Get 6G-ready!
R&D Toolkits for building open beyond 5G and pre-6G Testbeds
—

Fraunhofer FOKUS / TU Berlin

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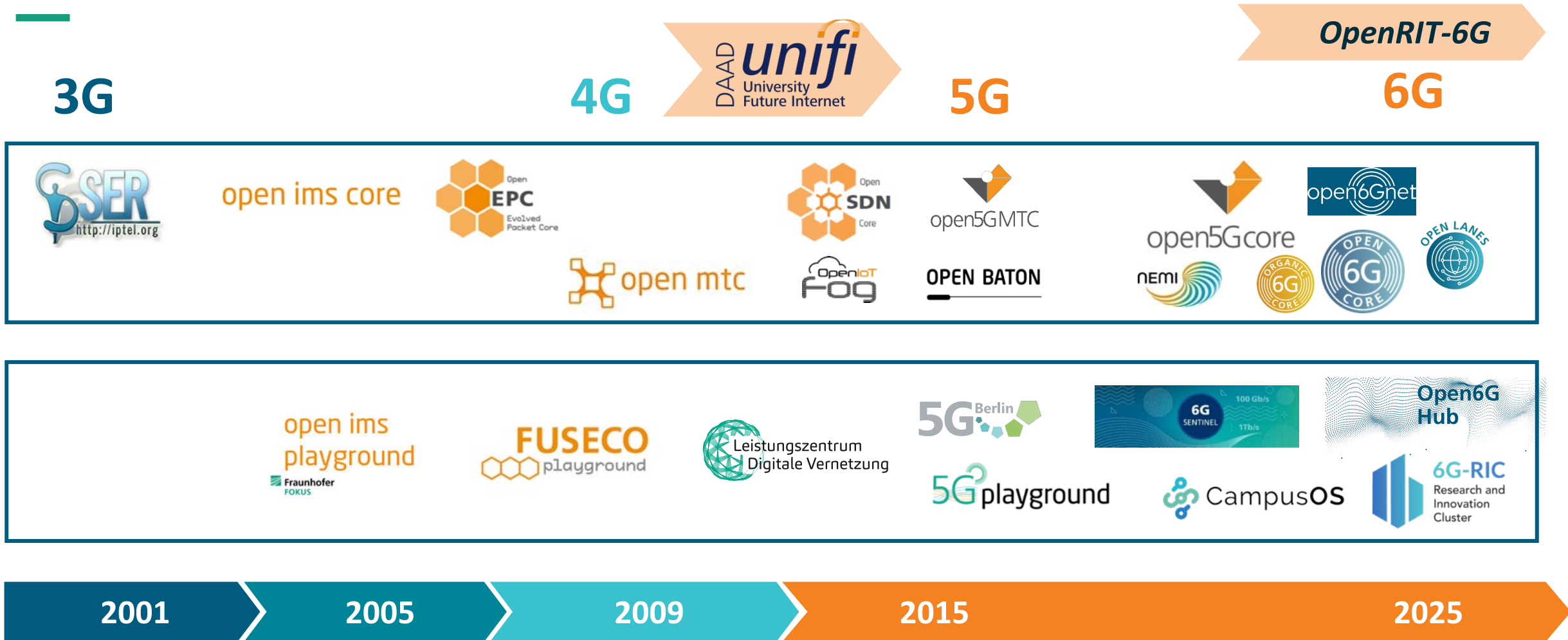https://www.6g-ready.net/

Open6GHub

Open Testbeds and Toolkits for sustainable and international R&D
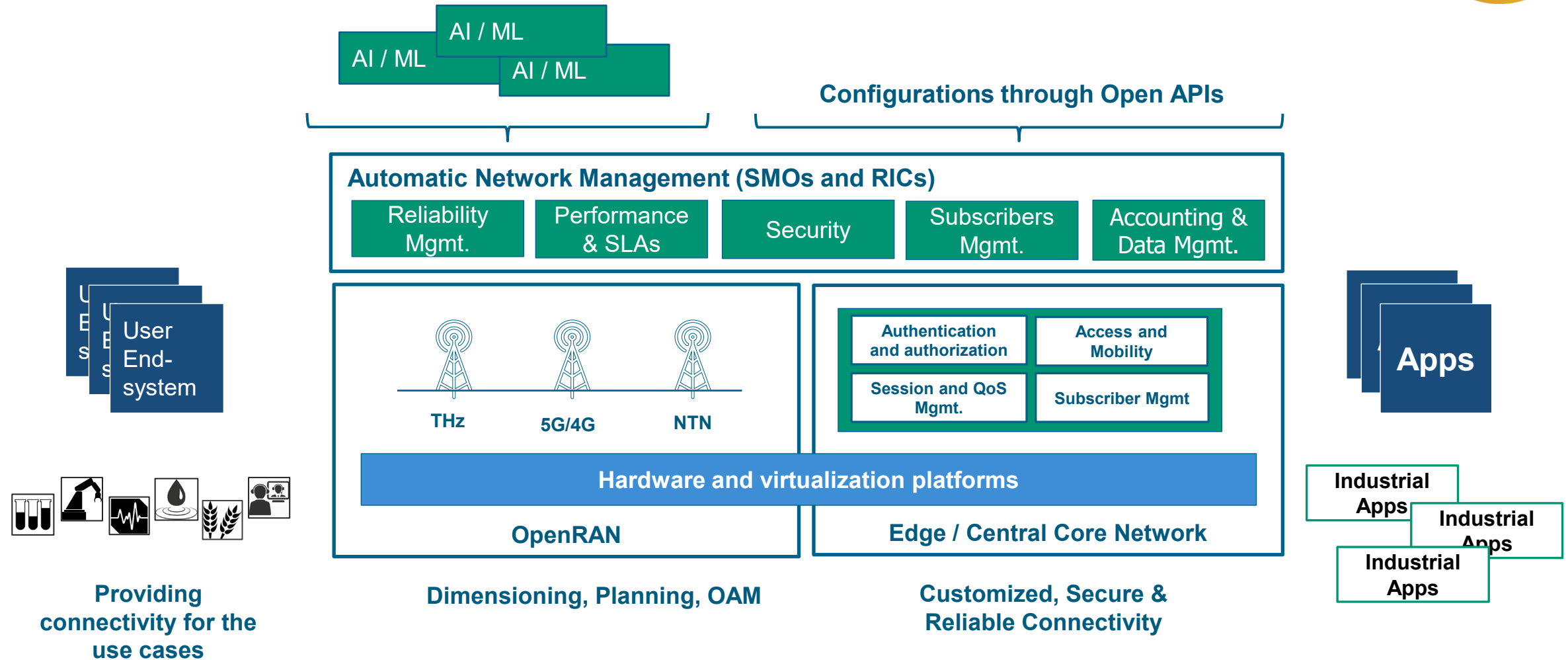
- Since 30 years open testbeds and toolkits represent the foundation for our R&D projects

- Our mission is „DEMO OR DIE" ➔ we do applied research

- International standards (e.g. 3GPP) are key for international cooperations

- Open as licensed source code (via FOKUS) vs. open source (via TUB)

- We are testbed pioneers since 3G and the softwarization of networks, and have managed to keep momentum up to today

- ***We believe 6G will be an evolution of 5G with Campus networks driving the evolution to 6G***

➔ *6G-ready testbeds & toolkits will originate from 5G testbeds & toolkits*

# Foundation for R&D Projects: FOKUS/TUB Testbed and Toolkit Evolution

OpenRIT-6G

3G **4G** DAAD **unifi** University Future Internet **5G** **6G**

SER http://iptel.org — open ims core — Open EPC Evolved Packet Core — Open SDN Core — open5GMTC — open5Gcore — open6Gnet — OPEN LANES

open mtc — OpenIoT Fog — OPEN BATON — nemi — ORGANIC 6G CORE — OPEN 6G CORE

open ims playground — Fraunhofer FOKUS — FUSECO playground — Leistungszentrum Digitale Vernetzung — 5G Berlin — 6G SENTINEL 100 Gb/s 1Tb/s — Open6G Hub

5G playground — CampusOS — 6G-RIC Research and Innovation Cluster

2001 **2005** **2009** **2015** **2025**

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6G-ready System simplified – to be seen as a 5G Evolution …

