



Supporting Architectural and technological Network evolutions through
an intelligent, secured and twinning enabled Open experimentation facility

6G SNS

Collaborations between C/D and A/B projects
The 6G-SANDBOX case

Online, October 4, 2024

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6G-SANDBOX – project overview

6G-SANDBOX: Supporting Architectural and technological Network evolutions through an intelligent, secured and twinning enabled Open experimentation facility

 [SNS experimental Infrastructure: HORIZON-JU-SNS-2022-STREAM-C-01-01](https://cordis.europa.eu/project/id/101096328) 

✓ *The 6G-SANDBOX project is about the definition and the development of a pan-European 6G experimentation infrastructure*



17 Partners
8 Countries

Project Coordinator: Michael Dieudonne (Keysight)
Technical Manager: Pedro Merino Gomez (UMA-ITIS)

<https://6g-sandbox.eu/>
<https://cordis.europa.eu/project/id/101096328>

Project Information

6G-SANDBOX
Grant agreement ID: 101096328

DOI
[10.3030/101096328](https://doi.org/10.3030/101096328)

EC signature date
24 November 2022


Start date 1 January 2023 **End date** 31 December 2025


Funded under
Digital, Industry and Space

Total cost
€ 8 546 551,53

EU contribution
€ 8 039 821,26

Coordinated by
KEYSIGHT TECHNOLOGIES BELGIUM

 Belgium
















6G-SANDBOX ongoing collaborations with SNS projects

6G-SANDBOX is already active on setting up collaborations with other SNS projects.

Stream A/Bs bring their solutions for validation (e.g., the AI air interface of Centric)

Stream Ds use the 6G-SANDBOX experimentation facility / methodology to run tests (e.g., FIDAL)

	Active	In discussions
Stream A		
Stream B	 	    
Stream D	  <p>Deploying TNs to run use cases</p>	



Section 1

6G-SANDBOX FUNDAMENTALS

6G-SANDBOX – The Trial Network concept

Key challenges in experimentation over network and compute infrastructures:

- The experimenter is not able to access internal configuration of the network components
- Manual (re)configuration and provisioning of the setup is applied for medium- or long-term experiments as well as for concurrent experiments that use the same resources

Response to the challenges from the 6G-SANDBOX:

- Give the experimenter the opportunity to create in an automated way its own isolated network and resources which are tailored to the needs of the experiments to be conducted.

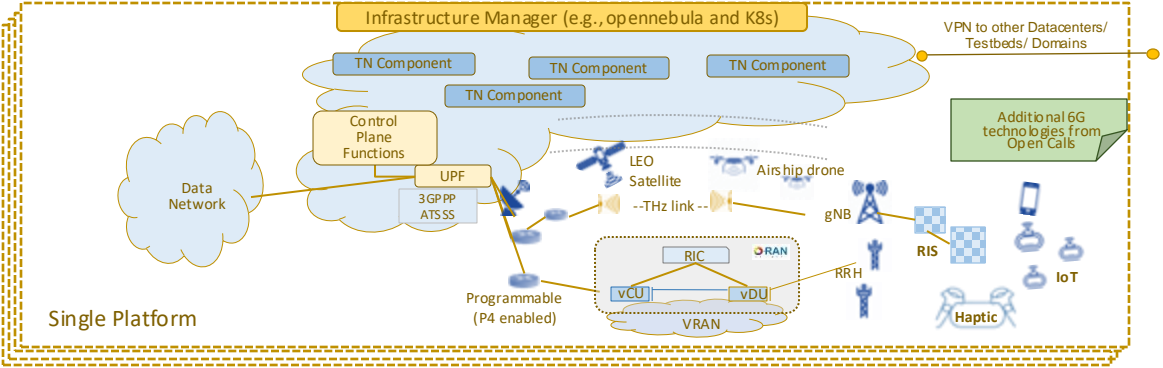
Trial Network: fully configurable, manageable and controllable network which combines digital and physical nodes and provides services for 6G technology validation and 6G KPI measurements



