



From Open IMS Playground to Open 5G Playground -
*Addressing the Prototyping Challenges of emerging 5G
Standards, Platforms and Applications*

Prof. Dr. Thomas Magedanz

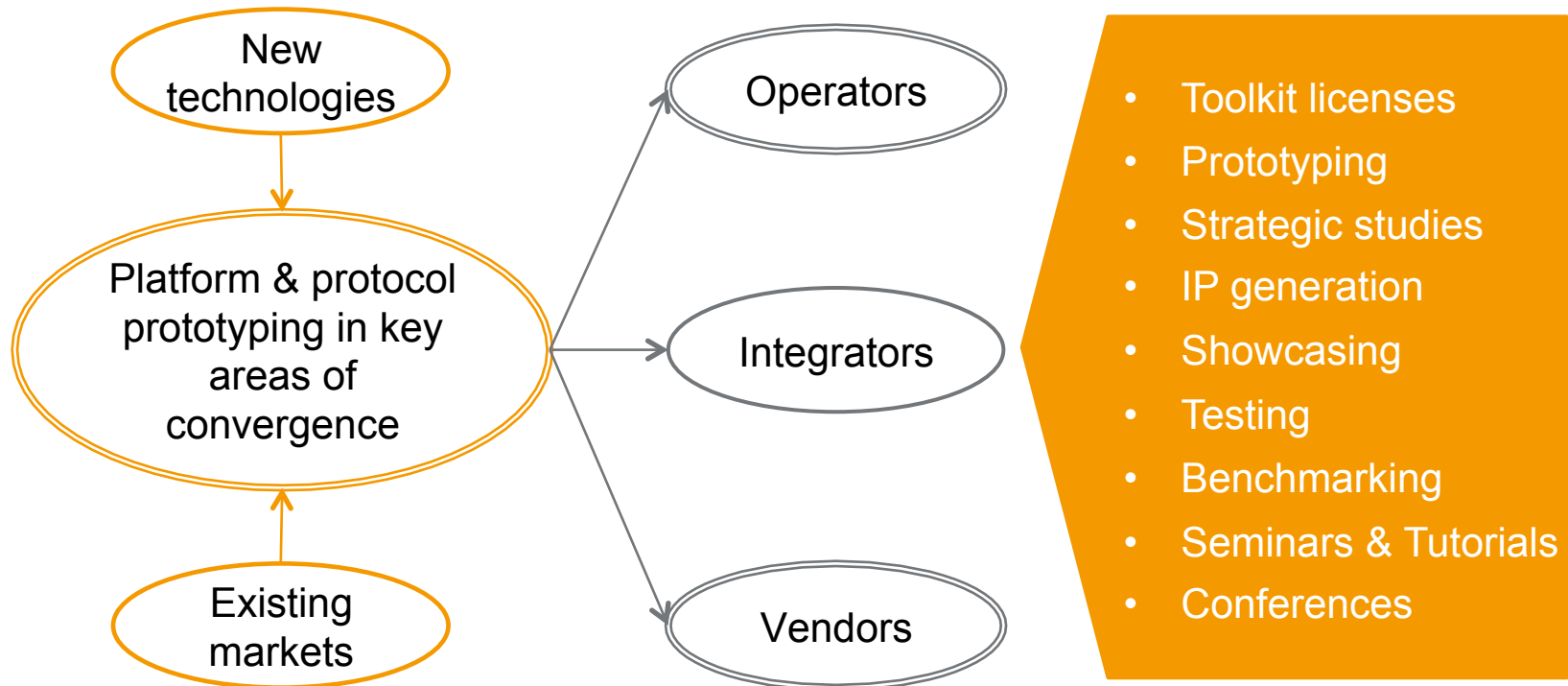
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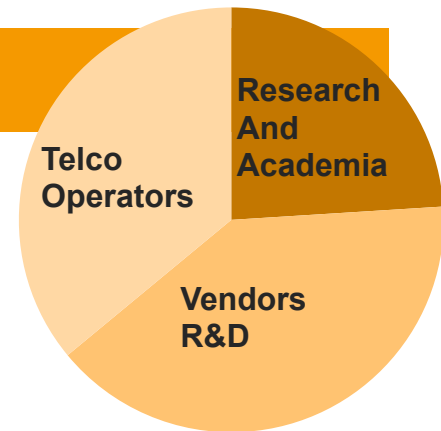


FOKUS NGNI GENERAL BUSINESS STRATEGY



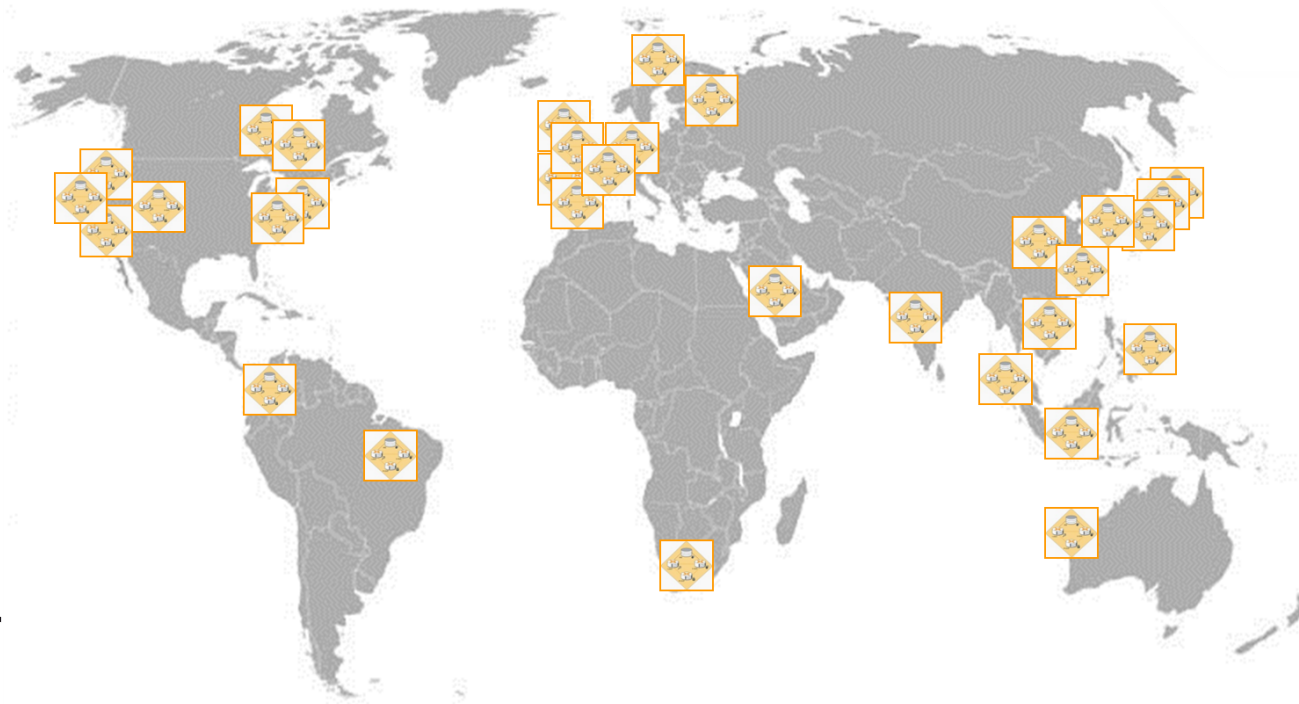
Based on our OpenXXX toolkits
Provided via a 'Testbed as a Service' or 'Testbed2Go Model'
Cross-financed by industry, EU and public funding

Deployed FOKUS Testbeds 2 Go around the World



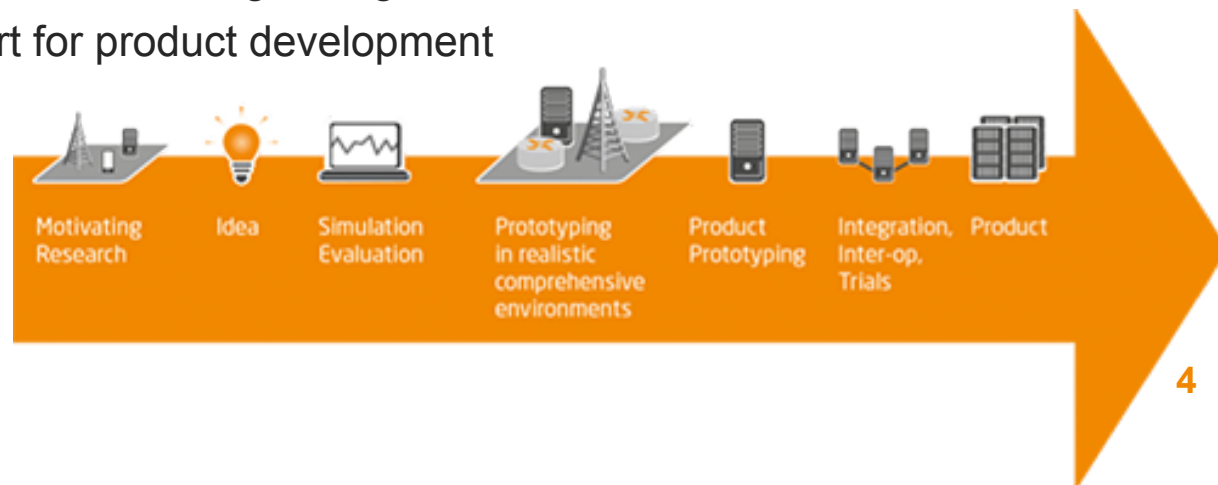
Testbeds are located at the customer premises

- Under the complete control of the local partners
- Remote support via VPNs (for a reduced number of testbeds)
- Bug fixes and updates are done via: email reports (network traces, cores) → svn updates