AI / ML

AI / ML

AI / ML

Configurations through Open APIs

Automatic Network Management (SMOs and RICs)

| Reliability Mgmt. | Performance & SLAs | Security | Subscribers Mgmt. | Accounting & Data Mgmt. |

User End-system

THz | 5G/4G | NTN

Authentication and authorization | **Access and Mobility**

Session and QoS Mgmt. | **Subscriber Mgmt**

Hardware and virtualization platforms

OpenRAN

Edge / Central Core Network

Providing connectivity for the use cases

Dimensioning, Planning, OAM

Customized, Secure & Reliable Connectivity

Apps

Industrial Apps

Industrial Apps

Industrial Apps

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Open5GCore Rel. 8

An extended R&D oriented implementation of the 5G core network (3GPP Release 16 and 17)

- Software based core network – programs that can be deployed as containers, pods, VMs, …
  - Fundamental 5G core network functionality: AMF, SMF, UPF, PCF, UDM, AUSF, …
  - Additional services: non-3GPP, location

- Main features for 5G:
  - Integrating with 5G NR SA, non-3GPP and satellite
  - Data path diversity, local offload
  - Advanced bearers, QoS and session management
  - Network slice support
  - Location service support
  - Performance Benchmarking
  - Own UE emulation of regular Android OS App

- Highly configurable for:
  - Edge-central split
  - Dedicated, private and campus networks
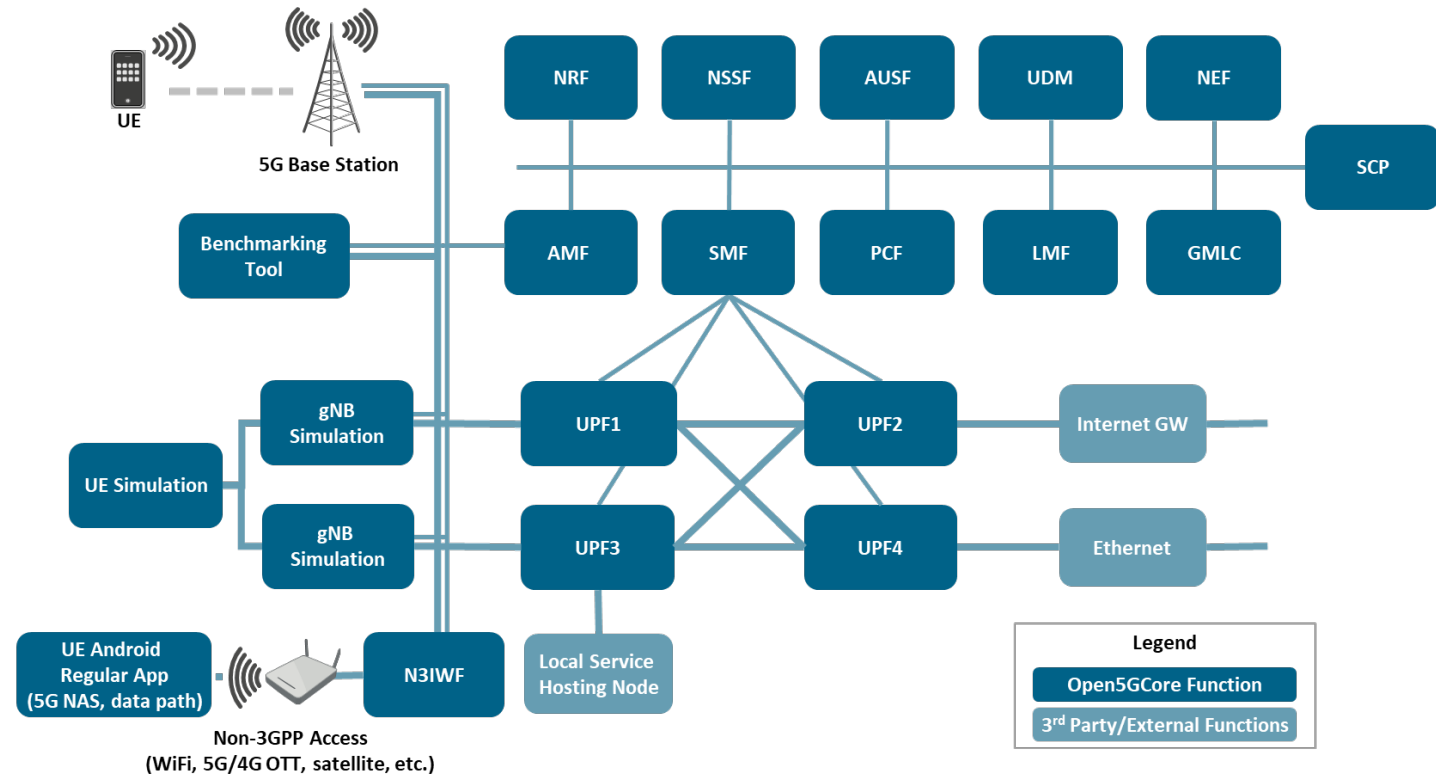
What is new in Open5GCore Rel. 8 and Rel. 9

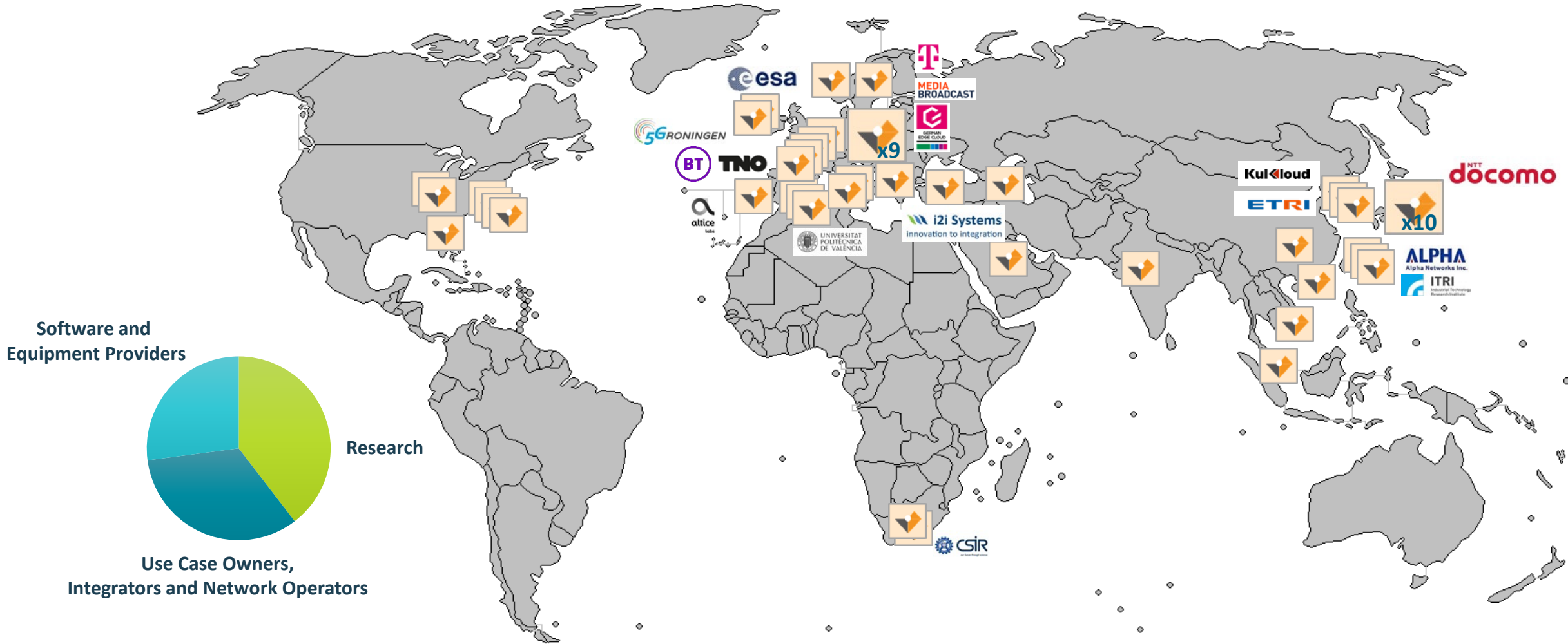## Release 8 features (available from April 2023)

- High capacity UPF
- Xn Handovers
- Roaming: H-SMF/V-SMF support, home and local routed
- SMSF
- Enterprise Slice from Android 13 + URSPs
- SBI API upgrade to 3GPP release 17
- QoS Flows support for dedicated bearers
- Location Services: Subscription cancellation support
- Heartbeat between NFs and NRF

Release 9 features (due April 2024):
- AWS & space payloads deployments
- TSN support
- Integration of location services with 5G UEs and gNBs

UE

5G Base Station

Benchmarking Tool

NRF | NSSF | AUSF | UDM | NEF

SCP

AMF | SMF | PCF | LMF | GMLC

gNB Simulation

UE Simulation

gNB Simulation

UPF1 | UPF2 | Internet GW

UPF3 | UPF4 | Ethernet

UE Android Regular App (5G NAS, data path)

N3IWF

Local Service Hosting Node

Non-3GPP Access (WiFi, 5G/4G OTT, satellite, etc.)

