下世代Network Slicing模組設計

課程單元：網路切片技術

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- 了解網路切片的核心技術與架構
- 熟悉網路切片的研究組織發展現況
- 理解網路切片的應用需求與挑戰

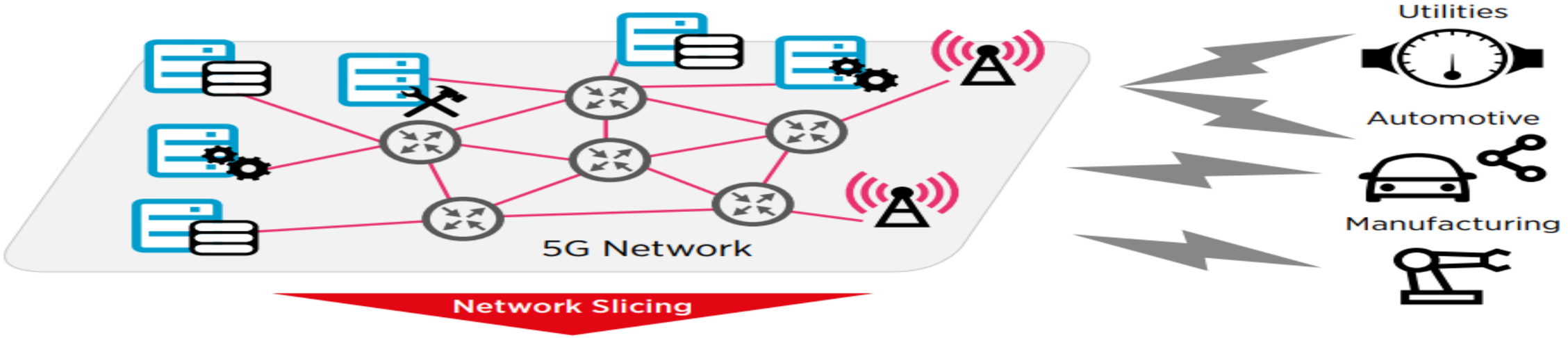
01 Introduction & History & Slicing Characteristics

Introduction

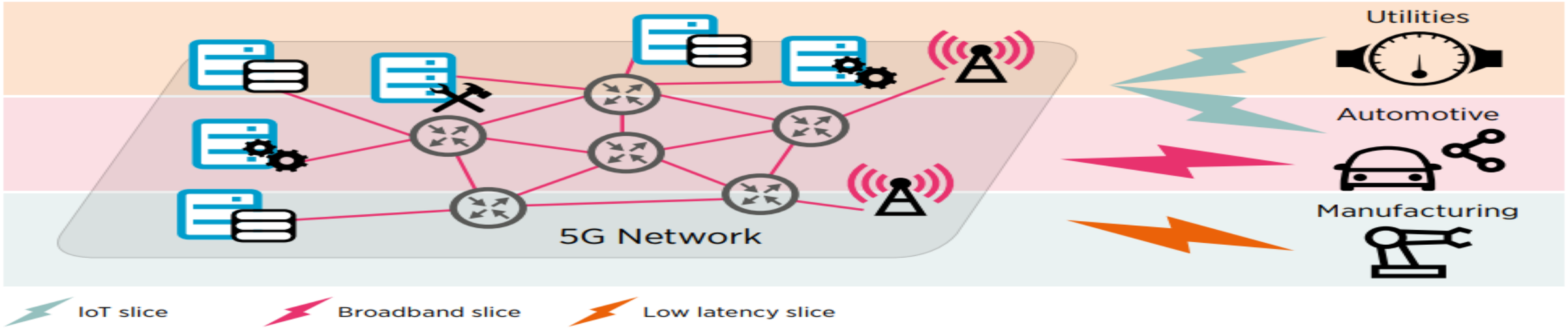
- 5G networks, in combination with network slicing, permit business customers to enjoy connectivity and data processing tailored to the specific business requirements that adhere to a Service Level Agreement (SLA) agreed with the mobile operator. The customizable network capabilities include data speed, quality, latency, reliability, security, and services.

Introduction

5G networks need to serve customers with very different needs

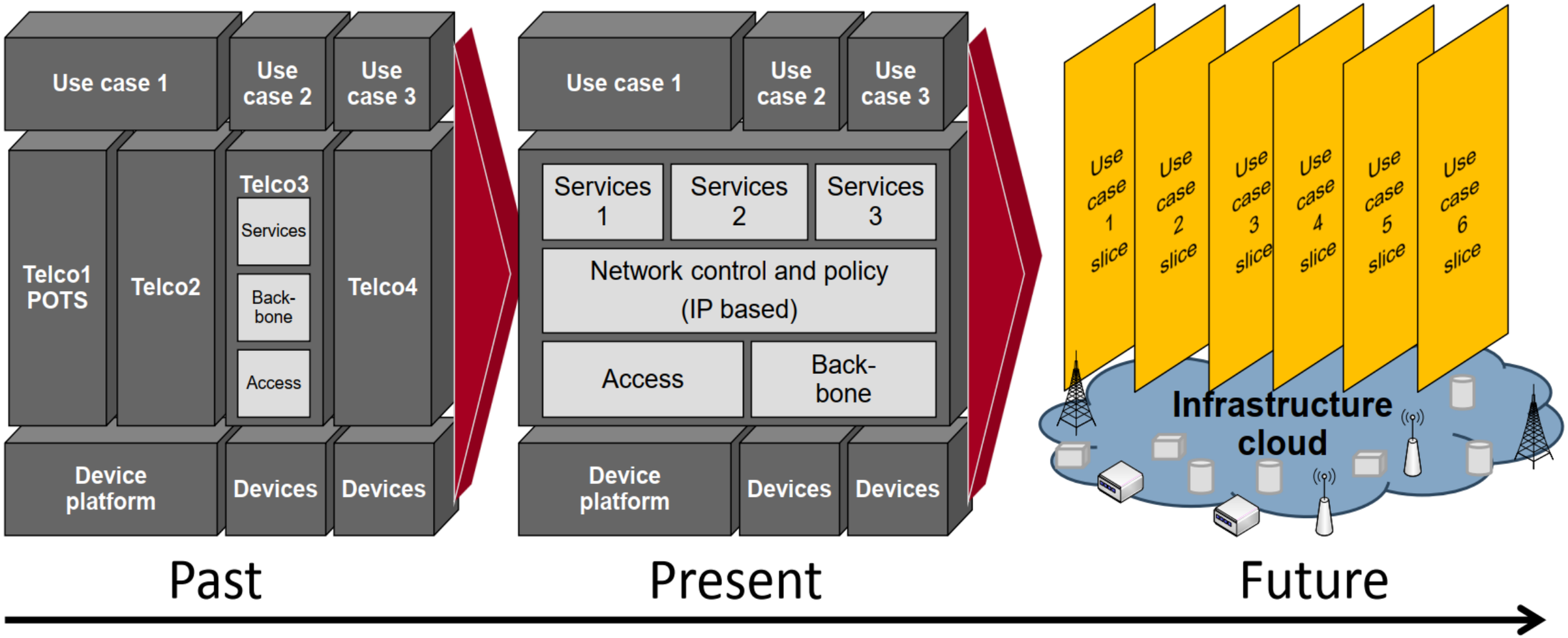


5G networks subdivided into virtual networks each optimised for one business case



Ref: An Introduction to Network Slicing - GSMA

Introduction



Ref: Network slicing in 5G - Hans J. Einsiedler

Network Slicing Blueprint

- The salient feature of network slicing is the ability to customize the capabilities and functionality that a mobile network offers to business customers. Such customized service can be logically separated into two components: **Network Connection Service** or **Network Resources Service**.

Network Connection Service (1)

- The functionality offered to business customers at a connectivity level.
- Comprise a set of technical attributes that determine the behavior of the slice, as well as the topology and geographical spread of a slice.

Network Connection Service (2)

A non-exhaustive list of characteristics that a business customer may require an operator to provide includes:

- **Near real-time latency** (end-to-end delay) for services with requirements on very low and stable latencies.
- **Stable and reliable** high upload and download speeds.
- **Guaranteed SLA**: the capability of a network slice to provide certain level of E2E assurance to the requested system functional and performance requirements with appropriate Service Level Reporting (SLR) method.
- **Coverage to ensure** seamless service experience across networks and country boundaries.
- **Connected device management** (of an agreed number), from only a few devices, up to extreme high density of devices/connections also including very specific Device to Device (D2D) connectivity and/or hardware requirements.

Network Connection Service (3)

- **Seamless mobility** for uninterrupted service delivery and stable quality in scenarios with medium to high velocity (e.g. high-speed train, aviation), across heterogeneous (licensed and unlicensed – e.g. 5G and WiFi) networks that may also belong to multiple different service providers.
- **Energy efficiency** could be provided in the case where ultra-low energy utilization is required (e.g. NB-IoT scenarios) on the network side, as well as on the device terminal side (e.g. very long battery life).
- **Data security** to satisfy security & privacy requirements beyond today ‘s capabilities and also for extremely sensitive data transmission (e.g. National security, fraud/cyber crime sensitive).

Network Resource Service (4)

- Business customers may be granted access to the operator network resources for running proprietary applications.
- The operator will commit to provide a lifecycle management service,
- To offer additional platform services as follows:
  - Big Data analytics could be offered as a service to support the data management for orchestration of complex processes or ecosystems.
  - ID / Asset management for secured, real-time, automated authentication of (and between) assets/ devices/users including ID management as a service.
  - Platform security as a service to provide various levels of security in order to satisfy data security & privacy requirements beyond today's capabilities.
  - Dynamic charging of real-time interactions, based on adaptive customer/market demands.

