Fraunhofer FOKUS 5G Playground

Internet: www.open5Gcore.net / www.5G-playground.org

Contact: info@open5Gcore.net

Fraunhofer FOKUS

open5Gcore

open5GMTC

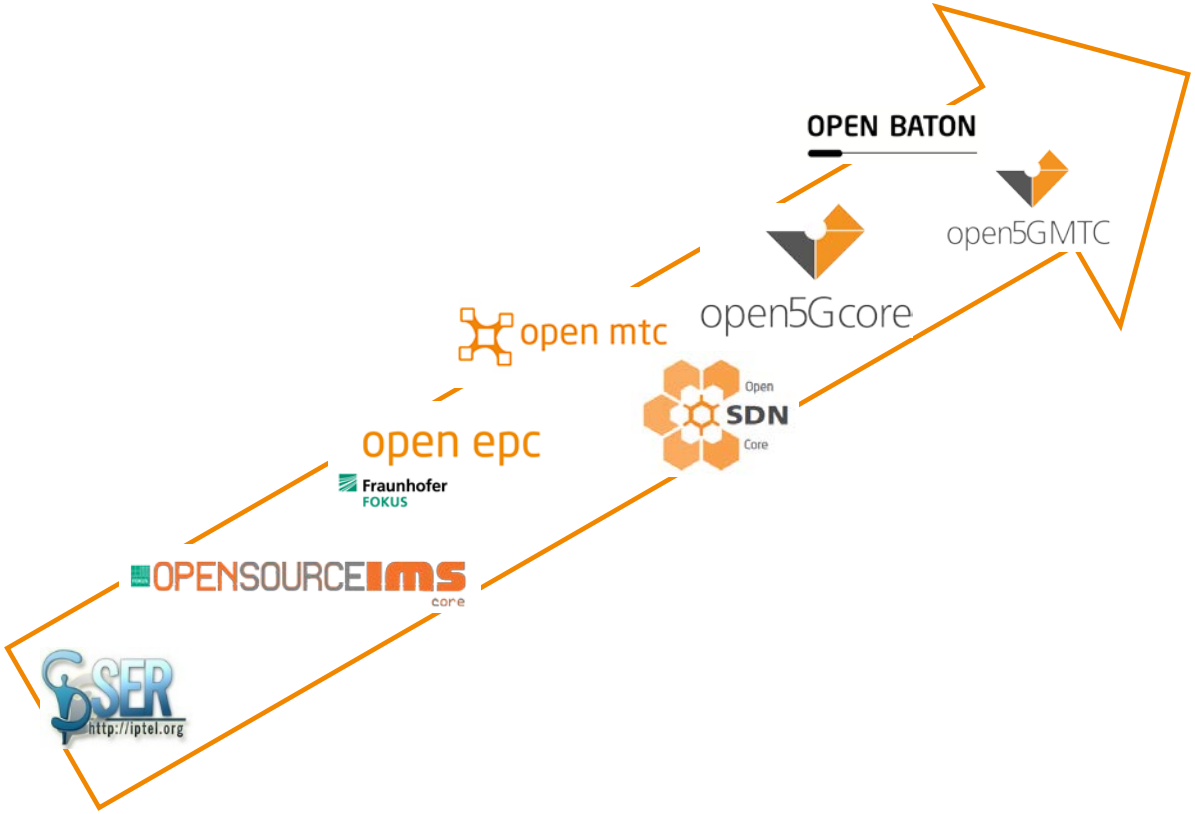
Open SDN Core

OPEN BATON

5G playground

Fraunhofer

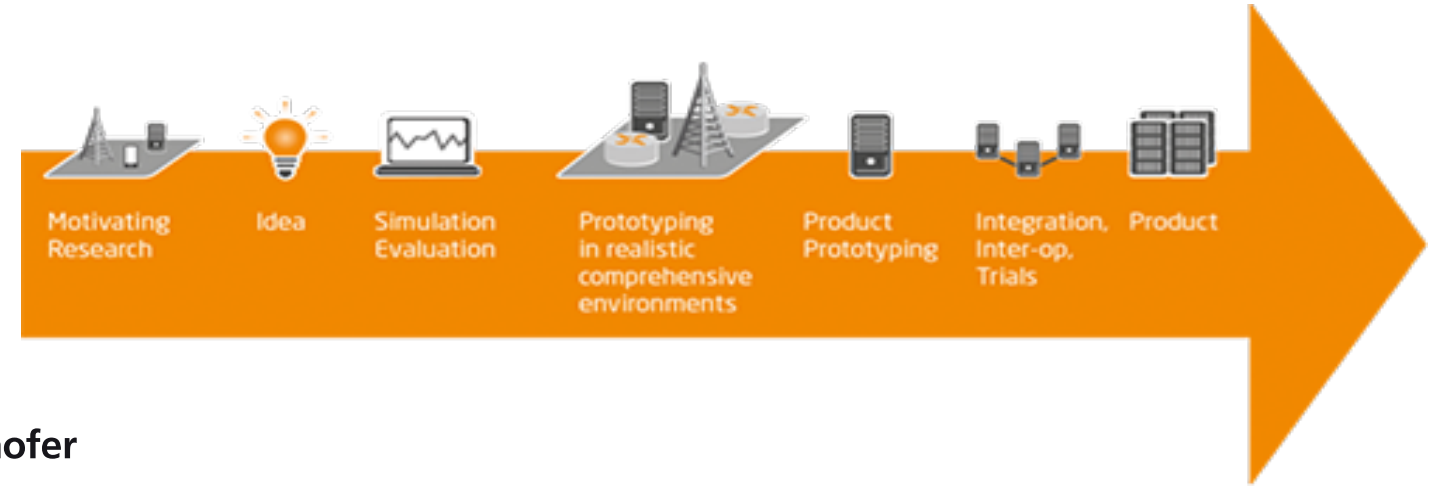
Providing testbed Platforms for R&D



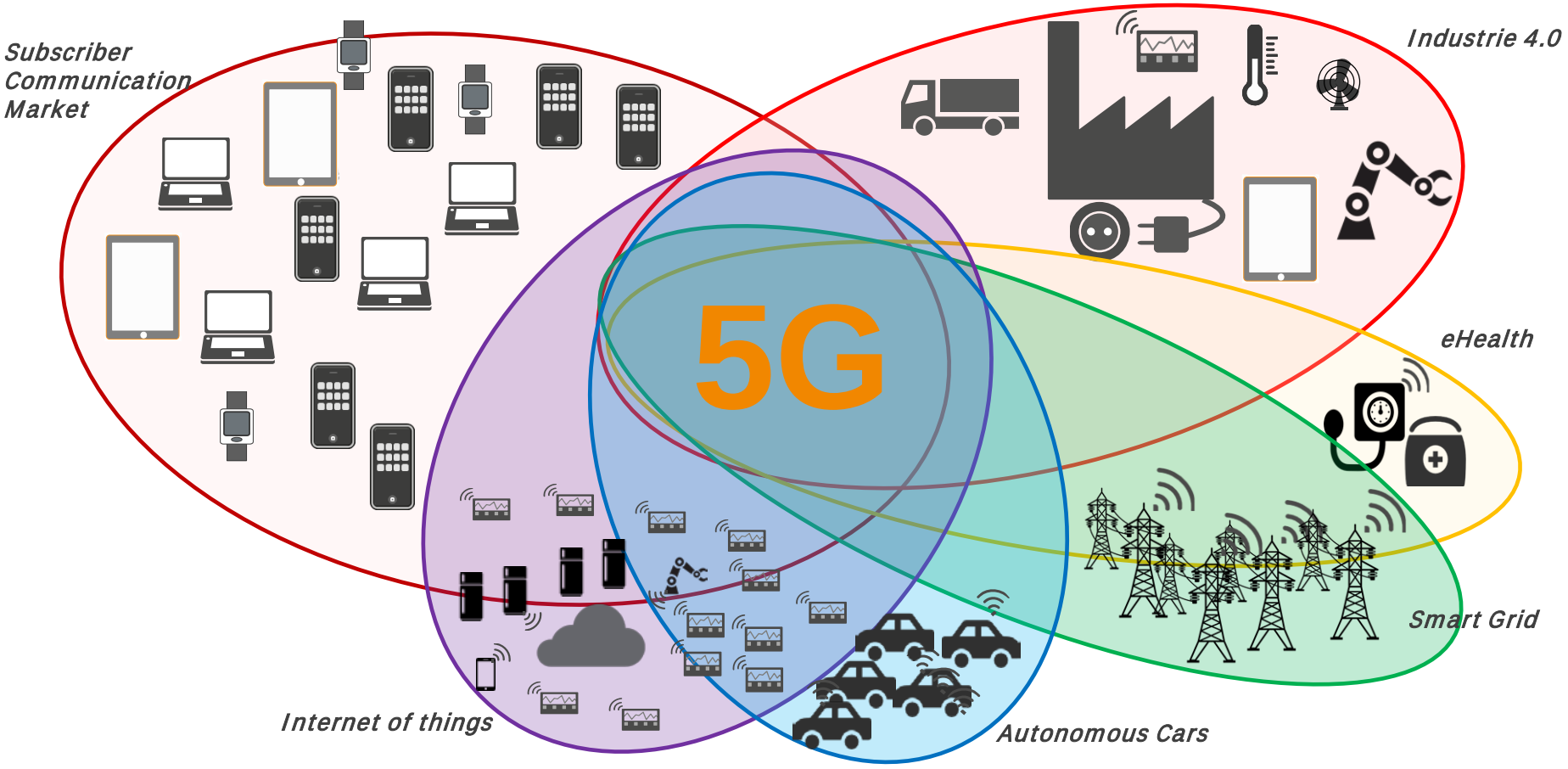
BEST PRACTICE EXAMPLE FOR R&D

There are some R&D steps which can not be missed for reaching relevant research and innovation results

- Motivating Research – showcasing the possible of a new technology
- Novel Ideas – direction, planning, literature study and hands-on implementations
- Simulation Environment – evaluations of ideas on complex models
- Prototyping in Real Environments – realistic, comprehensive PoCs
- Product Prototyping – and the appropriate counterpart network environment
- Integration, Inter-op and Trials – comprehensive environments
- Product Implementation and Marketing



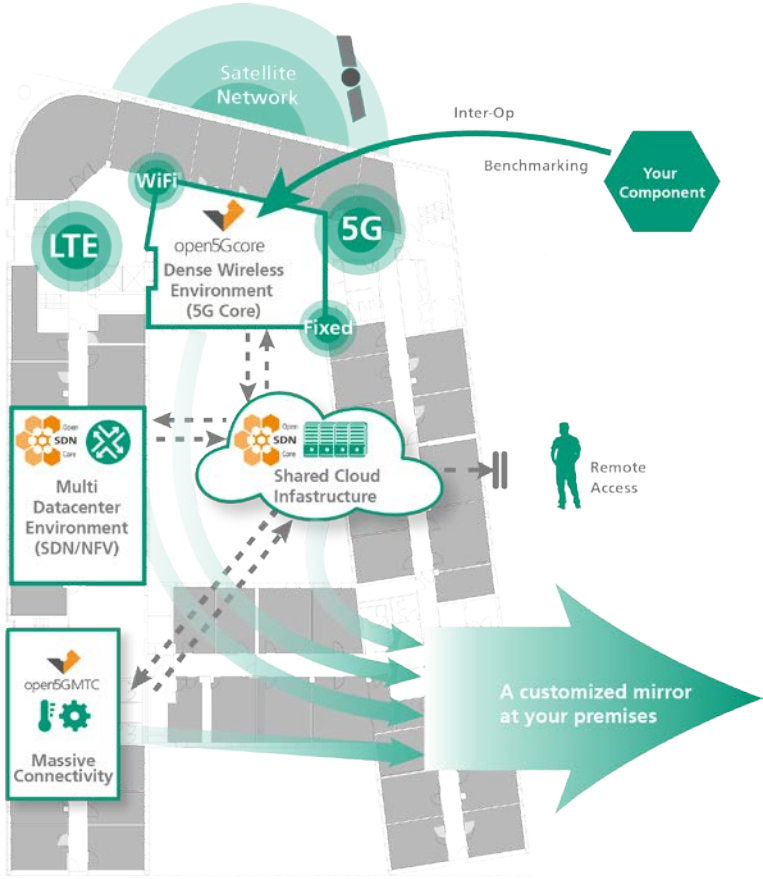
Market opportunities for 5G



Fraunhofer FOKUS

What is the 5G Playground?

