategic goals of the 6G-SANDBOX project, ensuring effective utilization and impact of the research results within Telefónica and beyond.

3.5.7 NCSRD

NCSRD's participation in the 6G-SANDBOX project represents a strategic step toward establishing a leading research and scientific position in the field of Beyond-5G/6G *Experimentation-as-a-Service*. Through the updates and enhancements introduced by the 6G-SANDBOX initiative, the Athens platform will leverage NCSRD's existing expertise and excellence in integrating 6G innovations and emerging technologies. The overarching objective focuses on advancing the concept of the trial network, supported by the implementation of the *Trial Network Lifecycle Manager* and integrated measurement and testing tools—key enablers in strengthening the framework for *Experimentation-as-a-Service* and *Infrastructure-as-a-Code* approach. These developments will not only shape NCSRD's contribution to future EU-funded R&D activities but also feed into research directions, PhD theses, and dissertations addressing the project's core topics.

Moreover, the 6G-SANDBOX Toolkit and the Trial Network concept, providing advanced experimentation capabilities, are planned to be further exploited as services offered by NCSR Demokritos to external SMEs through the Digital Innovation Hub Ahedd[19], hosted within the institute's premises. Additionally, leveraging its "Lefkipos" Technical Park—which accommodates a large community of private companies and start-ups in ICT—NCSRD aims to promote the results of the Athens platform, seeking synergies and potential joint ventures with industry partners.

Building on these high-level exploitation plans, several concrete technical developments and integrations have been realized within the scope of 6G-SANDBOX, significantly expanding the Athens-6G platform and its cross-site capabilities between NCSRD and the OTE. These include:

- Establishing a direct 10G interconnection between NCSRD and OTE Academy, replacing the previous Q-in-Q link and achieving full network harmonization for high-performance, cross-site experimentation.
- Installation at the NCSRD site of COSMOTE-owned Ericsson gNBs (including both indoor/outdoor antennas, DOTs, IRU, and BBU systems) operated via an enterprise-grade HPE core, enabling enterprise-level experimental scenarios.
- Integration of OpenNebula as the unified virtualization infrastructure with the main node and the management Interface being deployed at NCSRD, while expanding the

[19] https://ahedd.demokritos.gr/

infrastructure across both sites, facilitating automated and flexible service deployments in both sites.

- Implementation of MOCN (Multi-Operator Core Network) functionality in an Ericsson gNB located at the OTE Academy edge, allowing the testing with open-source network hosted at NCSRD's site and interaction across two geographical locations under a common RAN.
- Realization of a Digital Twin of RAN segment of the Athens-6G platform (NCSRD site).

3.5.8 OTE

The broad scope of OTE's exploitation potential within the 6G-SANDBOX project has already been extensively outlined in Deliverable D6.2. It leverages the unique experimentation capabilities offered by the 6G-SANDBOX facility, the development of the Athens-6G platform in collaboration with NCSRD, and the enhancement of OTE's technological leadership by becoming the first Greek MNO to experiment with advanced 5G+ and 6G technologies developed in the project, such as Digital Twins and Reconfigurable Intelligent Surfaces (RIS).
In this context, the noteworthy developments related to the expansion of the Athens-6G platform that are attributed to 6G SANDBOX and are demonstrated at the OTE Academy edge include:

- Direct 10G Interconnection with NCSRD, replacement of the previous Q-in-Q link and network harmonization among the two sites to enable high-performance, cross-site experimentation.
- Installation in the NCSRD site of COSMOTE owned Ericsson gNBs (Indoor/Outdoor Antenna, DOTs, IRU and BBU systems) operated by an enterprise-grade core (HPE), to offer cross-site, enterprise-grade experimentation.
- Installation of mmWave Ericsson base station.
- Installation of OpenNebula as the common, cross-sites virtualization infrastructure that allows automated and flexible deployments seamlessly at both sites.
- Implementation of MOCN (Multi-Operator Core Network) in an Ericsson gNB located at OTE Academy's edge that allows experimentation with test, open-source networks implemented at the NCSRD site in two different geographical locations.
- Implementation of the Digital Twin of the COSMOTE side of the Athens-6G platform.
- Installation of GPU server for the support of XR use cases.
- Implementation of satellite backhaul solution using Starlink connectivity.