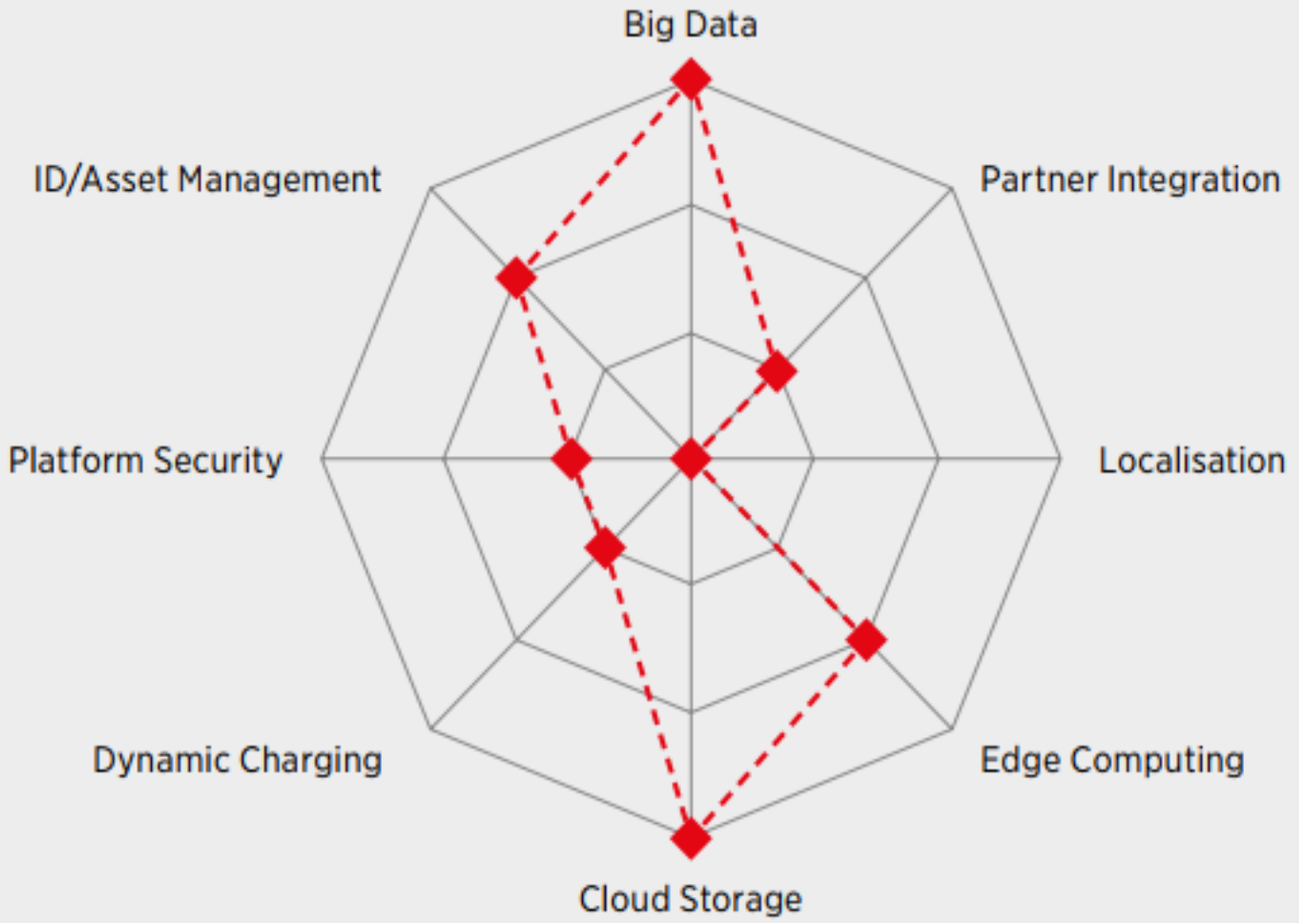
Network Resource Service (5)

- **Cloud computing**, that is ubiquitous access to operator’ s resources such as storage and computing power.
- **Edge computing** for distributed computing and data storage for services with low latency requirements to enable ultra-fast interactions/responsiveness.
- **Partner integration** for easy and instant integration of partners, new entities etc.
- **Positioning** as a service which is tailored to the requirements of the service, e.g. in terms of accuracy and frequency.
- **API**s providing different control and management capabilities to a vertical, e.g. to adapt the geographical spread of a slice, as well as the provisioning of various types of information from different sources, e.g. perceived service quality, current network conditions, etc. could be provided via the API.

Network resource Services (6)

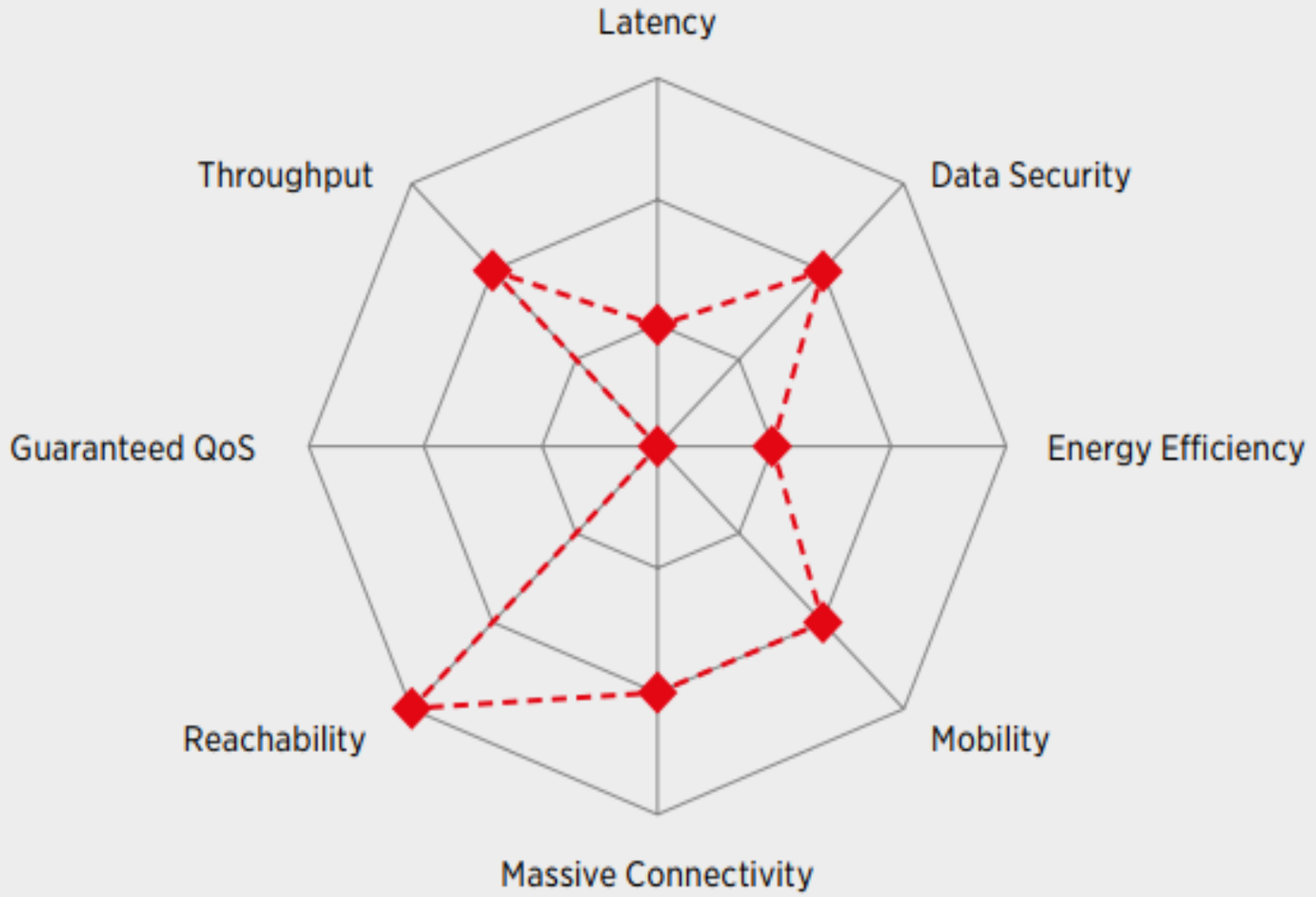
Network Services

- Big Data
- Partner Integration
- Localisation
- Edge Computing
- Cloud Storage
- Dynamic Charging
- Platform Security
- ID Management



Ref: Network slicing in 5G - Hans J. Einsiedler

Network Capability



Network Capability

- Latency
- Data Security
- Energy Efficiency
- Mobility
- Massive Connectivity
- Reachability
- Guaranteed QoS
- Throughput

Ref: Network slicing in 5G - Hans J. Einsiedler

Slicing Key Characteristics

- **A managed group of infrastructure resources, network functions and services** (e.g. Service Instance component, A Network Slice Instance component, Resources component , Slice Capability exposure component).
- Concurrent deployment of **multiple logical, self-contained and independent, shared or partitioned networks on a common infrastructure platform**.
- A **dedicated network** part that is built on an infrastructure mainly composed of, but not limited to, connectivity, storage, and computing.
- A**n operator** that sees it as a complete network infrastructure and uses part of the network resources to meet stringent resource requirements.
- Support **dynamic multi-service support, many/multi-tenancy** and the integration means for vertical market players.
- **NS is programmable and has the ability to expose its capabilities**. The behavior of the network slice realized via network slice instance(s).
- **Service customized Network Slices (enabled by NFV) + Smart Network Fabric for coordinating/orchestration, control of network resource**.
- **Guarantee service level for end to end across multiple (administrative) domains**.
- **Flexible customizability** - automation as the way for simplifying the provisioning

Slicing Key Characteristics

- **NS has dynamic and non-disruptive re-provisioning.**
- **Automation of network operation.**
- **Automated life-cycle management of network slicing (Deploy, Change, Delete)**
  - Optimization resources (Auto-scaling/migration)
  - Auto-healing
  - Efficient Interplay between Management and Data Planes
- **High-Scalability**
  - Separating to 100~ slices (the order will vary depending on the use cases)
  - Handling million ordered customers
- **High-Reliability**
  - Redundant mechanisms
  - High Level of Isolation
  - Immediate fault detection
- **Network Slicing with cross-domain by using open network configuration model design**
- **Cost effective and prompt service/network deployment**
  - Utilization of virtualizing technologies (SDN and NFV)
  - Harmonizing hardware and software appliances

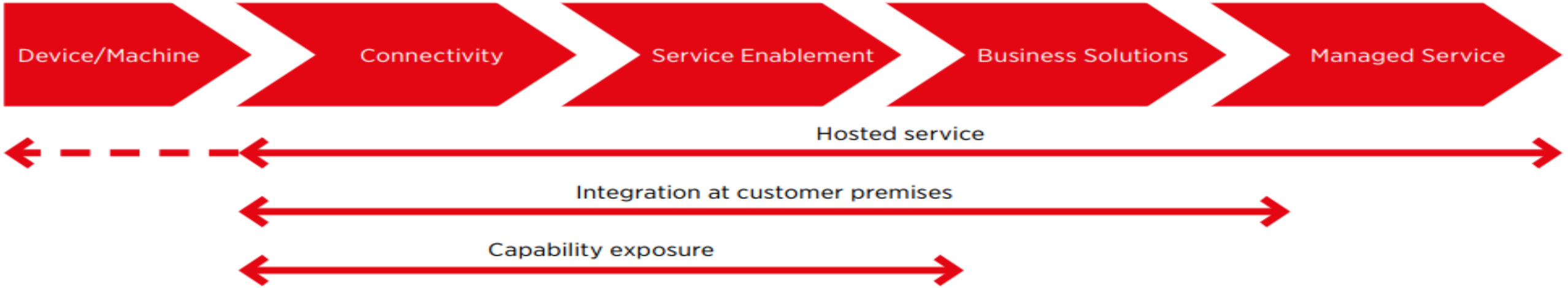
Slicing Key Characteristics

- **Network operators/ ISP can exploit network slicing** for
  - Enable other industrial companies to use networks as a part of their own services (e.g. vertical players: connected car with high reliable network, online game with ultra-low latency, video streaming with guaranteed bandwidth, etc.)
  - Reduce significantly operations expenditures, allowing also programmability necessary to enrich the offered tailored services.
  - mean for network programmability to OTT providers and other market players without changing the physical infrastructure.
- **NS** simplifies the provisioning of services, manageability of networks and integration and operational challenges especially for supporting communication services.
- **Expecting realization of E2E network slices and creation of new business model**
- **Introduce an additional layer of abstraction** by the creation of logically or physically isolated groups of network resources and (virtual) network functions configurations.
- **Considerably transform the networking perspective** by
  - abstracting, isolating, orchestrating and separating logical network behaviors from the underlying physical network resources.