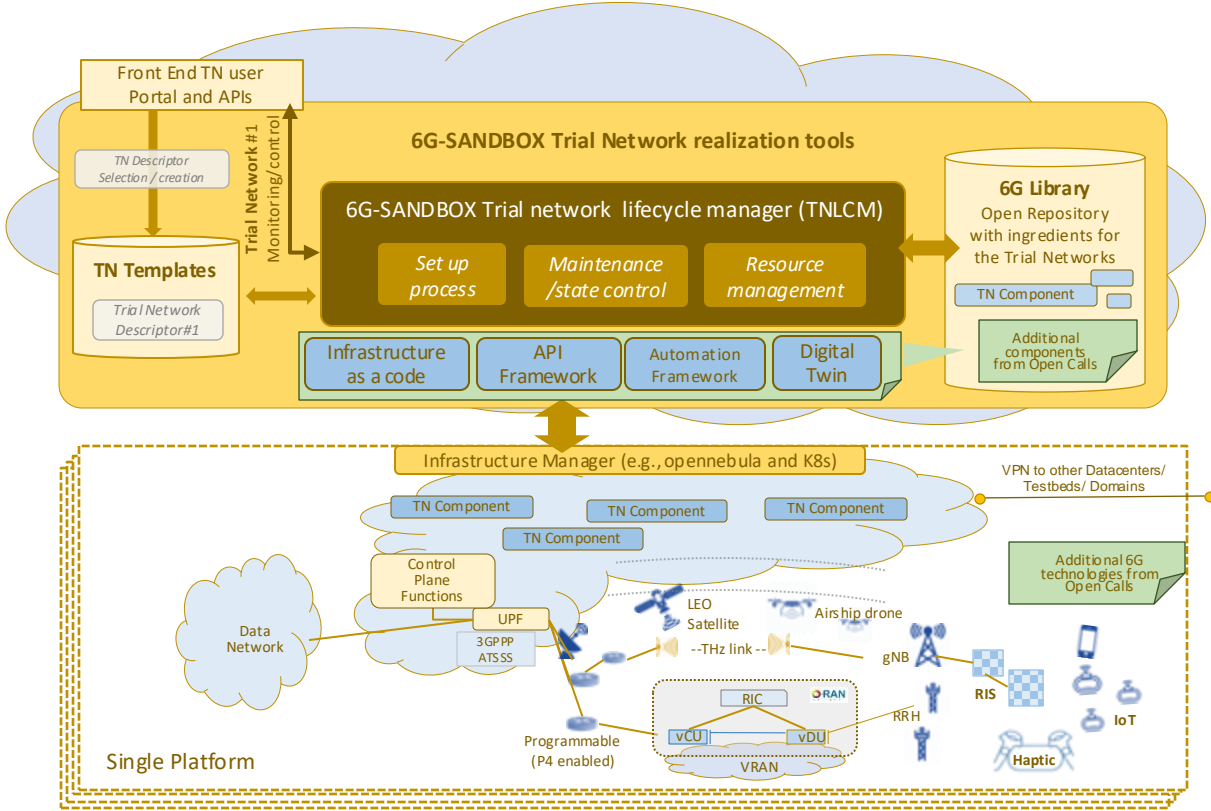
6G-SANDBOX – Architectural view

The basis of the 6G-SANDBOX architecture is the network and compute infrastructure:

- 4 experimentation platforms in EU provide their network and compute infrastructure
 - MALAGA | ATHENS | BERLIN | OULU
- Rich set of access technologies (RIS, O-RAN), wide coverage, satellite links, network core (open-source and commercial), ..
- Management and orchestration capabilities (based on Opennebula services) make the platforms *“Trial Network -ready”*
- The platforms are being expanded with technologies **a)** developed in the project, **b)** brought by Open Call projects, and **c)** brought by other third parties (e.g., through MoUs)

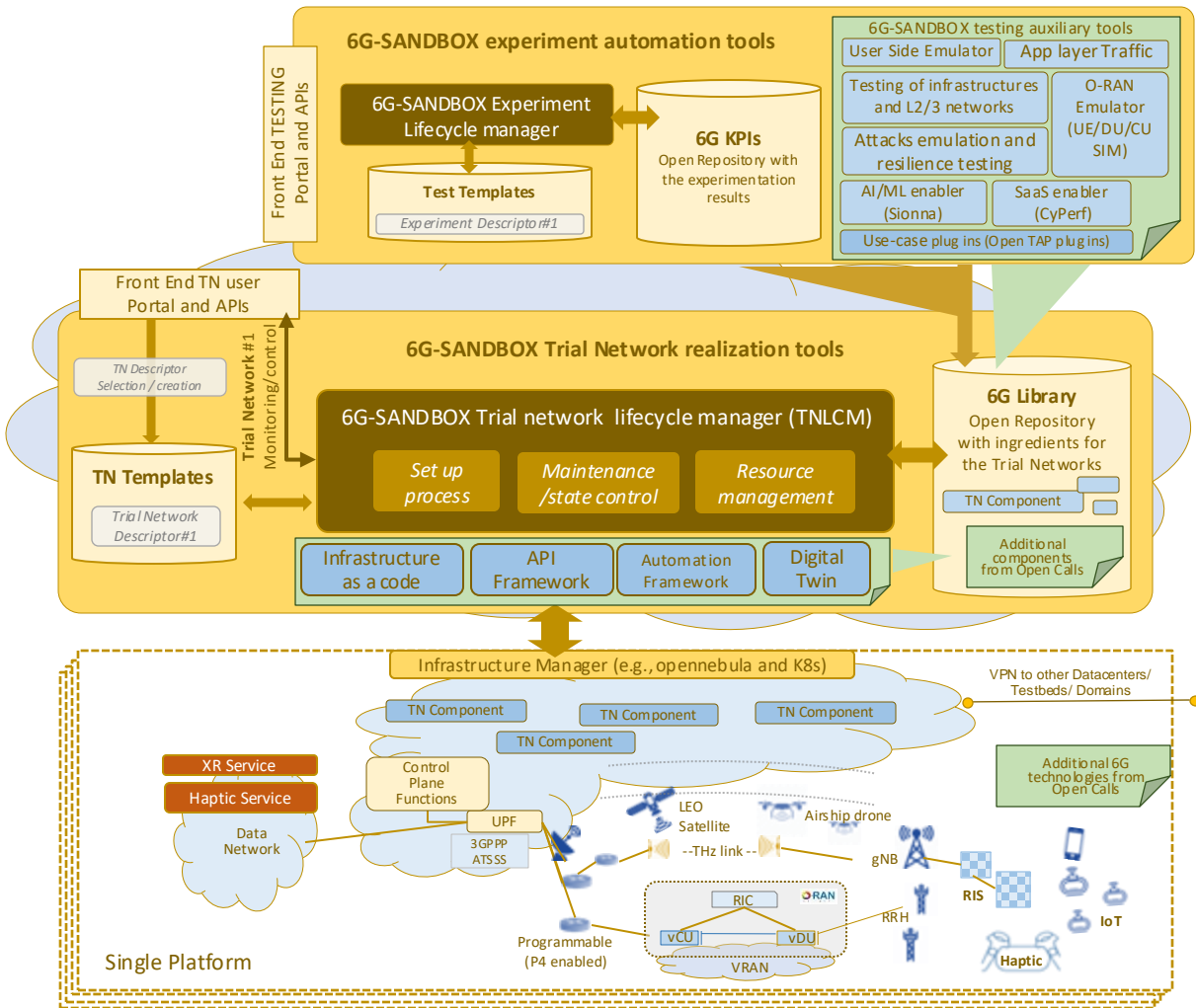


6G-SANDBOX – Architectural view



The heart of the architecture is the set of components that realize the TN concept:

- The TNLCM (see [D4.1](#)) (with a TN portal)
- The 6G library (see [D3.1](#)) (hosting components that are the ingredients for creating TNs)
- Additional software components from OCs are hosted in the Library



Experimentation tools are also treated as TN components:

- Fundamental
 - ELCM and OpenTap-based campaign Manager
 - 6G KPI data repository
- Auxiliary
 - A very rich toolbox for testing / measurement campaigns is available from Keysight

Any vertical use case can be hosted for experimentation

- An XR/Haptic use case is developed as PoC
- Open Calls bring new 6G use cases



Section 2

6G-SANDBOX POTENTIAL EXPERIMENTS

6G-SANDBOX Potential Experiments

- **Application-level Measurement campaigns.** Third parties can bring for validation their applications (from various vertical sectors). More specifically, 6G-SANDBOX is looking for use cases like those described in [FG-NET2030-Sub-G1](#) and in the scope of the [ITU IMT-2030 framework](#).
 - **Network Applications utilizing Network exposure capabilities.** Focusing on the network core, NEF APIs are available in our facility, while from any domain of the network standardised exposure APIs can be provided through the CAPIF API manager. This facilitates any experiment that brings a new Network application as defined in the related [SNS white paper of the SoftNet WG](#)

6G-SANDBOX Potential Experiments

- **Network-level Measurement campaigns.** 6G-SANDBOX provides a rich toolbox for network level measurements. Beyond the conventional measurements on packet and flow related KPIs (throughput, latency, error rate, goodput etc.) experiments with less examined KPIs are in scope. Including for instance energy and security assessment of mobile network components and architectures.
 - **Energy.** 6G-SANDBOX is equipped with different **energy measurements probes** (AC/DC, virtual). The probes can enable experiments around energy consumption optimization via incremental technology deployment in the platforms. This can be combined with the different network topologies from 6G-SANDBOX.
 - **Security.** Different tools have been deployed to allow security testing of the platforms and their application. This can be a security test such as **penetration (pen) testing** or fuzzing based techniques. **Different attacks can be simulated** to verify the robustness of applications or network components.

6G-SANDBOX Potential Experiments

- **Technology/component-specific validations.** Third parties can bring for validation their component/product and integrate it in the 6G-SANDBOX facility. Antennas, emulators, software components, end-devices etc., that realize innovative functionality are welcomed. Special interest is in Integrated Communication & Sensing (ICAS) and Joint Communication & Sensing (JCAS) solutions, as well as in devices that implement 3GPP Rel. 18 and onwards features.
 - **Intelligent Applications for O-RAN.** O-RAN deployments in 6G-SANDBOX facility are available for hosting new xApps. For more information on the available O-RAN deployments please check D3.2. For instance, xApps can be developed to trigger experimentation around network optimization and network monitoring or to enable new ORAN services (such as JCAS) based on off-the-shelf components.
 - **Reflective/Reconfigurable Intelligent Surfaces.** 6G-SANDBOX has Lab and Live environment that are particularly suited to executing RIS validation experimentation. In Lab, RIS can be measured and characterized. In Live environment, the RIS deployment can be done including controlling the network to enable experimentation on network densification, network coverage extension can be realized. This can be done in FR1 as well as in FR2.

6G-SANDBOX Potential Experiments

- **Network management and optimisations.** Third parties can take advantage of the end-to-end experimentation platforms and **provide their optimisations by changing / configuring the management and control plane.**
 - **Time sensitive networks.** 6G-SANDBOX has deployed **P4 switches allowing work around deterministic network**, low latency network and time-sensitive network. The platforms can also control arbitrary packet loss, delay and jitter on selected traffic.
 - **Transport network optimizations with NTN links.** 6G-SANDBOX integrates NTN links and allows for measurements including real LEO satellites. As the first project that brings experimentation potential to NTN, we seek for use cases that integrate terrestrial and non-terrestrial links, **bring radio/core functionality to the satellite**, and/or utilize connect and compute resources in network infrastructures that include satellite components. 6G-SANDBOX is working also on connectivity with ESA facility, enabling the inclusion of ESA experimental capabilities.



Section 3

6G-SANDBOX OPENNESS (COLLABORATION PROCESS)