- The 5G Playground a common R&D ground where researchers and engineers around the world are able to build together the future 5G environment
- 5G PG enables the following use cases:
  - Interoperability
  - Product Prototyping
  - Remote experimentation
  - Calibration and benchmarking
- The fundament of the 5G playground includes:
  - A comprehensive set of toolkits mirroring the advances towards 5G
  - Methodology and tools for benchmarking
  - Automation and commodity tools:
    - Federation tools
    - Automatic network customization and management for experiment control
    - Independent experimentation slices

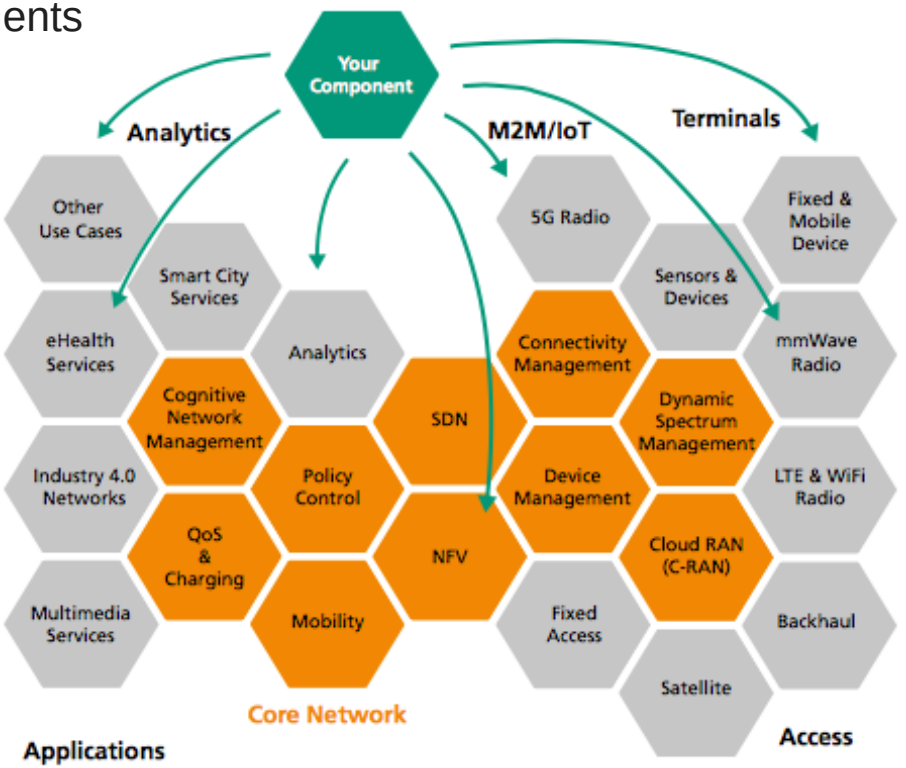


5G Playground answers industry experimentation requirements

Interoperability	Providing a common ground for product development
Product Prototyping	Usage of parts of the 5G Playground software for developing proof-of concept prototypes for new products
Remote Experimentation	Experimenting using the Fraunhofer FOKUS Facilities
Calibration and Benchmarking	Customizing prototypes and products for the specific market

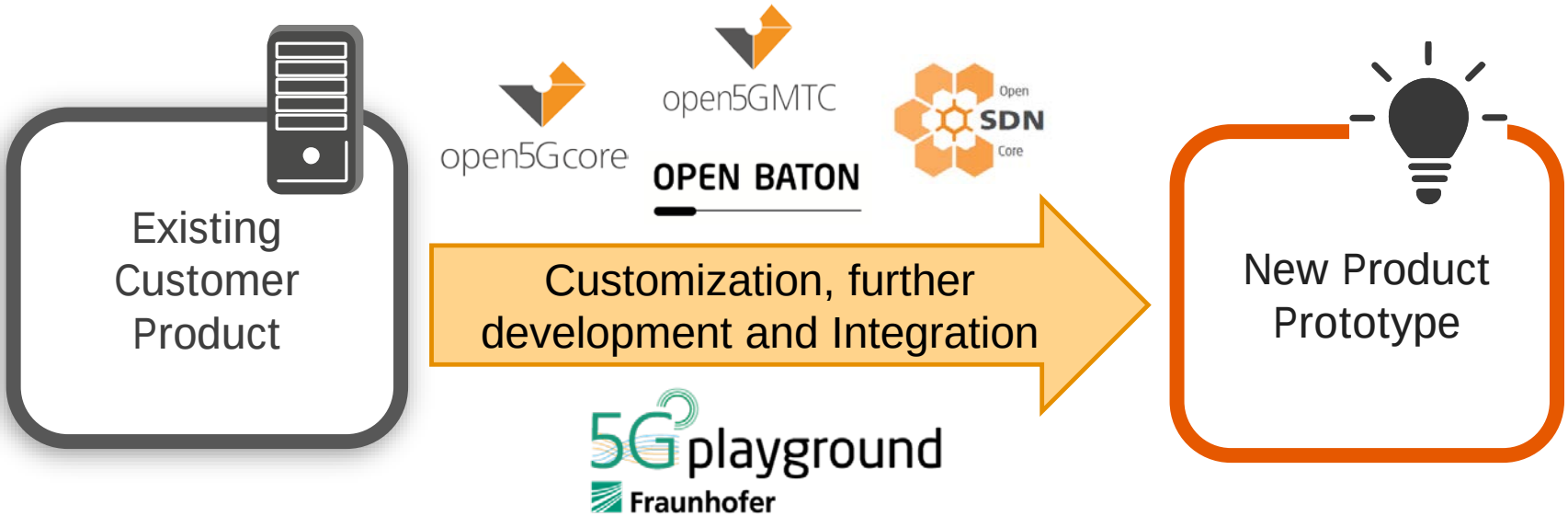
I. Interoperability

- The 5G Playground offers from the beginning a comprehensive environment where new prototypes and products can be tested for interoperability
  - Covering a comprehensive set of functionality
  - Mirroring the 5G standard advancements
  - Addressing end-to-end use cases
- Enabling a coherent development with other areas of the 5G ecosystem
  - By interoperability with other partners
- The live demonstration offers the possibility to advertise the new products as part of a growing ecosystem
  - Visibility towards other stakeholders
  - Visibility towards customers



II. Product Prototyping

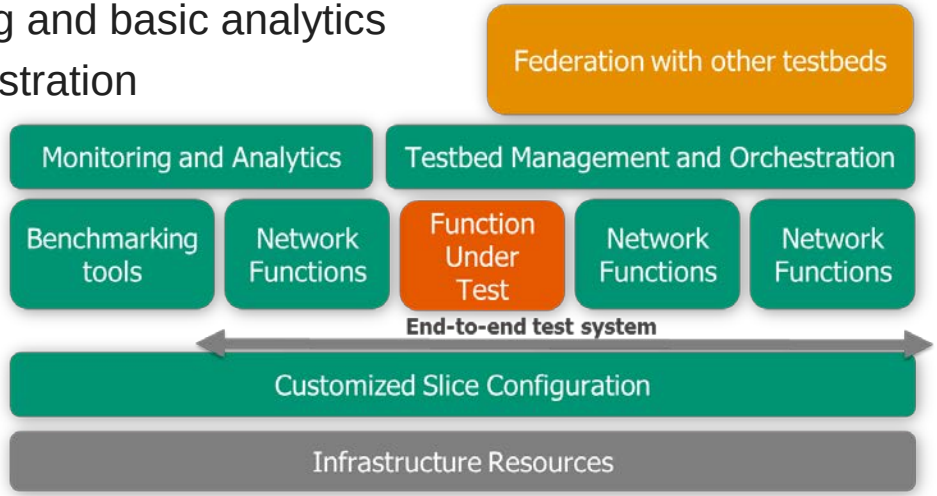
- Customizing and further extending the toolkits of Fraunhofer FOKUS to provide innovative product prototypes
  - Based on the existing product base of the customers (or third parties)
  - Using a customized version of the Fraunhofer FOKUS toolkits
  - Providing new functionality coming directly from research
  - Prototyping the new product
  - Opening new market opportunities through raising awareness (demos, whitepapers)



III. Remote Experimentation

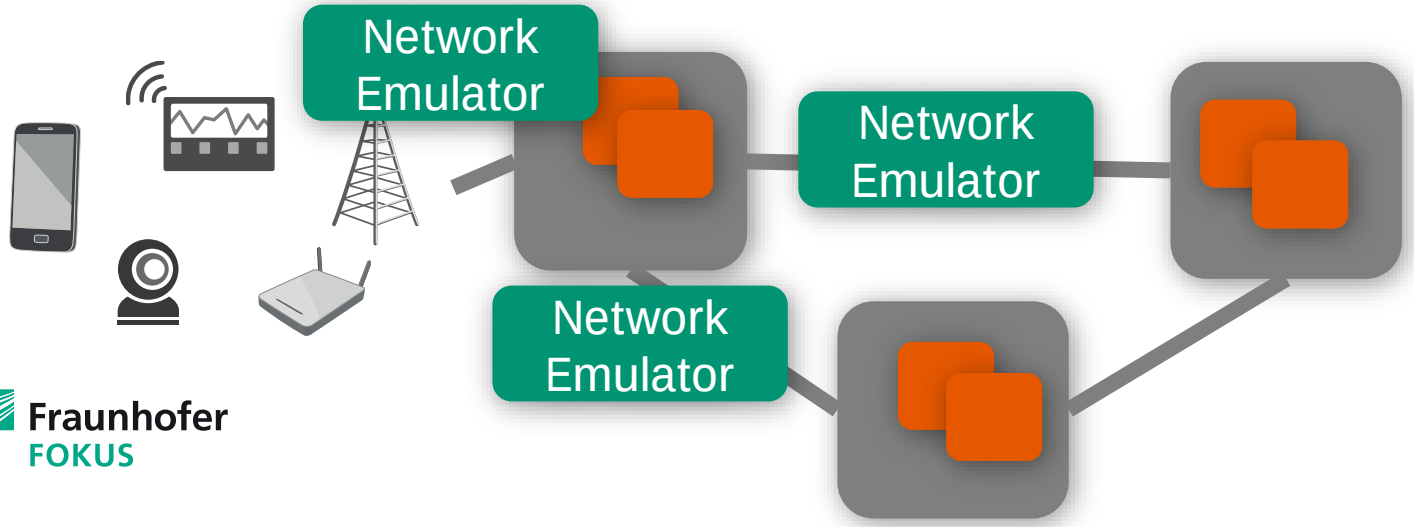
- Options:
  - Adding a new functionality as a black box in a comprehensive system
  - Using the 5G Playground installation for new algorithms and optimizations

- Separated by functional layers:
  - Based on customized slices on top of multi-data center environment
  - Composing an end-to-end service with NFs based on FOKUS toolkits
  - Loaded by benchmarking tools
  - With integrated end-to-end monitoring and basic analytics
  - With testbed management and orchestration
  - Federated with other testbeds



III. Remote Experimentation (cont.) – Slice Configuration (IaaS)

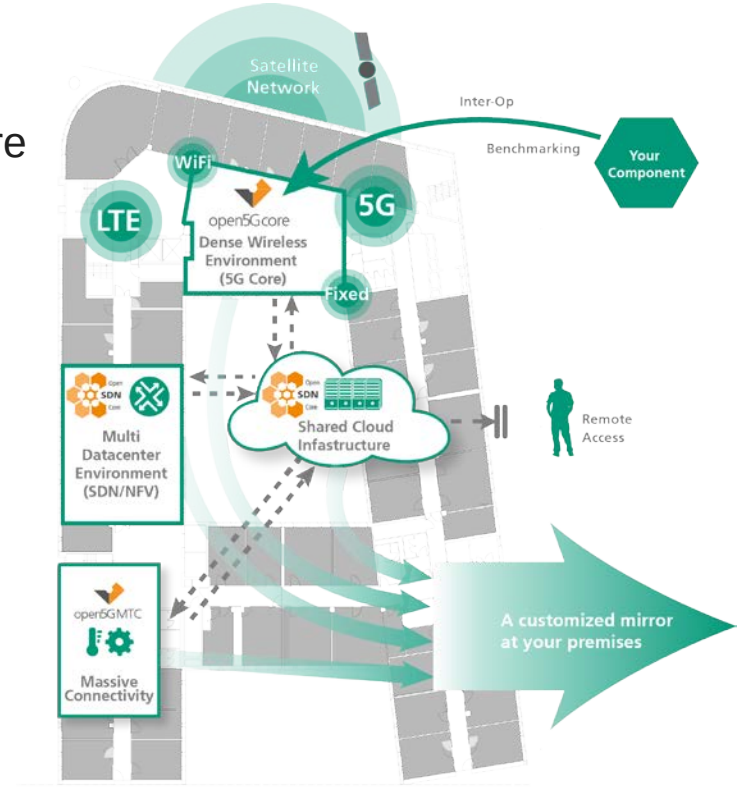
- Creating a virtual network with virtual functions for each experiment
  - With multiple deployment models on top of multiple data centers
    - Edge networking
    - Central/edge interoperation
  - Emulating the communication on top of different network environments:
    - Wireless and satellite networks
    - Inter-data center high capacity backhauls
  - With different network programmability levels
    - Creating a virtual SDN network infrastructure
  - Interworking with real devices and real radio networks (if needed)



Fraunhofer FOKUS

What the 5G Playground contains?