Slices Usage Scenarios

- Mission-critical Ultra low latency communication
- Massive-connectivity machine communication (e.g. Smart metering, Smart grid and sensor networks)
- Extreme QoS
- Independent QoS isolation design
- Independent operations and management
- Independent autonomic management functionality
- Independent cost and/or energy optimization
- Independent multi-topology routing
- Sharing Infrastructure: Enablers for sharing infrastructure safely and efficiently (Multi-tenant)

Network Slicing Value Chain

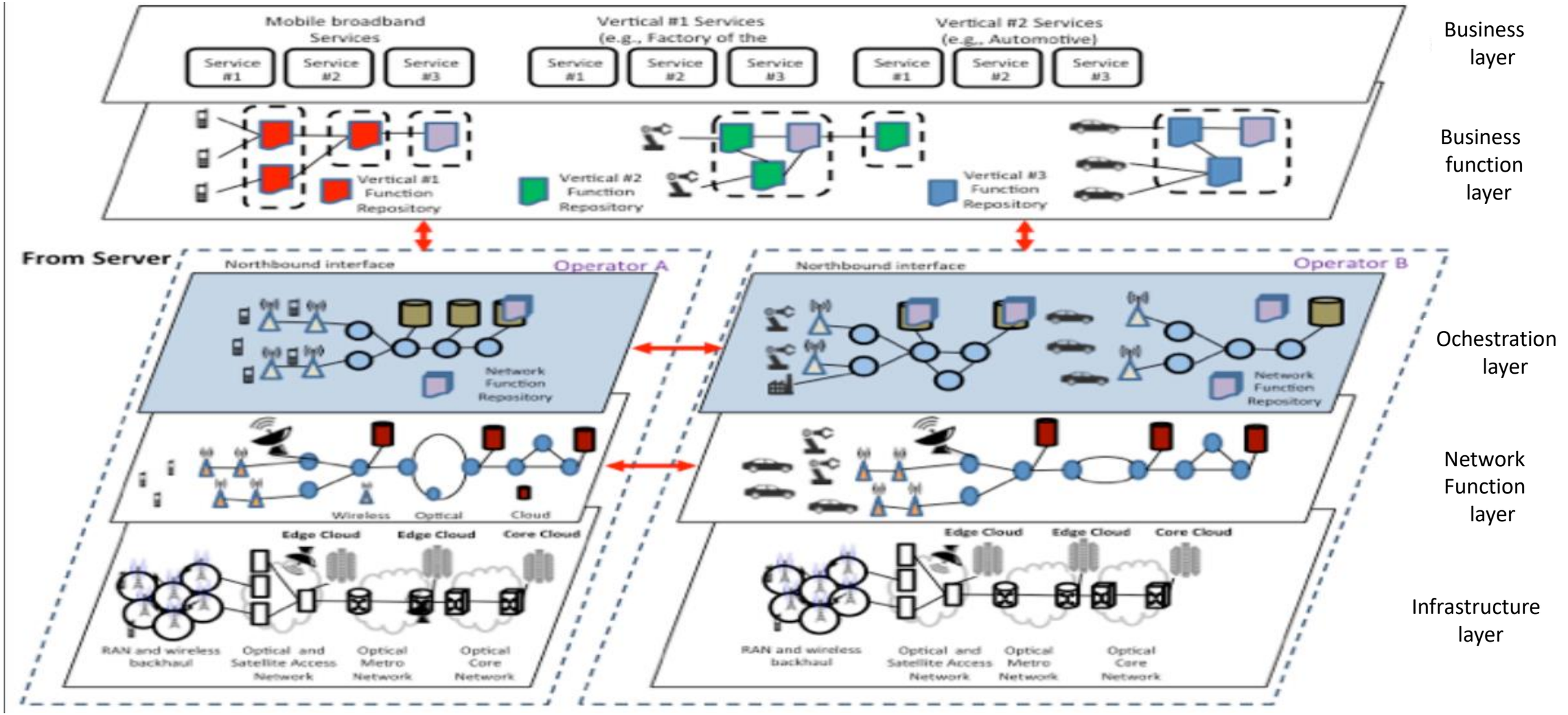


- **Capability exposure**: through this utilization model, the providers can offer Application Programming Interfaces (APIs) to the vertical business customers for granting the capability of managing their own slices. Such management actions can include e.g. dimensioning, configuration, etc.
- **Integration at customer premises**: complementary network segments, in some cases pertaining to the vertical business customer, become an integral part of the solution, requiring a truly convergent network including the integration in existing business processes as defined by the vertical customer.
- **Hosting applications**: the provider offer the capability of hosting virtualized versions of network functions or applications, including the activation of the necessary monitoring information for those functions.
- **Hosting on-demand 3rd parties / OTTs**: empower partners (3rd parties / OTTs) to directly make offers to the end customers augmenting operator network or other value creation capabilities.

Ref: Network slicing in 5G - Hans J. Einsiedler

02 Key Slicing Concepts

5G Networking Infrastructure Ecosystem



Ref: Network Slicing A holistic architectural approach, orchestration and management with applicability in mobile and fixed networks and clouds – prof. Alex Galis

Roles

- **Infrastructure Owner** Owns the physical infrastructure (network/cloud/data centre) and lease them to operators. It becomes an ISP and leases the infrastructure in network slicing fashion.
- **Infrastructure Slice Provider** – An infrastructure slice provider (ISP), typically a telecommunication service provider, is the owner or tenant of the infrastructures from which network slices can be created.
- **Infrastructure Slice Tenant** – An infrastructure slice tenant (IST) is the user of specific network/cloud/data center slice, in which customized services are hosted. Infrastructure slice tenants can make requests of the creation of new infrastructure slice through a service model.

Concepts

- **Infrastructure Slice -** A set of infrastructure (network, cloud, data centre) components/network functions, infrastructure resources (i.e. managed connectivity, compute, storage resources) and service functions that has attributes specifically designed to meet the needs of an industry vertical or a service.
- **Infrastructure Slicing** - A management mechanism that Infrastructure Slice Provider can use to allocate dedicated infrastructure resources and service functions to Network Slice Tenant.
- **Partition Types**
  - Physical separation (e.g., dedicated backbones) → not cost efficient
  - A resource only partition is one of the components of a Network Slice, however on its own does not fully represent a Network Slice.
  - Underlays / overlays supporting all services equally (“best effort” support) are not fully representing a Network Slice.
  - Underlays / overlays, in the form of VPN as overlay solution → not flexible nor agile
  - Slicing, through network resource (including SF) allocation → dedicated resources per customer / service to ensure isolation on top of the same infrastructure

Concepts

A Network Slice is a managed group of subsets of resources, network functions / network virtual functions at the data, control, management / orchestration, and service planes at any given time. The behavior of the network slice is realized via network slice instances (i.e. activated network slices, dynamically and non-disruptively re-provisioned).

- A network slice is programmable and has the ability to expose its capabilities.
- An end-to-end logical network/cloud running on a common underlying (physical or virtual) infrastructure, mutually isolated, with independent control and management that can be created on demand.

Concepts

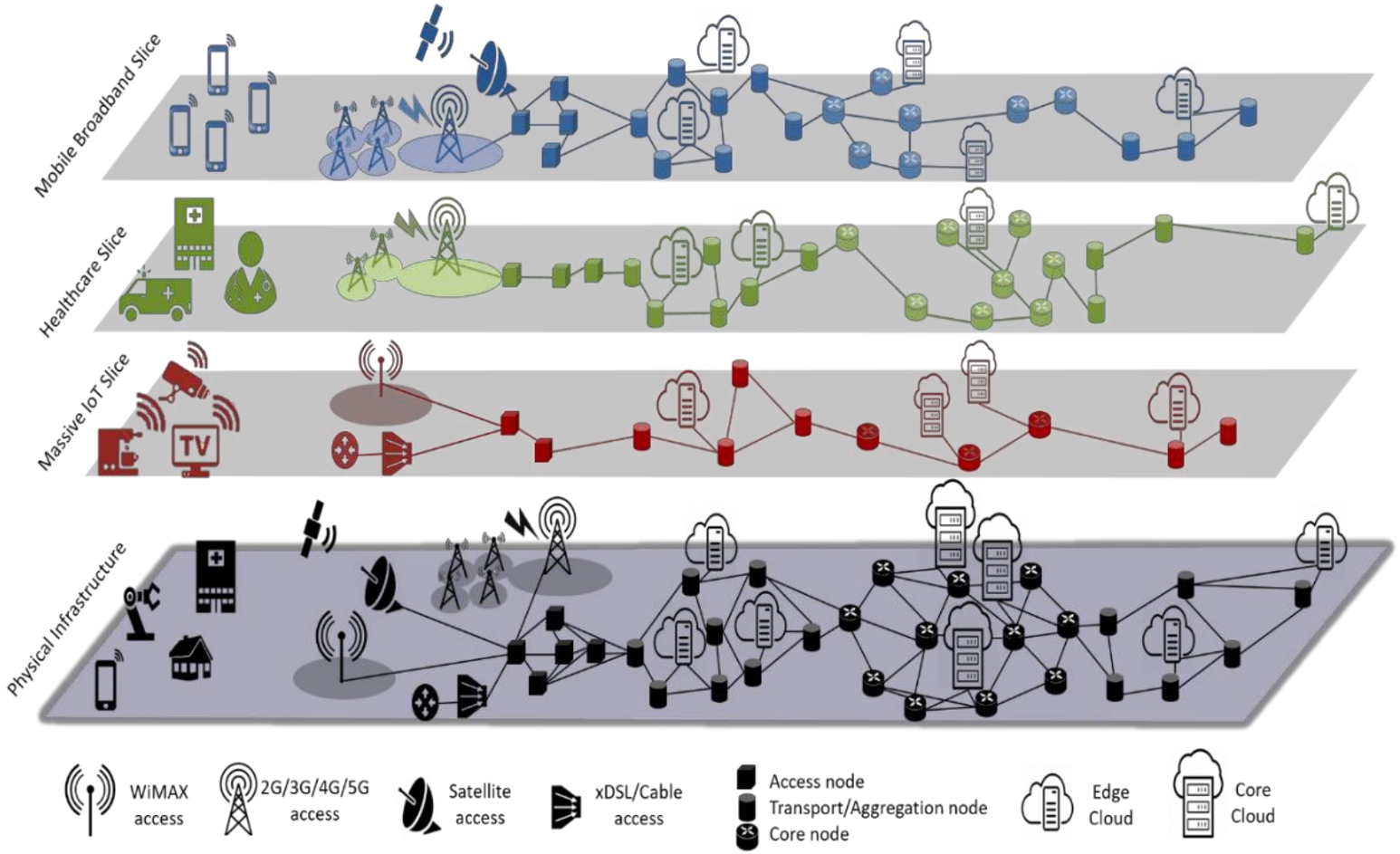
- From **a business point of view, a slice** includes *a combination of all the relevant network resources, functions, and assets required to fulfill a specific business case or service, including OSS, BSS and DevOps processes.*
- From the **infrastructure point of view, infrastructure slice instances** require *the partitioning and assignment of a set of resources that can be used in an isolated, disjunctive or non-disjunctive manner for that slice.*
- From the **tenant point of view, infrastructure slice instance provides** different capabilities, specifically in terms of their management and control capabilities, and how much of them the network service provider hands over to the slice tenant. Two types of slices:
  - **Internal slices**, *internal services of the provider, retaining full control and management of them.*
  - **External slices**, *hosting customer services, appearing to the customer as dedicated networks/clouds/data centres.*
- From the **management plane point of view, infrastructure slices** refers to the managed fully functional *dynamically created partitions of physical and/or virtual network resources, network physical/virtual and service functions that can act as an independent instance of a connectivity network and/or as a network cloud.*
- From the **date plane point of view, infrastructure slices** refers to *dynamically created partitions of network forwarding devices with guarantees for isolation and security.*

Concepts

Novel solutions in search of flexibility, agility, cost efficiency Network Slicing Services & Vertical industries may bring diverging use cases and application scenarios.