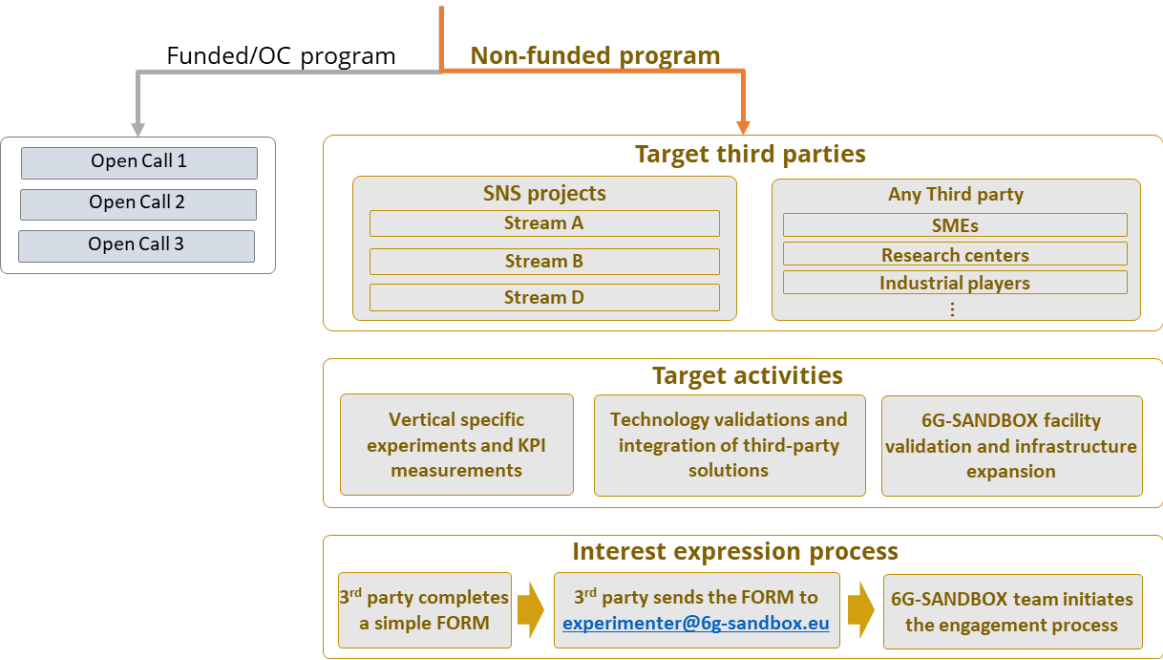
6G-SANDBOX – Openness approach

- Long-term impact and external stakeholder engagement
 - MoUs (Memorandum of Understanding)
 - SDO contributions
 - Open-source contributions and usage
- 6G-SANDBOX facility usage and expansion
 - Funded program
 - Open Calls (funded sub-projects, 3 open calls)
 - Non-funded program
 - SNS projects (contractual obligation)
 - Company-level (non-funded extensions and experiments)

6G-SANDBOX facility usage and expansion



3rd party interested in technology validations and KPI measurement campaigns



<https://6g-sandbox.eu/wp-content/uploads/2024/09/6GSANDBOX-Expression-interest-FORM.docx>

DOWNLOAD THE FORM



experimenter@6g-sandbox.eu



6G-SANDBOX facility usage and expansion



Interaction level (4 basic roles for 3rd parties)



6G-SANDBOX Trial Network User (TNU)

- Someone that creates test cases (or uses the available ones) and conducts measurement campaigns. The TNU can also bring an application, deploy it, and link it (through API interaction) to a Trial Network that is selected and activated for the experiment.
- The TNU has access to the portals used for experiments conduction, and the TNU software has secure API interaction to every component that is part of the selected Trial Network and provides API services through CAPIF.

6G-SANDBOX Trial Network Owner (TNO)

- Someone that creates a Trial Network from the components that the 6G-SANDBOX facility provides (i.e., the 6G-Library and the technologies physically integrated in the 6G-SANDBOX Platforms). The TNO can also play the role of a TNU or allow other TNUs to conduct experiment to the Trial Network created.
- Access level of a TNU plus i) admin rights to configure a specific portion of computational resources where the TN is set / hosted and ii) remote access to platform specific physical or virtual components to set the Trial Network.

6G-SANDBOX 3rd Party Technology Provider

- Someone that brings 6G component(s) or software solutions and is willing to integrate them with one or more Platforms for expanding the 6G-SANDBOX capabilities.
- Access to platform specific physical or virtual components and interfaces needed to integrate a specific SW/HW component

3rd Party Platform owner (6G-SANDBOX host)

- Owner of an end-to-end experimentation platform / testbed who is interested in adopting 6G-SANDBOX framework (i.e., the concept of creating TNs on top of the testbed)
- Access to an instance of the 6G-SANDBOX Toolkit that has been developed in the project to support the TNs concept.

The first release of the 6G-SANDBOX Toolkit is available !

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

SNS-JU Projects and 6G-SANDBOX 3rd party roles

<i>SNS stream</i>	<i>Proposed Role</i>	
Stream A/B	Technology Provider	
Stream D (without a platform)	Vertical App / data plane traffic	HW/SW integration is required
	TN Owner/operator	Technology Provider
Stream D (with a platform)	Platform Owner	

Conclusion

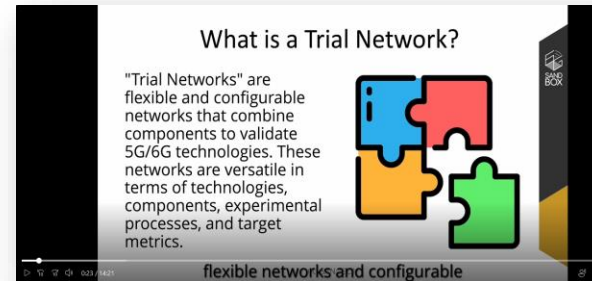
- 6G-SANDBOX realizes the concept of **Trial Networks** (isolated experimentation networks built on top of shared resources).
- 6G-SANDBOX includes a very rich portfolio of B5G technologies ready to compose Trial Networks.
- Third Party network and compute infrastructures can adopt the TN concept by installing the **6G-SANDBOX toolkit**.
- SNS Stream A/B and D projects can take advantage of the 6G-SANDBOX facility to run their measurement campaigns or validate their technologies.