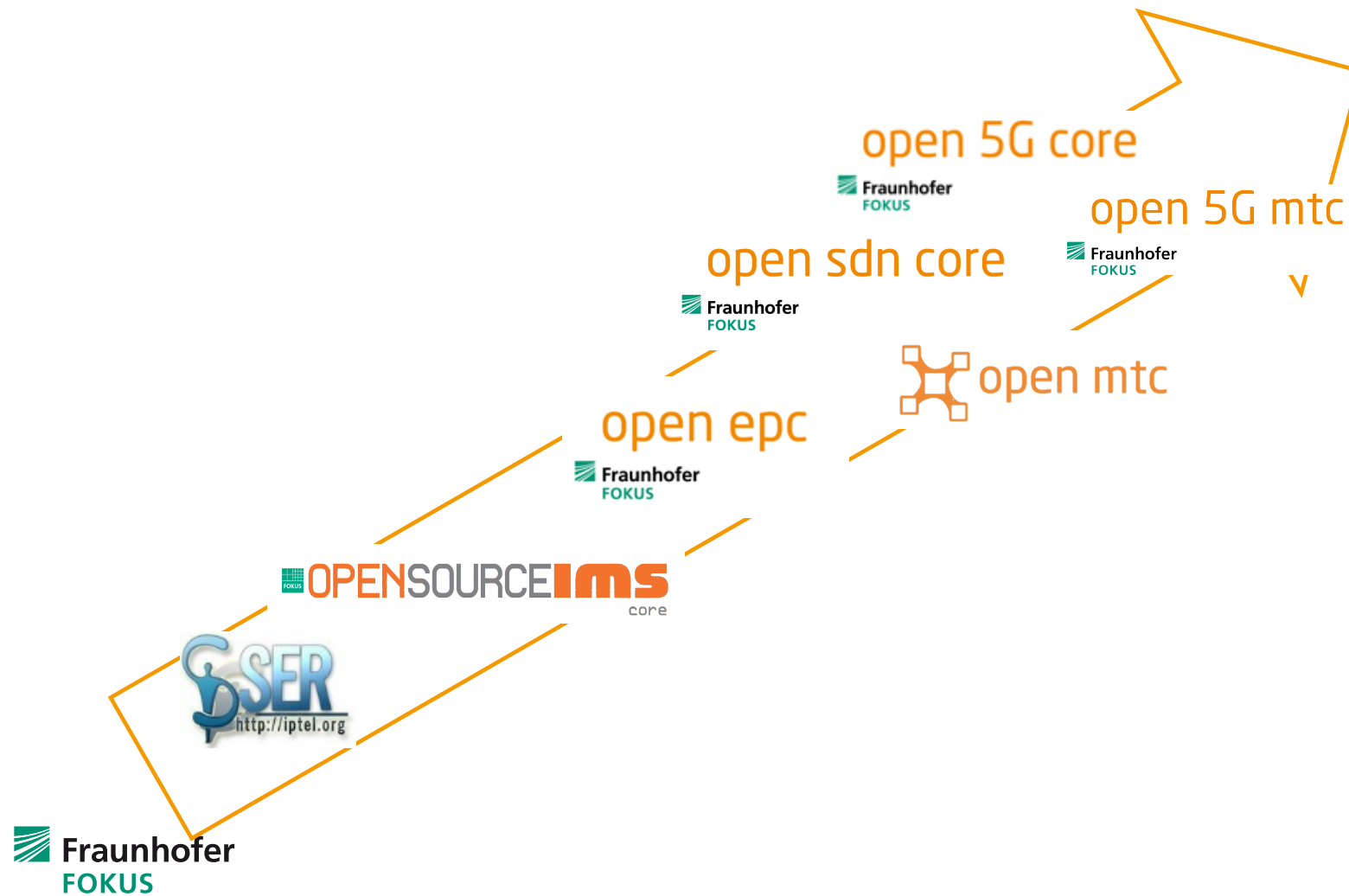


Addressing the R&D Requirements of an emerging Digital World

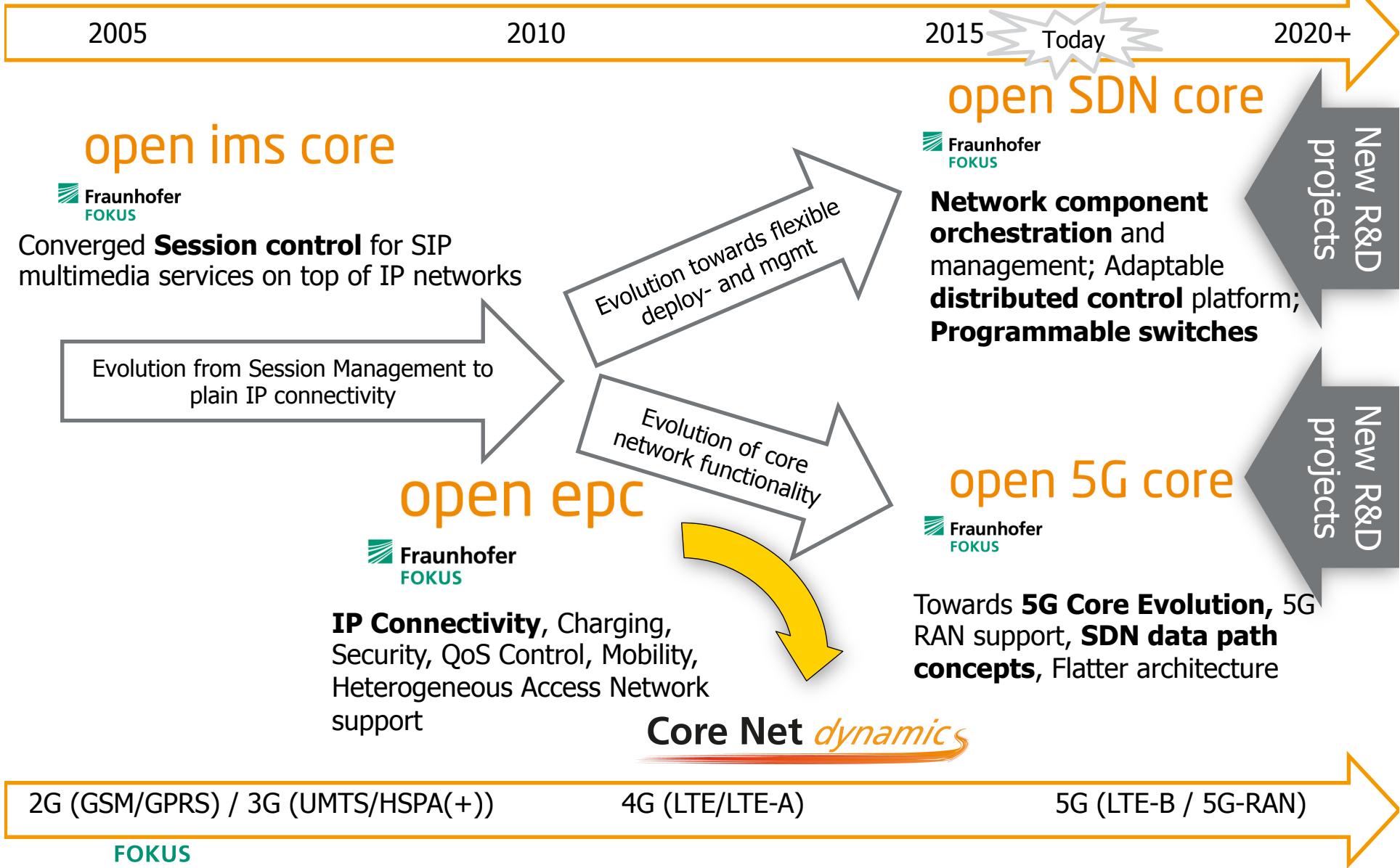
- Enabling the hands-on understanding of converging network and service technologies
 - Motivating research activities
 - Generating new relevant ideas / concepts / design & specification
- Filling the gap between research and product development by providing initial realistic environment prototyping
- Providing trust in research through realistic environments testbeds
- Mirroring operator core network functionality
- Providing a vendor independent platform
- Providing standard interfaces for product prototyping
- Providing missing components for large integrated testbeds and trials
- Providing the counterpart for product development



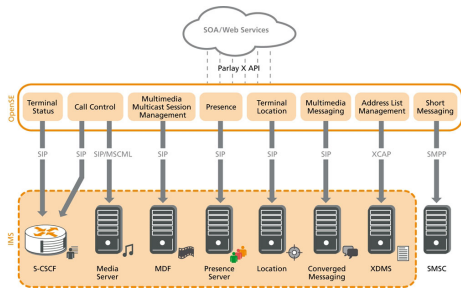
Target: Providing Realistic Testbed Platform Toolkits