Network slice are:

- Self-contained
- Mutually isolated
- Manageable & Programmable
- Support for multi-service
- Support for multi-tenancy



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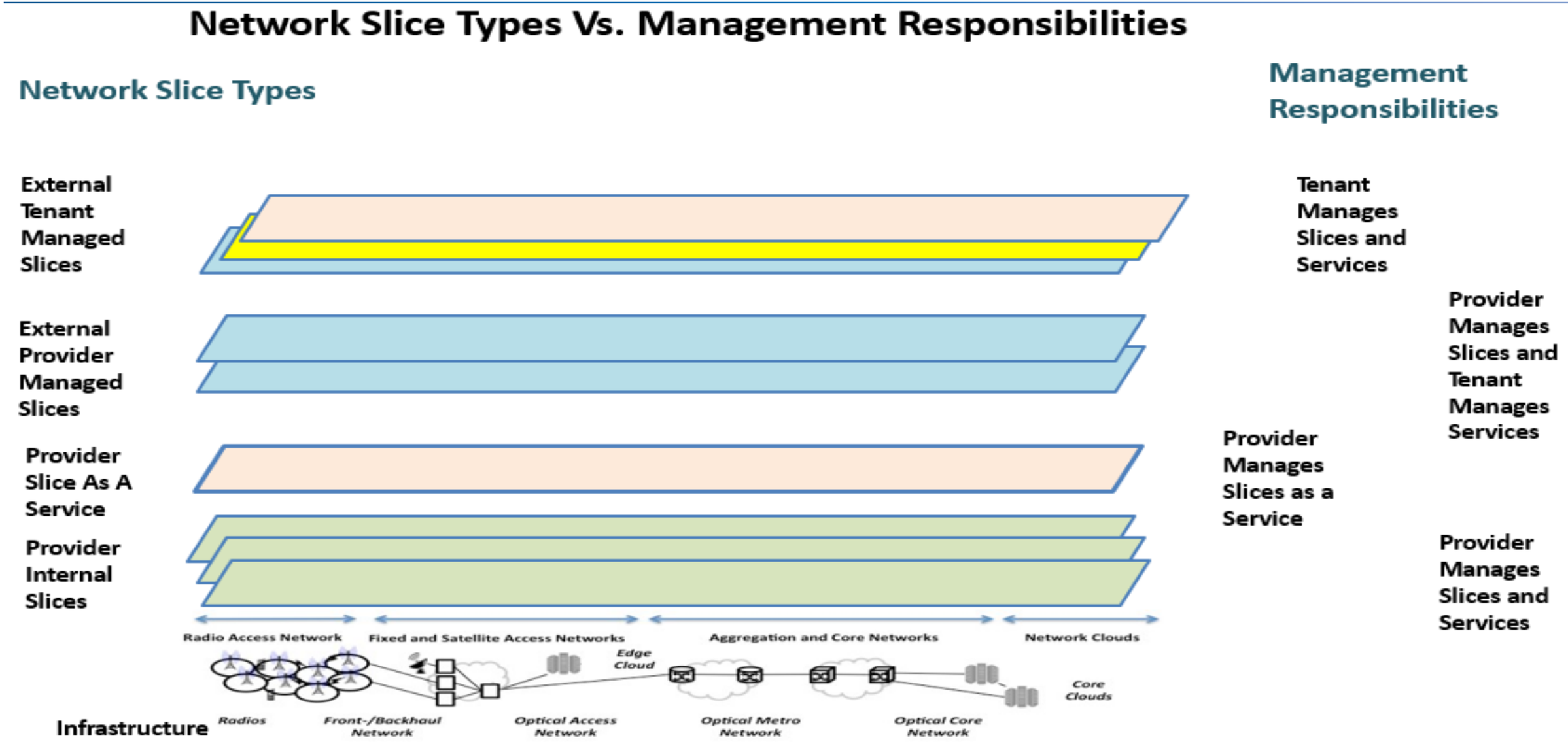
Concepts



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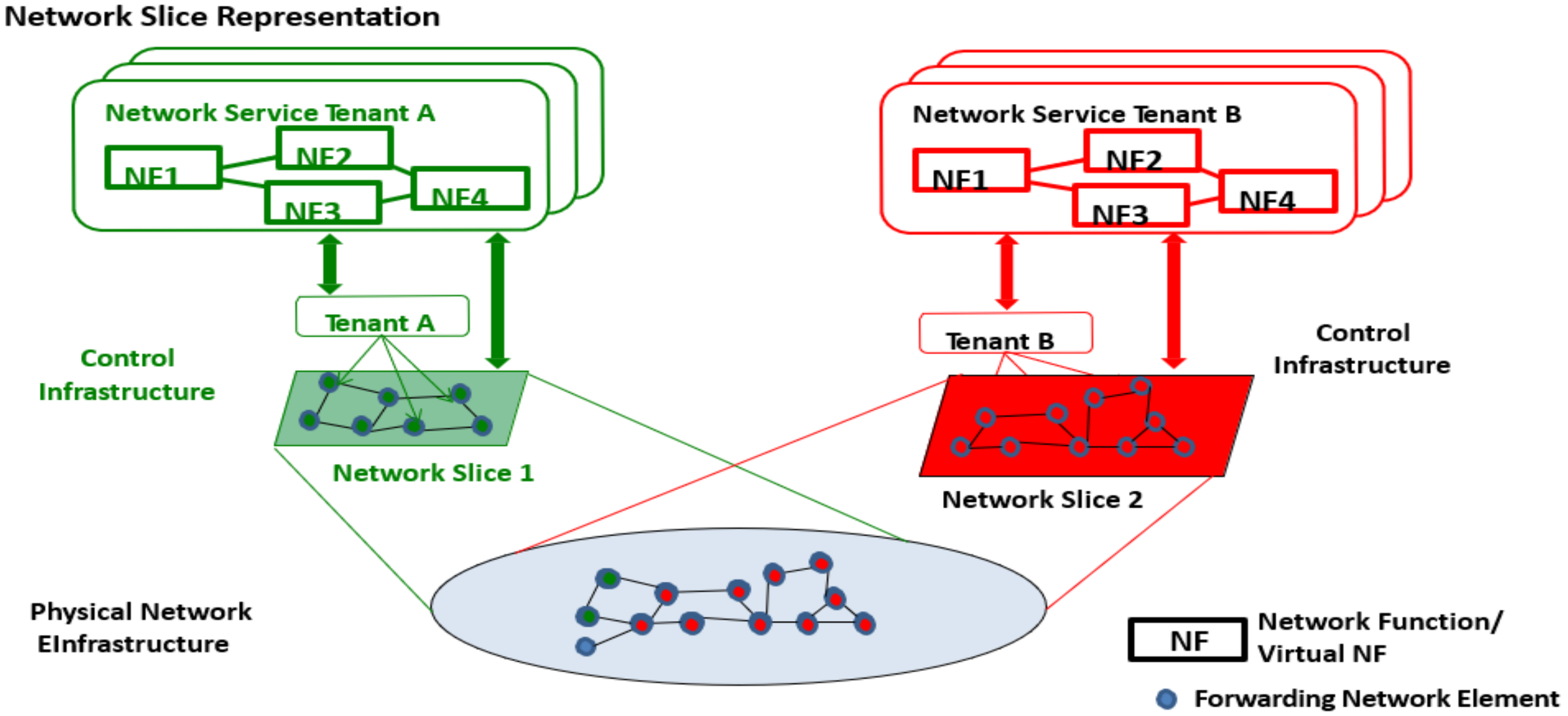
Concepts



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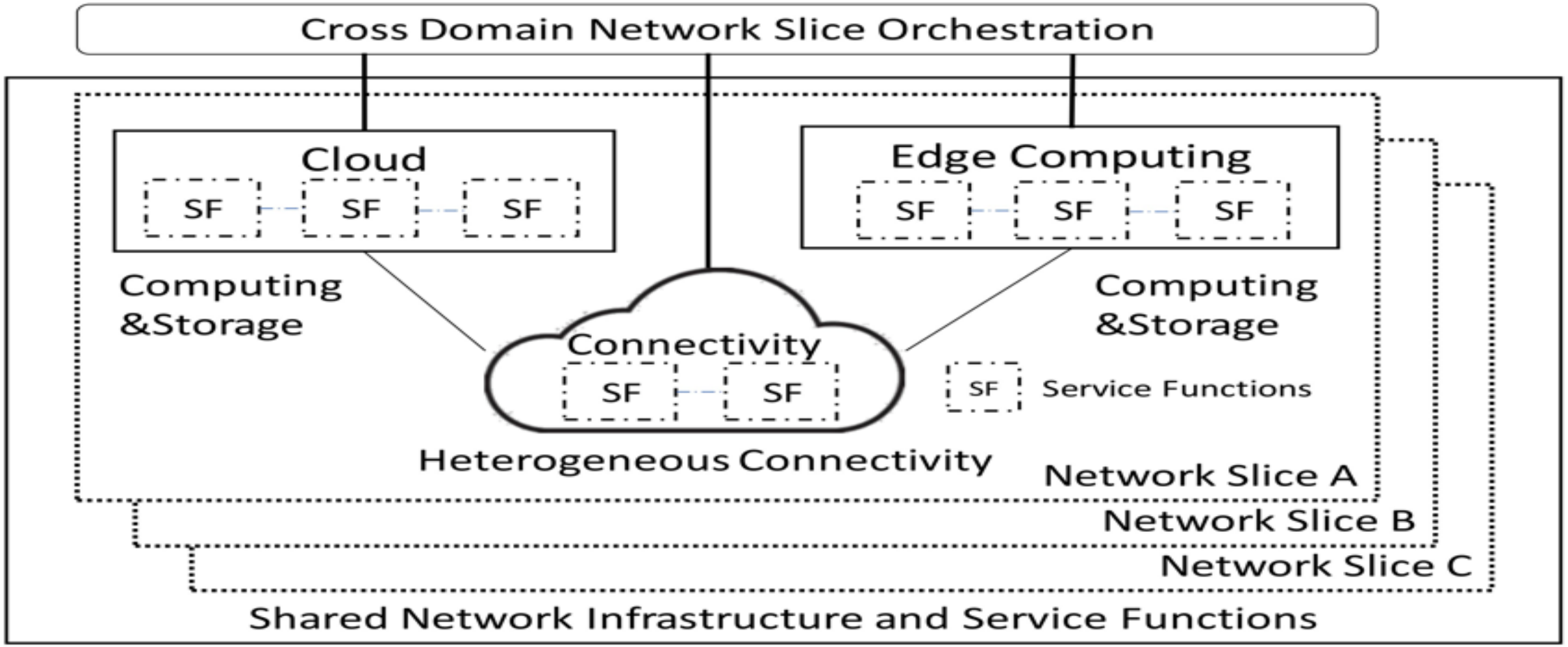
Concepts