These capabilities have already been exploited by OTE in various ways:

i. They are already offered as the foundation for experimentation in various SNS research projects as part of the Athens-6G platform and OTE is committed in proliferating the co-operation with NCSRD through the establishment of an MoU (Memorandum of Understanding) under discussion.
ii. They have been used to showcase to COSMOTE's commercial and engineering departments the 5G+ capabilities, such as demonstrating the XR/VR use cases.

iii. The satellite backhaul solution served as a proof of concept towards the respective product development for 5G connectivity services to be offered to passenger ships.

In conclusion the participation of OTE in 6G-SANDBOX is considered a unique opportunity to address the 6G new business ecosystem and challenges, and has helped OTE to strengthen its technological superiority.

3.5.9 NOKIA

Within 6G-SANDBOX, Nokia has successfully developed an end-to-end immersive communication platform with haptics functionality, integrating an Internet of Senses application into a 6G testbed using a Network as Code control layer. This demonstrates a significant commercial opportunity.

1. Concept and Commercial Target: The platform is an immersive communication service, evolving current videoconferencing, offering a multi-peer, real-time, bidirectional experience with 360 video, audio, and haptics. It aims to provide users with a "teleported" feeling, leveraging state-of-the-art VR goggles, 360 cameras, and haptic vests.

2. Application Scope: The platform has broad applications across sectors including Healthcare, Education, Collaborative work, Personal events, Elderly care, Tourism, Hybrid conferences, Therapy, Remote Expert services, and Entertainment. Demand is expected to be substantial, potentially exceeding current videoconferencing.

3. Impact and Benefits: Expansion of this platform promises significant benefits:

- *Cost Savings*: Reduces travel and lodging expenses for remote expertise.
- *Increased Efficiency*: Enhances teleworking, education, and training through simulated presence.
- *New Business Models*: Creates opportunities by connecting remote users to physical venues.
- *Environmental Benefits*: Reduces travel-related carbon footprint.
- *Accessibility*: Improves access for individuals with disabilities or social isolation.

4. Productization Plan: Transforming the prototype into a commercial product requires substantial effort beyond the project scope. Key steps include:

- *Device & Software Development*: Designing final capture devices, optimizing and stabilizing platform software (capture, backend, end devices), and enhancing user interfaces.
- *Security & Integration*: Hardening security and integrating with various network and hardware vendors.
- *Business & Team Building*: Defining a clear roadmap, building a dedicated development and testing team, selecting a cloud platform, and establishing a comprehensive business plan with sales and marketing strategies.

- *Support & Compliance*: Implementing field support and ensuring regulatory compliance.

5. *Go-to-Market Strategy*: A first commercial version is anticipated within 12 months with adequate funding. The product will be offered "As a Service" primarily through existing commercial channels, such as telecommunications companies or network providers. The main challenge is overcoming the novelty of the concept through effective marketing and user education.

6. *Further Exploitation Options*: Beyond direct commercialization, other avenues include licensing platform technology, monetizing Intellectual Property Rights (IPR) through patents, and leveraging the platform for new funded innovation projects.

3.5.10 OULU

University of Oulu exploitation plan mainly focuses on utilizing the technologies developed in 6G-SANDBOX in the locally or internationally funded research projects as well as in the research done by the researchers of the University of Oulu. As the 6G-Toolbox has been integrated and is offered as part of the 5GTN offering it is available for researchers to use both locally in Oulu and remotely through the federated platform. This gives researchers broader toolkit with multiple access modes available in 5GTN to utilize the vast offering of technologies and more means to measure the performance of the developed systems.