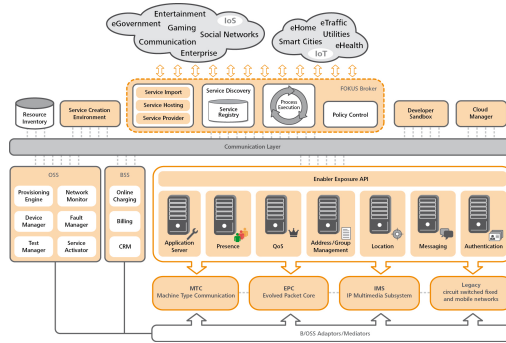
FRAUNHOFER FOKUS OPENXXX TOOLKITS AND TECHNOLOGY



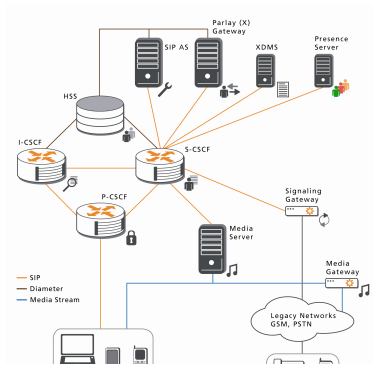
FOKUS Testbed Evolution



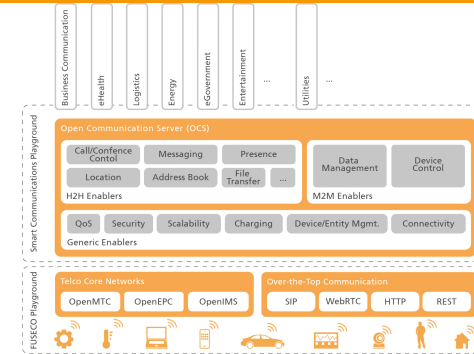
OSA/Parlay Playground



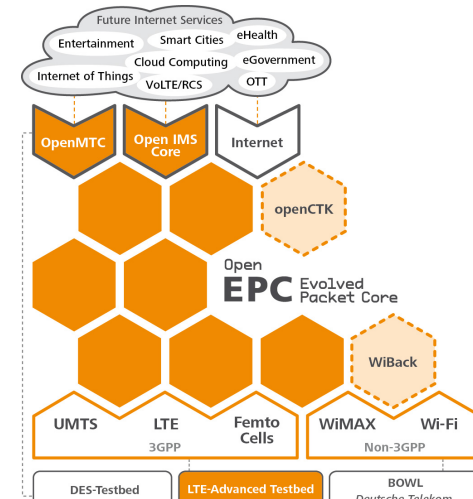
open soa telco playground



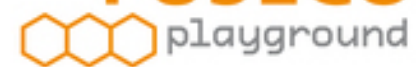
open ims playground



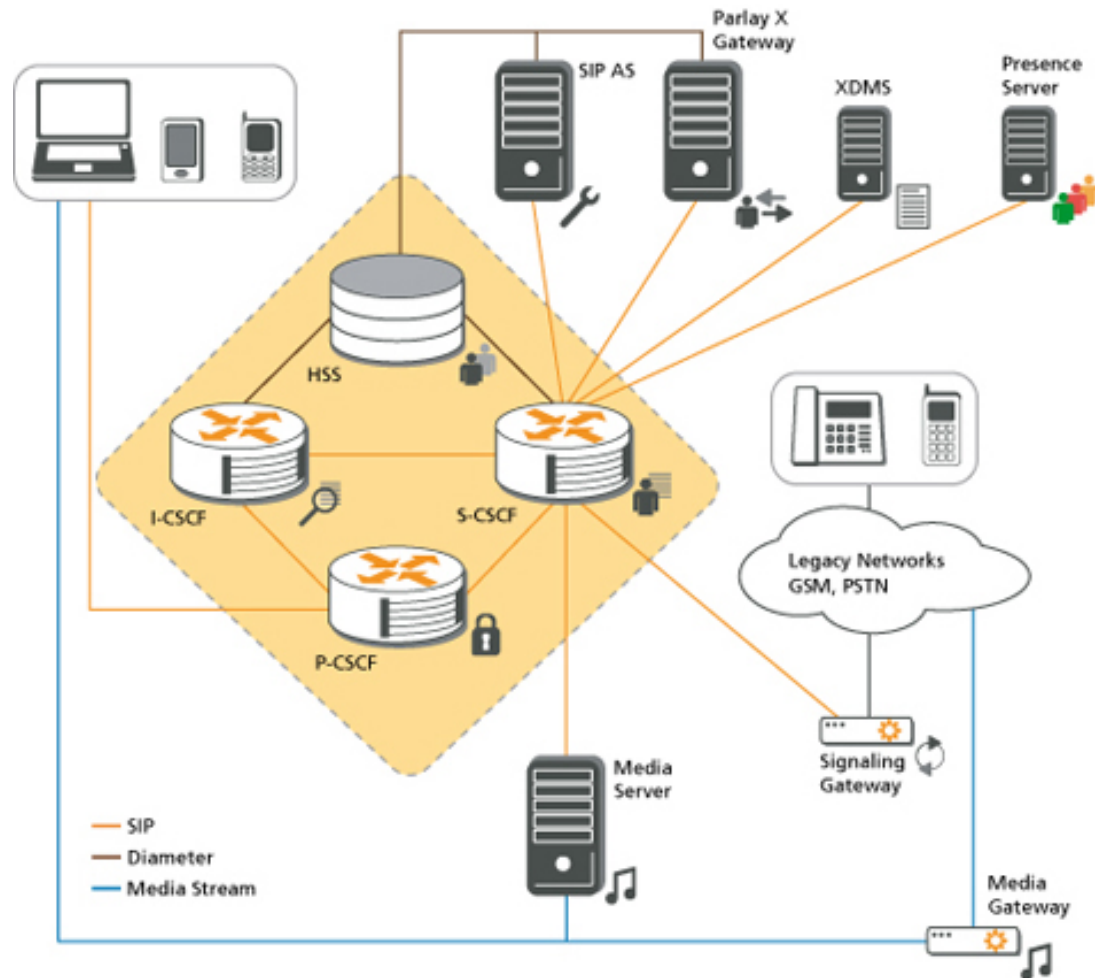
Smart Communications Playground



FUSECO playground



FOKUS OPEN IMS PLAYGROUND

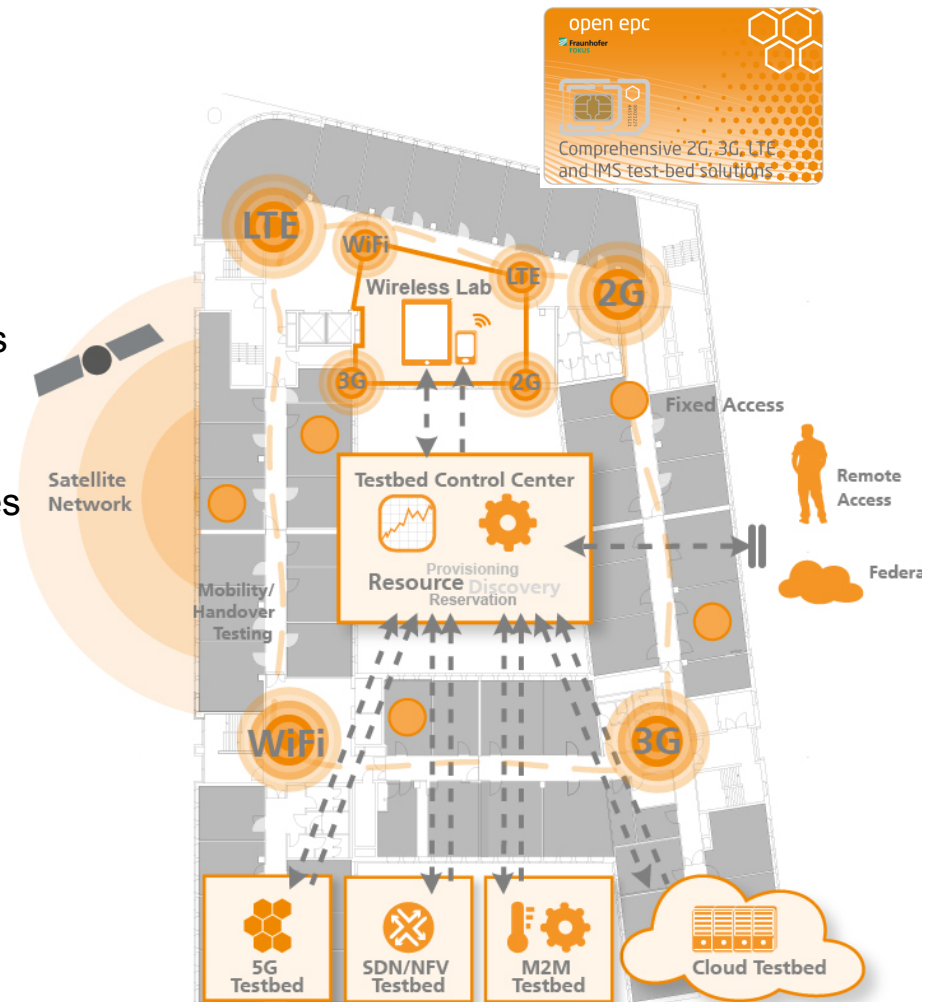


The FUSECO Playground - Testbed aaS

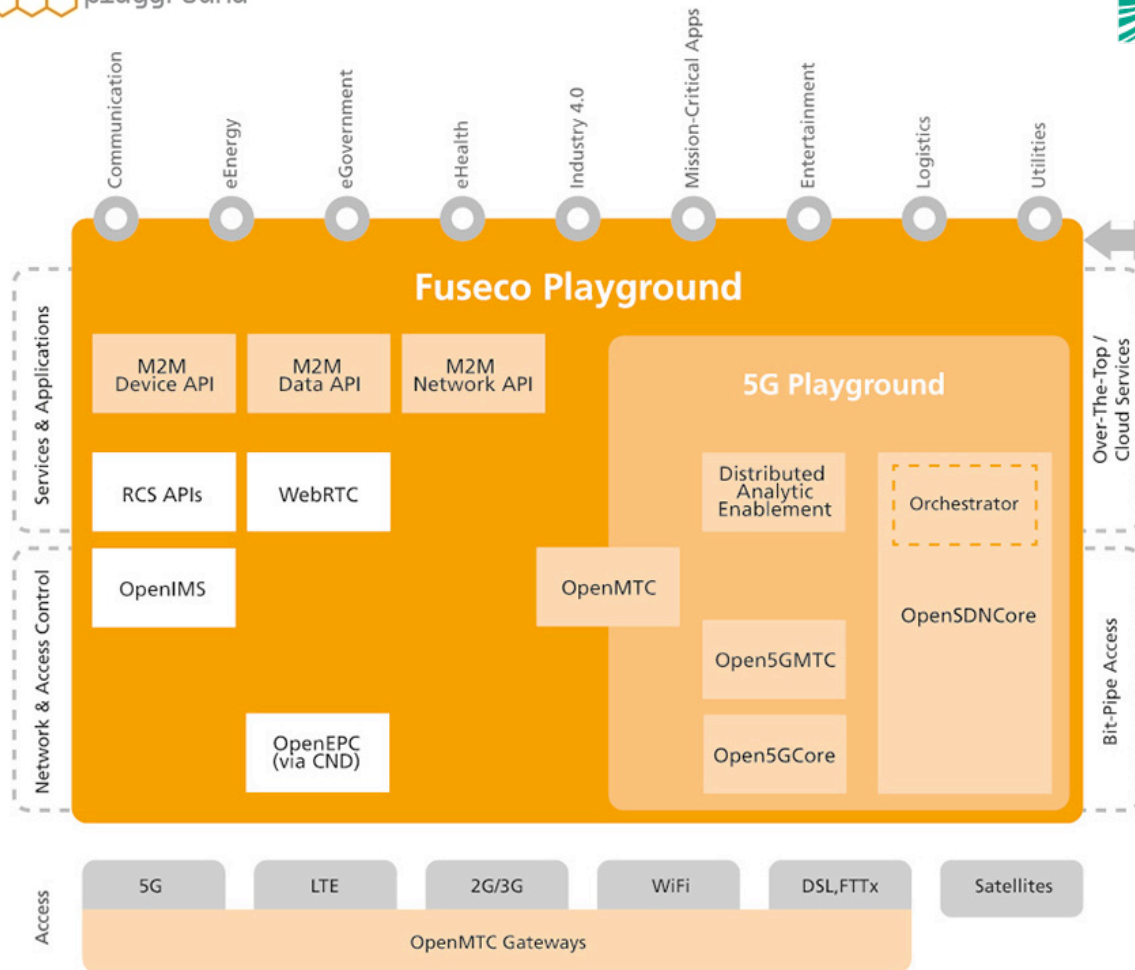
ONE-STOP-SHOP TESTBED FOR FUTURE SEAMLESS COMMUNICATION TECHNOLOGIES

Multi-technology testbed uniting:

- **Wireless Lab** based on *Open5GCore* – a prototype implementation of the emerging 5G Core inspired by 3GPP EPC - enabling Mobile Broadband Applications and based on *Open Source IMS Core* – key technology enabling VoLTE and RCS and next generation mobile multimedia communication services
- **Cloud Testbed** based on *OpenStack* enabling IaaS and PaaS
- **M2M Testbed** based on *OpenMTC*, ETSI & oneM2M standards, enabling Machine Type Communication systems
- **SDN Testbed** – based on *OpenSDNCore*, realizing Network Functions Virtualisation (NFV) and Software Defined Network (SDN) concepts

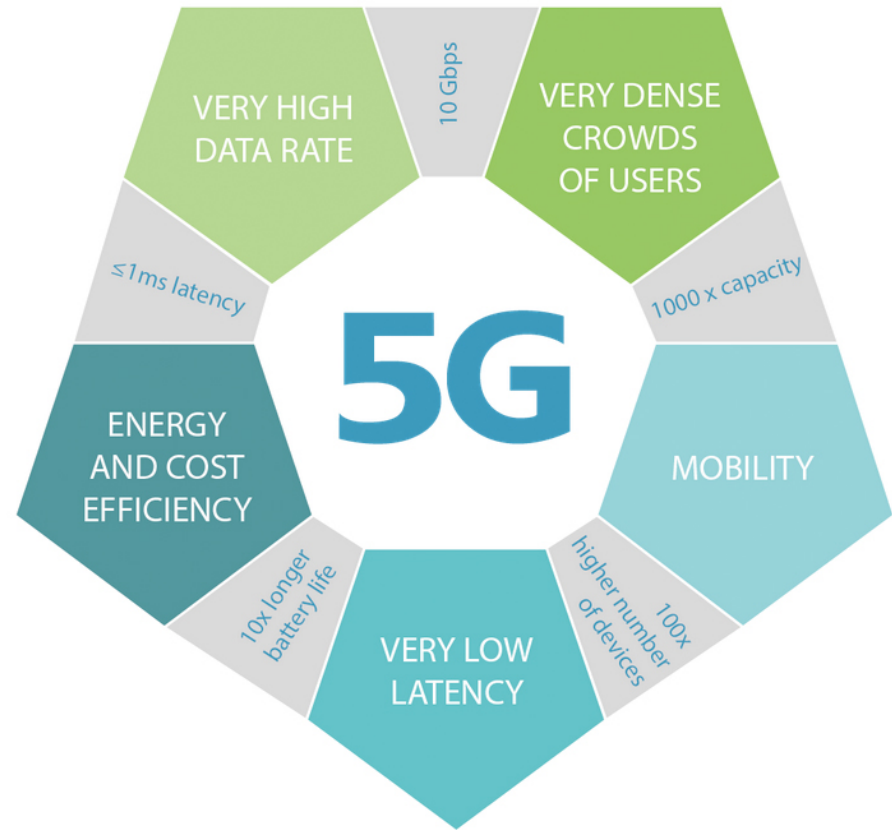


FROM FUSECO TO 5G PLAYGROUND



5G KEY CAPABILITIES

<p>Guaranteed user data rate</p> <p>$\geq 50\text{Mb/s}$</p>	<p>Capable of human-oriented terminals</p> <p>≥ 20 billion</p>
<p>Capable of IoT terminals</p> <p>≥ 1 trillion</p>	<p>Aggregate service reliability</p> <p>$\geq 99.999\%$</p>
<p>Mobility support at speed $\geq 500\text{km/h}$ for ground transportation</p>	<p>Accuracy of outdoor terminal location</p> <p>≤ 1 meter</p>