Cross-domain management of network slices in network infrastructure and service functions



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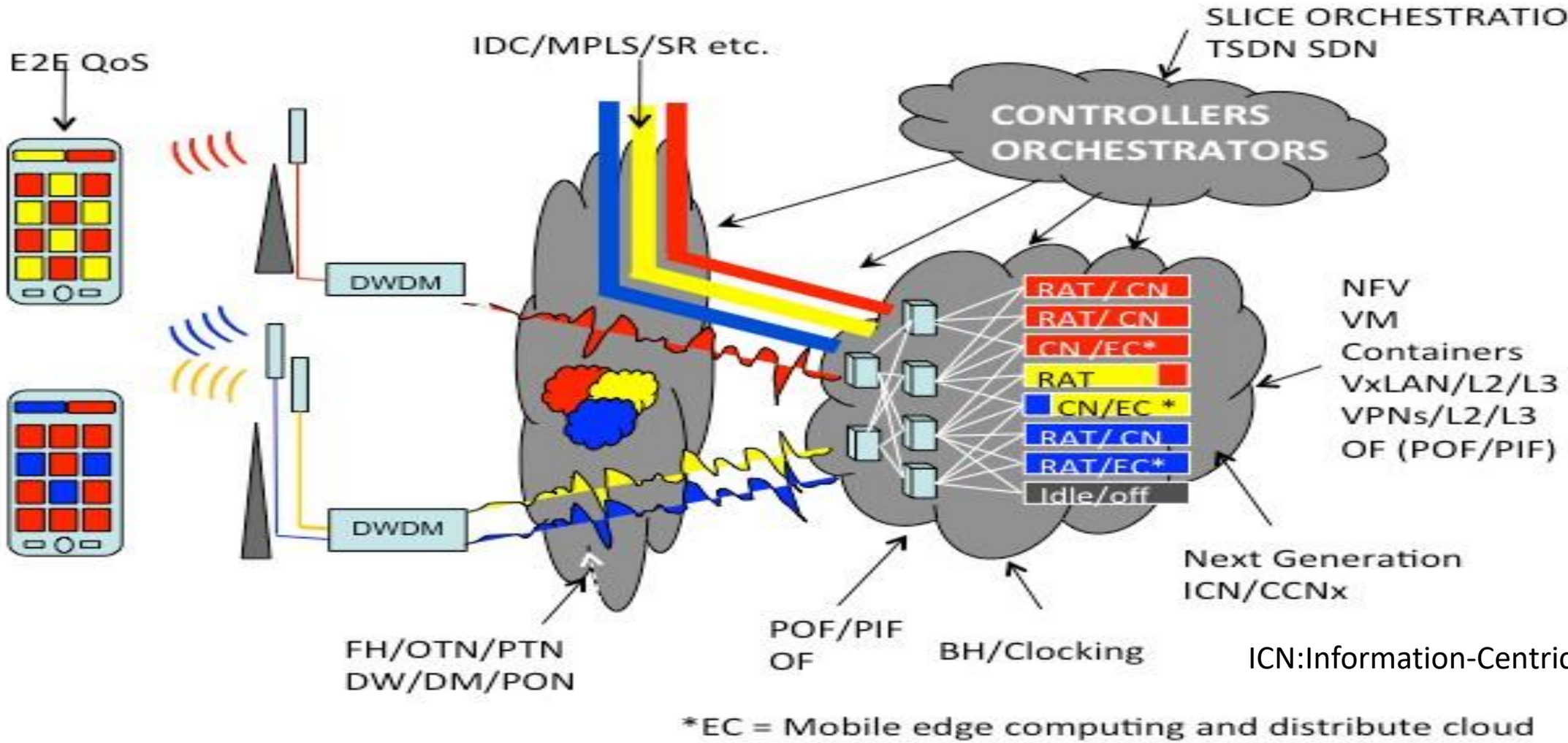
C-RAN Virtualization & Slicing under Software Control



ICN:Information-Centric Networking

Ref: Report of Gap Analysis – Focus group on IMT-2020– Nov 15 T13-SG13-151130-TD-PLEN-0208!!MSW-E.docx

POF:Protocol Oblivious Forwarding
PIF : Probabilistic Interest Forwarding

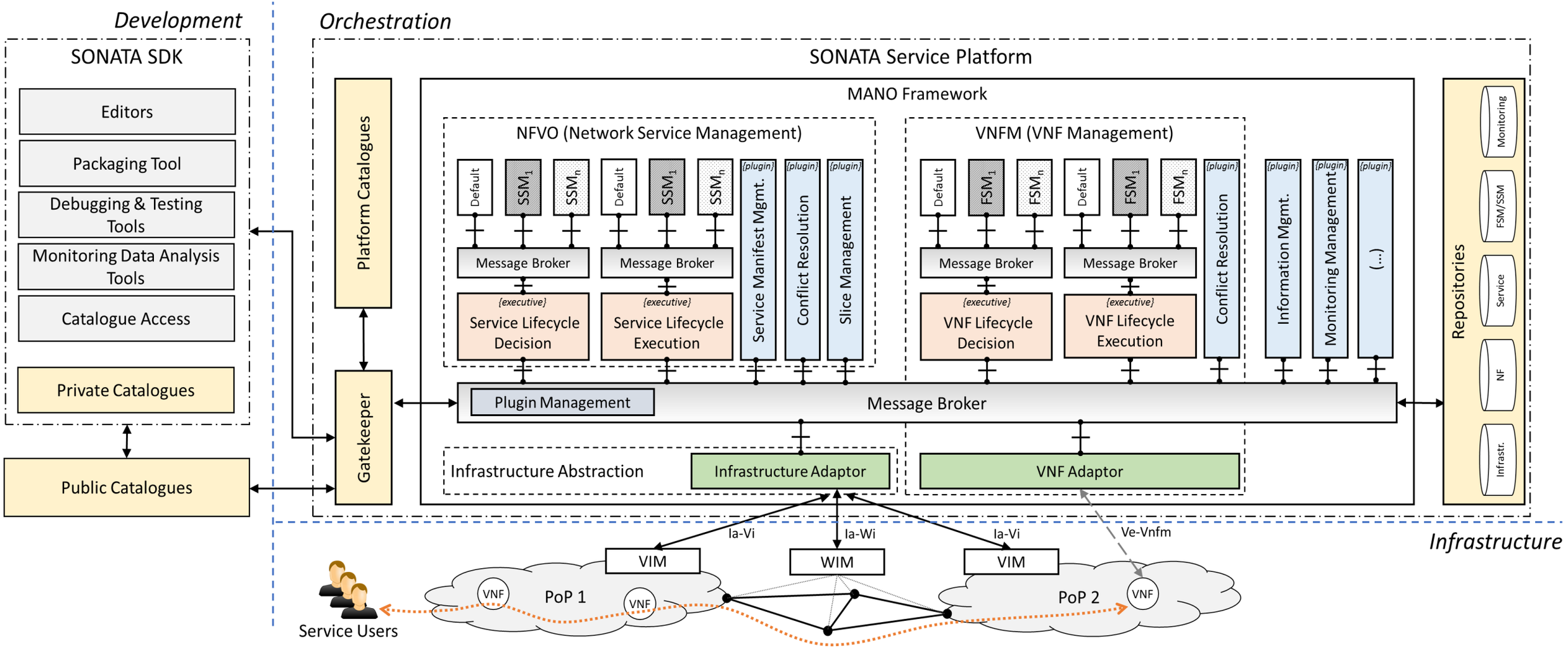
03 Review of Research Projects in Slicing

Review of Research projects and results in network and cloud slicing

- **EU Projects:**
  - SONATA
  - 5GEX
  - NECOS
  - 5G TRANSFORMER
  - 5G PAGODA
  - 5G NORMA
  - 5G SLICENET

5G SONATA– H2020 Project

Agile Service Development and Orchestration in 5G Virtualized Networks



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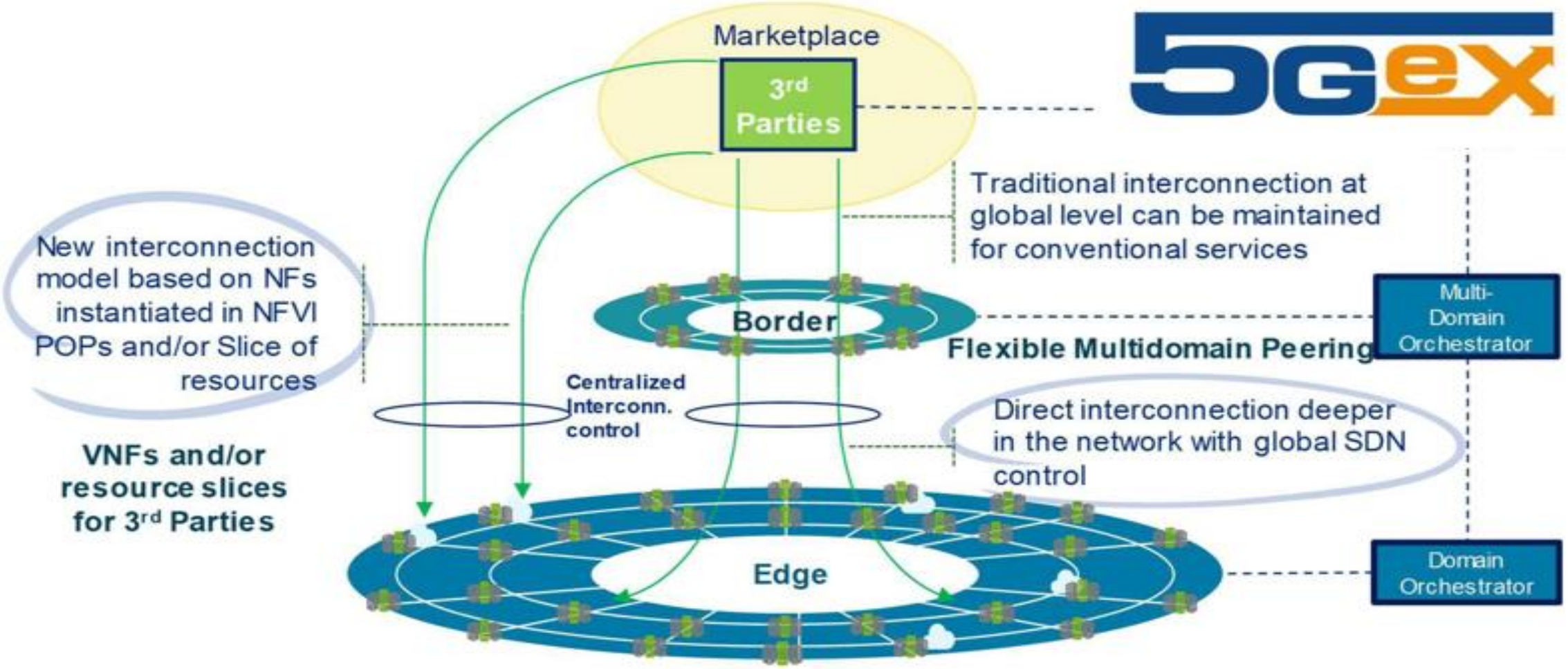
5GEx– H2020 Project