During the development of the components required by the 6G-SANDBOX platform and 6G-Toolkit, 5GTN personnel has gained new competencies and skills in the respective area. New skills have been acquired at least in the areas of Keysight tools, OpenCAPIF and OpenNebula and they can be used in supporting both internal and external researchers when utilizing 5GTN.

3.5.11 ICTF

ICTF will incorporate the project results to the knowledge base of the company's staff and will enrich its product portfolio. Project outcomes will also enhance the company's competitiveness in the field of city digital twinning by offering a better service to their clients. Leveraging the 6G-SANDBOX platform, ICT-FI will enhance the cloud nativeness of their application while dynamically consuming APIs of internet of senses offered by third parties, which is an ongoing activity.

3.5.12 ON

In the scope of the 6G-SANDBOX project, OpenNebula Systems has focused its exploitation strategy on utilizing the project's research results to drive the evolution of its commercial and open-source cloud-edge orchestration platform. A fundamental part of this strategy has been the successful deployment and utilization of OpenNebula as a foundational component across the project's four diverse testbeds. This practical, multi-site validation has been

instrumental in verifying our federation capabilities and infrastructure lifecycle management under rigorous 6G conditions.

The insights gained from these real-world deployments have been directly integrated into the platform, resulting in tangible product improvements such as enhanced automation, precise energy consumption metering at the virtual element level, and optimized hosting capabilities for O-RAN solutions. Beyond these technical enhancements, the deep knowledge acquired in 6G technologies creates a recursive value loop, positioning OpenNebula to lead in future R&D initiatives. Ultimately, these results serve as powerful engagement assets for our community, reinforcing OpenNebula's competitiveness and long-term standing in the emerging 6G ecosystem.

3.5.13 EURE

EURESCOM, having the mandate to advance technology for the benefit of the telecommunications industry, is providing advice for the exploitation of the project results to its shareholders and members who all have a business interest in the telecommunication market, as well as in the definition of further joint collaborative undertakings that cover all emerging issues in the context of new services over future networks. Exploiting the possibilities with respect to the research performed in 6G-SANDBOX can easily result in provision of new services to customers and will enrich the EURESCOM service portfolio.

EURESCOM has been leveraging the project results in many ways, most prominently during the interaction with its shareholders, members and other stakeholders of the future networks ecosystem in Europe, and globally. EURESCOM’s shareholders and major clients are leading European telcos, including Deutsche Telekom, Orange, and BT. According to this position, the main exploitation path for EURESCOM in regard to exploiting the 6G-SANDBOX results is to strengthen EURESCOM’s consulting competency to provide the best possible services to its shareholders and clients.

Further exploitation channels, explored within the 6G-SANDBOX project, are:

- Current commercial EURESCOM contracts exist with the European Space Agency (ESA) through which the agency endeavors capture the opportunities for SatCom stakeholders in the 5G/6G value chain. In this context the concepts developed in 6G-SANDBOX are a valuable pool of knowledge.
- EURESCOM is also participating in German 5G/6G initiatives, having opportunity to contribute to by promoting the 6G-SANDBOX research results.
- Furthermore, as EURESCOM has a leading role in several European R&D programmes and initiatives – CELTIC-next Eureka cluster as well as NetWorld Europe and NEM Initiative (European Technology Platforms), we ensure that 6G-SANDBOX project points of views are integrated in the corresponding Strategic Research and Innovation Agendas and the CELTIC-next funding programme.

3.5.14 ISRD

On the ISRD (IS-Wireless) side, 6G-SANDBOX was discussed with external partners (e.g. Telekom Malaysia) to explain the value and benefits of replicating the testbed node. Moreover, ISRD was actively participating in the Webinar on the 11-12.12.2025 presenting the slides on 'Programmable/scalable ORAN networks". These slides were summarizing experiments with 'workload placement" of the 5G functions (CU-UP) coordinated by the AI/ML placement algorithm as developed in 6G-SANDBOX. Additionally, ISRD was presenting reminder of the slides from partners of the EuCNC JCAS demo (2025). We have also responded to the NTN survey from the EC commission. Besides that, ISRD was reposting some LinkedIn social media messages about the recent project achievements on its channels in social media. The 6G-SANDBOX approach to trial network concept was also considered in the internal discussions about the designs of the solutions for emerging technologies (and their architectures) like e.g. digital twin. Moreover, the experiences with JCAS demo, have contributed largely to internal discussions on designs of telemetry delivery systems for the novel 6G-related use-cases.