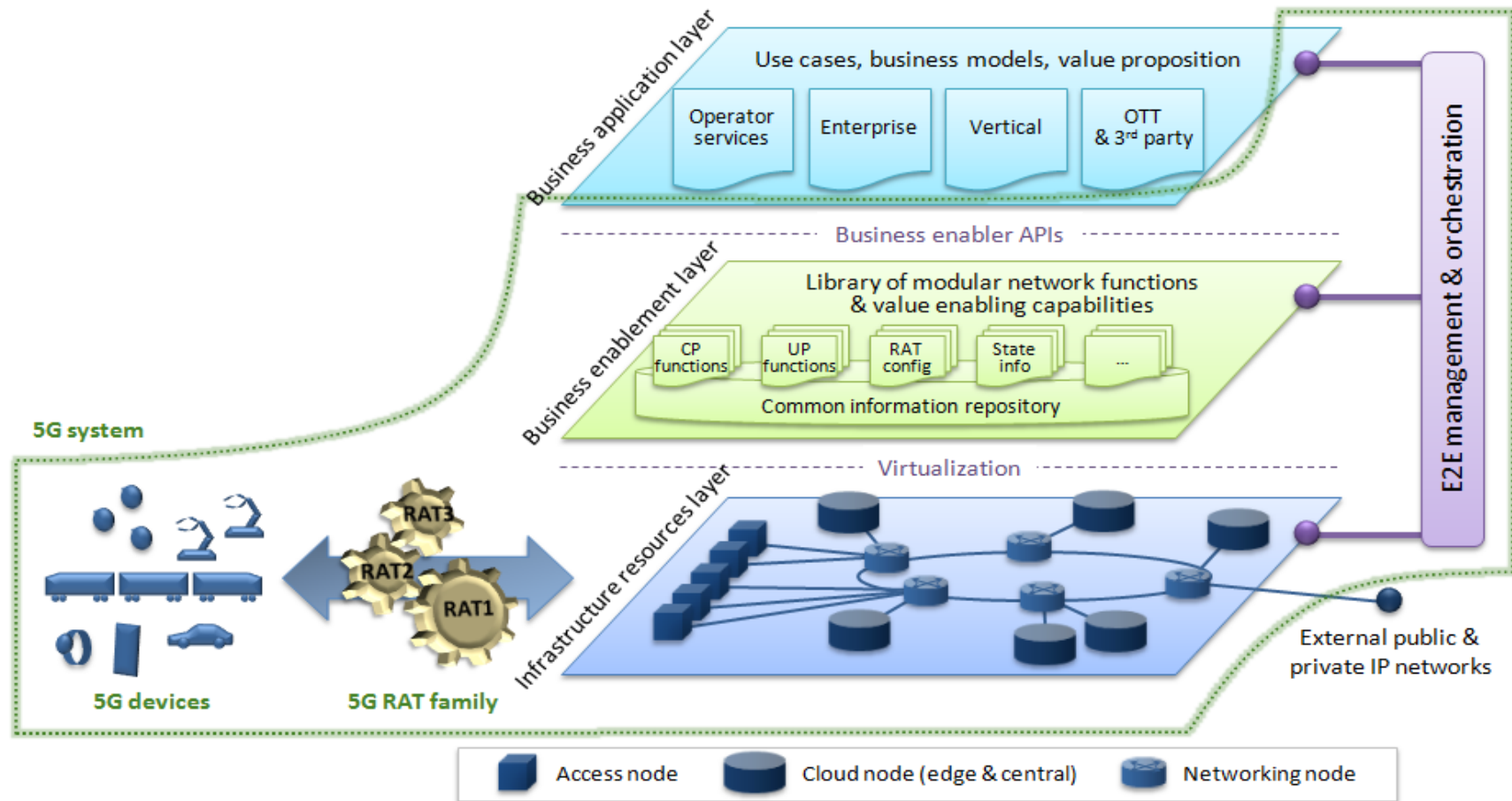
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“5G is an end-to-end ecosystem to enable a fully mobile and connected society.

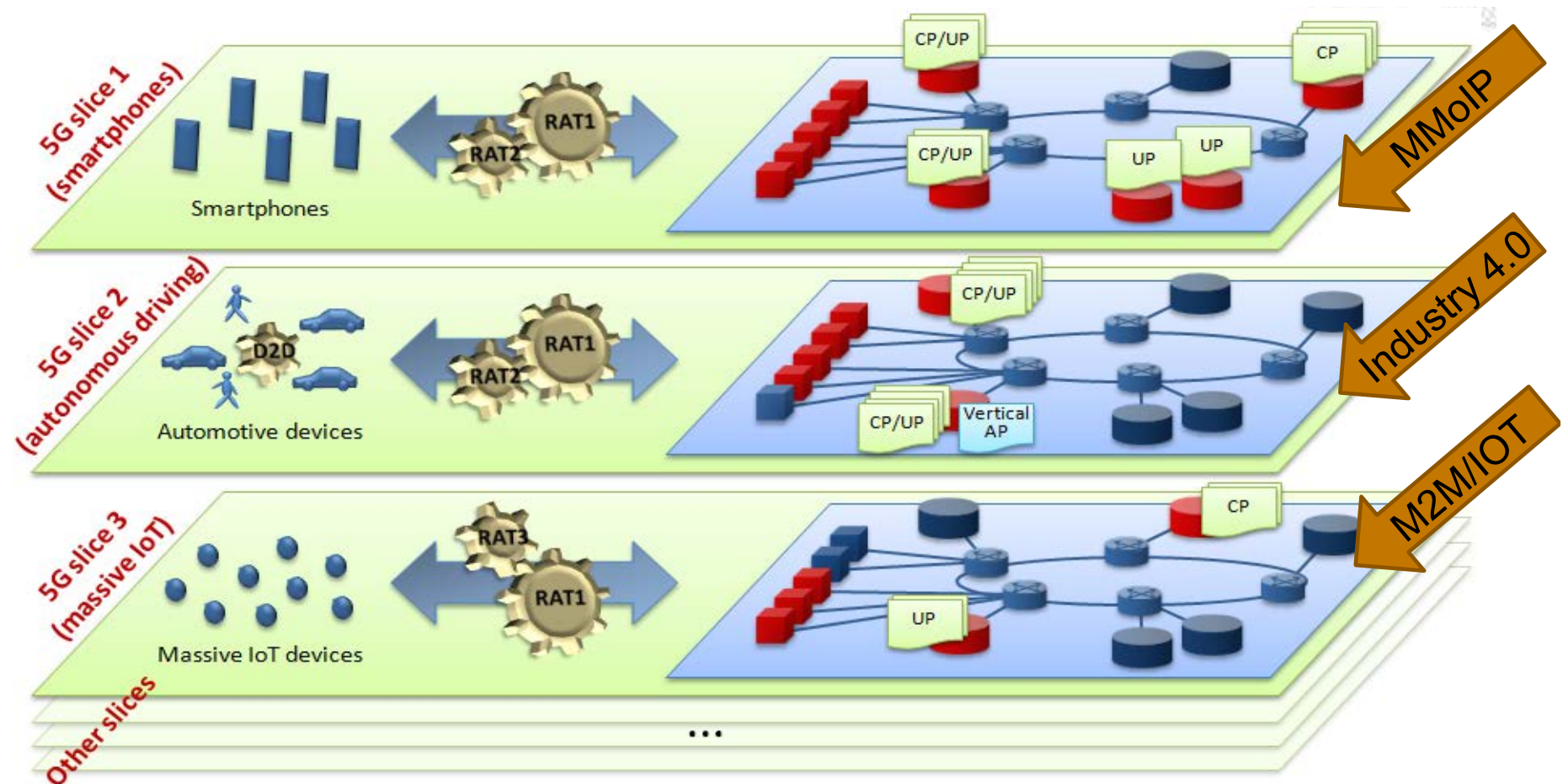
It empowers value creation towards customers and partners, through existing and emerging use cases, delivered with consistent experience, and enabled by sustainable business models.”