- A comprehensive set of toolkits enabling the setup of the environment and the development of an end-to-end testing environment
  - OpenBaton – for automatic deployments, experiment control and runtime management
  - OpenSDNCore – the underlying SDN infrastructure
  - Open5GCore – radio and core network components + benchmarking tool
  - Open5GMTC – device connectivity control, emulated device management and benchmarking tool
  - FITeagle – for federation and remote access
- Methodology and tools for benchmarking prototypes and products
- Commodity and price efficiency:
  - Automatic installation & Experiment control
  - Independent experimentation slices



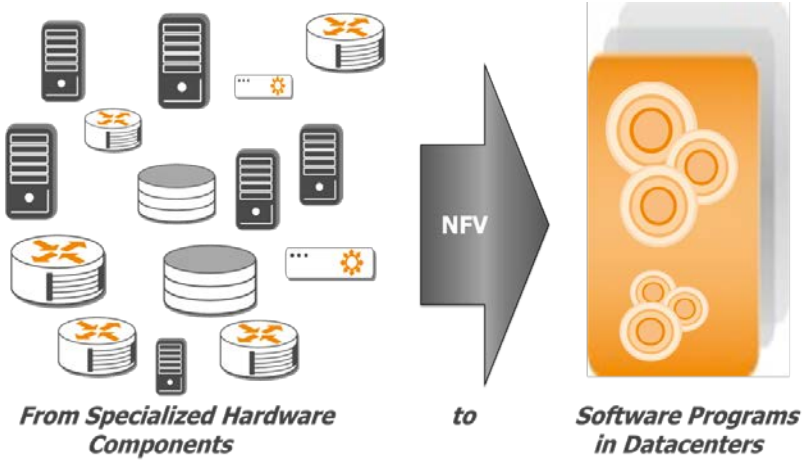
Fraunhofer FOKUS

ETSI Network Functions Virtualization (NFV)

- The objective of NFV is to translate the classic network appliances to software modules
  - Running on high volume servers with high volume storage
  - Interconnected by generic high volume switches
  - Automatically orchestrated and remotely installed

- NFV is a novel paradigm that presumes that the network functions:
  - Are implemented only as software (programs)
  - Can run on top of common servers

- NFV has to fix the following main issues:
  - Performance
  - Co-existence and portability
  - Automation
  - Scalability
  - Resilience
  - Vendor Integration

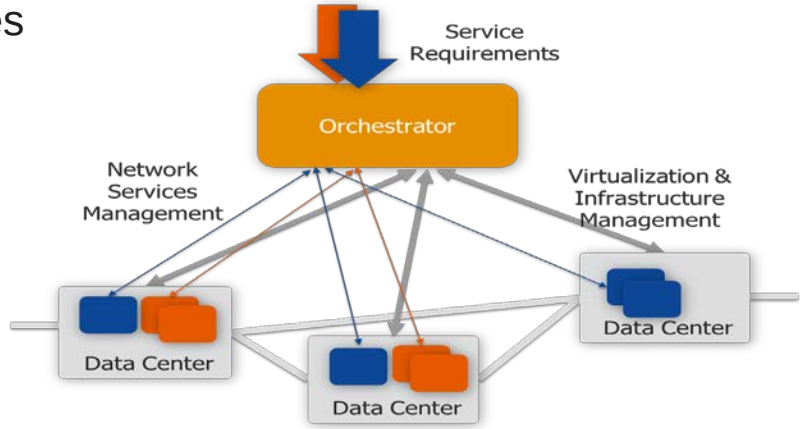


Network Functions Virtualisation (NFV) Whitepaper, launched at SDN and OpenFlow World Congress, October 2012, Darmstadt, Germany

Why we need an orchestrator?

In the ETSI NFV architecture, the Orchestrator is the main decision point in the interaction between services and infrastructure.

- The Orchestrator is the only component which has a complete view of the infrastructure resources
- The Orchestrator allocates the resources for the services based on their requirements
- The Orchestrator maintains the resources of the network services at the expected parameters during the life-cycle management
- Functionality roles of the orchestrator:
  - Life-cycle management of the network services
  - Ensuring the network KPIs are fulfilled
  - Ensuring dynamic management functionality:
    - Keeping system coherence while scaling
    - end-to-end fault management,
    - end-to-end reliability

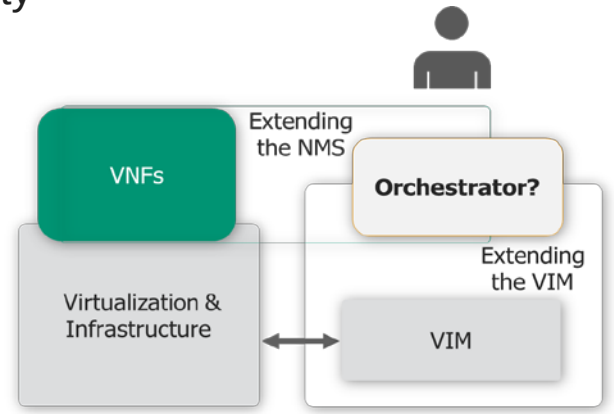


A comprehensive MANO orchestrator is (still) missing…

Two approaches in regard to orchestration were taken:

- Orchestrating from the infrastructure perspective
  - Extending the VIM functionality towards proving service orchestration. Missing:
  - Adaptation to complex network services requirements:
    - e.g. fault management, scaling, network function placement, virtual network configuration, information flow paths, security, reliability

- Orchestrating from the network service perspective
  - Extending the Network Management System to handle orchestration. Missing:
    - Capitalize through native developed components on the cloud opportunities: scaling, dynamic resource allocation
    - Fix the remaining problems: define the appropriate network service KPIs, end-to-end fault management, providing end-to-end reliability insurance, etc.

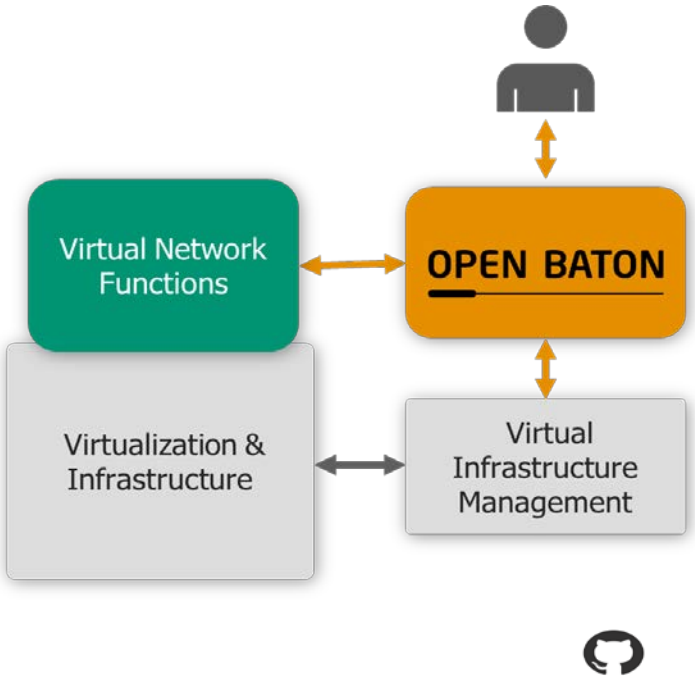


What is OpenBaton?

OpenBaton is an Open Source implementation of the ETSI MANO specification

- OpenBaton aims to foster, within the NFV framework, the integration between the:
  - Virtual Network Function providers
  - Cloud Infrastructure providers

- Functionality:
  - Installation, deployment and configuration of network services
  - Runs on top of multi-site OpenStack
  - Provides independent infrastructure slices
  - Support for generic or specific VNF management
  - A large amount of virtualization use cases e.g. core networks, M2M and Multimedia communication

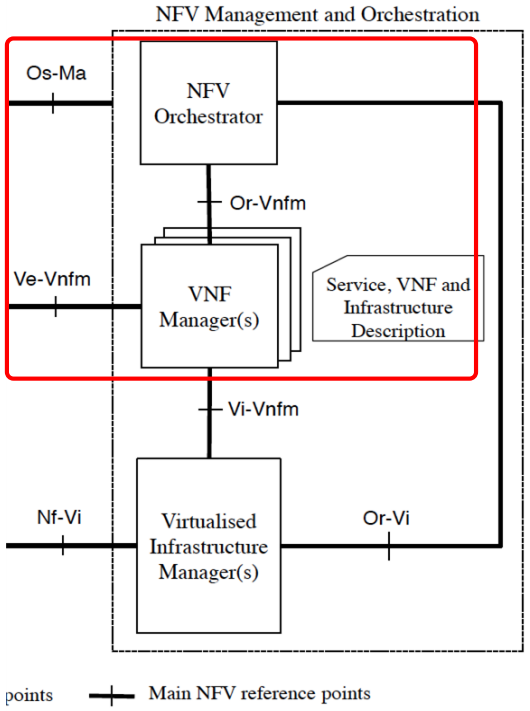


- Available on github: https://github.com/openbaton

OPENBATON

The reference implementation of the ETSI NFV MANO specification

- OpenBaton is based on the ETSI NFV MANO v1.1.1 (2014-12) (*) specification. It provides
  - A ***NFV Orchestrator*** managing the lifecycle of Network Service Descriptors (NSD) and interfacing with one or more VNF Manager(s) (VNFM)
  - A ***generic VNFM***, which can be easily extended for supporting different type of VNFs
  - A ***set of libraries*** which could be used for building your own VNFMs (vnfm-sdk)
  - A ***dashboard*** for easily managing all the VNFs
- It integrates with OpenStack as main VIM implementation

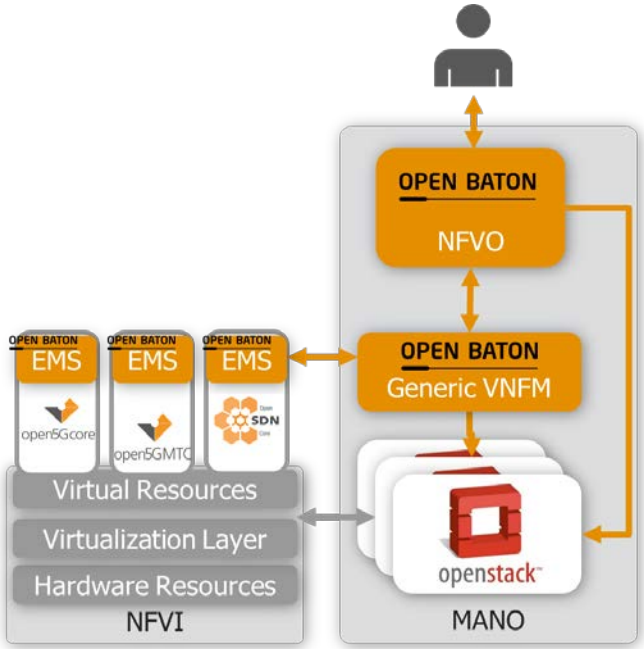


(*) http://www.etsi.org/deliver/etsi_gs/NFV-MAN/001_099/001/01.01.01_60/gs_nfv-man001v010101p.pdf

OpenBaton Environment

OpenBaton is the missing piece of the larger virtualization ecosystem

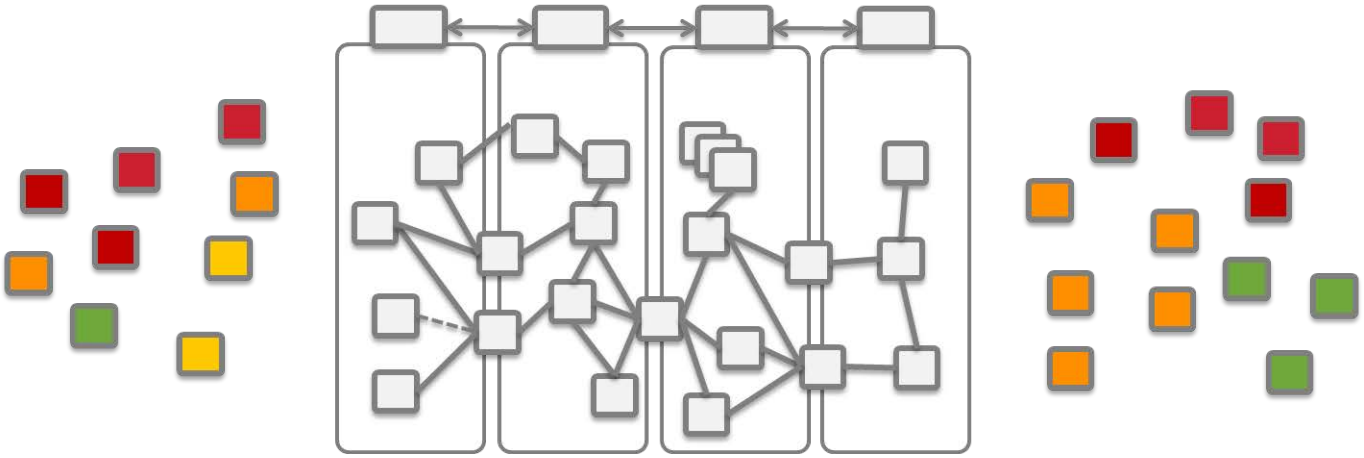
- OpenBaton was designed to interact with multiple VIMs
  - Currently OpenStack is supported
- OpenBaton extends the basic orchestration towards network functions management
  - Includes a generic VNFM and a generic EMS
  - Can interoperate with other VNFMs
- Enables the deployment of multiple customized network slices
- OpenBaton environment includes multiple data centers
  - Allocating resources on top of multiple OpenStack installations



Why now a new approach for M2M?