Multi-Domain Network Service Orchestration



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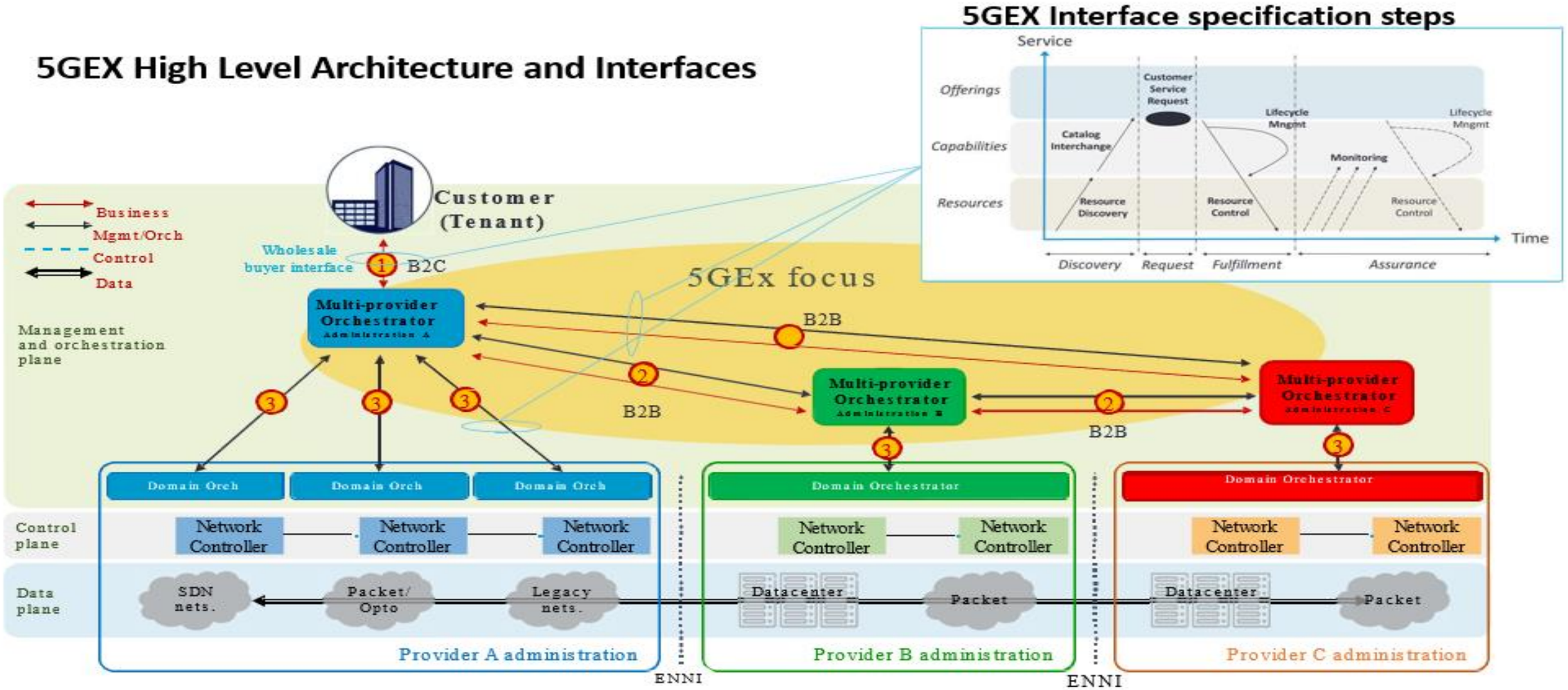
https://www.youtube.com/watch?v=i9DfGoOzqJo

5GEx– H2020 Project

Multi-Domain Network Service Orchestration



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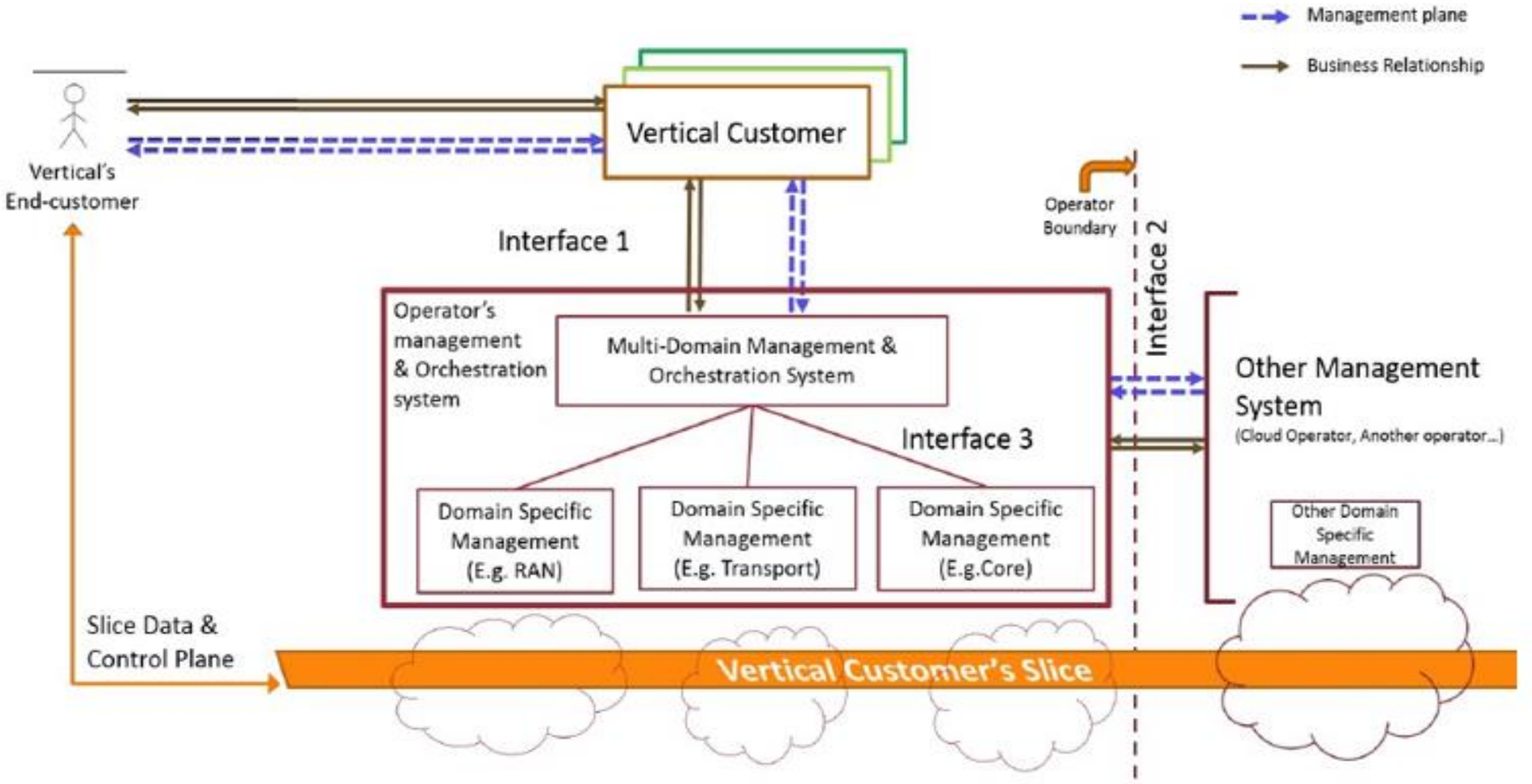
5GEx– H2020 Project

Multi-Domain Network Service Orchestration



MdO - Multi-domain Orchestrator -

I1 - MdO exposes service specification APIs (Customer-to-Business, C2B) allowing business customers/Tenants to specify their requirements for a given service.

I2- MdO interacts with peer MdOs.

I3- APIs to orchestrate resources and services within the same administrative domains