Legend
Open5GCore Function
3rd Party/External Functions

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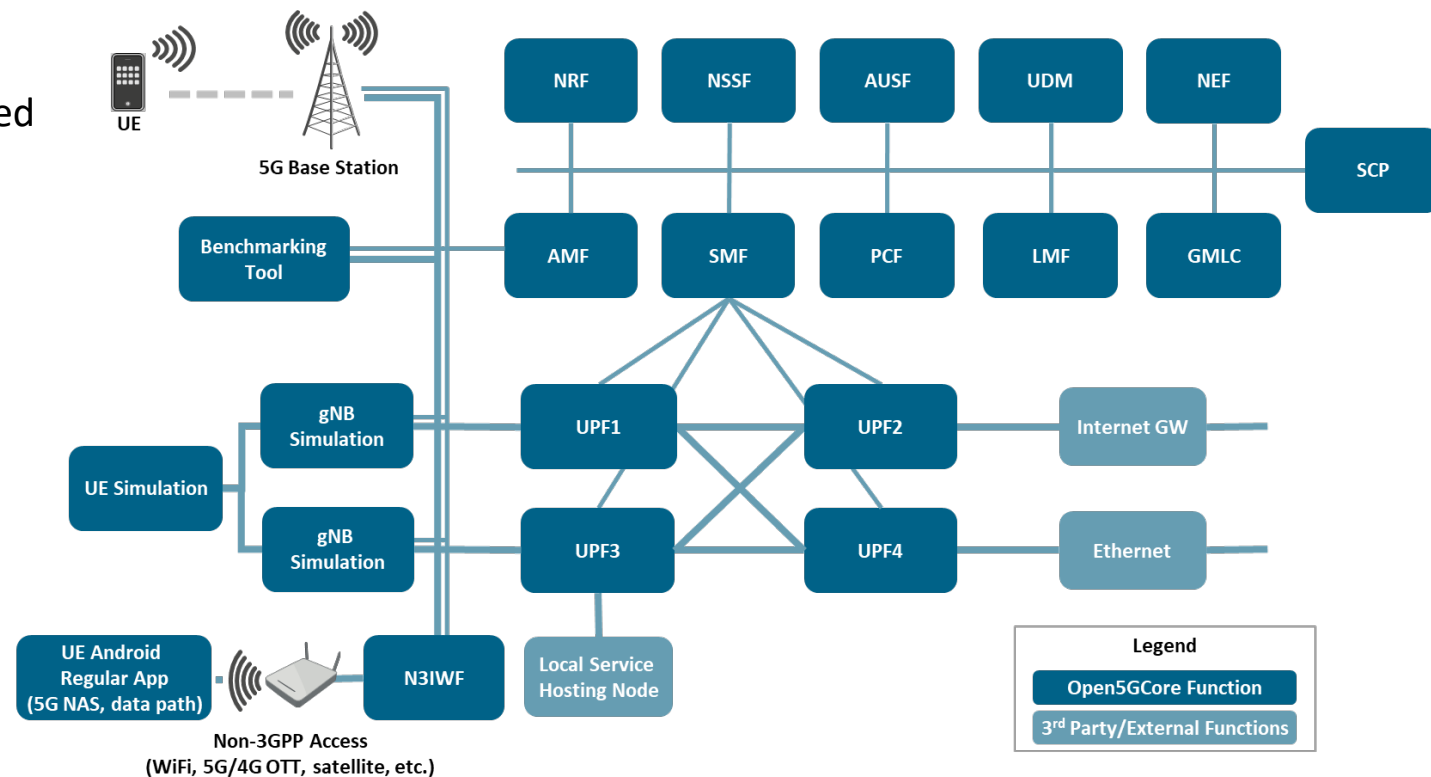
Deployments and Reference Customers (from 2014 on)

5G Playground: Implemented Use Cases

Public Events: 5G Nomadic Node at Festival of Lights 2019 in Berlin

Industry 4.0: 5G-ACIA Testbed, 5G Campus Network for the Software-defined Factory

Disaster Management: ALADIN project, Forest Firefighting in Brandenburg with 5G

eHealth: FUDGE-5G project, Private 5G Networks for hospitals

Railway: 5G VICTORI project, 5G Campus Network in the train stations

Aeronautics: ESA SATis5, In-cabin entertainment with local 5G network

Mobile testbed: 5Genesis project, ALADIN, CampusOS 5G out of the box with our modular Nomadic Node

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Open, modular Campus Networks – German Flagship Project - CampusOS

Reference Architecture, Component Catalogue, Blueprints for building open campus networks for different use cases

Nomadic Construction Sites — TOPCON

Industry 4.0 Intralogistics (ITS*) — STILL

Industry 4.0 Intralogistics (SCS*) — STILL
Supported by: DEMATIC

Connected Mobility — BOSCH

Reference Test Sites
Fraunhofer HHI
Fraunhofer FOKUS
5G BERLIN

Hamburg
Berlin
Hildesheim
Herne
Frankfurt

* ITS = industrial transport system
SCS = supply chain system

Supported by:
Federal Ministry for Economic Affairs and Climate Action

on the basis of a decision by the German Bundestag

https://campus-os.io/

Fraunhofer FOKUS

FOKUS Nomadic 5G Node – an open, modular, scalable 5G testbed in a box to go

An adapted solution, addressing all the high variation in mobility, coverage area variation, energy consumption and size

1 Large scale nomadic network for long duration setups
for infrastructure failures, construction sites
Small size racks including large battery supplies,
COTS servers and macro-base station

2 Portable in-car setup for long duration emergencies
for firefighters, disaster relief, maritime
Small size rack with environment protection with
1-2 COTS server and macro-base station and battery

3 Small size setup for nomadic 5G hotspot connectivity
for portable 5G networks, logistics, public transport
Single PC and micro-base station

4 Low energy/low size for constraint environments
for backpacks and space payloads
ARM based board (with FPGA) & micro-base station

5 Smallest of them all
for a new ultra-dense IoT 5G environment
All in micro-base station or raspberry.pi and micro-base station

- https://www.fokus.fraunhofer.de/en/fokus_testbeds/5g-node

Nomadic and Mobile 5G Networks

Comprehensive systems which can be dynamically deployed at use case location

- Integrate with local devices
- Fit the local constraints: energy, weight, size, vibrations, weather, etc.
- Support for localized communication
- Trustful and reliable communication

This functionality is developed as part of:

CampusOS · ALADIN Advanced Low Altitude Data Information System · Open6G Hub Germany · SATis5

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5G out of the box
Robust, transportable set-up

Edge Compute and Network

Virtualization environment for Open5GCore of Fraunhofer FOKUS and for application services

Radio Technology and battery

5G SA multi-vendor support (band n78)