Have a look at our recent White paper
<https://zenodo.org/records/13594165>



Check out the Trial Network set up process

<https://youtu.be/hNKSbPAILE8>
<https://youtu.be/zzhxuN4WxEw>





Thank you



Co-funded by
the European Union

6G SNS

The 6G-SANDBOX project has received funding from the Smart Networks and Services Joint Undertaking (SNS JU) under the European Union's Horizon Europe research and innovation programme under Grant Agreement No 101096328

Network and compute infrastructure



HW/SW	Description	Identifier	Berlin	Athens	Malaga	Oulu
<i>Radio Access Domain</i>						
HW	5G Radio + Baseband	Nokia Airscale	X			
HW	5G Radio + Baseband	Nokia Airscale , Huawei	X			
HW	5G Radio + Baseband	Amarisoft Classic		X		
HW	5G Radio + Baseband	Ericsson		X		
HW	5G Radio + Baseband	Nokia Airscale			X	
HW	Software Defined Radio	B210	X			
HW	Software Defined Radio	N310			X	
HW	5G Indoor Pico	N/A				X
SW	OAIBOX Full 5G with USRP	N/A				X
HW/SW	B210 and N310 USRP	N/A				X
HW	RU	Benetel RAN650, Benetel RAN550	X		X	
SW	DU + CU	IS-Wireless solutions			X	
HW	Radio Access Domain	QUB-RIS solutions			X	
SW	gNodeB + UE Simulator	UERANSIM	X	X	X	

Network and compute infrastructure



HW/SW	Description	Identifier	Berlin	Athens	Malaga	Oulu
Transport Network						
HW	Datacenter Switches to connect RAN, Servers, etc	Mellanox		X		
HW	Datacenter Switches to connect RAN, Servers, etc	Mikrotic, CISCO Nexus, HP Aruba/Flexfabric	X	X		
HW	Datacenter switches to connect, RAN, Servers, etc	Netgear, P4 switches			X	
HW	TSN endpoints and bridge	N/A			X	
SW	Firewall/Bastion to provide access to Trial Network through VPN	PFSense		X	X	
SW	NTP service for Time synchronization	OpenNTPD			X	
SW	DNS service for Trial Networks	BIND			X	
HW/SW	Satellite Backhaul for the testbed	Starlink	X	X	X	
SW	end-to-end satellite communication system	OpenSAND		X		
SW	Multipath protocol	N/A			X	
SW	Firewall FortiNet Fortigate	N/A				X

Network and compute infrastructure



HW/SW	Description	Identifier	Berlin	Athens	Malaga	Oulu
Network Core						
SW	Full 5G Core	Open5GS	X	X	X	X
HW/SW	Full 5G Core	Amarisoft Classic	X	X		
SW	Full 5G Core	free5GC		X		
SW	Full 5G Core	Open5GCore	X			
SW	Full 5G Core	ATHONET 5GC		X		
SW	Full 5G Core	Polaris 5GC			X	
SW	LMF	LMF		X		
SW	NWDAF	NWDAF		X		
SW	NEF	NEF Emulator		X		
HW/SW	Stand Alone UPF	UPF from Open5GS, P4-UPF		X	X	
HW/SW	Stand Alone UPF	ATHONET UPF		X		

Network and compute infrastructure

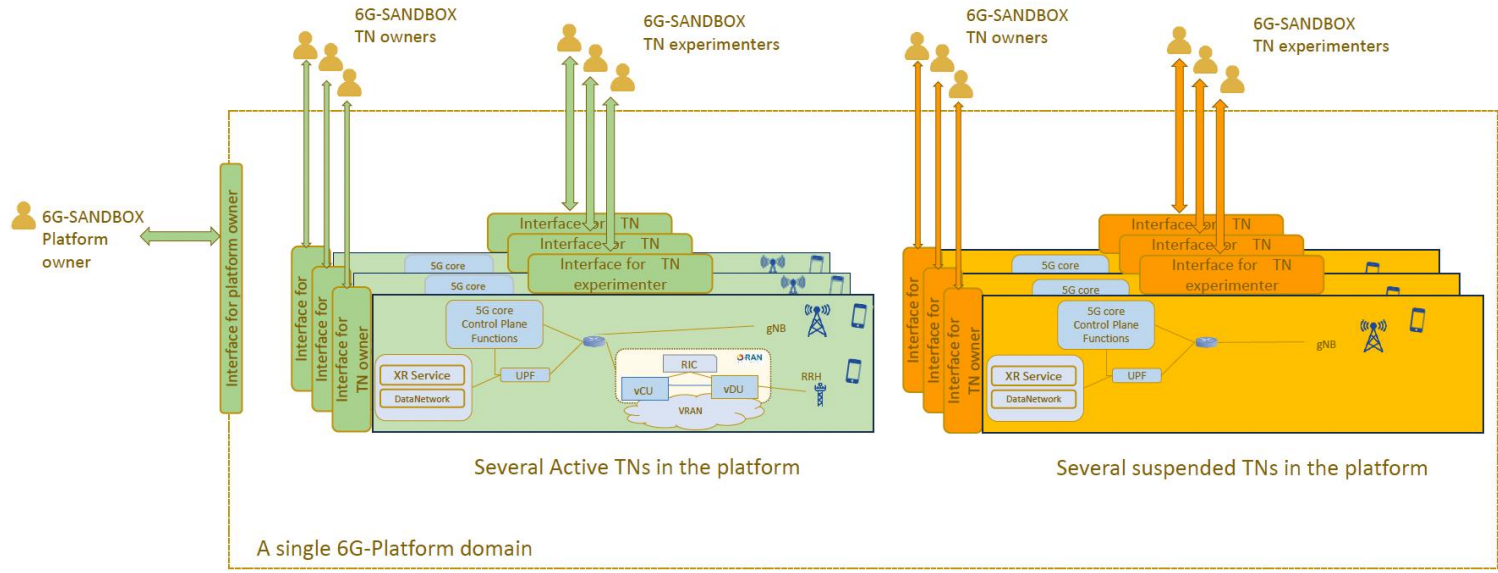
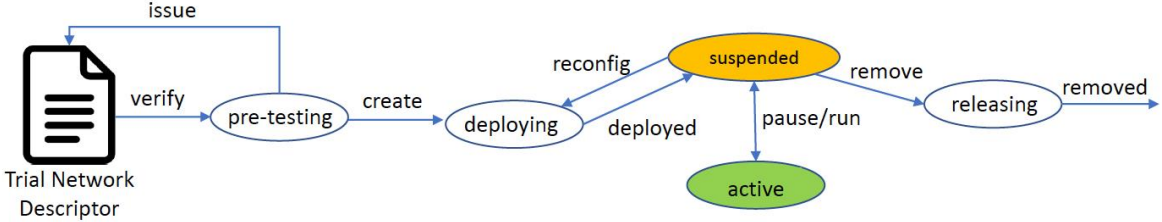
HW/SW	Description	Identifier	Berlin	Athens	Malaga	Oulu
Compute infrastructure						
SW	Server manager to create VMs, Containers, etc	Open Nebula, XXX	X	X	X	
SW	KVM Virtual Machine	KVM Virtualization	X		X	
SW	VMware Virtual Machine	N/A	X			
SW	Virtual Networks, VLAN, VXLAN, ...	Open Nebula, XXX	X	X	X	
SW	Kubernetes Cluster solution compatible with vanilla K8s	ONEKE			X	
HW	GPU Cards with PCI bus	Nvidia RX2070 Super				
HW	GPU Cards with PCI bus	Nvidia A10		X		
HW	GPU Cards with PCI bus	Nvidia RTX4080, Nvidia T4			X	
HW	Accelerators cards with PCI Bus	FPGAs, SmartNICs, ...				
SW	NFVI performance testing	CloudPeak		X	X	
SW	Cloud scalability and security	Cyperf		X	X	
SW	Kubernetes Cluster solution compatible with vanilla K8s	N/A				X
SW	VMware Virtual Machine	N/A				X