3.5.15 FOKUS

Fraunhofer FOKUS will use results developed during this project to strengthen its portfolio in the testbed related research activities. This will include 5G and 6G core network software developments and Nomadic 5G/6G network customization towards the industry and other European funded Projects. The developed tools will strengthen the portfolio of testbeds and campus networks. The ongoing research in the field of TN-NTN and 6G core networks will benefit from the lesson learned from the 6G-SANDBOX project, and particularly the execution of the various open-call projects on the Berlin platform.

Fraunhofer FOKUS presented a life trial network at the Thinknet 6G Summit Event showcasing the TN concept with local RAN resources. Furthermore, Fraunhofer FOKUS organized the NTN Workshop which was also used to present the NTN activities of the 6G-SANDBOX project. Besides that, FOKUS was reposting some LinkedIn social media messages about the recent project achievements on its channels in social media. Fokus presented the technical details of the four Experimentation platforms within the 6G-SANDBOX Webinar to further spread technical knowledge on the Platforms to interested parties who would either run experiments or even host their own experimentation Platform on the tools developed inside the Project.

3.5.16 QUB

The Queen's University of Belfast (QUB) has a long-standing international reputation for the dissemination of cutting-edge research, knowledge transfer, and commercialization of innovations. QUB is interested in developing its research, academic, and industrial links within the wider European technology sector. QUB prides itself on enriching its teaching program through modern research and innovation and is committed to integrating the knowledge gained from this project into its teaching activities.

During the course of the project, QUB developed a mm-wave Reconfigurable Intelligent Surface (RIS). This device was tested in local and wider campaigns, including those led by experimenters in the Open Call campaign. The results have been widely disseminated through publications and presentations at conferences and workshops. Furthermore, social media publications on LinkedIn have been produced and distributed via the 6G-SANDBOX network.

The RIS is being integrated into several PhD and Master's projects as part of an experimental testbed for RIS-assisted 6G communications. This testbed is now offered to a wider community, including 6G-SANDBOX-ITRI collaborative experiments and other research programs. QUB is working to leverage the results obtained in this program to further research activities across key areas of wireless technology, from mobile networks to future Space programs.

3.5.17 LNV

Lenovo is a leading technology company committed to pushing forward the development and delivery of cutting-edge technologies, incorporated into its own high-tech products. Lenovo specializes in the design and manufacturing of smart devices, including among others consumer electronics and high-tech enterprise products, as well as in the provision of business solutions and innovative services.

In the course of the project, Lenovo brought numerous contributions, pertinent to 6G-SANDBOX activities, to international SDOs, such as 3GPP and ETSI. Nevertheless, Lenovo has also benefited from their participation in the project by contemplating on new ideas which will boost the company's product and IPR portfolio, and which are stemming from the technological advancements of the project. In particular, the understanding of the intrinsic protocol characteristics which have been revealed through the project's experimentation campaign and are related to performance and energy efficiency under diverse scenarios including TN/NTN interaction, will assist Lenovo's internal research activities toward better, high-quality, and energy-efficient products.

3.6 Intellectual Property Rights (IPR)

An additional achievement of 6G-SANDBOX which contributes to the project's envisioned impact, has been the below patent filing, entitled:

- "ENABLING NON-5G CAPABLE DEVICE ACCESS TO 5G NETWORKS VIA UNTRUSTED NON-3GPP ACCESS"

This patent has been submitted by the 6G-SANDBOX consortium partner *Lenovo* in the context of their own research activities which, however, align well with the project's actions. This patent builds upon and extends current 5G network architecture, by defining a new network function and the necessary methods which enable non-5G capable devices that do not support the 5G NAS protocol over untrusted non-3GPP access, to connect to the 5G-and-beyond networks in a seamless and secure way. This patent contribution enables non-5G capable devices to i.e. make use of common WLAN access points to connect to the 5G network and exploit the advanced network services.