Various backhauling and non-3GPP technologies

Satellite backhaul and WiFi-6 / 60GHz links for front- or backhaul access

Nomadic version of a 5G-ACIA approved tested

Blueprint for 3rd party, industrial nomadic deployments

Open5GCore licensable for R&D and proof-of-concepts

Technology Impacts for 5G Evolution towards 6G
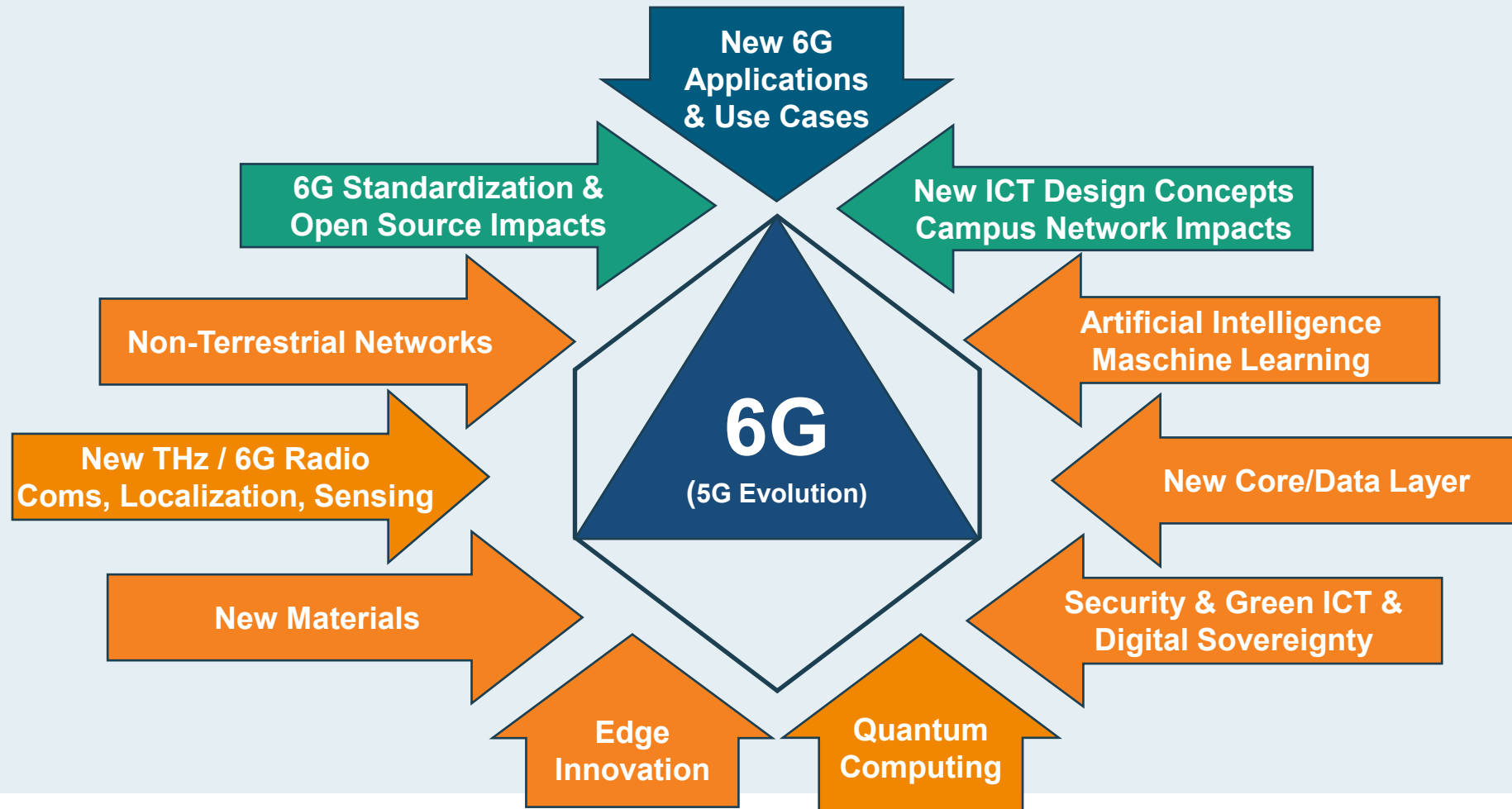
Towards 6G: Long Term Roadmap

Demonstrations of limitations of 5G

5G-6G features which could be immediately used in the 5G+ core

First 6G-ready 5G Core network 6G features in the 5G core

6G-ready End-to-end Demonstration A complete 6G ready system

Open6GCore Version 1 New software toolkit addressing the specific 6G architecture

Open6GCore Version 2 New software toolkit addressing the specific 6G architecture

2020 **2021** **2022** **2023** **2024** **2025** **2026**

Standardization Start

6G SENTINEL
100 Gb/s
1Tb/s

6G-RIC Research and Innovation Cluster

Open6G Hub Germany

Fraunhofer FOKUS

Open6GHub

A network of academic excellence in Germany with 11 universities and 6 research institutes

- Open, Organic 6G Networks
- Integrated in real use cases
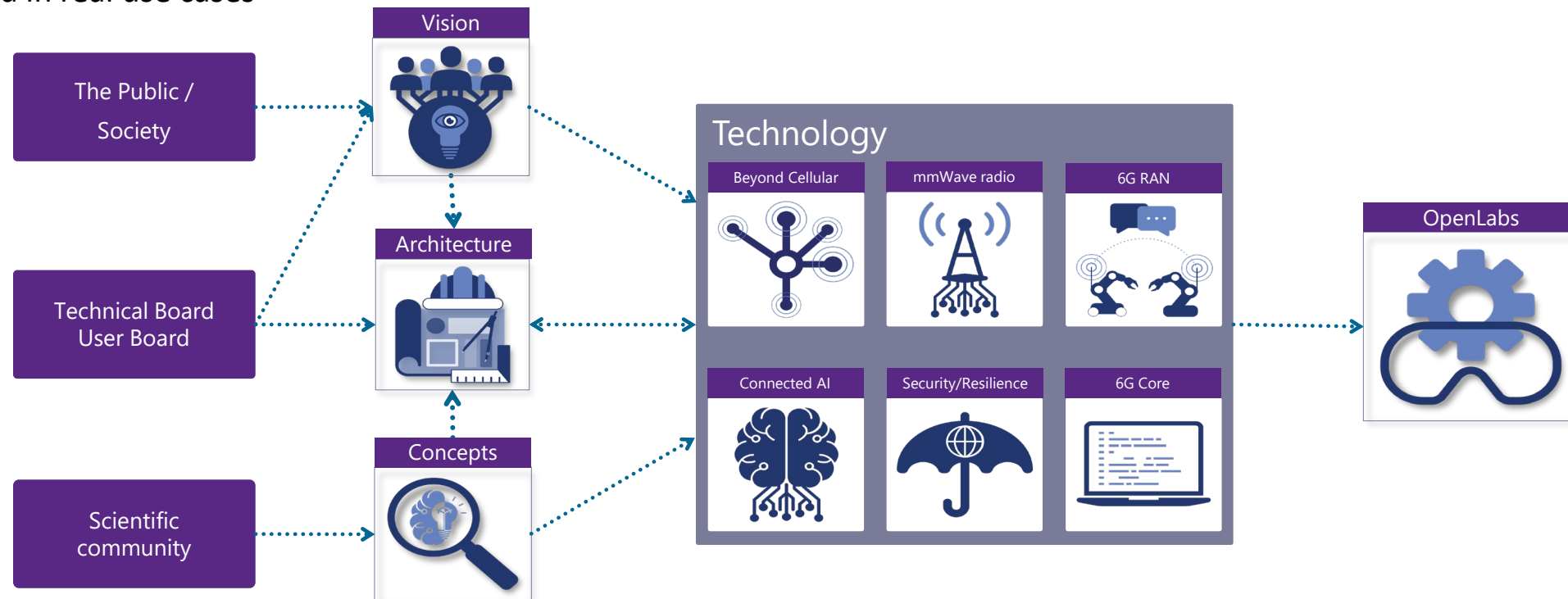
6G-RIC

Conceptually, 6G-RIC comprises six Technological Innovation Areas (TIA), which aim to develop disruptive solutions that go far beyond the current state of the art