Auxiliary Experimentation Toolbox

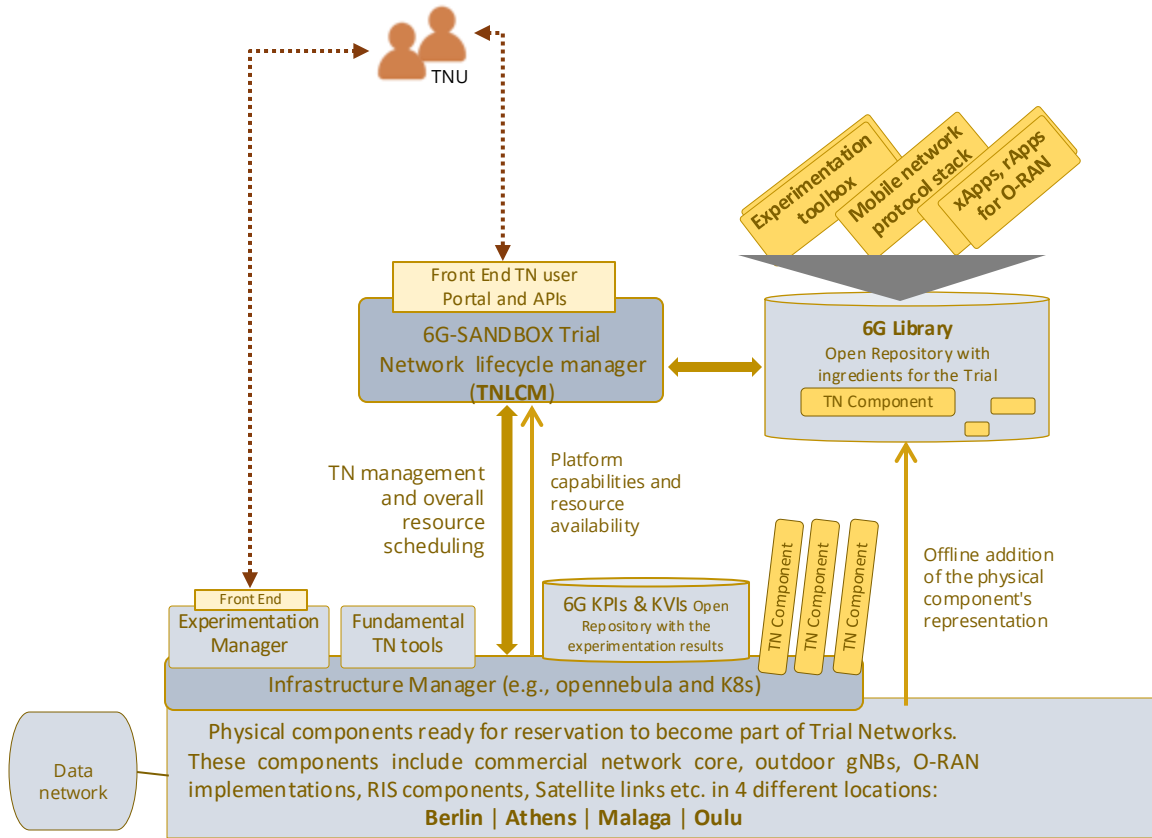
HW/SW	Description	Identifier	Berlin	Athens	Malaga	Oulu
<i>Testing and validation tools</i>						
SW	Performance and Cybersecurity Testing	Breakingpoint		X	X	
SW	Virtual network infrastructure validation	Cloudpeak		X	X	
SW	Scalable network application and security testing for distributed cloud	CyPerf		X	X	
SW	Active network performance monitoring (QoS monitoring, application & web monitoring, Wi-Fi monitoring, cloud monitoring)	HawKeye		X	X	
HW/SW	5G Wireless Test Platform	UXM			X	
SW	L4-7 performance testing and QoE testing	IxLoad		X	X	
SW	L2-3 network infrastructure performance testing	IxNetwork	X	X	X	X
SW	5G Core Testing and Validation	LoadCore	X	X	X	X
SW	Breach and attack simulation platform	ThreatSimulator			X	
SW	Network Digital Twin	EXATA	X	X	X	X
HW/SW	Emulation of O-RAN network nodes and traffic profiles on different RAN Intelligent Controller's (RIC's) interfaces	RIC test			X	
HW/SW	O-RAN Radio Unit (O-RU) Testing and Validation	O-RAN studio			X	
SW	Radio Access Network Testing	UeSIM			X	
SW	O-RAN Midhaul solution	CuSIM			X	
SW	O-RAN Fronthaul solution	RuSIM			X	