4 PROJECT INNOVATIONS

The 6G-SANDBOX developments have produced several outcomes, many of which are considered innovative in the way they approach and resolve specific issues. These innovations take several forms, such as: i) new products, ii) new or significantly enhanced services, and even iii) new or substantial updates of existing methodologies. To this end, the 6G-SANDBOX consortium came upon a list of innovative outcomes which have been conceived, analyzed, and developed during the lifetime of the project. To demonstrate their potential for high impact, the consortium has been committed to submitting them to the **EU Innovation Radar** for subsequent evaluation and prospective publication. The submission of the innovative outcomes to the EU Innovation Radar will take place gradually during the project's extended period (M36-M42).

The areas of the project these innovations are stemming from, are summarized hereinafter:

- The identified three Key Exploitable Results (KERs) are apparently innovative.
- Innovation pertinent to *Ambition #1* on experimentation processes and facilities as well as testing methodologies (partner: KEY).
- Innovation pertinent to *Ambition #2* on the workload placement (partner: ISRD).
- Innovation pertinent to *Ambition #3* on dual connectivity (partner: UMA).
- Innovation pertinent to *Ambition #4* on P4 language (partner: UMA).
- Innovation pertinent to Ambition #12 on Digital Twin in RAN. The tool has already been installed in the platform and customized (partners: UMA, NCSRD, OTE for customization of the tool in the platform for trials; partner: KEY for the feasibility to customize).
- Innovation pertinent to *Ambition #1* on the use of LLM for experimentation provisioning (partner: TID).
- Innovation pertinent to *Ambition #8.* Deployment of the continuum has taken place between the OTE and NCSR "Demokritos" sites (partner: NCSRD will declare the functionality as innovative).

5 CONCLUSIONS

In conclusion, the 6G-SANDBOX project successfully reached its Standardization, Exploitation, and Intellectual Property Right (IPR) goals, both the quantitative as well as the qualitative ones.

The Standardization activities which commenced from the very beginning of the project, included numerous contributions to several *3GPP Working Groups (i.e., SA2, SA3, SA6)*, and to the *ITU SG12*. The high quality of these contributions is reflected to their high adoption rate, since more than 70% is now part of standards, while their relation to the project is appropriately justified through the reporting tables included within the current as well as the previous deliverables. The Standardization activities did not solely remain in the areas where standards are usually drafted; 6G-SANDBOX tried to shape a culture around standards impact through active engagement toward the formation of the *ETSI ISG RIS*, as well as the organization and participation in various activities which took place during the lifetime of the project, such as the *MCX PlugFest*, and the *1st ETSI SDG_OpenCAPIF Hackathon* event.

On the Exploitation activities, the 6G-SANDBOX consortium identified a long list of all project outcomes; then from this list, the most promising outcomes were selected for which i) a *GAP analysis* has been conducted, ii) a detailed description based on *EU Innovation Radar template* was provided, and iii) *Business Value Proposition Canvas* was filled in. This ensures that the three most valuable outcomes of the project with high exploitation potential have been analyzed and assessed in detail, facilitating the next steps toward commercialization.

Regarding the IPR activities, even though no formal KPIs had been indicated within the Description of Action (DoA), consortium members were always seeking for possible opportunities to extend the project's impact. In this direction, a patent has been filed which is relevant to the activities of the project in the area of *multi-access communications*.

Overall, the 6G-SANDBOX project focused not only on satisfying its official KPIs but sought to increase impact in the areas of standardization and exploitation, which is of utmost importance for the SNS JU program and the EU Commission. Through its contributions and the high adoption rate to international standardization organizations as well as the various synergies and MoUs signed in the context of the project with various global universities and organizations, the project left its footprint laying the experimentation ground for beyond-5G and future 6G networks.

6 REFERENCES

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