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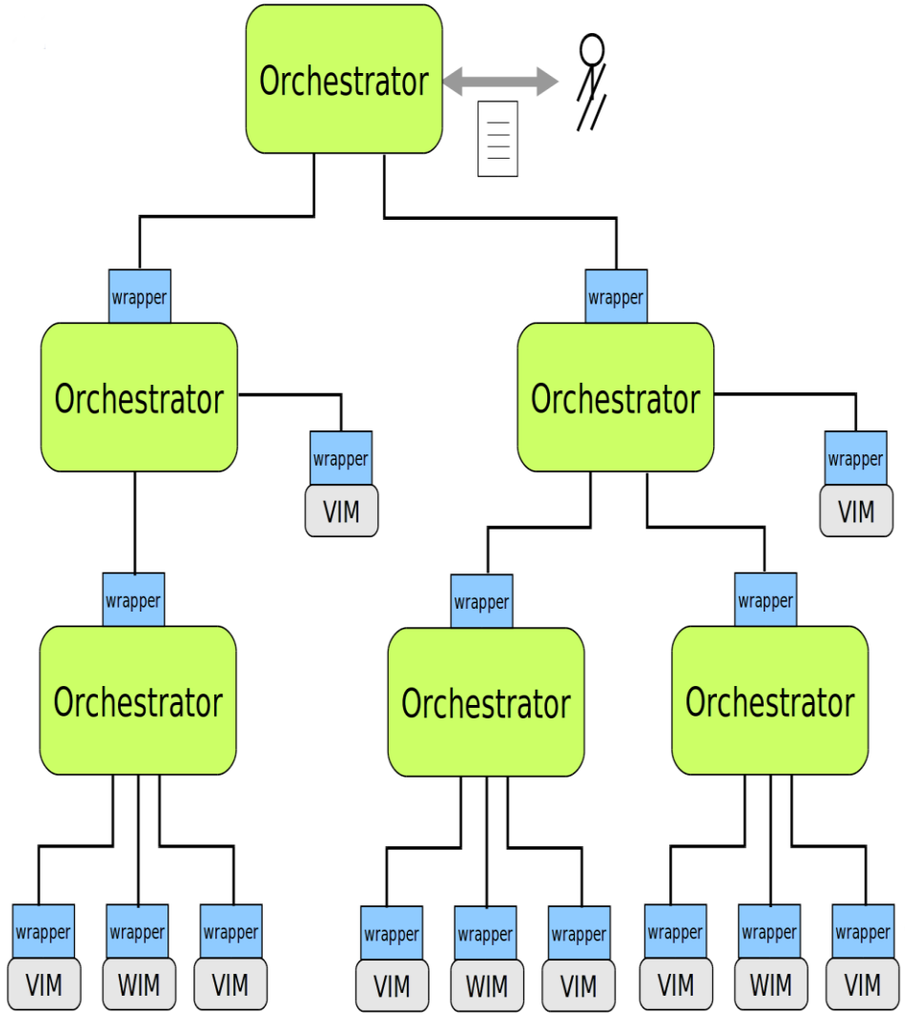
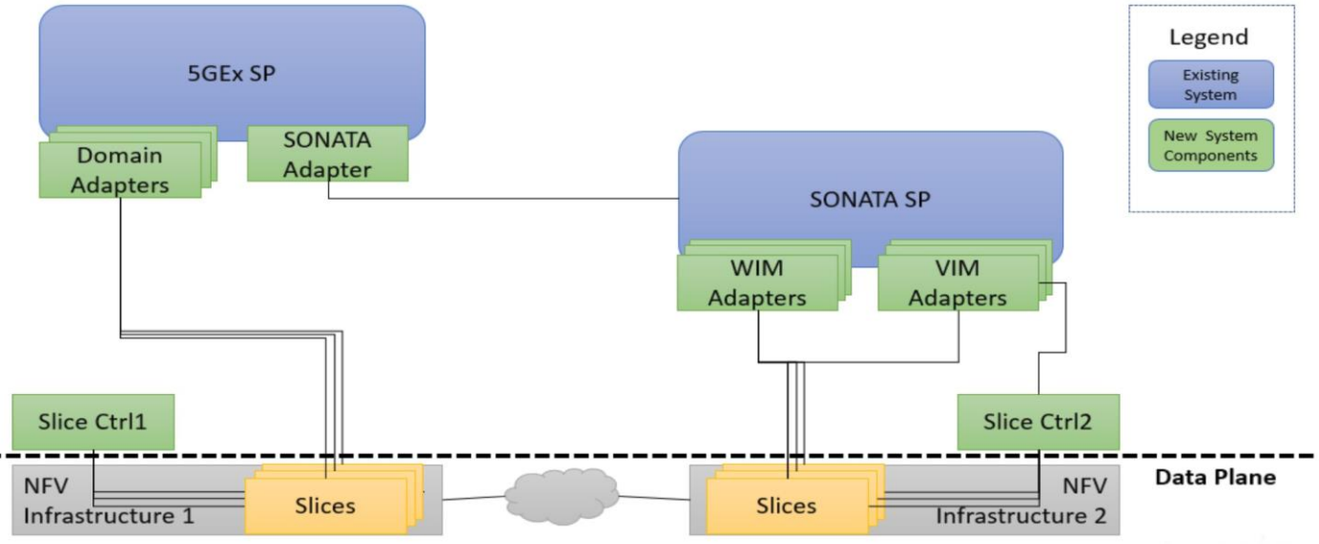
5GEX & SONATA– H2020 Projects

Hierarchical Service Provider & Multi- Mano Interaction



Hierarchical Service Provider & Multi-Mano Interaction

– UCL developed Open Source Solutions



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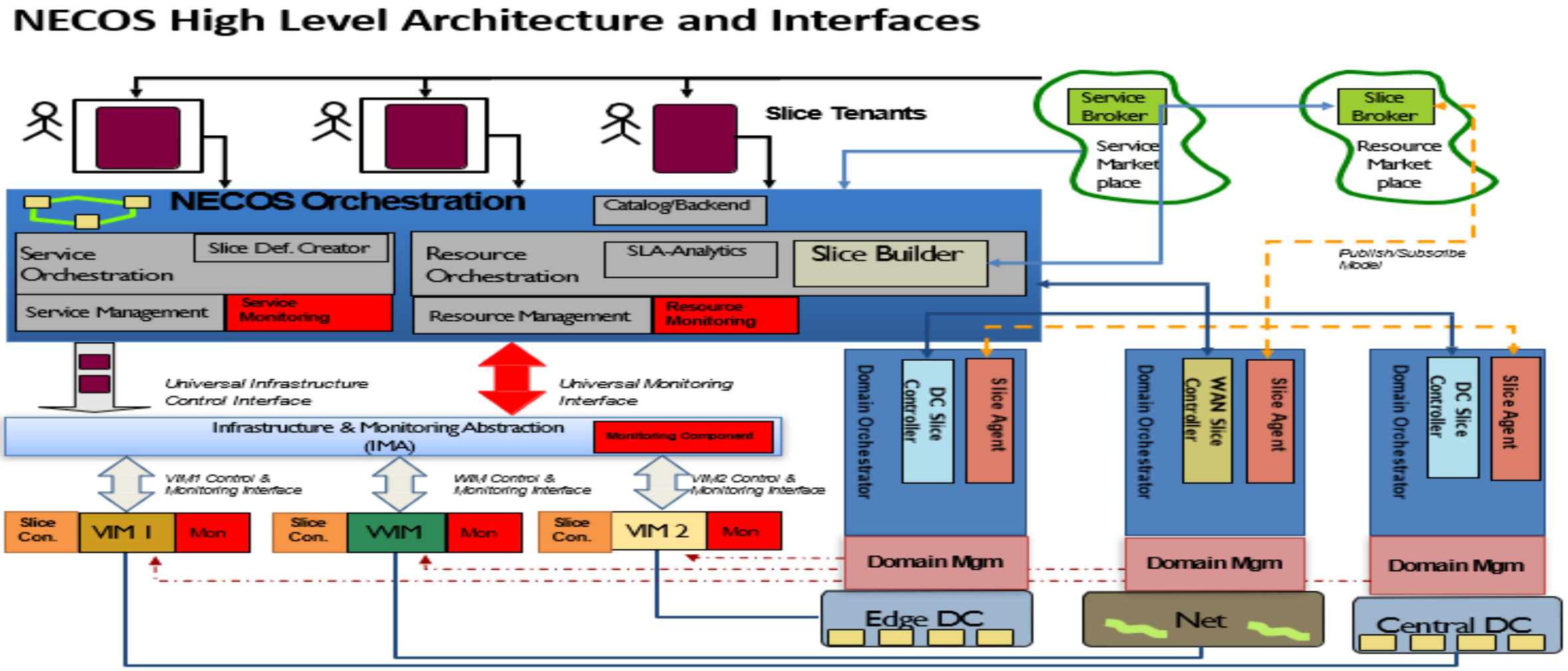
NECOS– H2020 Project

https://www.youtube.com/watch?v=TbnRtUfWGm0

Novel Enablers for Cloud Slicing



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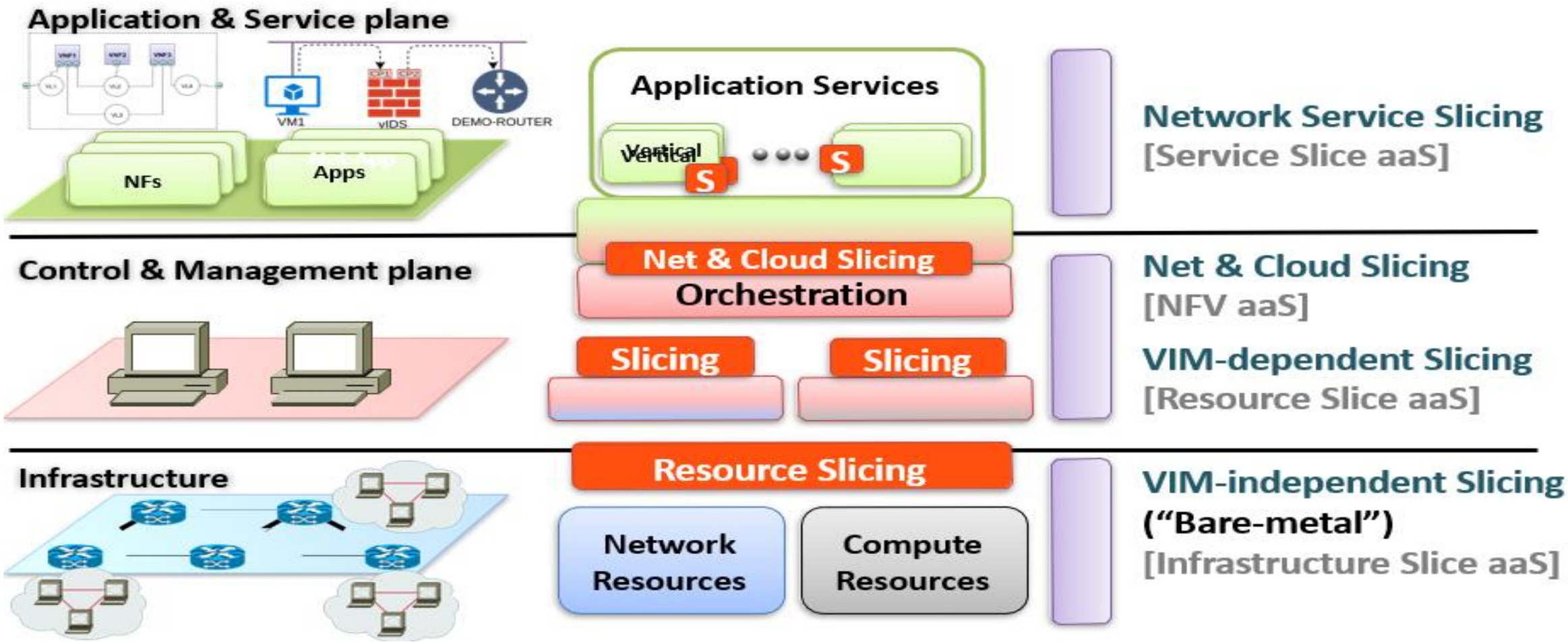
Novel Enablers for Cloud Slicing