Trial Network stages



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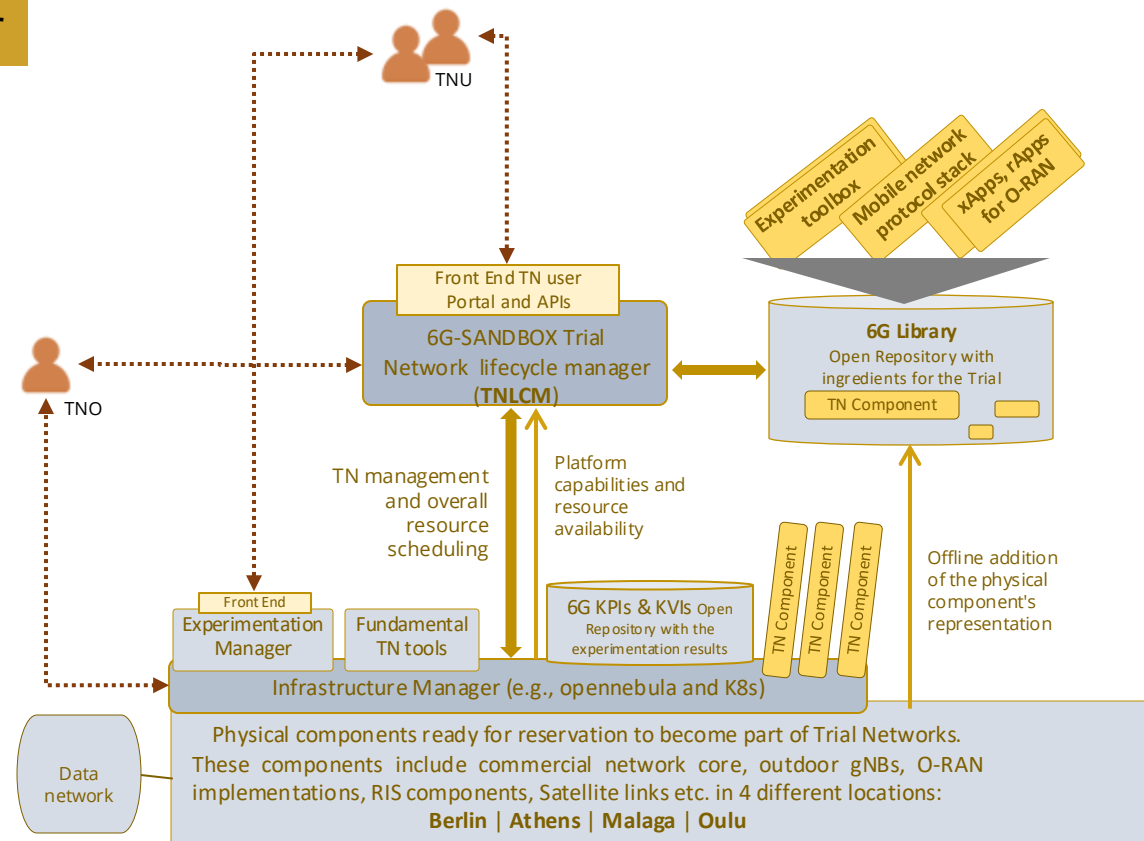
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TN Owner/operator

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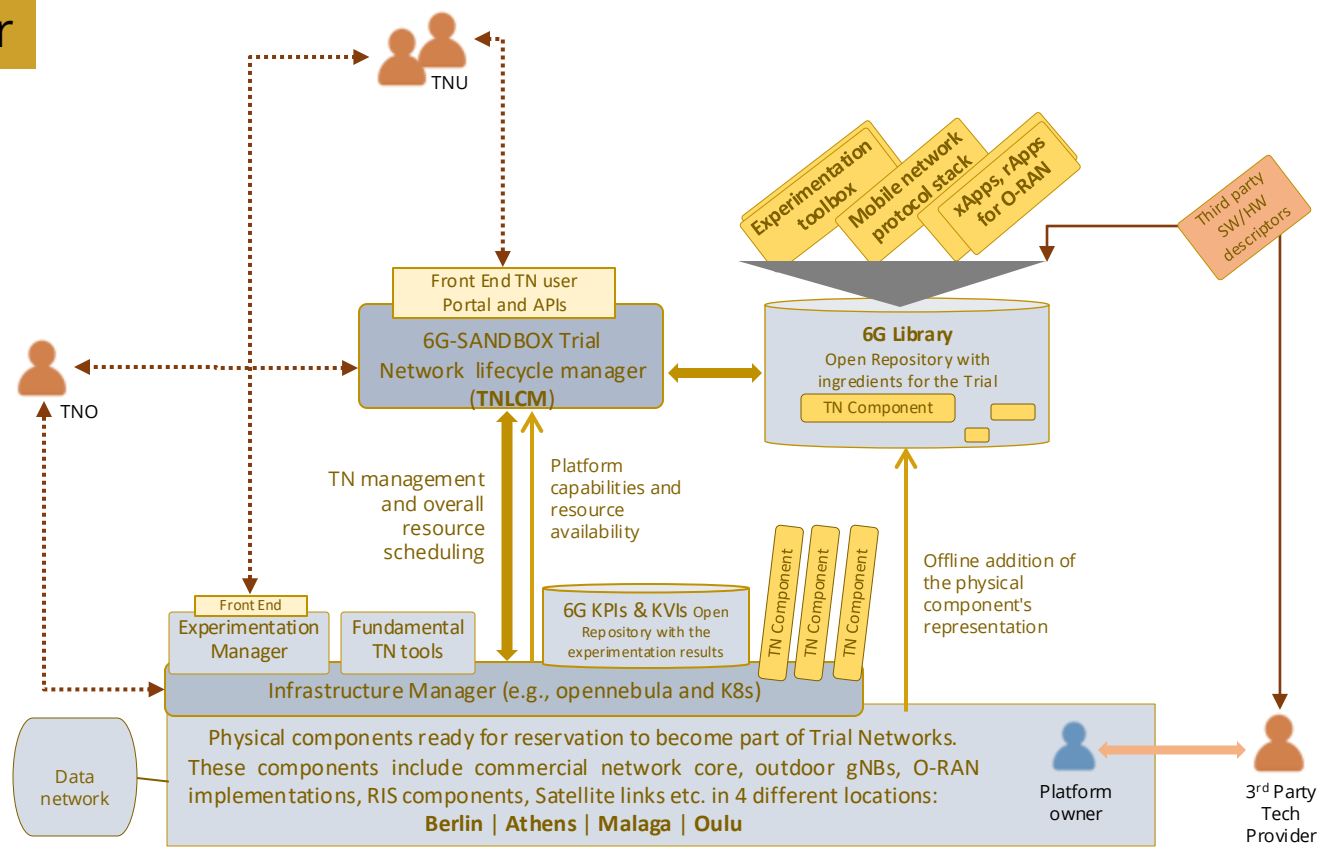
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Technology Provider