5G White Paper – Executive Version, Version 1.0, 22nd December 2014

5G ARCHITECTURE



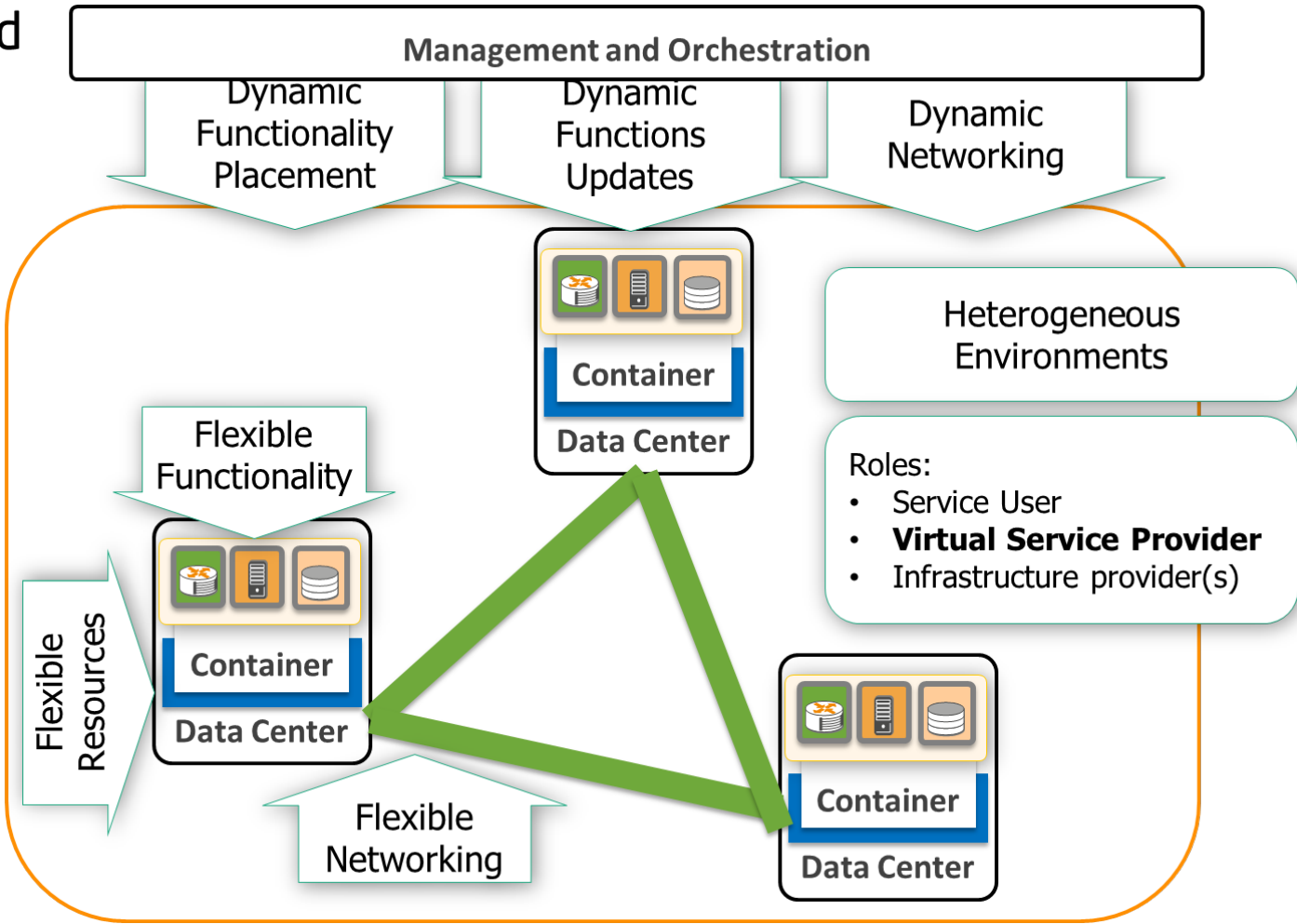
5G PARALLEL NETWORK SLICES - DYNAMIC VNO ENABLEMENT



OPEN 5G PLAYGROUND - THE FIRST REAL 5G TESTBED TO USE



- Automation
- eUtilities
- Logistics
- E-Energy



FOKUS TESTBED TOOLKITS FOR INDUSTRY 4.0 PROTOTYPING



open 5G mtc



Provides the most open, cloud-enabled solution for conducting applied research activities and developing innovative Machine-to-Machine (M2M) and Internet of the Things (IoT) applications..

www.open5Gmtc.org

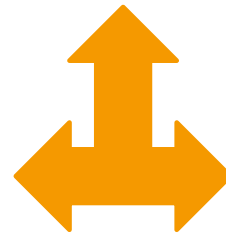


open 5G core



A practical implementation of the carrier-grade network towards the 5G environment. It mirrors, in a prototypical form, the pre-standard advancements on the core network, radio network integration, distributed management and virtualisation.

www.open5gcore.net



open SDN core



A practical implementation of the future network evolution paradigms, realizing Network Functions Virtualisation (NFV) and Software Defined Network (SDN) concepts, providing early prototyping of a service enablement platform on top of common infrastructure components.

www.openSDNcore.org

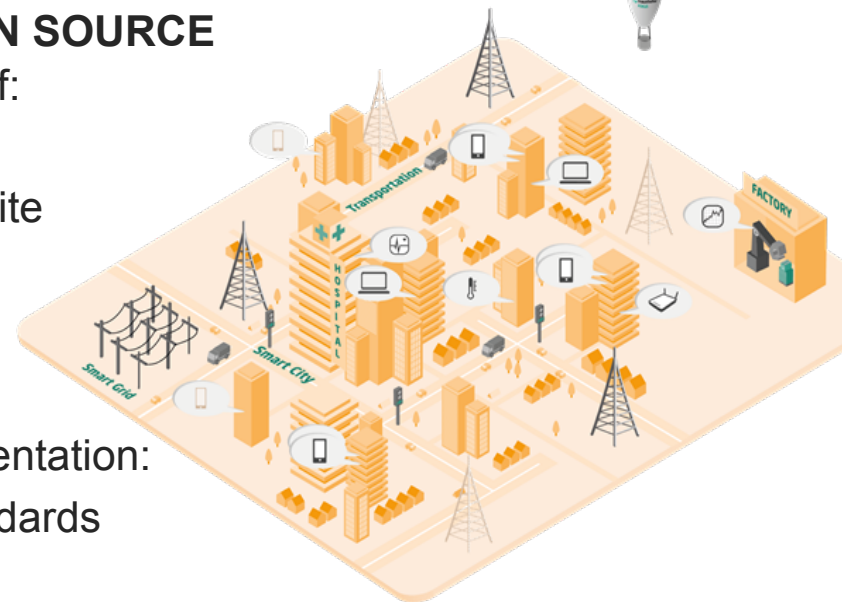


What is Open5GCore?



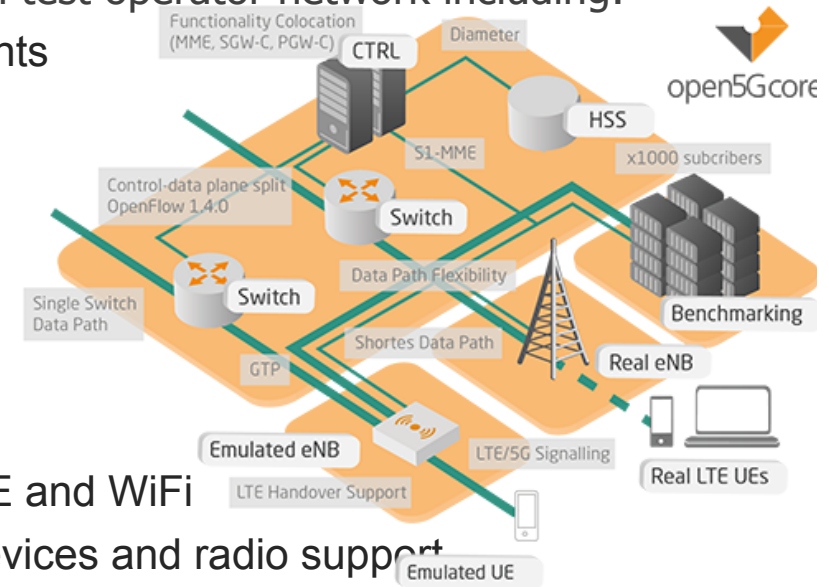
Pre-standard Research & Testbed for the 5G ecosystem

- 5G ecosystem aims to provide the next wireless system beyond LTE/EPC
 - More efficient communication for the subscribers (low delay/high capacity)
 - Providing the users a means to control their environment (automation/reliability)
 - Providing communication for other markets (Industry 4.0, eHealth, energy, critical)
- Fraunhofer FOKUS is developing the **NON-OPEN SOURCE** Open5GCore toolkit enabling R&D in the fields of:
 - 5G Radio Support
 - Convergence with LTE, WiFi, Fixed and Satellite
 - Intelligent network management
 - Virtualisation and softwareization
 - Devices and applications
- Open5GCore is a pre-standard software implementation:
 - Addressing 3GPP, ETSI NFV, IETF, ONF standards
 - Designed for the specific R&D needs



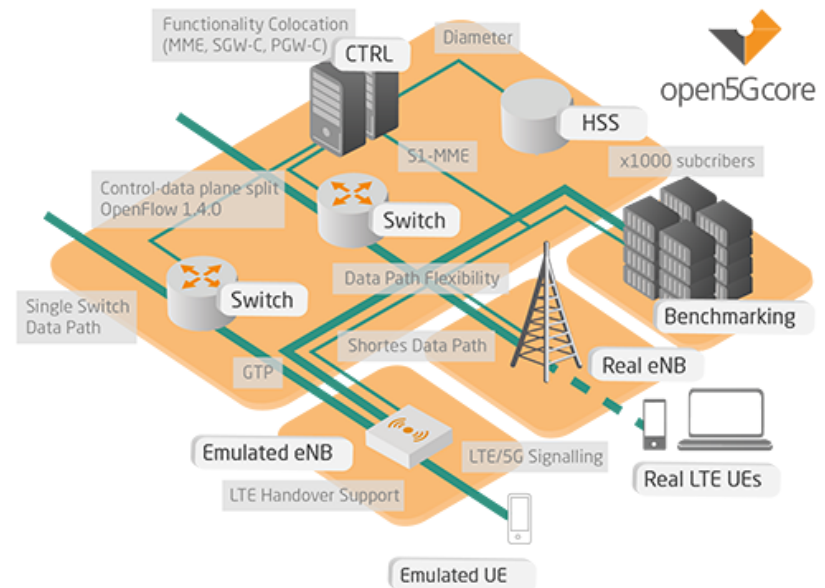
Providing the basis for 5G research

- Open5GCore is an R&D prototype, including features with high industry relevance from the Fraunhofer FOKUS research activities, based on 3GPP standards (Rel. 11, 12, 13, ...)
- The principles of standard alignment, configurability and extensibility have been respected in the overall architecture and in the specific components implemented
- Open5GCore enables the establishment of a small test operator network including:
 - LTE/5G signaling protocol stack and components
 - Multi-access devices support
 - Runtime flexibility and robustness features
 - Functionality co-location features
 - Control plane selection
 - Shortest data paths
 - Benchmarking
 - Fundamental core network functionality for LTE and WiFi
 - Mobility, AAA, access selection, common devices and radio support



Features, Functionality and Components

- 5G Radio Enhancements
- Functionality Co-Location
- Runtime Flexibility and Robustness
- Data Path Flexibility
- Benchmarking
- Fundamental Core Network Functionality
- Advanced Access Network Selection



AVAILABILITY AND ROADMAP

March 2014:

Open5GCore Basic version

Stripping down OpenEPC of legacy functionality
Initial requirements, metrics and benchmarking tools developed

September 2013:

OpenEPC Rel. 5

Including comprehensive functionality for supporting LTE, 3G, 2G and WiFi

November 2014:

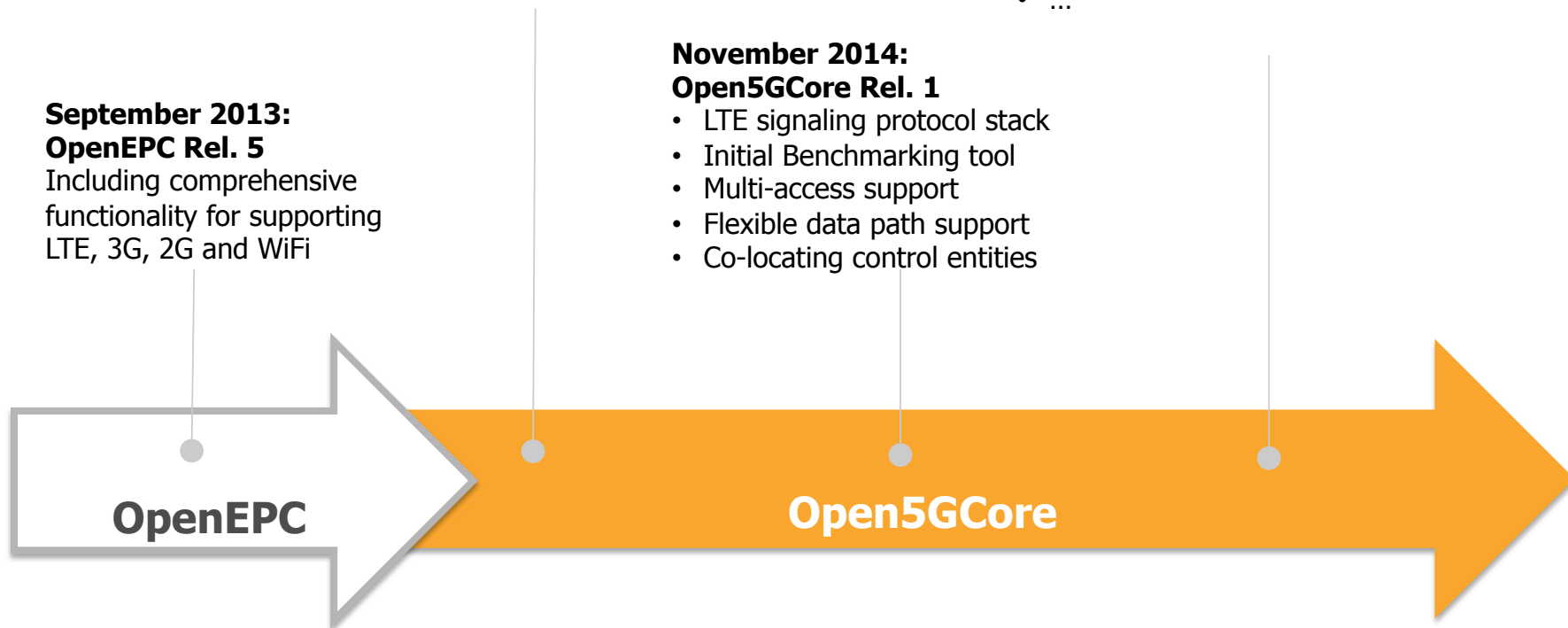
Open5GCore Rel. 1

- LTE signaling protocol stack
- Initial Benchmarking tool
- Multi-access support
- Flexible data path support
- Co-locating control entities