Adoption of M2M is determined by the reliability, security and availability of the connectivity of the devices

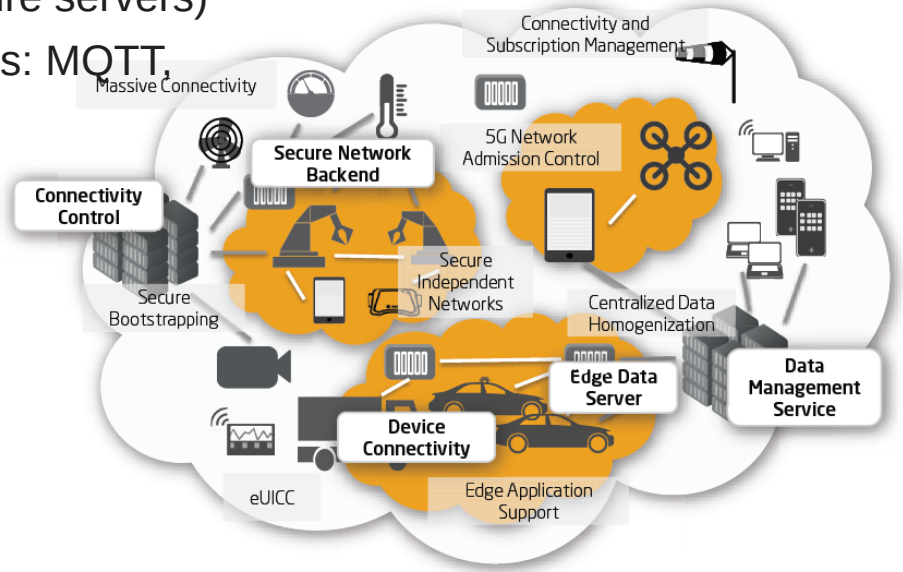
- The interaction with the complex network in the middle is the most important factor for going over “best-effort” M2M
- M2M needs appropriate data handling functionality to reduce the network overhead and the end-to-end service delays



What is Open5GMTC?

Open5GMTC represents for a new approach to device communications (M2M & Multimedia)

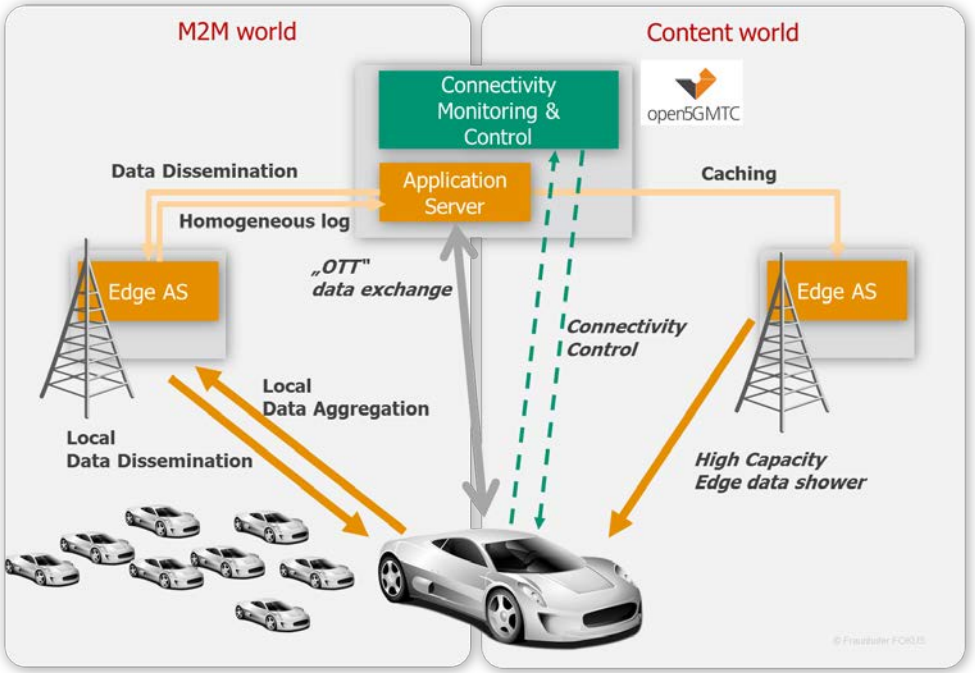
- Open5GMTC concentrates mainly on providing communication services for the devices on top of highly heterogeneous and dynamic environments
- Aims at features usually underestimated by application developers
  - Considers a high number of connected devices
  - Addresses heterogeneous networks in terms of:
    - Security (and private) network zones
    - Customized connectivity (e.g. ultra low delay)
    - Service capabilities (edge nodes, secure servers)
- Open5GMTC is based on standard protocols: MQTT, CoAP, OMA LW M2M, Diameter, etc.



Fraunhofer FOKUS

Open5GMTC: Edge Applications Scenario

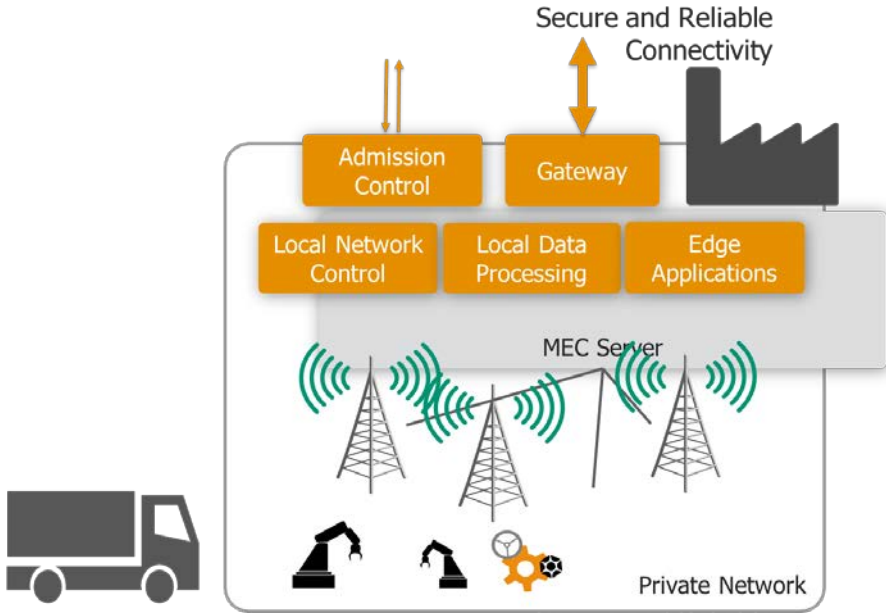
- M2M world
  - Local data exchange
  - Minimal data dissemination
  - Homogeneous “logging”
- Content world
  - Caching at specific network points
  - High capacity edge data shower
    - Within the same network
    - Within other networks (e.g. home network)



Providing A Comprehensive Solution For Private Networks

By combing Open5GMTC with the Open5GCore and OpenSDNCore a comprehensive flat network solution for private networks can be achieved

- Open5GMTC provides
  - Device admission control (security and QoS)
  - Customization of local data control
  - Local data processing framework
  - Data homogenization
- OpenSDNCore provides:
  - Specific WAN Optimizations
  - Secure connectivity between “edge” applications
- Open5GCore provides:
  - Local network control
- Edge applications and protocols are added on demand (MQTT, CoAP, OneM2M, SCADA, OPC, etc.)



What is Open5GCore?

Open5GCore is a pre-standard implementation of the 5G ecosystem

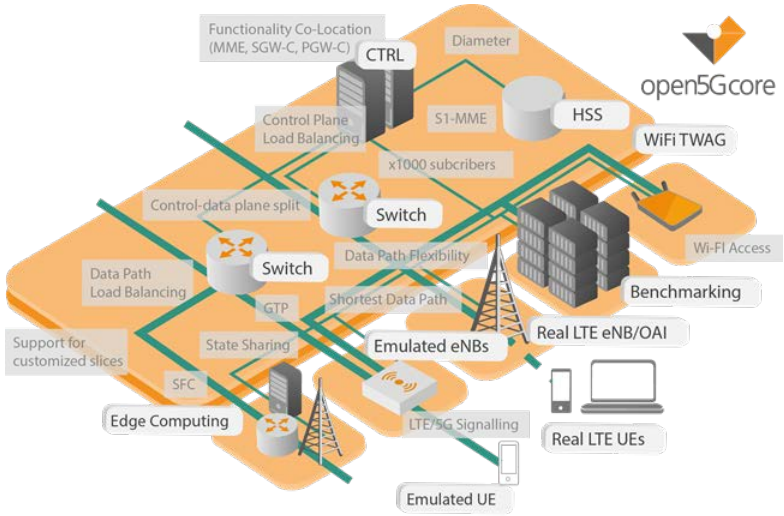
- Open5GCore aims to foster 5G development beyond LTE/EPC
  - More efficient communication for the subscribers (low delay/high capacity)
  - Providing the users a means to control their environment (automation/reliability)
  - Providing communication for other markets (Industry 4.0, eHealth, energy, critical)

- Open5GCore Rel. 2 is a **NON-OPEN SOURCE** R&D toolkit enabling:
  - Deployment of testbed small scale operators
  - Integration with common radio boxes (LTE, WiFi, 5G prototypes)
  - Using common phones
- Open5GCore is designed for 5G ecosystem R&D needs:
  - Based on standard components (3GPP, ETSI, IETF, ONF)
  - Easy to customize, modify and extend
  - Enabling large input loads & comprehensive monitoring

Open5GCore Rel. 2

A radical innovative core network for 5G, LTE and WiFi

- 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 Release 2 features:
  - Support for LTE and WiFi access networks
  - Cloud-native core network customized for NFV slices
  - Seamless elasticity, state sharing and load balancing
  - Mobile edge computing support
  - Service oriented data paths
  - Benchmarking
  - LTE/5G radio signaling protocol stack

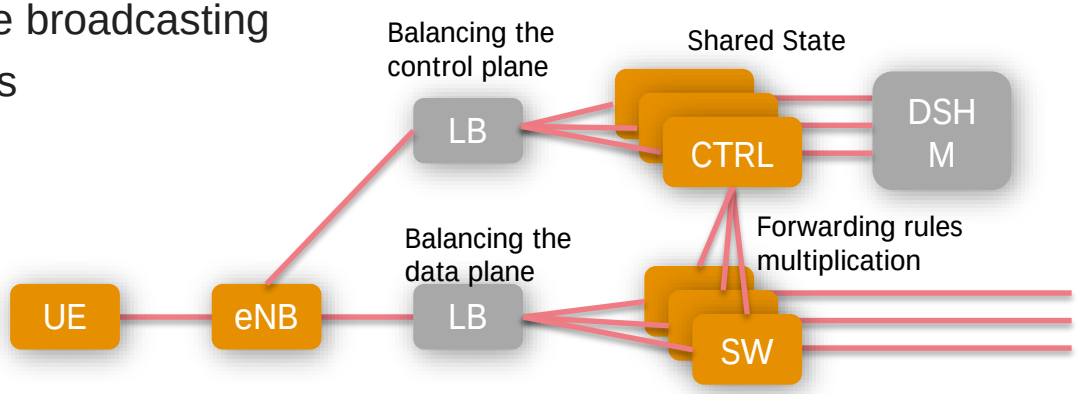


Cloud-Native functionality

Enabling graceful scaling, load scheduling and high availability

- Load Balancing
  - Low footprint S1-AP load balancer for appropriate MME selection
  - OpenFlow controlled data path load balancer

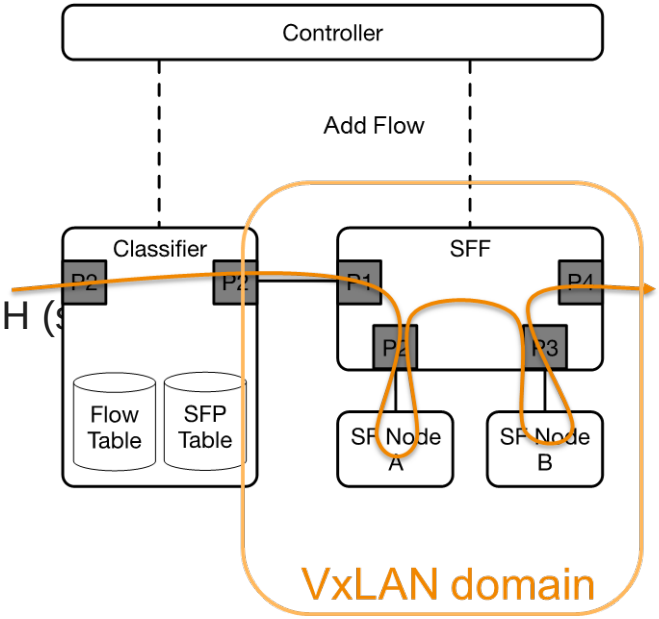
- State sharing mechanisms
  - Distributed shared memory
  - ASN1 based protocol for state broadcasting
  - Replication of forwarding rules