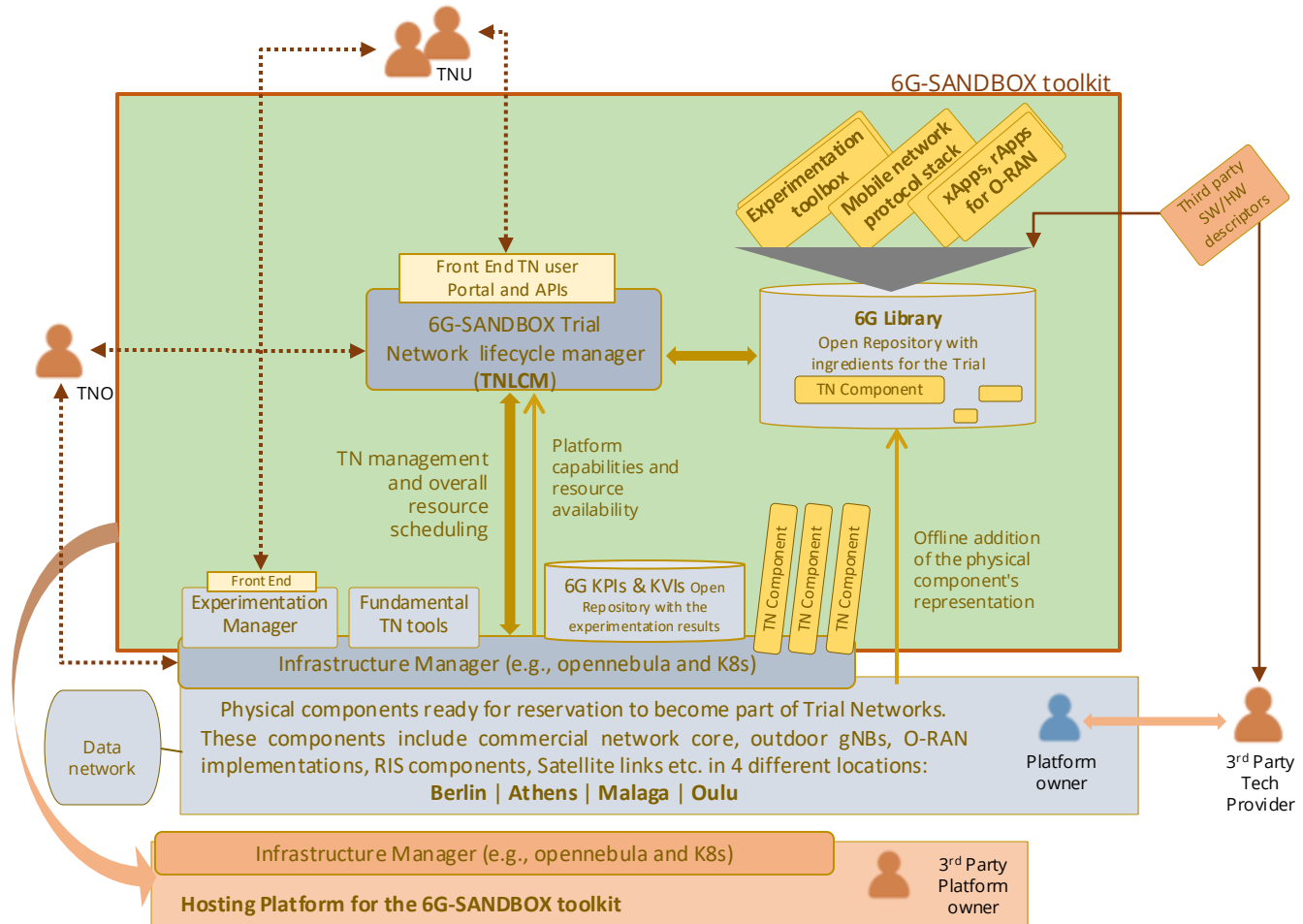
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The 6G-SANDBOX Toolkit

All the software component and reference descriptors & data that needed to for making a platform capable to offer Trial Networks

The first release of the 6G-SANDBOX Toolkit is available !

https://6g-sandbox.eu/wp-content/uploads/2024/09/6G-SANDBOX-Toolkit-Installation-G-V1.0_F.pdf

Toolkit Documentation

Installation Guide V1.0