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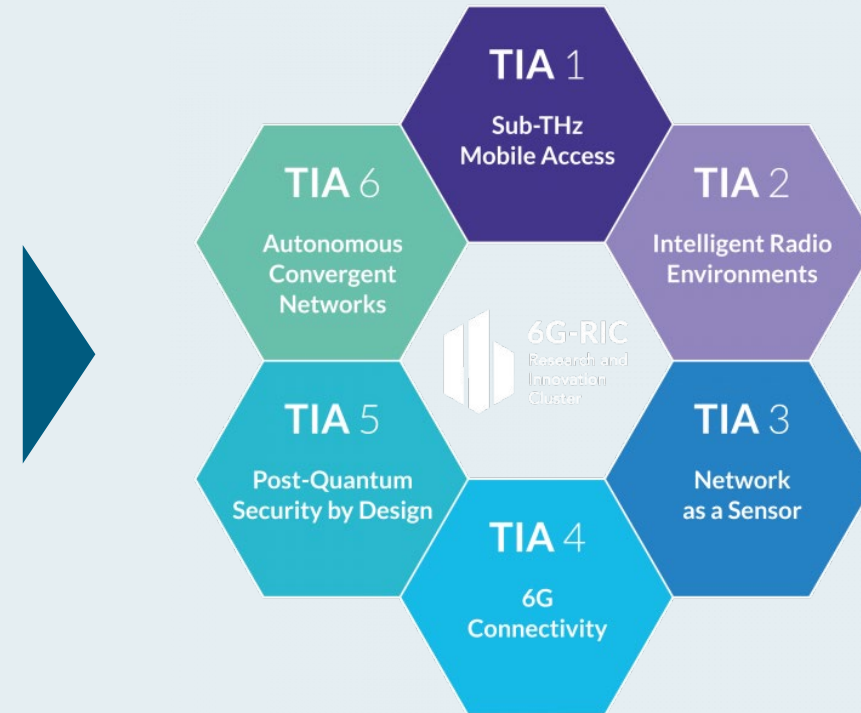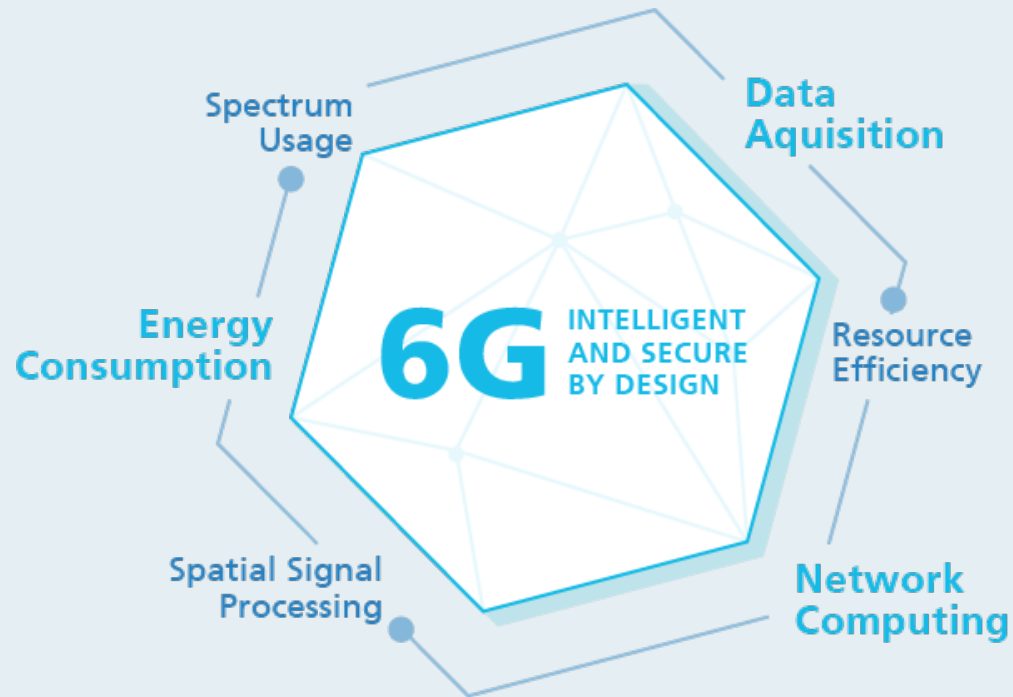
Core network for Beyond 5G and 6G

Two toolkits with different goals:

- Open5GCore:
  - further development of beyond 5G core network functionality
  - customized deployments for use cases
- Open6GCore:
  - New flexibility, low complexity concepts
  - Docking of new services e.g. sensing

- Both should be able to connect to 5G and 6G UEs and RAN
- At the current moment we assume data path remains the same
- In time, Open6GCore would replace the Open5GCore

Option 1: Control Plane with a Large Functionality (developed from 2014)

Option 2: Minimal control plane with new flexibility features

Selected functionality

Open5GCore Control Plane

Open6GCore Control Plane

5G

5G UE

5G gNB

6G

Third party components

Open5GCore Data Plane

High-Capacity Ultra-Flexible Data Path

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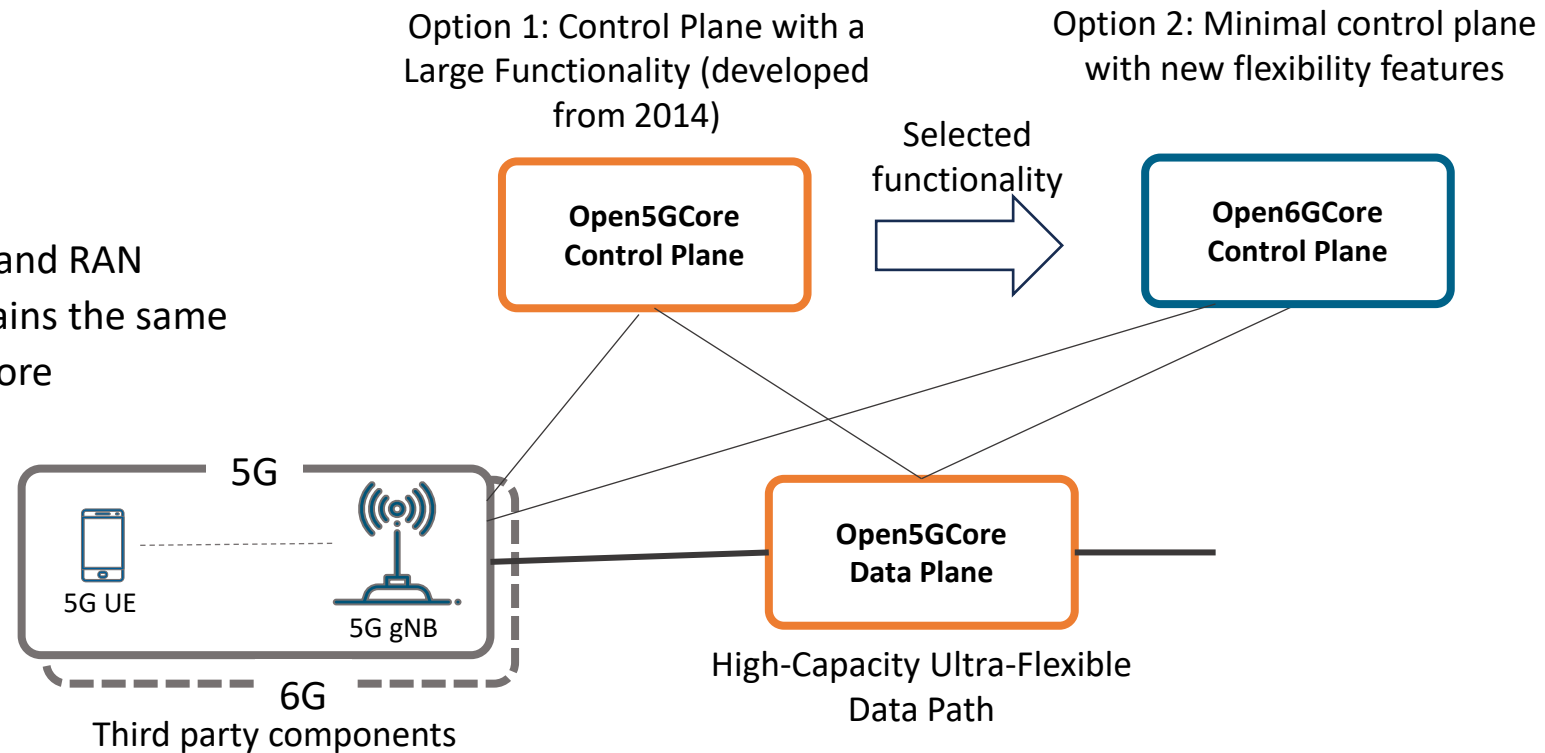
Organic 6G Network: A definition

The organic network concept is an approach to network architecture that enables the morphing of functionality in different network locations to be able to address the momentary needs with the available infrastructure resources.

Organic networks enable a very high customization and ultra-flexible network enabling the network providers to provide coherent and fluid best possible services to connected devices, automatically adapted to the underlying dynamic network infrastructure.