Service Functions Chaining

SFC provides the next step for efficient, programmable of the data path

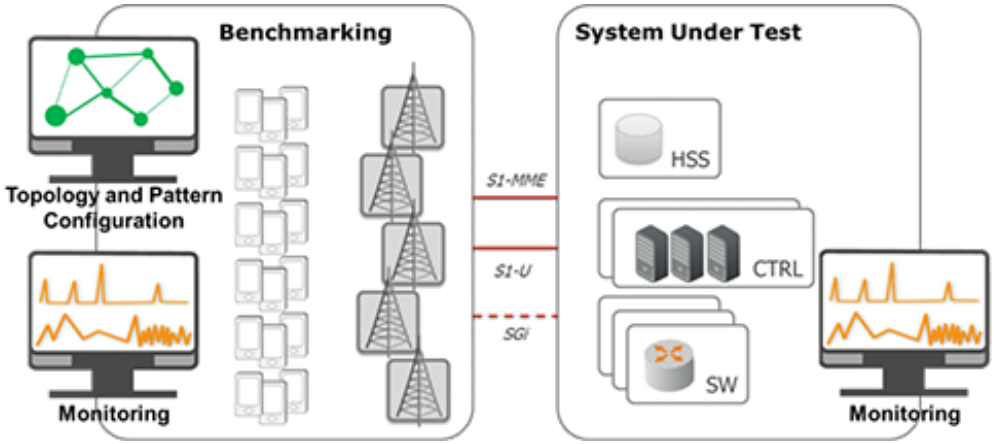
- SFC provides a flexible end-to-end data encapsulation
  - Forms dynamically network topologies
  - Very fast forwarding
- Current Fraunhofer solution:
  - Following IETF SFC
  - Allows multiple flows to be classified with the same NSH (
  - Implemented on top of the OpenSDNCore switch
  - Transport headers for inter-data center forwarding



Benchmarking

Providing quantitative evaluations of different core network implementation architectures

- The benchmarking tool and environment include the following functional features:
  - Flexible and intuitive eNB topology configurations
  - Flexible subscriber mobility and load patterns –
  - Support for x1000 emulated subscribers
  - Support for x10 eNBs running within different processes
  - Support for S1-MME and S1-U interfaces,
  - Attachment, detachment and active handover procedures (S1-based)
  - Monitoring
    - Quality: Success rate, procedure delay
    - Performance: compute, storage and network
- On demand extensible for different:
  - RAN topologies or functionality,
  - mobility and resource patterns
  - interfaces towards the network



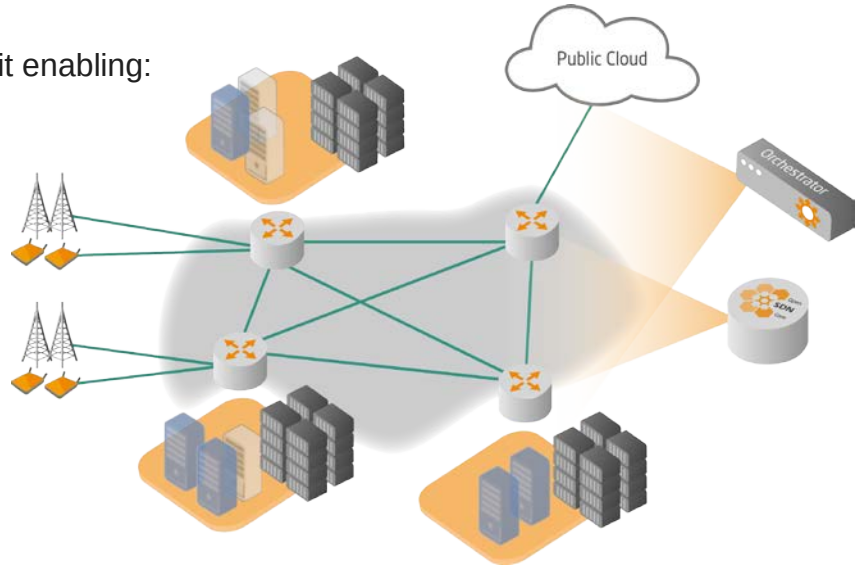
What is OpenSDNCore?

OpenSDNCore is a standard implementation of added value functionality and applications on top of an SDN framework

- OpenSDNCore Rel. 3 user-space software toolkit extends the basic SDN functionality to address:
  - Heterogeneous backhaul deployments,
  - Inter-cloud networking
  - Network function chaining and data path support for mobile networks

- OpenSDNCore Rel. 3 is a **NON-OPEN SOURCE** R&D toolkit enabling:
  - Development of added value features into SDN
  - Establishment of dynamic data paths
  - Distributed network programmability

- OpenSDNCore is designed for the R&D needs:
  - Based on standard components (IETF, ONF)
  - Easy to customize, modify and extend
  - Enabling large input loads & comprehensive monitoring

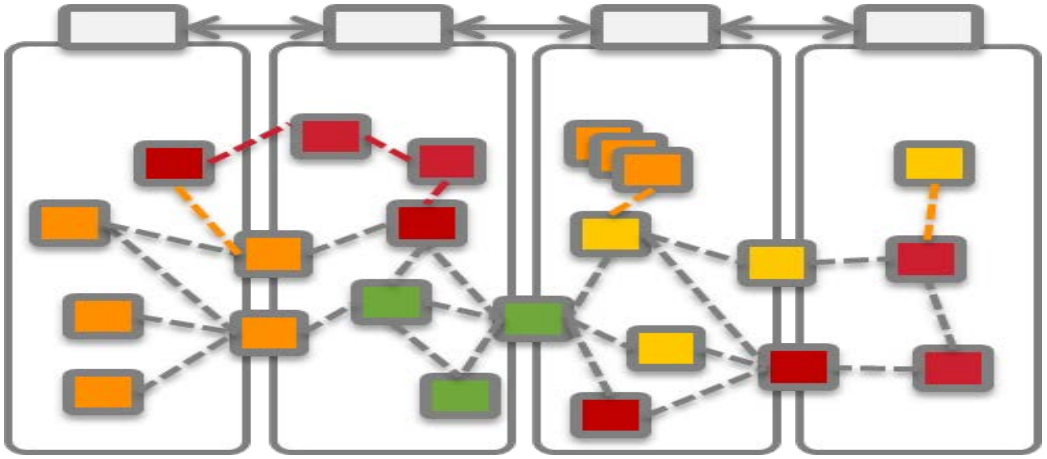


Fraunhofer FOKUS

OpenSDNCOre functionality & Features

- GTP/GRE/VLAN/MPLS encapsulation
- IP and GTPU load balancing
- Fast packet processing (acceleration)
- Topology discovery and learning switch applications
- Adaptive Flow Placement
- Open Shortest Path First (OSPF) module
- SFC (Service Function Chain Controller)

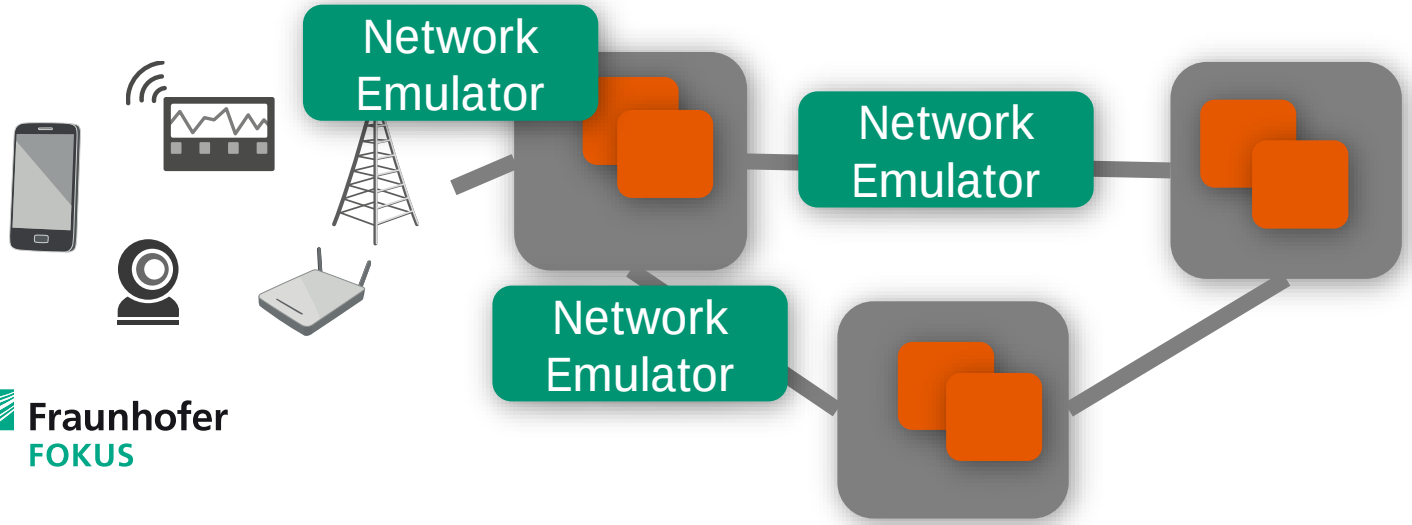
- OpenSDNCore integrates with Open5GCore for mobile core networks
- OpenSDNCore is used by OpenBaton for inter-cloud data center



Fraunhofer FOKUS

Benchmarking and Experimentation – Slice Configuration (IaaS)

- Creating a virtual network with virtual functions for each experiment
  - With multiple deployment models on top of multiple data centers
    - Edge networking
    - Central/edge interoperation
  - Emulating the communication on top of different network environments:
    - Wireless and satellite networks
    - Inter-data center high capacity backhauls
  - With different network programmability levels
    - Creating a virtual SDN network infrastructure
  - Interworking with real devices and real radio networks (if needed)



Fraunhofer FOKUS

Dedicated core and edge networks

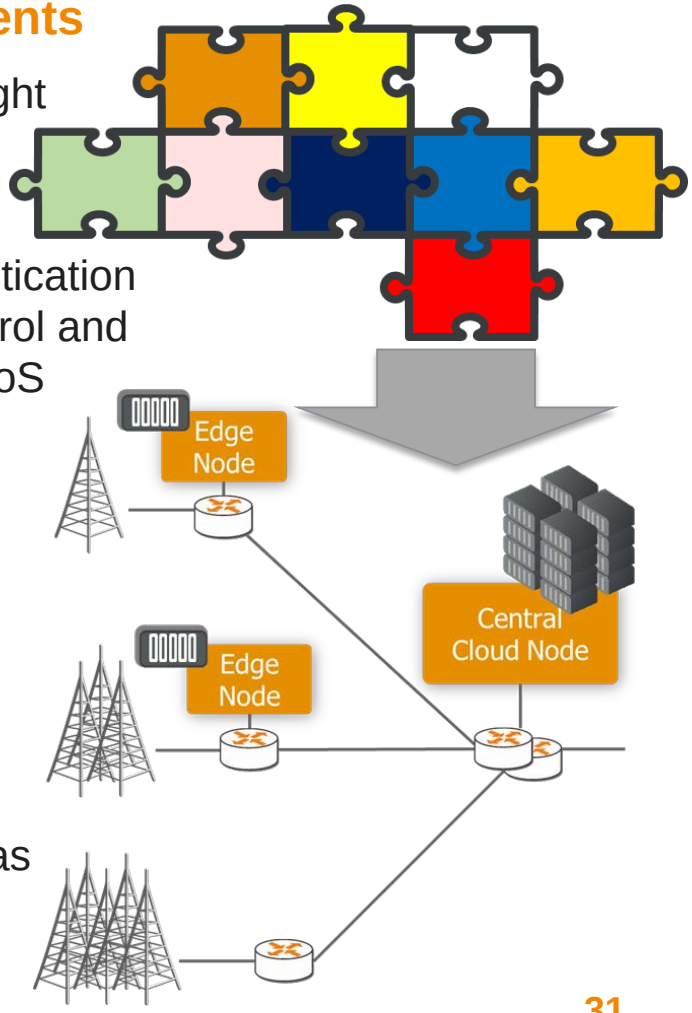
Scope: Providing highly customized core networks appropriate to the infrastructure availability and service requirements

By defining a basic interface, micro-services can be brought together and deployed into an end-to-end service

- **Dedicated core networks (network slices)**
  - Based on a modular software platform – e.g. Authentication and Authorization, Identity Management, Policy control and charging, Reachability and Mobility Management, QoS and security