June 2015:

Open5GCore Rel. 2

- Integration with PHY/MAC
- Comprehensive load balancing
- Extended benchmarking
- ...



OpenEPC

Open5GCore

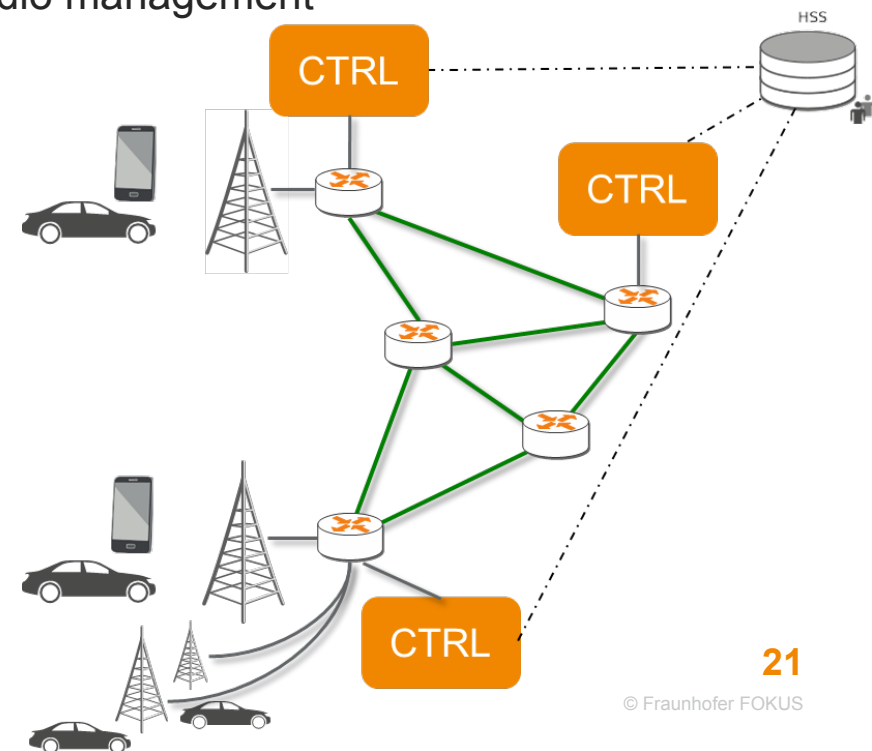
Fraunhofer FOKUS is actively looking for partners interested in early research in the area of 5G core networks

Outlook: Open5GCore November 2015 Release



The November release will feature a revolutionary set of features towards a more flexible network architecture

- Requirements:
 - Separating the network management from the subscriber control
 - No specific subscriber state at data path level
 - Dynamic data path selection based on network topology
 - Distributed control plane separated from radio management
 - Fluid subscriber state (edge/central)
 - Simple control plane communication
 - Adapted charging mechanism
 - Single subscription profile
 - Convergence with fixed networks
- Interoperable with WLAN and LTE
- Interconnected with CRM



Features

- Separation of management functionality
 - Radio resource management → separate system
 - Subscriber management (AAA, QoS) → access dependent
 - Data path selection → based on SFC/SDN
- New charging system
- Service based data paths
- Background data traffic support
- Analytics on demand
- Controller-to-controller communication
- Mobile edge computing
- Network functions placement
- Dynamic spectrum allocation

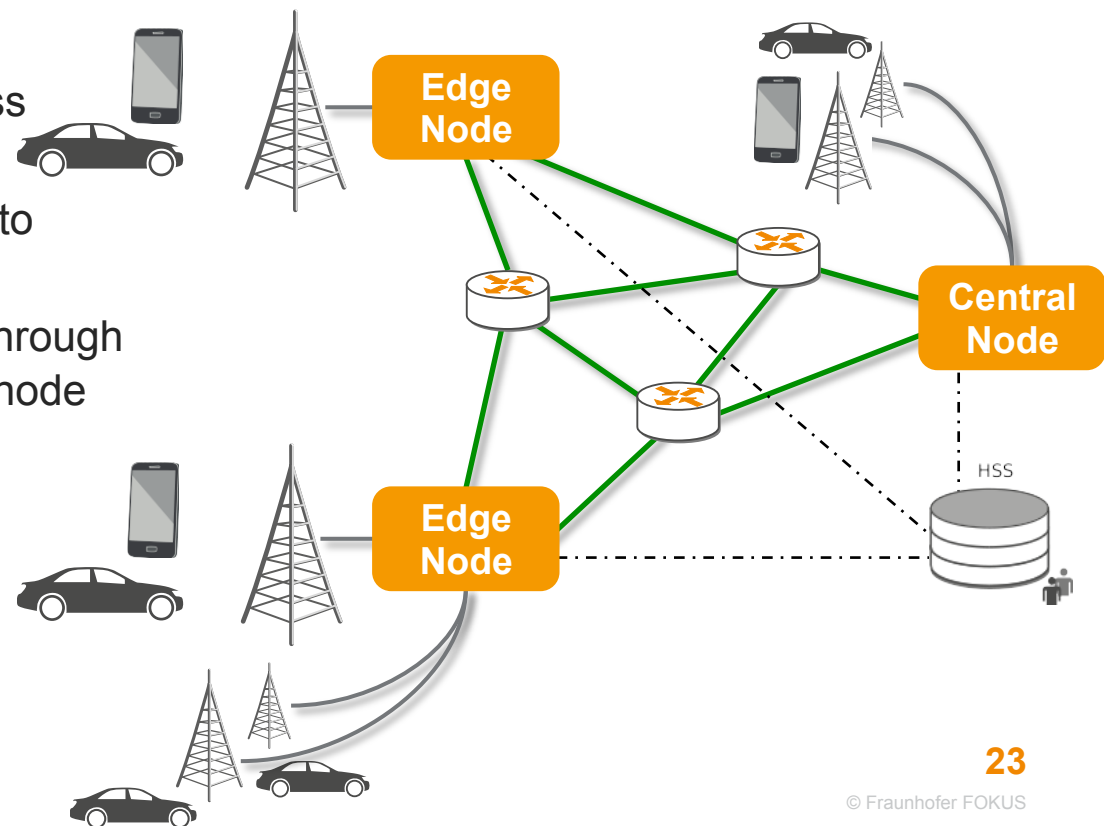
Developing Mobile Edge Computing in Open5GCore

Main architectural features:

- Edge Node: Open5GCore controller and switch are moved next to the base station
- Central node: very large capacity central node
- SDN/SFC interconnection network controlled by edge and central nodes

Deployment options:

- Each edge node has direct access to Internet and to the HSS
- Multiple eNBs can be connected to the same edge node
- UEs may connect transparently through the edge node or directly to central node

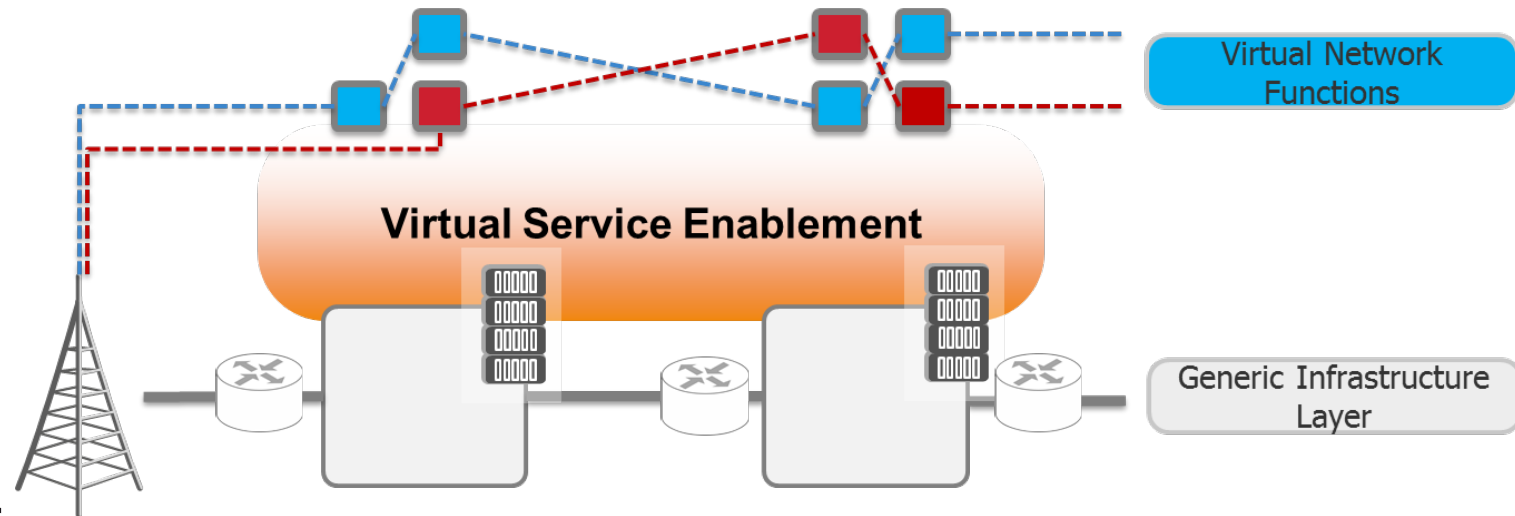


Role of SDN/NFV in the Networking Stack



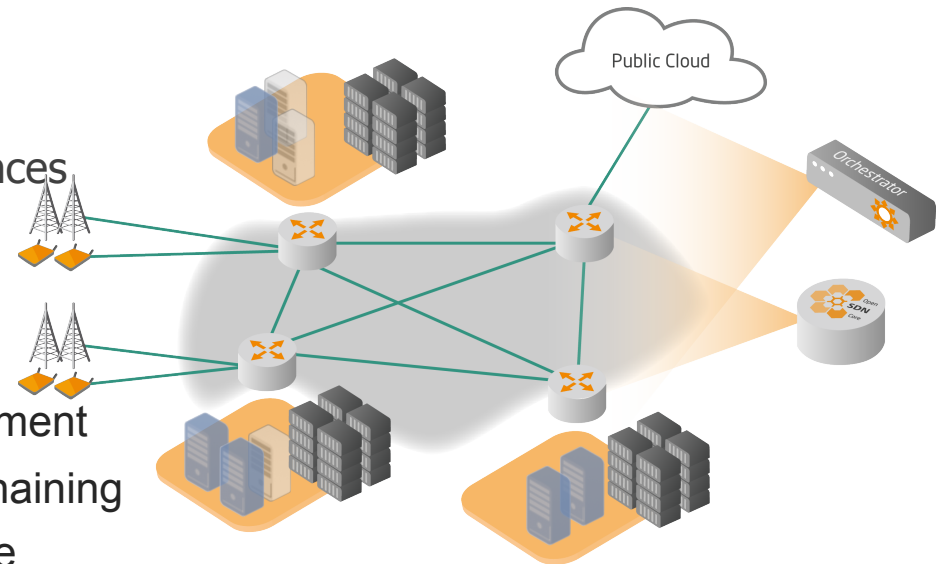
SDN/NFV provide a novel virtual service enablement layer