Dynamically providing the dynamic subscriber state to where and when needed

Organic 6G Networks:
Morphing the functionality in each location to address the momentary needs and available infrastructure

Dynamically providing a front-end to subscribers where and when needed
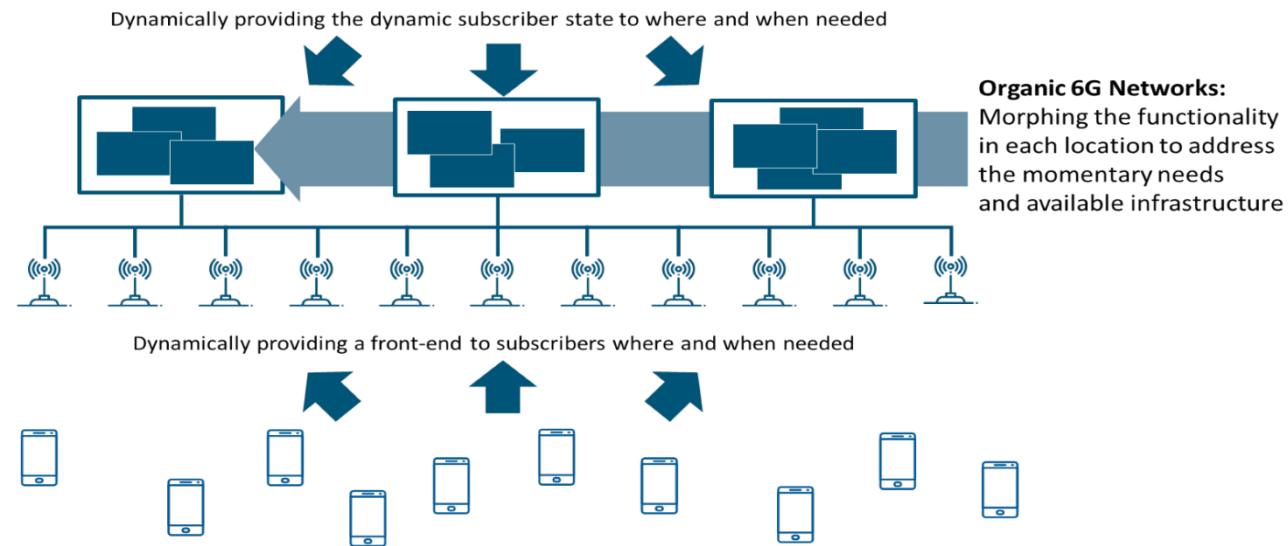
This functionality is developed as part of:

Open6G Hub Germany

6G Organic Core Network Concept

Dual usage of the web-services architecture

1. Implement the core network functionality as a macro-web service
- Different front-ends for UE, RAN, data path, external, …
- Single subscriber state

2. Implement the macro-web service workers as stateless micro-services
- Services are fully stateless
- Services should be procedural oriented – as much of a procedure as possible to reduce horizontal communication between micro-services

- Other requirements:
  - No parallel requests from the same UE – regulation at Front-end possible
  - Requests are triggered by the UE – or a "puppet UE" in the core
  - Unified subscriber state
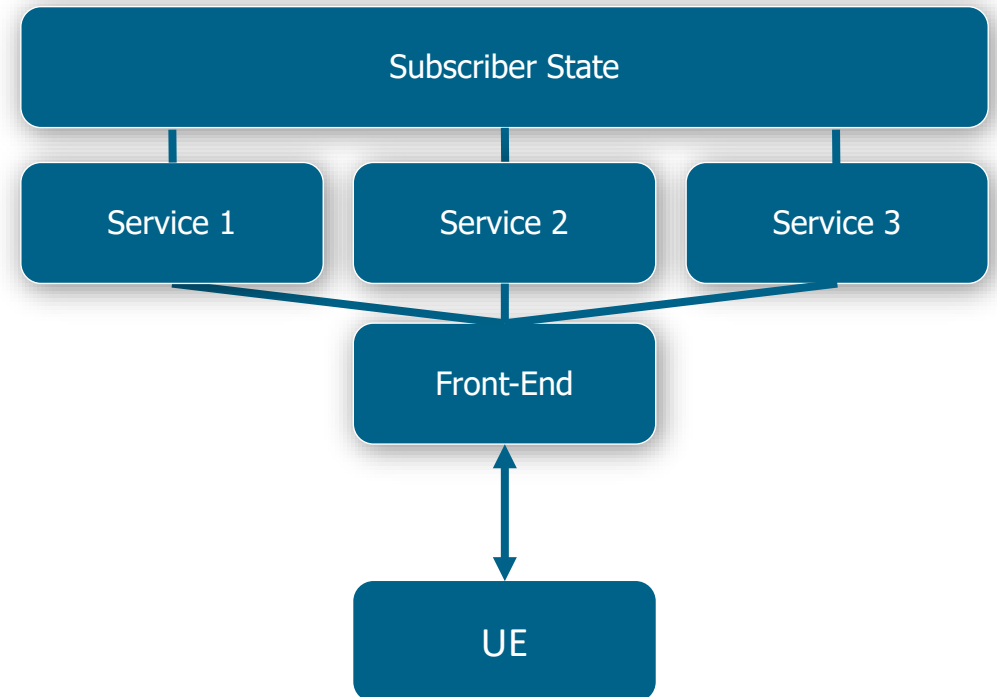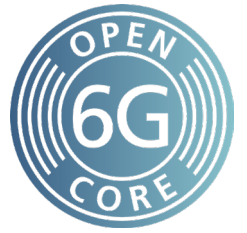
Open6GCore Blueprint