Edge network computing enables resource virtualization, sharing and isolation

- **Dedicated edge networks**
  - Vertical – e.g. low-delay industrial wireless
  - Application specific – e.g. vehicular communication
  - Distributed – e.g. content caching, data aggregation
  - Private – e.g. isolation between distinct security areas



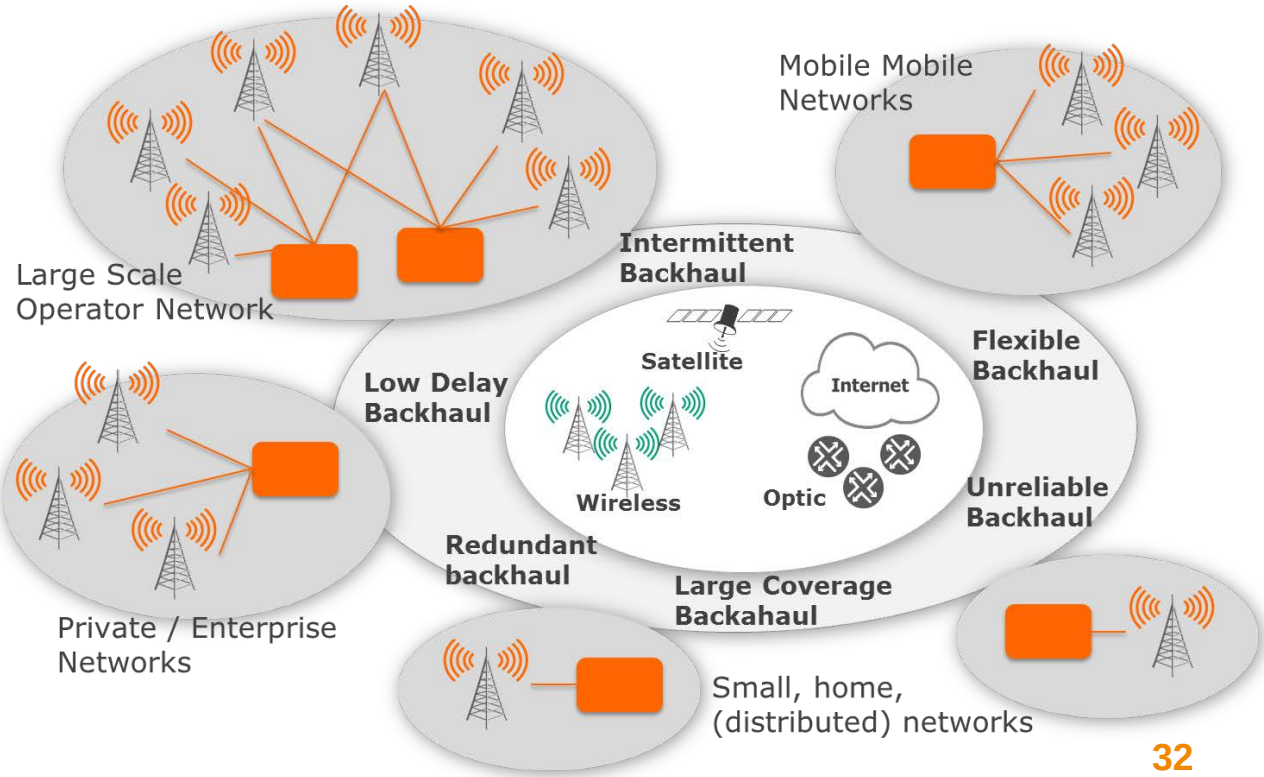
Fraunhofer FOKUS

Flexible backhauls

Scope: Backhaul communication in heterogeneous edge network infrastructures

- Management of intermittent and unreliable backhaul connections
- Satellite backhaul adaptations
- Flexible backhaul selection

- Backhaul services
  - Redefining multicast
  - Edge node caching
  - Redundant backhauls
  - Cost-based selection
  - Latency optimization

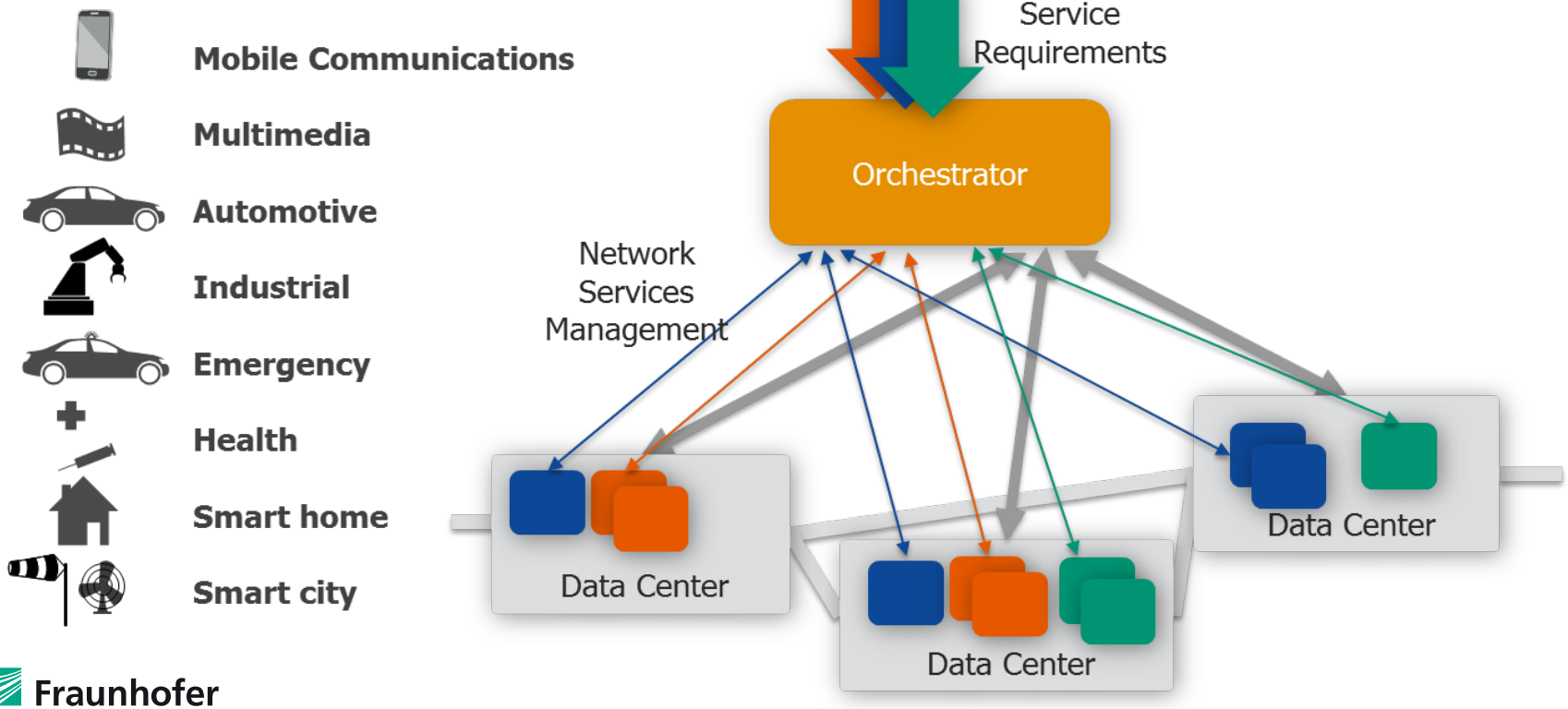


Fraunhofer FOKUS

Network Function Virtualization

Scope: Multiple service slices on top of a dynamic federation of heterogeneous compute and storage nodes

- NFV in distributed, heterogeneous environments
- NFV as a platform for micro-services

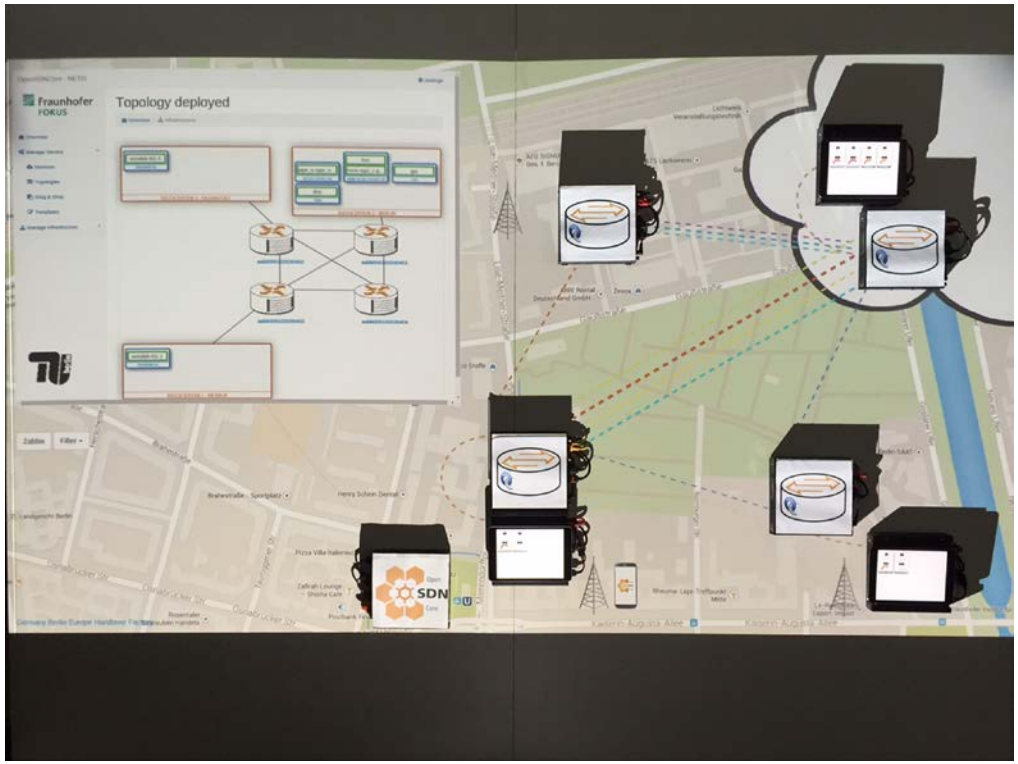


Fraunhofer FOKUS

The 5G Playground @ FOKUS infrastructure

Permanent Demonstration Environment

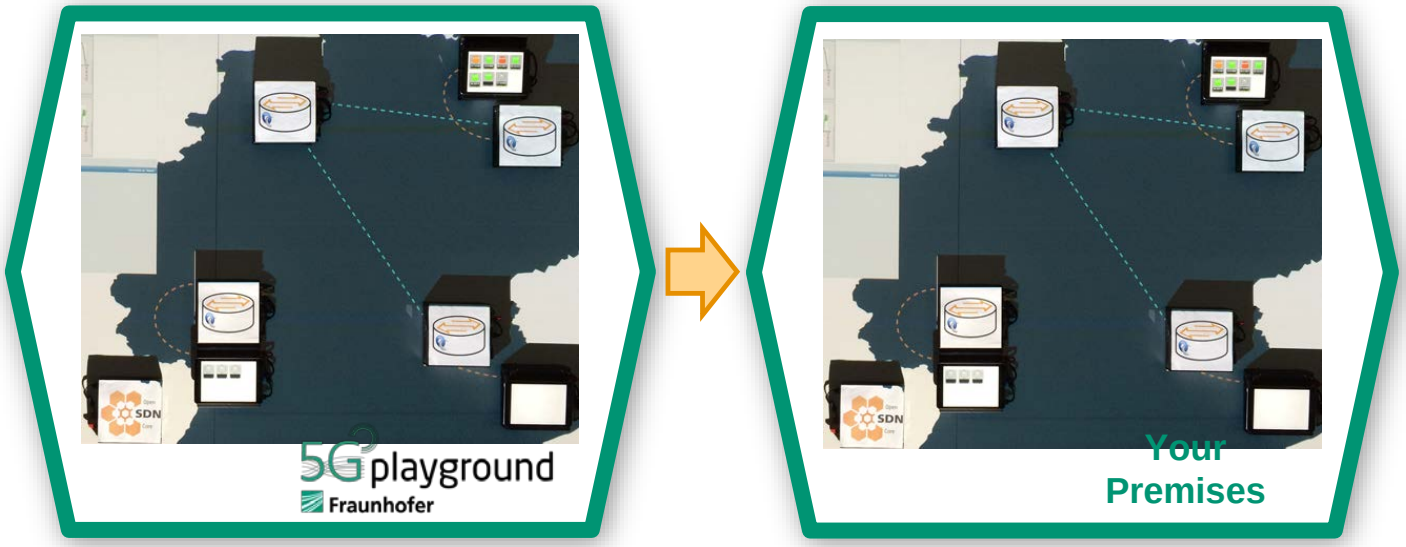
- Facilitates 5G Playground toolkits and infrastructure in a comprehensive micro-operator scenario (network slice)
- Placed on a vertical setup (“4G/5G Wall”)
- Showcases
  - Comprehensive environments
  - Different features within the same environment
  - Effects on live testbeds
  - Edge mobility
  - Live monitoring information