- SDN/NFV platform acts as an end-to-end middleware between:
 - A distributed heterogeneous infrastructure including dedicated components (e.g. radio), heterogeneous data centers (compute & storage) and inter-connecting networks (fronthaul, backhaul, third party backbone, etc.)
 - Generic network functions implemented in software and running in virtual machines
 - Virtualised IMS, EPC, radio and SGI components, home and enterprise networks, Application Servers, etc.



Beyond basic NFV/SDN and towards carrier-grade cloud

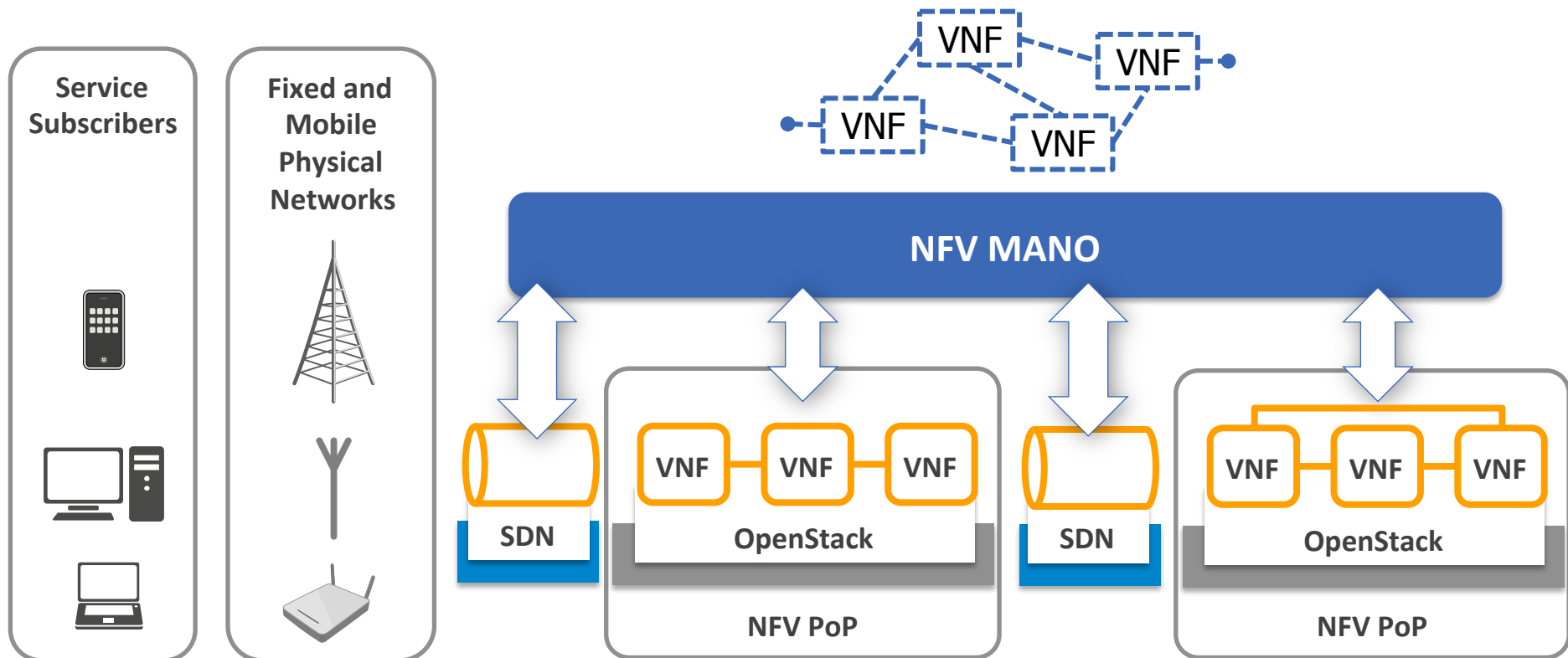
- OpenSDNCore is an R&D prototype, providing advanced features with high industry relevance for carrier-grade NFV/SDN solutions
- The principles of standard alignment, configurability and extensibility have been respected in the overall architecture and in the specific components implemented
- Addressing a multi-data center infrastructure, OpenSDNCore includes:
 - Network Functions Orchestration (based on ETSI MANO)
 - Policy based orchestration
 - Network functions placement
 - Controlling multiple OpenStack instances
 - Enabling public cloud deployments
 - Managing vEPC, vIMS, v5Gcore, ...
 - Software Defined Networks (SDN)
 - Highly customizable network environment
 - Inter-data center Service Function Chaining
 - Integration with physical infrastructure



OpenSDNCore Rel. 2: complete NFV/SDN environment



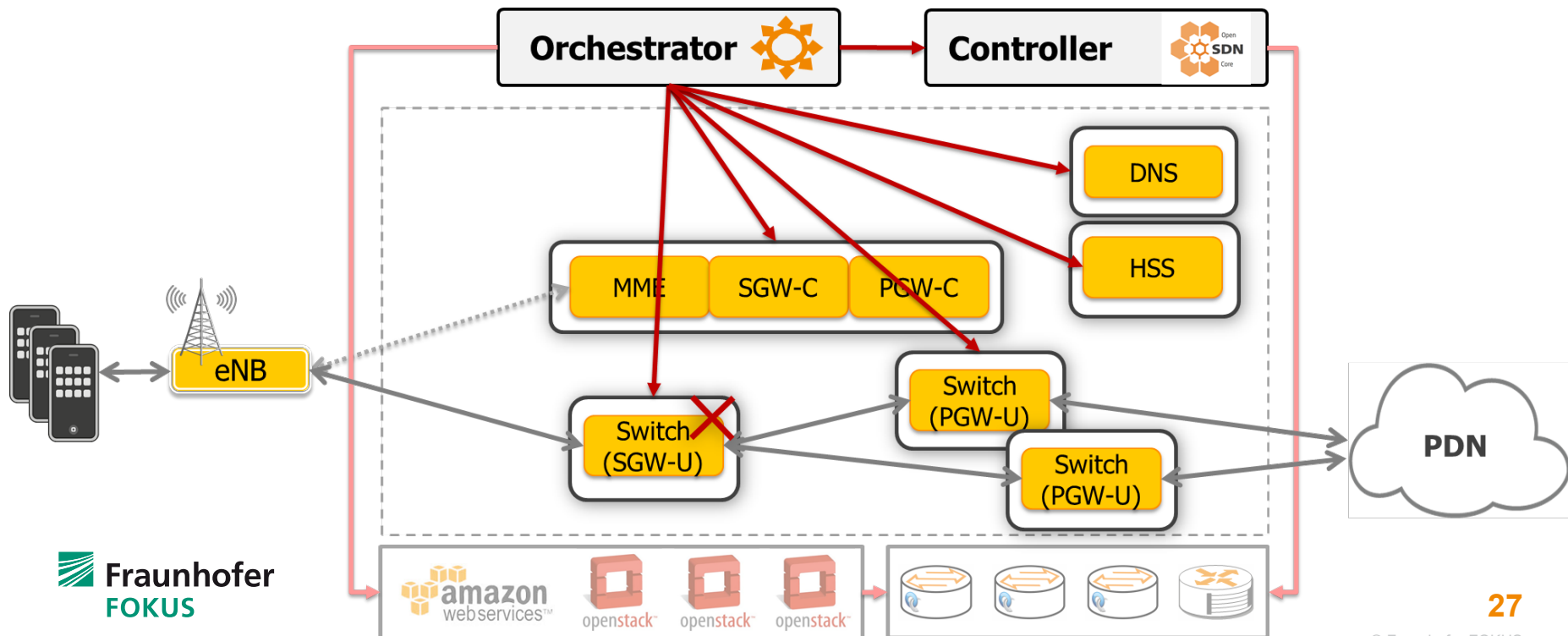
- Complete control of the inter-data center networks (SDN based)
- Management and orchestration (NFV MANO) of OpenStack based Virtual Network Infrastructures



Virtual Network Functions: Open5GCore

Deployment of various core network implementation architectures

- N:3 architecture with Switch, Controller and HSS:
 - With a merged MME SGW-C and PGW-C
 - With a merged SGW-U in the PGW-U



OpenSDNCore Default Infrastructure – The Running Testbed

Underling infrastructure mirrors the essential features of a carrier-grade cloud service provider

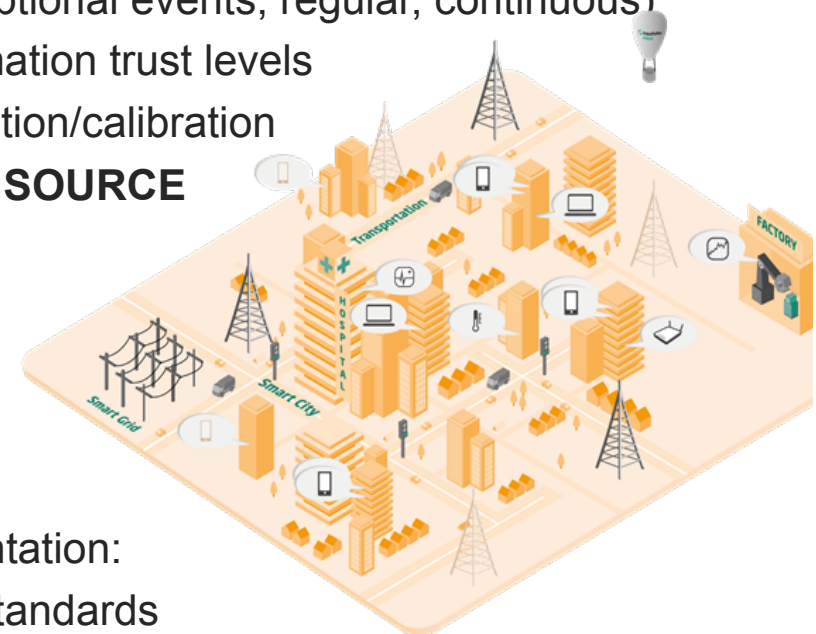
- Integrated with real radio networks
 - WiFi and LTE
- Distributed Network Function Virtualization Infrastructure (NFVI)
 - 3 OpenStack data centers
 - Public cloud integration
- Realistic simplified inter-connection network
 - Managed or un-managed
 - Enabling connectivity to Internet



What is Open5GMTC?