Each high-level functionality of 5G Core Network is a separate service

- Access Control, Authentication and Authorization (ACAA) –subscriber authentication and authorization to use the network
- Connection Management (CM) – idle mode related operations
- Mobility Management (MM) – handover procedures
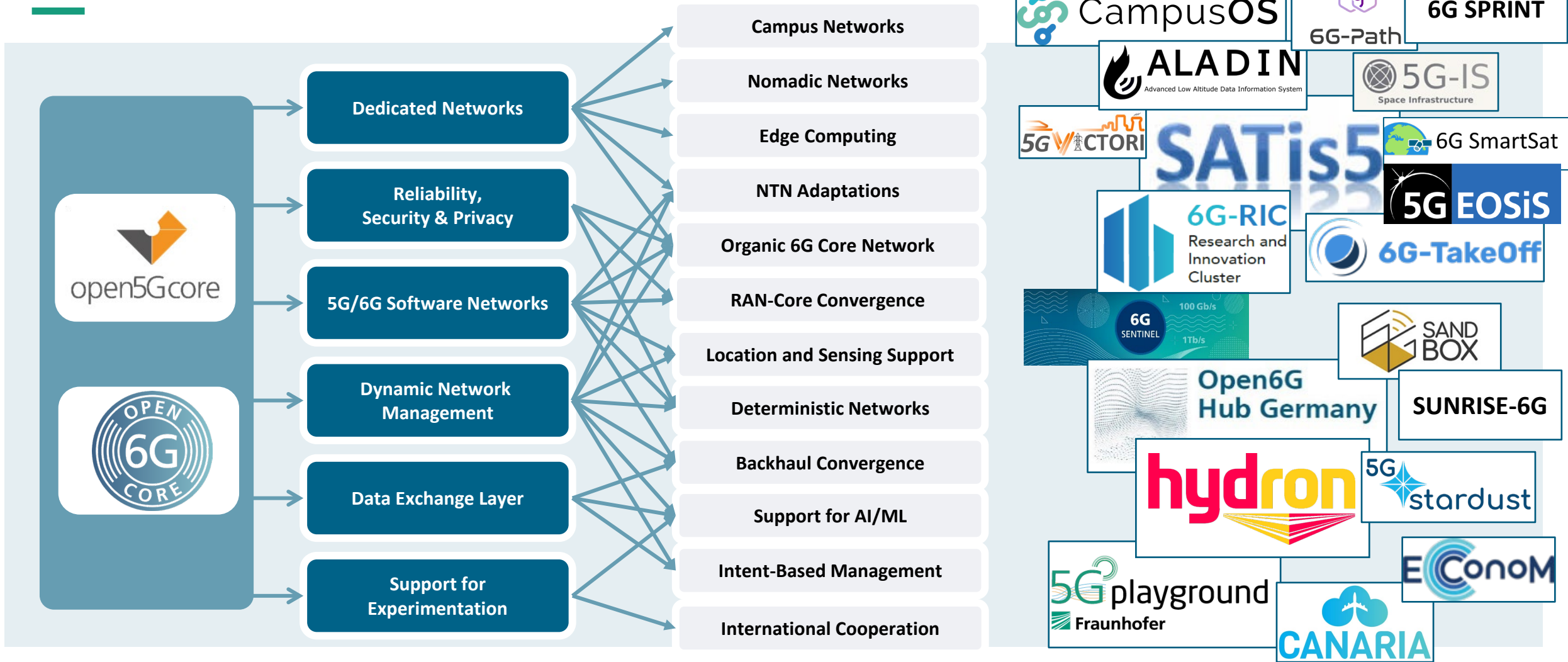- Session Management (SM) – data path resource allocation procedures
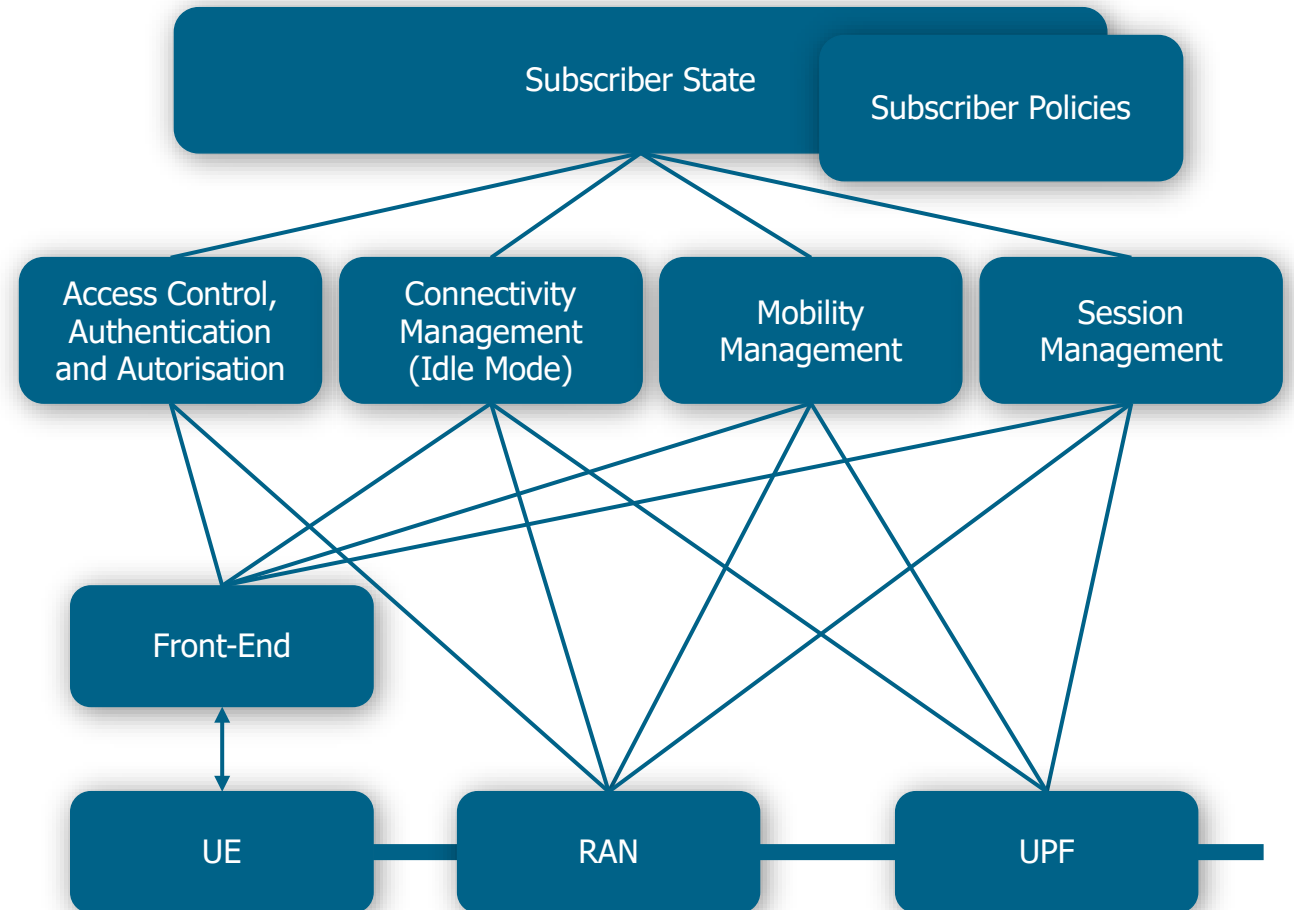
Open6GCore Architecture
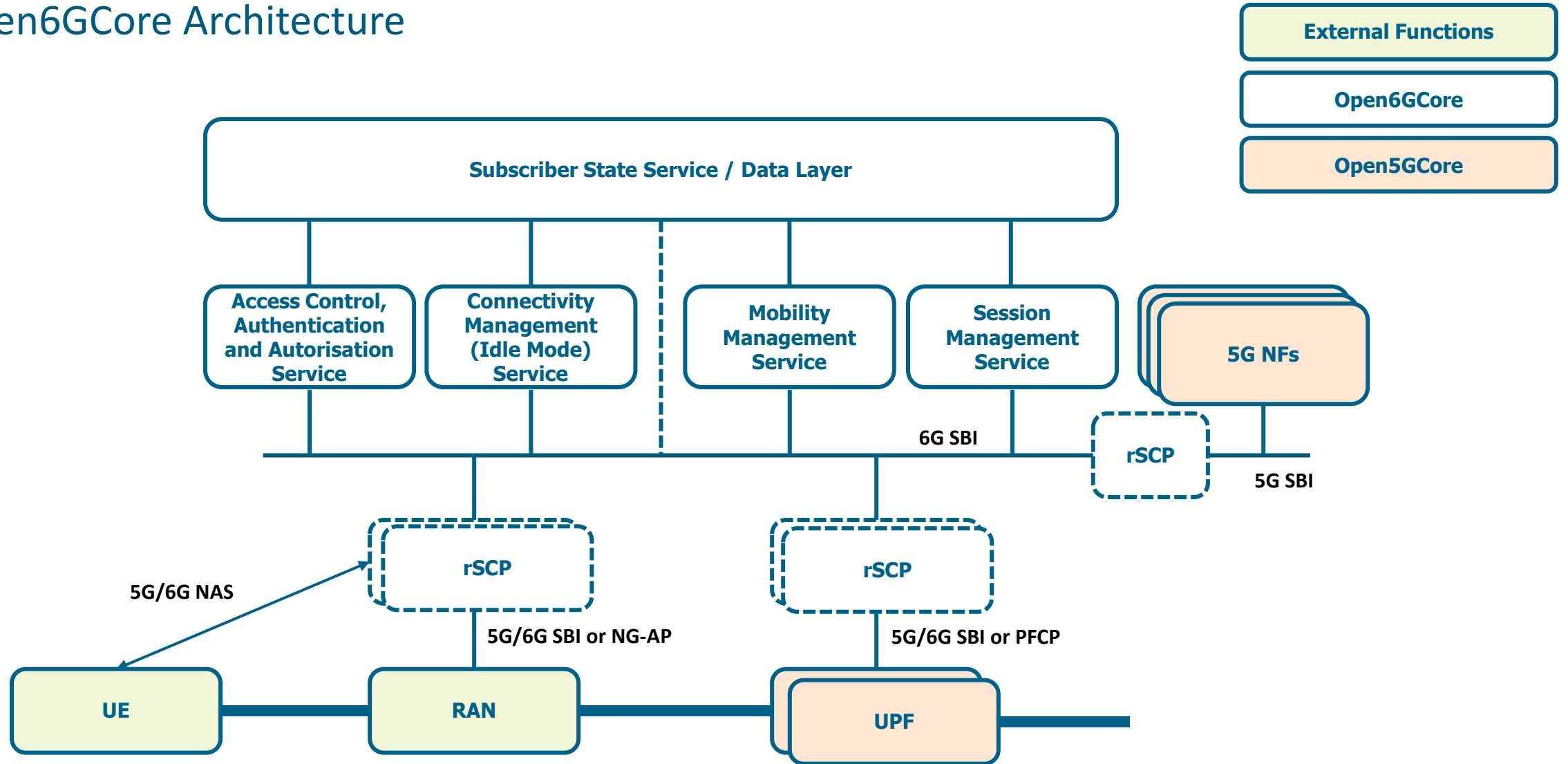
Open6GCore – binding of new services