Fraunhofer FOKUS

Clone and customize your own 5G Playground

- The 5G Playground was designed from the initial phases for commodity for being deployed at customer premises
  - Mirroring the advancements from the Berlin testbed
  - Providing a separate isolated testing facility
  - Including only the interesting functionality from the comprehensive environment
  - Customizing the test environment for the specific requirements



Security Islands Motivation

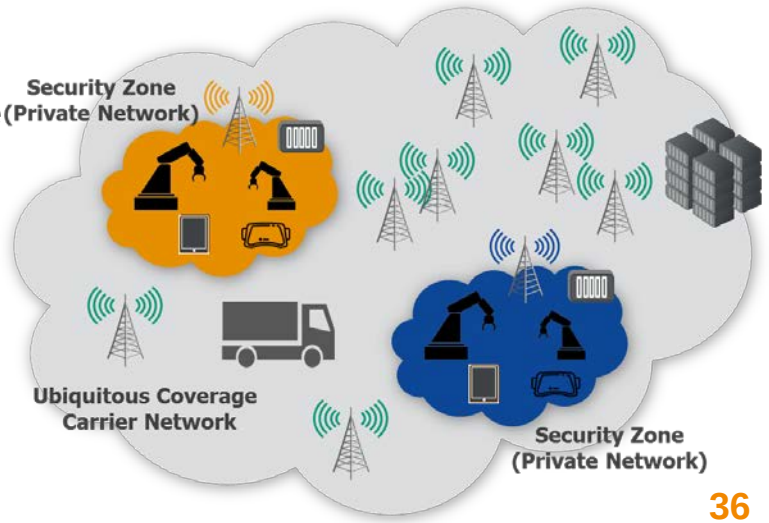
The network is becoming more heterogeneous and flexible in terms of flexible areas

- Enterprises have to connect their private networks to the carrier networks
  - For convergent service across distributed geographical areas
  - For interaction with other service providers (e.g. logistics, manufacturing, safety)

- Still a very high security level has to be maintained for the private networks
  - A large amount of confidential information is available in the private network
  - A large amount of detailed short living monitoring information

- A continuous flow of connected devices
  - I4.0 requires that devices change their security zone while executing the industrial process

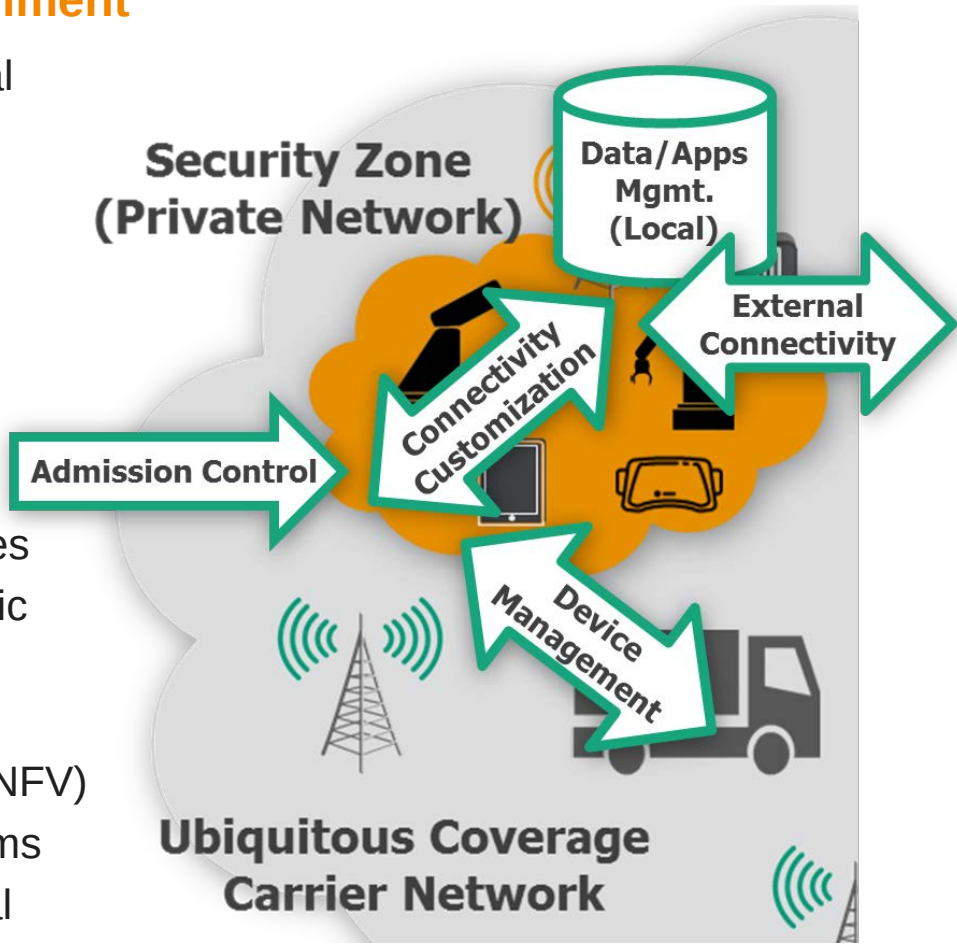
- Virtualized Network Service / NFV
  - Provides the ability to replicate functionality within different network areas, customized to the local needs



Requirements for Security Islands

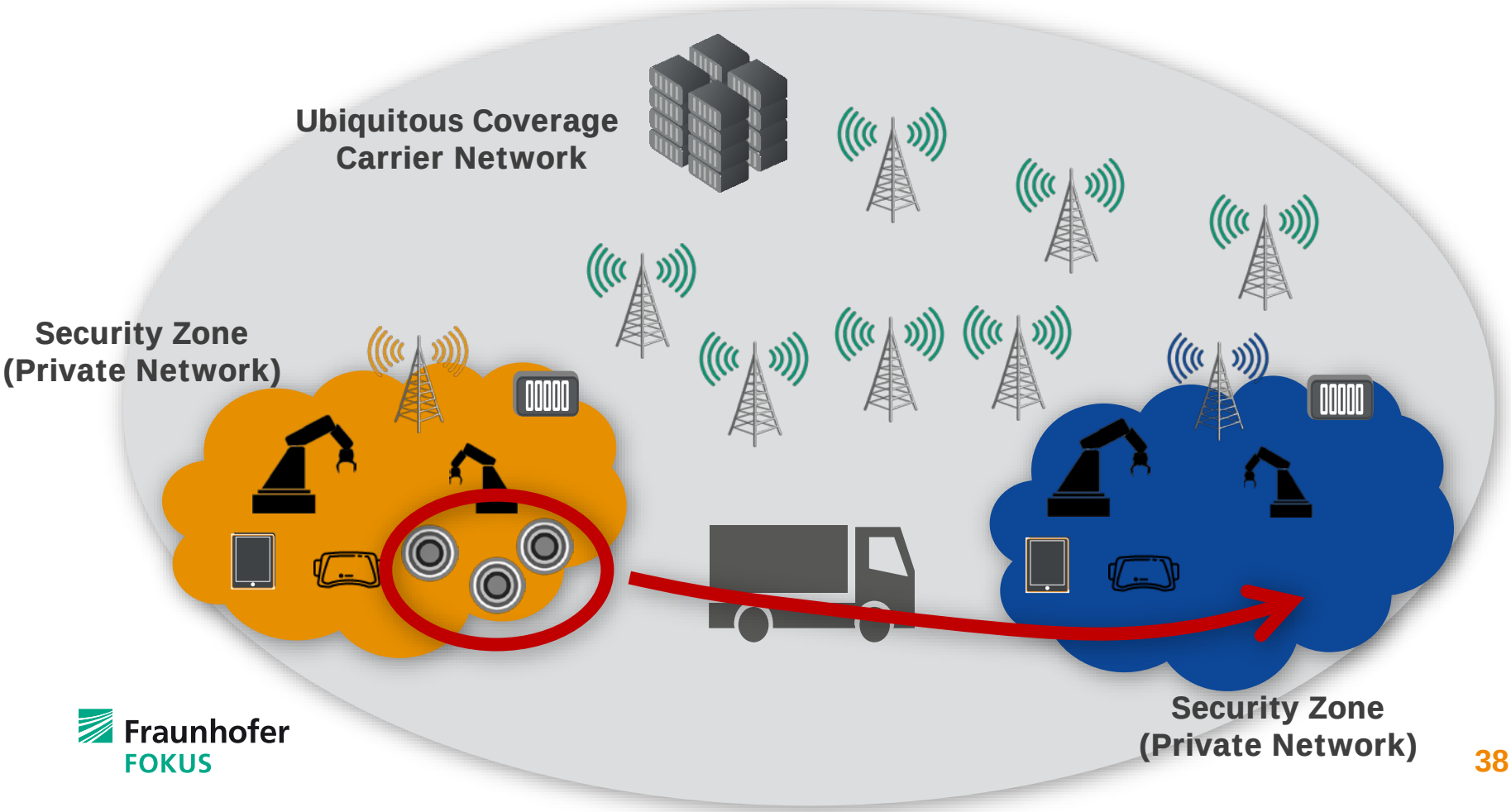
Features required for implementing a coherent, gracefully integrated wireless environment

- Customized connectivity – providing a local private customized network
  - QoS – scheduling the usage of network resources
  - Mobility support – if needed
- Admission control & device management
  - Secure admission of new devices (bootstrapping)
  - Customized/local communication policies
  - Authentication, authorization and specific communication profile
- Data/Apps Management
  - Scalable & reliable apps deployments (NFV)
  - Monitoring and broadcasting mechanisms
  - Time constraint data management (local cognitive)
- External connectivity
  - Programmable data paths (SDN)



Open5GMTC demo – Dynamic Admission Control

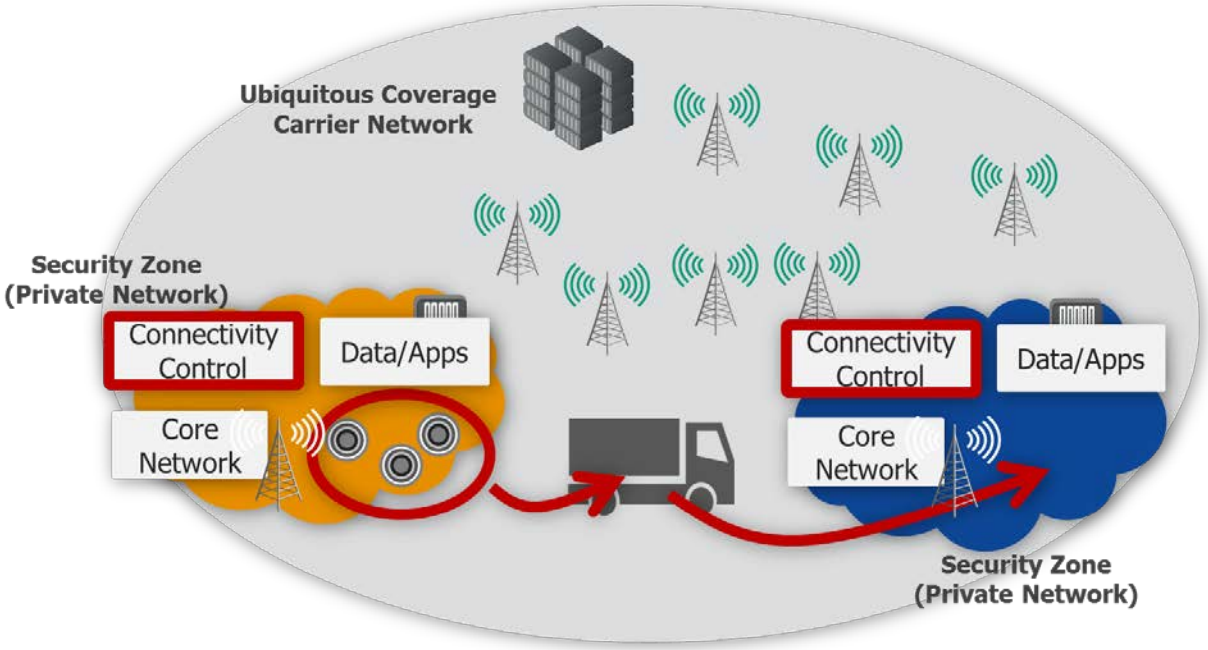
- Providing trustful admission control into a security zone
- Mechanisms for handing over a device from one security zone to another one



Demo Steps

Through the communication between the connectivity control and the truck, two major set of operations are executed:

- Authenticate and Authorize to e-load and e-unload (bring into/out of the security zone) of sensors and devices
- Authorize the truck to leave/enter a security zone