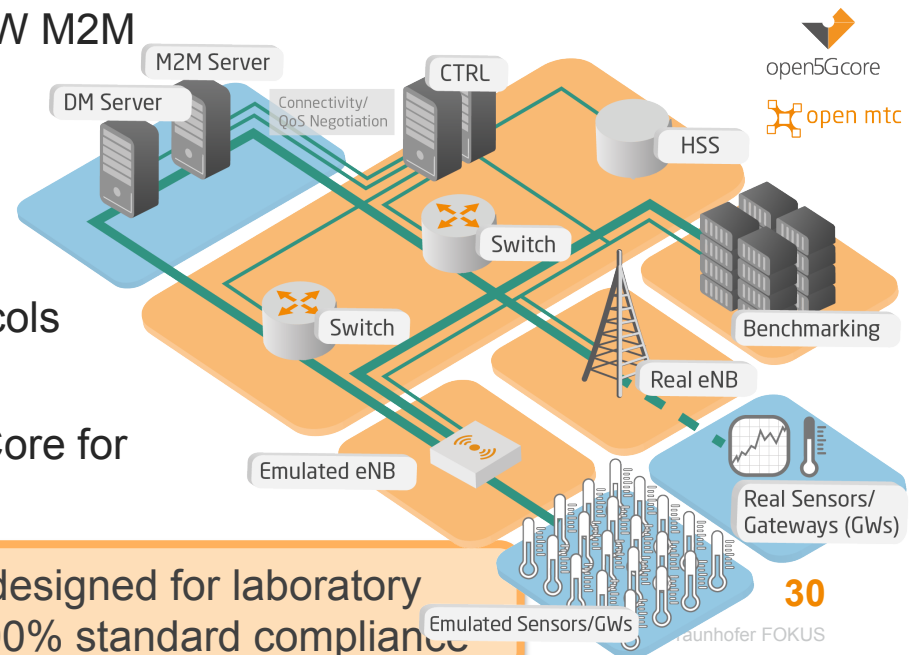
Toolkit providing the missing link towards the connected devices

- Within 5G environment a huge number of devices will be connected to the network
 - With different communication requirements (delay/capacity)
 - With different communication patterns (on exceptional events, regular, continuous)
 - With different reliability requirements and information trust levels
 - Requiring easy remote management/administration/calibration
- Fraunhofer FOKUS is developing the **NON-OPEN SOURCE** Open5GMTC toolkit enabling R&D in the fields of:
 - Connectivity management
 - End-to-end service establishment
 - Security and reliability of communication
 - Device management and automation
- Open5GMTC is a pre-standard software implementation:
 - Addressing 3GPP, OMA, ETSI NFV and IETF standards
 - Designed for the providing high capacity testbeds (x1000 of devices)



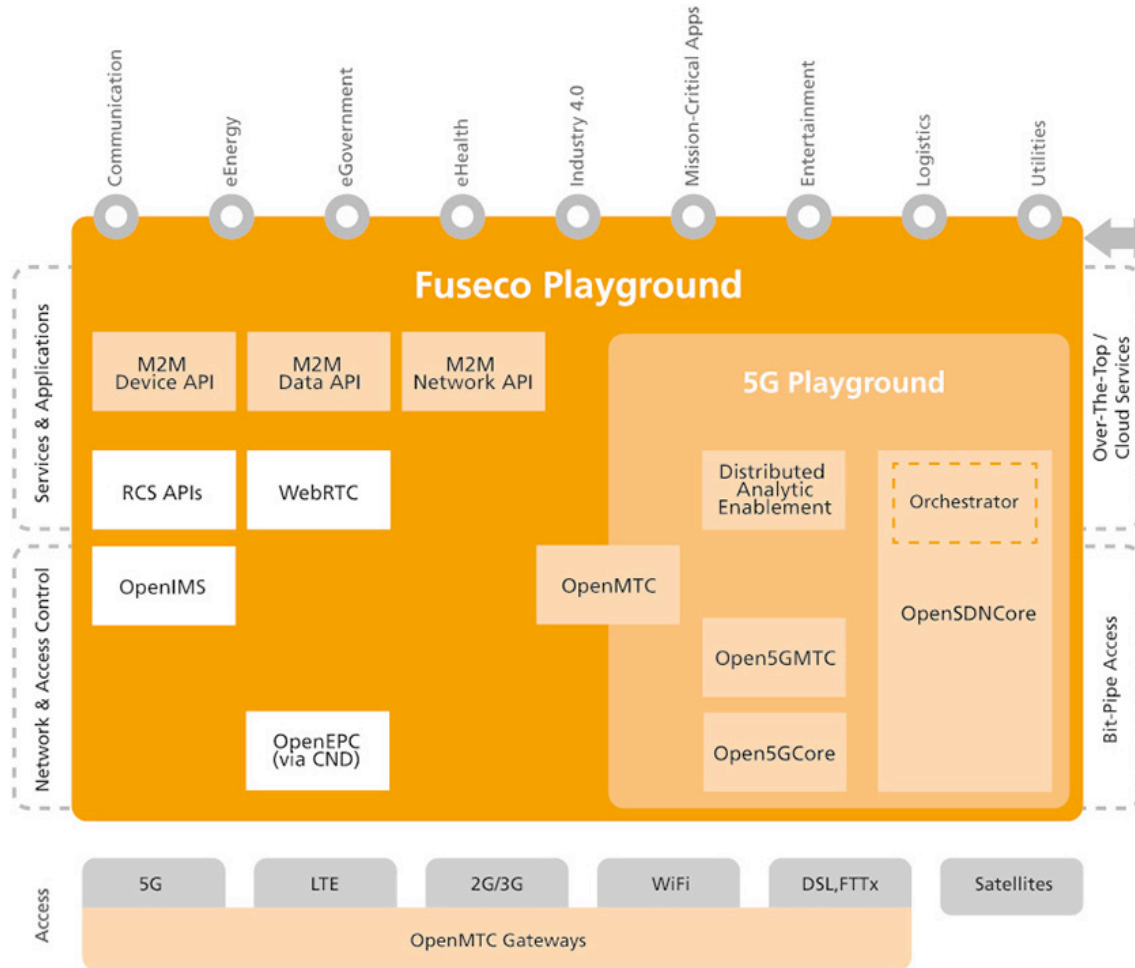
Providing a cost efficient testbed with a very high number of connected devices

- Open5G-MTC is an R&D prototype, providing advanced features for device and connectivity management of a very large number of wireless devices (human controlled or machines)
- The principles of standard alignment, configurability and extensibility have been respected in the overall architecture and in the specific components implemented
- Open5G-MTC enables the establishment of relevant device oriented testbeds including:
 - Device Management with OMA DM and LW M2M
 - Connectivity and transport management for virtualised network infrastructures
 - Cost effective support for x1000 devices testing and evaluation
 - Integrating with OpenMTC for M2M protocols
- Coming Soon: Integration with the Open5GCore for providing extensive 5G testbeds



Please Note: Open5GMTC is designed for laboratory testbeds and does not claim 100% standard compliance

FROM FUSECO TO 5G PLAYGROUND



FIWARE
Interworking with FIWARE Enablers

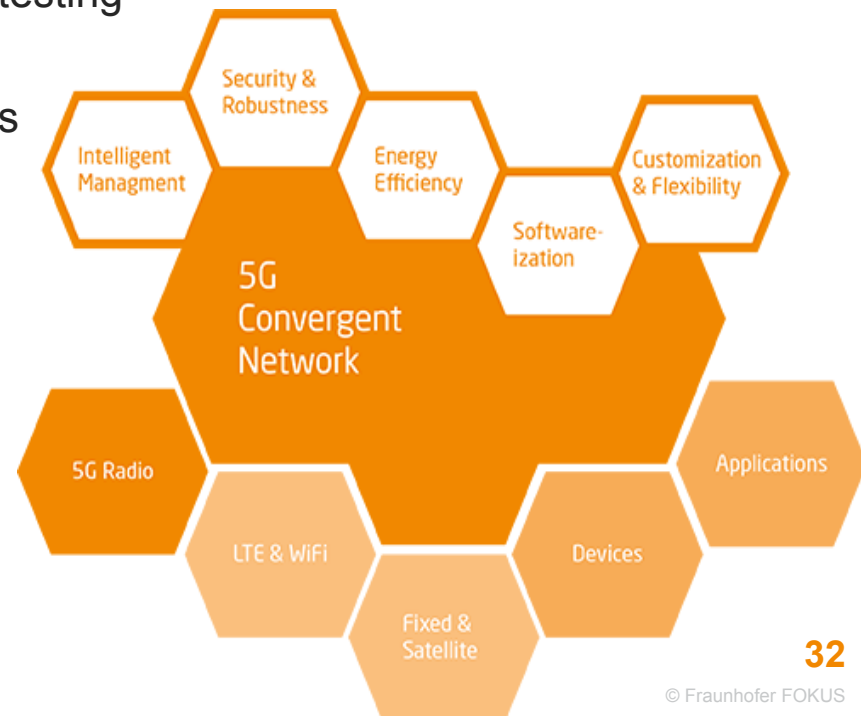
open5Gcore
Open SDN Core

open 5G mtc
Fraunhofer FOKUS

5G Berlin

Research directions list: Answering to the 5G environment needs

- Comprehensive emulation of heterogeneous real environments
- Using efficiently the 5G network capabilities
- Embedding the connectivity and data into the 5G network
- Providing highly robust infrastructures for different markets
- Resilience/reliability/trust
- Automatic testing of the environment / easiness of management
 - Automatic Firmware Upgrades including testing
 - Auto-Calibration process
- Integrating with virtualised network platforms
- Connectivity management
 - Connection status evaluation
 - Device communication status
 - Integrating with Open5GCore





FUSECO 2015
Forum 
FUTURE SEAMLESS COMMUNICATION

“Digital Convergence and Seamless Connectivity for everyone and everything – Bringing 5G, SDN/NFV and M2M/IOT together”

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**See you
in Berlin, Germany
November 5/6, 2015**

For more details see
www.fuseco-forum.org

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USEFUL LINKS



- Fraunhofer FOKUS NGNI Competence Center: www.fokus.fraunhofer.de/go/ngni
- TU Berlin Chair for Next Generation Networks: www.av.tu-berlin.de

Testbed Toolkits:

- Open IMS Core Project: www.openimscore.org
- Open MTC Project: www.open-mtc.org
- Open EPC Project: www.openEPC.net
- Open 5GMTC Project: www.open5GMTC.org
- Open 5G Core Project: www.Open5GCore.org
- Open SDN Core Project: www.OpenSDNCore.org
- Future Internet testbed federation tool FITeagle: www.fiteagle.org

Testbeds

- Future Seamless Communication Playground: www.fuseco-playground.org
- Open 5G Playground: www.5G-Playground.org
- DAAD UNIFI Project: www.daad-unifi.org

Workshops and Conferences

- Future Seamless Communications Forum: www.fuseco-forum.org
- Fraunhofer GI/KUVS Next Generation SDP Expert Talk series: www.KUVS-NGSDP.org