Fraunhofer FOKUS
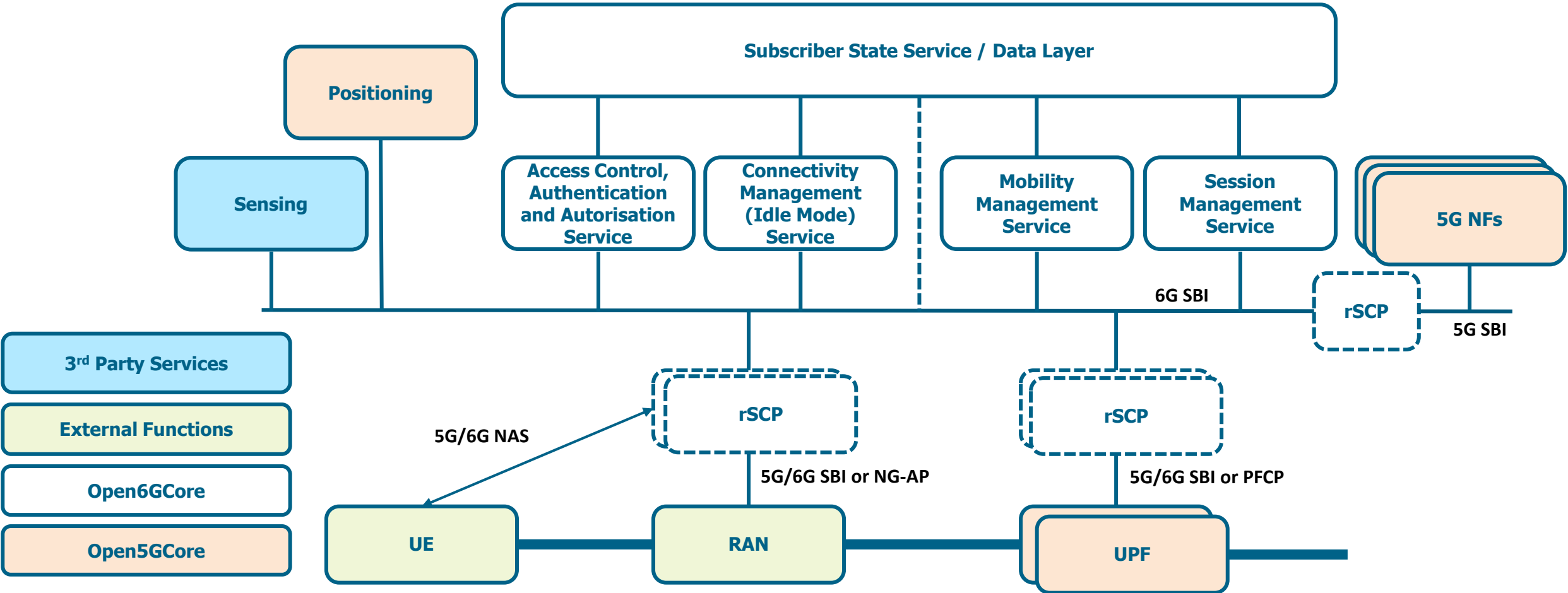
Open6GNet.org Initiative from TU Berlin looks at Open Source Toolkits

- Motivation:

  - Open5GCore might be to expensive for some universities and R&D partners

  - TU Berlin studends don´t have access to Open5GCore due to IP protection

  - We need some low cost 5G end to end Testbed (UE + RAN + CORE + SMO) for students to get hands onto 5G

- Initiative started with UCT in 2023

- Mission: Build a catalogue of useful 5G toolkits, plus useful blueprints plus tutorials to get students started

- Traget is to evolve from 5G towards 6G in the future

Open6GNet.org Initiative – State of Play

- 5G-Beyond testbed infrastructure and toolkits' collection
  for teaching and research:
    - students at TUB
    - visiting students
    - researchers

- Workshops for students to deploy 5G private networks setups
  using open source tools guided by experienced researchers

- Fostering open source adoption, dedicated events to meet open source projects' representatives

Open6GNet.org Initiative – Component Catalogue

- Technical foundations:
    - private spectrum
    - affordable SDRs for teaching and research activities
    - mobile network technologies based on NFV and SDN
    - open source tools for all components of a 5G system

- Current Catalogue
    - RAN: srsRAN, OpenAirInterface RAN
    - Core: Open5GS, Free5GC
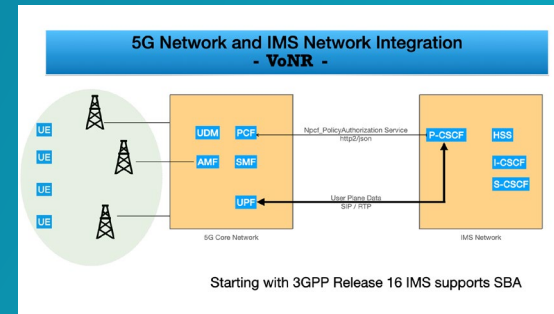   - UERANSIM, pySim, bareSIP, Kamailio

Open6GNet.org Initiative - Blueprints
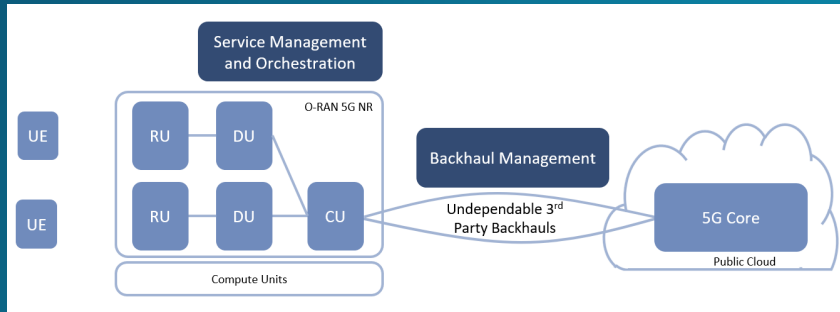
End-to-end testbeds performaces analysis
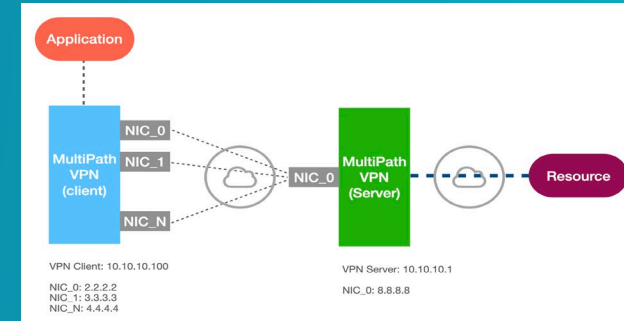
Affordable reliable backhauls for NPNs
with multipath VPN solution
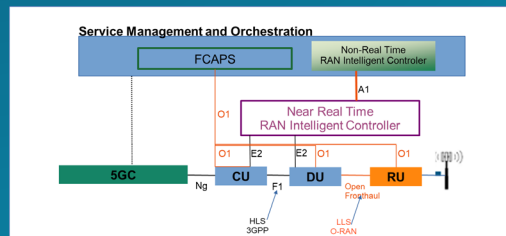
Automatic deployment and optimization of NPNs

VoNR Integration
OTT RTC services

Open6GNet.org Initiative – How to contribute

- Prepare a concise good description of the 5G setup and of the outcomes (proposal)

  - hardware used

  - architectural design picture

  - configuration of the deployed software tools

  - report on performances/outcomes achieved with the testbed experiments

- Submit the proposal for review

- More on www.open6gnet.org

- Contact: Ramona Modroiu, elena-ramona.modroiu@tu-berlin.de

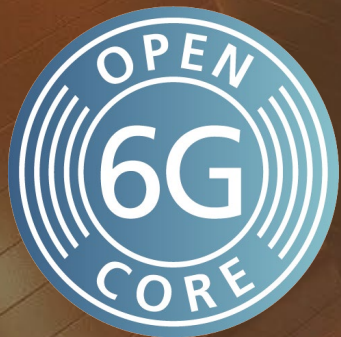**12th FOKUS FUSECO Forum**
Nov. 7–8, 2024 | Berlin

Save the Date!

Forward to 6G!

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Please contact us

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www.5G-playground.org

https://www.6g-ready.net