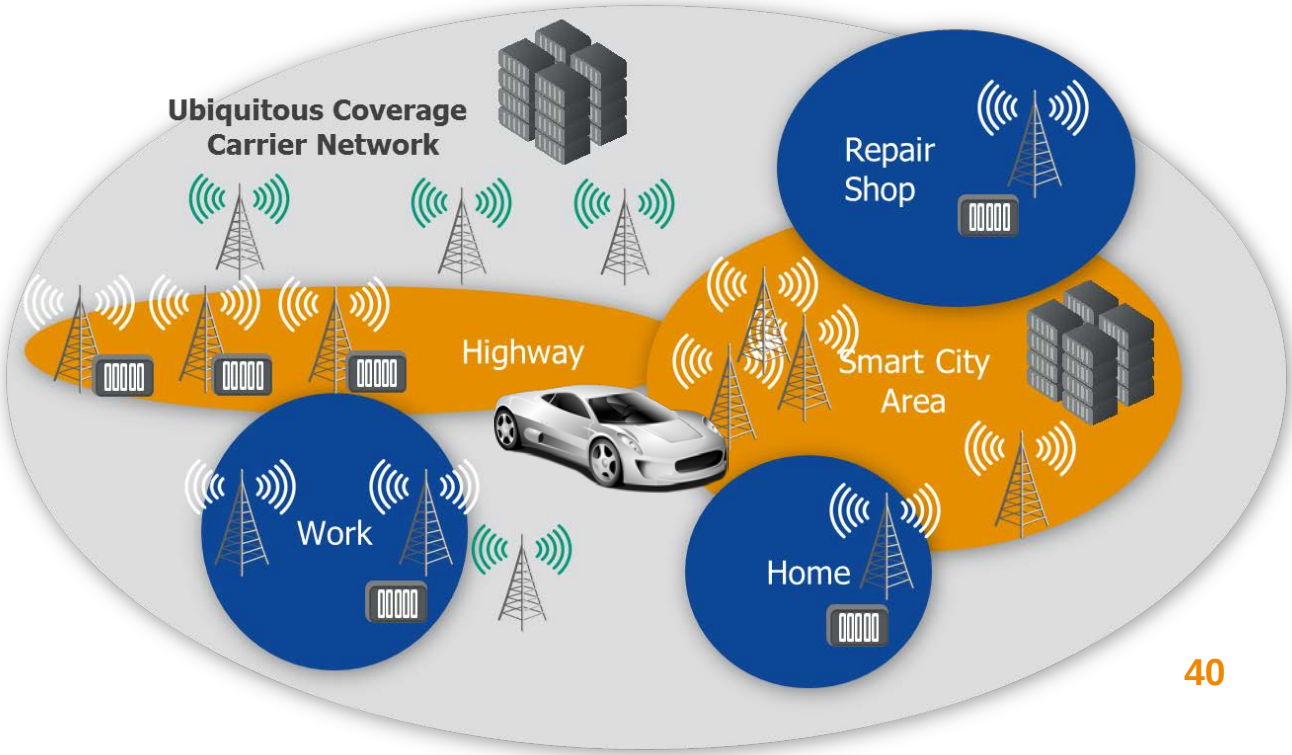


Fraunhofer FOKUS

Admission Control For Automotive

Any piece of the network to which the car connects to can be a private (virtual) network with its own security zone

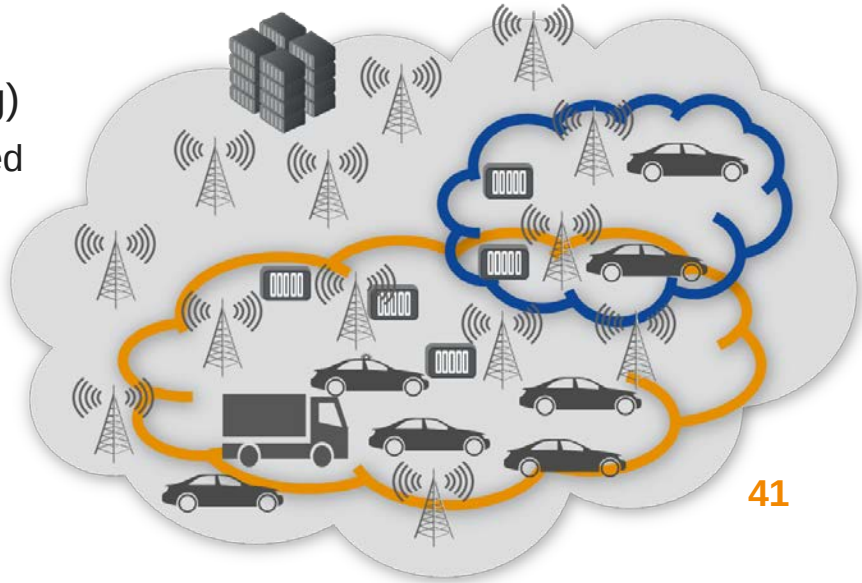
- The role of the car is changing for each of these networks (e.g. highway networks for congestions and accidents, smart city for parking places, home and work for private information, repair shop for technical related functions)
- A ubiquitous tracking of an after-market through an isolated network is also possible.



Connectivity Islands Motivation

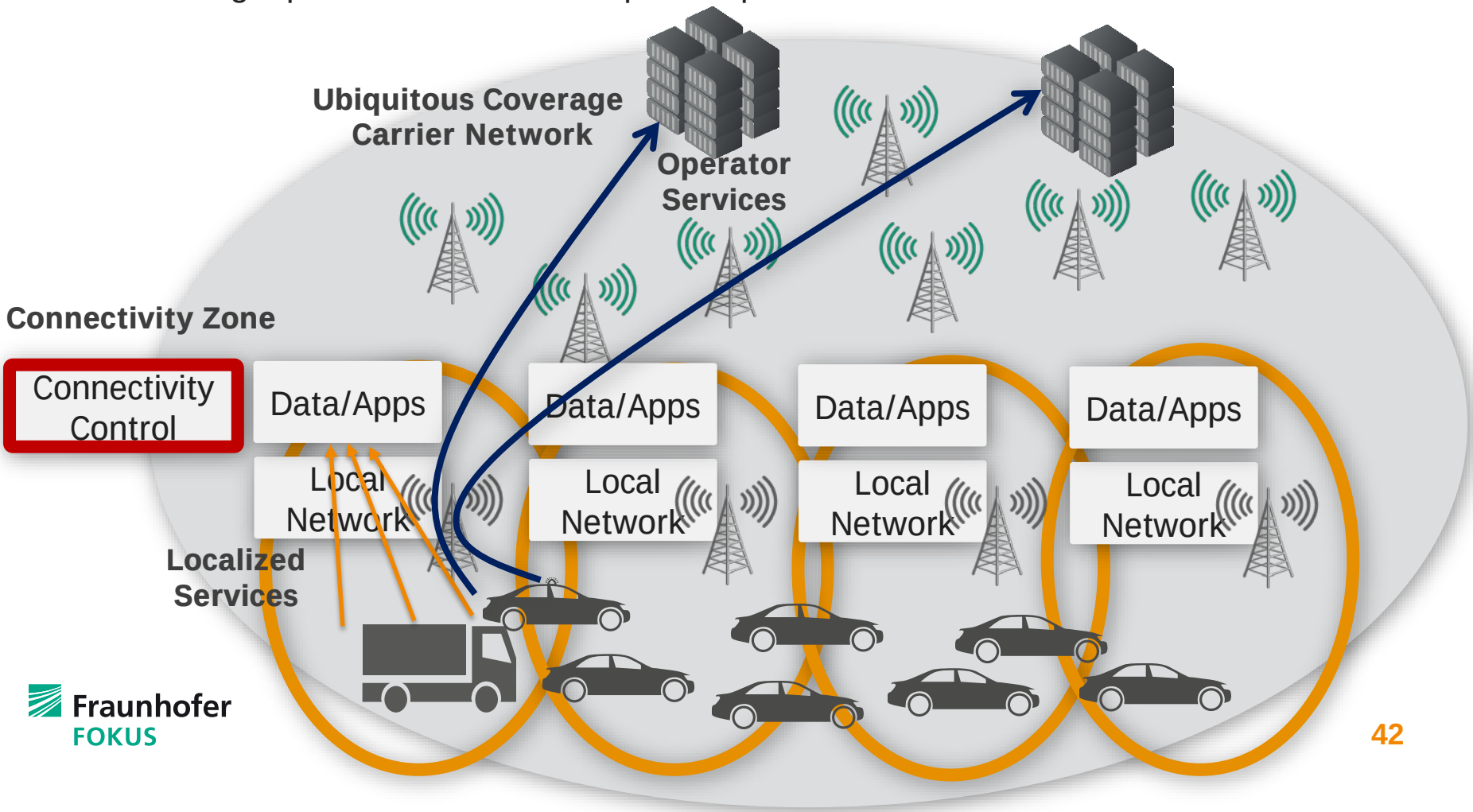
Using the same infrastructure a device can pertain to two different connectivity islands at the same time

- Specific added value applications may be deployed on top of the network focusing on immediate proximity
  - Deployment of applications which may use the proximity and the locality for their services (instead of the subscriber identity as at this moment)
  - Multiple actors may provide multiple applications in parallel (e.g. smart city infrastructure, roads administration, advertising companies in malls, emergency services and blue lights)
  - Support for specific device-to-device connectivity within the island coverage
- A continuous flow of connected devices which can pertain to different operators (e.g. roaming)
  - A very flexible admission control system is required
- Connectivity islands will have only partial coverage (e.g. car repair shop, malls, parking lots)
  - Address mainly applications which do not require ubiquitous connectivity



MEC Demo – proximity services

- Giving access to proximity services to the devices regardless of the operator providing the radio (e.g. traffic information, city information, advertising,
- Maintaining a parallel session to the public operator



Fraunhofer FOKUS

The 5G Playground @ FOKUS infrastructure

High Performance Data Center

- Cloud infrastructure providing high computing, storage and networking capacities
  - Dell Bladecenter (M620, >120 CPU cores, >640GB RAM)
  - Fully redundant NetApp Metro Cluster (>10TB Storage)
  - NVIDIA Tesla (C10, C20, K20)
  - SDN Datacenter copper/fiber switches (1/10/40Gbit/s, HP3800, Pica-8)
  - Cisco ASA Routers (redundant Internet connectivity)
  - Mostly Linux OS (Ubuntu LTS) and OpenStack (Juno & Kilo)
- Usage
  - Operational (high availability) shared cloud environment for multiple live instances of the 5G Playground
  - Computing and networking platform for experimenters
  - Toolkit and benchmark hosts
  - Update servers for remote 5G Playground instances
  - Public cloud complementing edge computing experiments

Fraunhofer FOKUS

The 5G Playground @ FOKUS infrastructure

Mini and Micro- data centers

- Orange Box: Facility edge network computing environment
  - Supports up to 20 4G small cell base stations
  - 10x Intel NUCs (Ivy Bridge D53427RKE model), i5-3427U CPU, 16GB of DDR3 RAM, 120GB SSD root disk, Gb Ethernet
  - D-Link DGS-1100-16 managed gigabit switch with 802.1q VLAN

- Lenovo M93P: Desktop core network for each researcher
  - Intel® CoreTM i5-4570T 2.9GHz 4M (4th generation), 16GB DDR3 RAM, Gigabit Ethernet, 3x USB 3.0, 1x USB 2.0
- Raspberry PI 3: The smallest core network available
  - 1.2 GHz 64-bit quad-core ARM Cortex-A53, 1GB SDRAM, 4 USB 2.0 ports, 100Mbit/s Ethernet

- Usage
  - Pool of heterogeneous edge computing environments for dedicated R&D use cases, trial experiments and showcases

Visit US!

IEEE CSCN

IEEE Conference On Standards for Communications and Networking

31 Oct – 02 Nov 2016
cscn2016.ieee-cscn.org

IEEE 5G SUMMIT

5G Prototyping – Emerging Testbeds, First Trials, and Relevant Standards

02 Nov 2016
www.5gsummit.org/berlin/

FUSECO Forum 2016
FUTURE SEAMLESS COMMUNICATION

Understanding 5G Application Drivers and Technology Evolution Towards Softwarized 5G Networks

03 Nov – 04 Nov 2016
www.fuseco-forum.org

FUSECO Forum 2016

FUTURE SEAMLESS COMMUNICATION

Fraunhofer FOKUS

7TH FOKUS FUSECO FORUM
GETTING READY FOR 5G

UNDERSTANDING 5G APPLICATION DRIVERS
AND TECHNOLOGY EVOLUTION TOWARDS
SOFTWARIZED 5G NETWORKS

NOVEMBER 3 & 4, 2016 IN BERLIN, GERMANY

WE MAKE YOU 5G READY

CALL FOR SPEAKERS AND SPONSORING

Become part of this year's event and join the Tutorials, Workshops and Conference, hands-on live demonstrations and in depth technical Discussions with Fraunhofer FOKUS, TU Berlin and fellow experts!

5G playground
Fraunhofer

For further information, technical questions, licensing and pricing requests, contact us at info@Open5GCore.net

www.5G-Playground.org