Slicing Models



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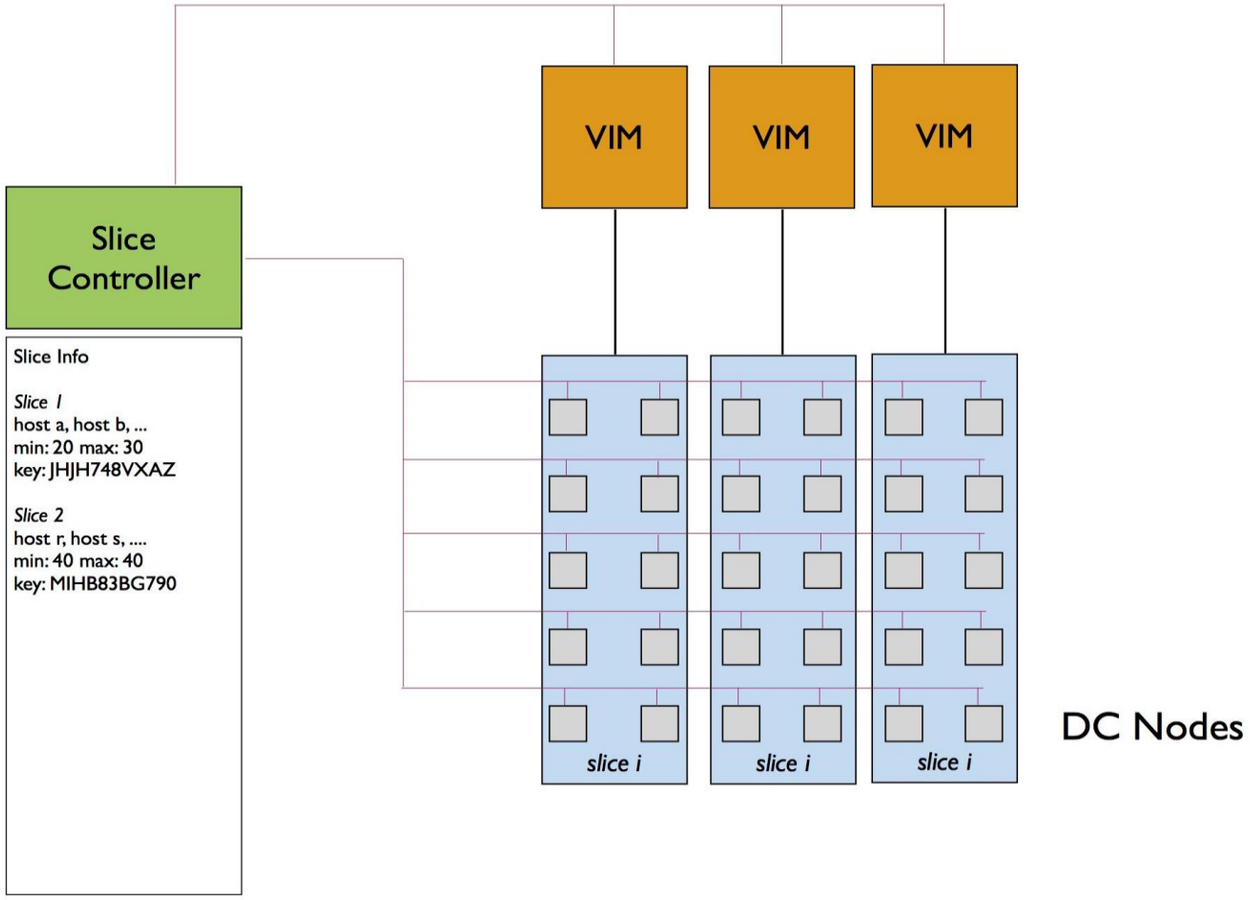
NECOS– H2020 Project

Novel Enablers for Cloud Slicing



NECOS Cloud Slicing Realization

– NFVi slicing with VIM on demand (UCL)

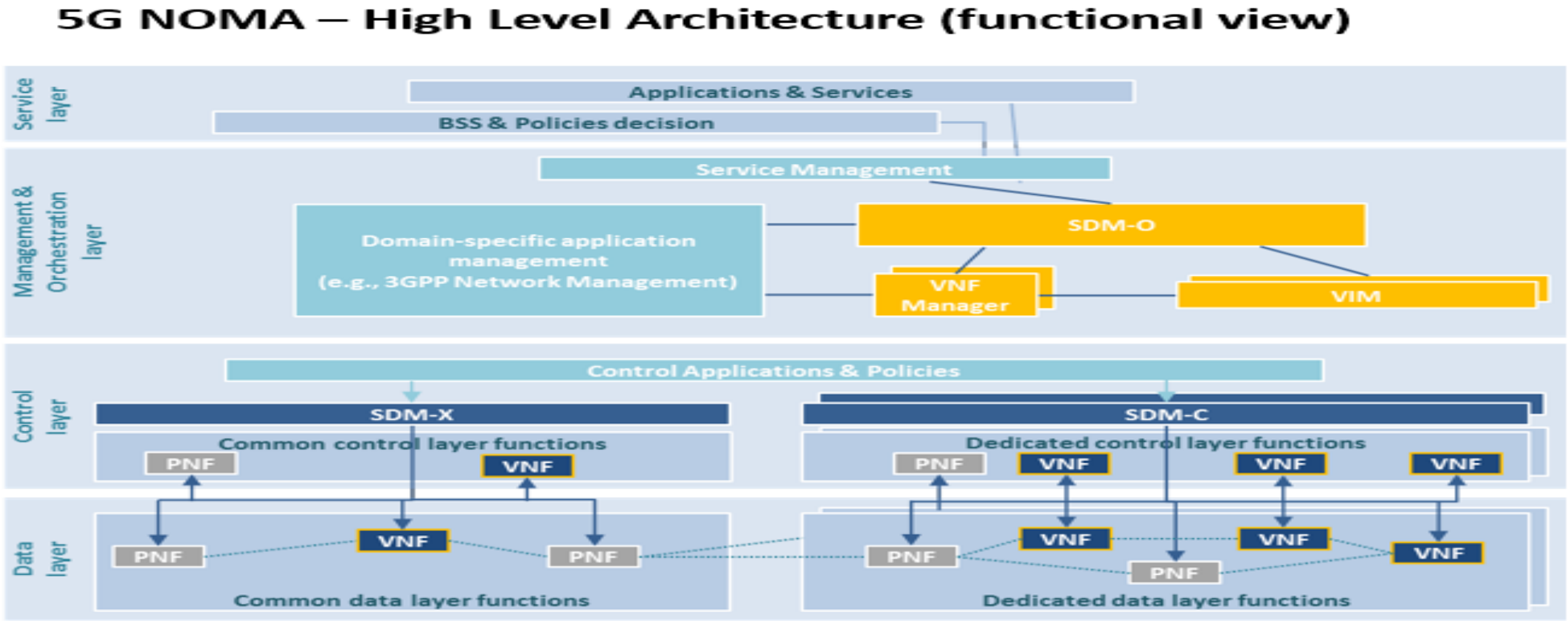
- **a Slice Manager**
- **a Slice Information Store**
- **a Slice Creator**
- **the VIM Factory**
- **the VIM Placement Manager**

Ref: Network Slicing A holistic architectural approach, orchestration and management with applicability in mobile and fixed networks and clouds – prof. Alex Galis

5G NORMA – H2020 Project

https://www.youtube.com/watch?v=lrAumMqIDNI

Novel Radio Multiservice adaptive network Architecture for 5G networks



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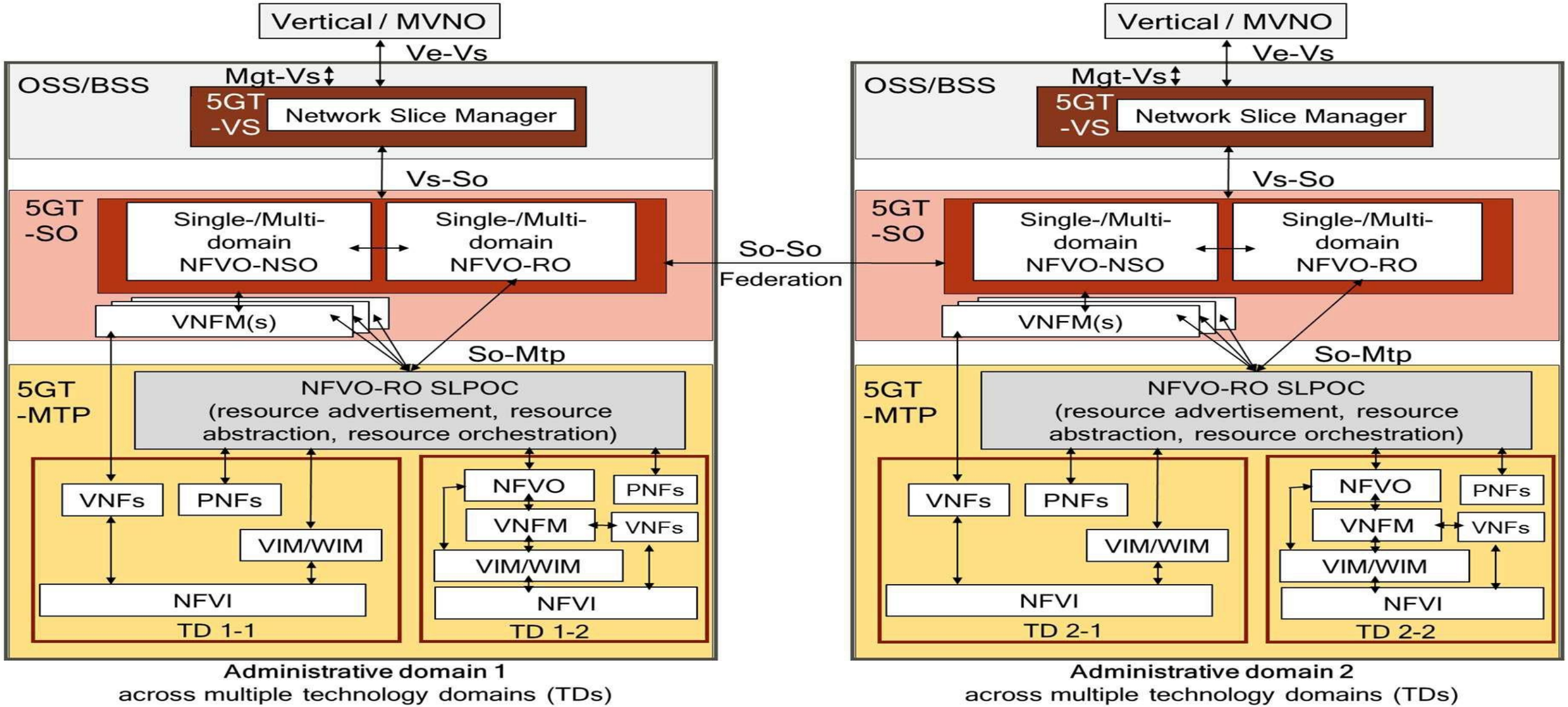
5G TRANSFORMER – H2020 Project

https://www.youtube.com/watch?v=lZALdNBLWBQ

5G Platform for Vertical Actors



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5G PAGODA – H2020 Project

A network slice for every service!

5G!Pagoda Project Scope

- Softwarized Network Realization w/ NFV, SDN and 5G
- Research-Innovation (experimentation)-Standardization

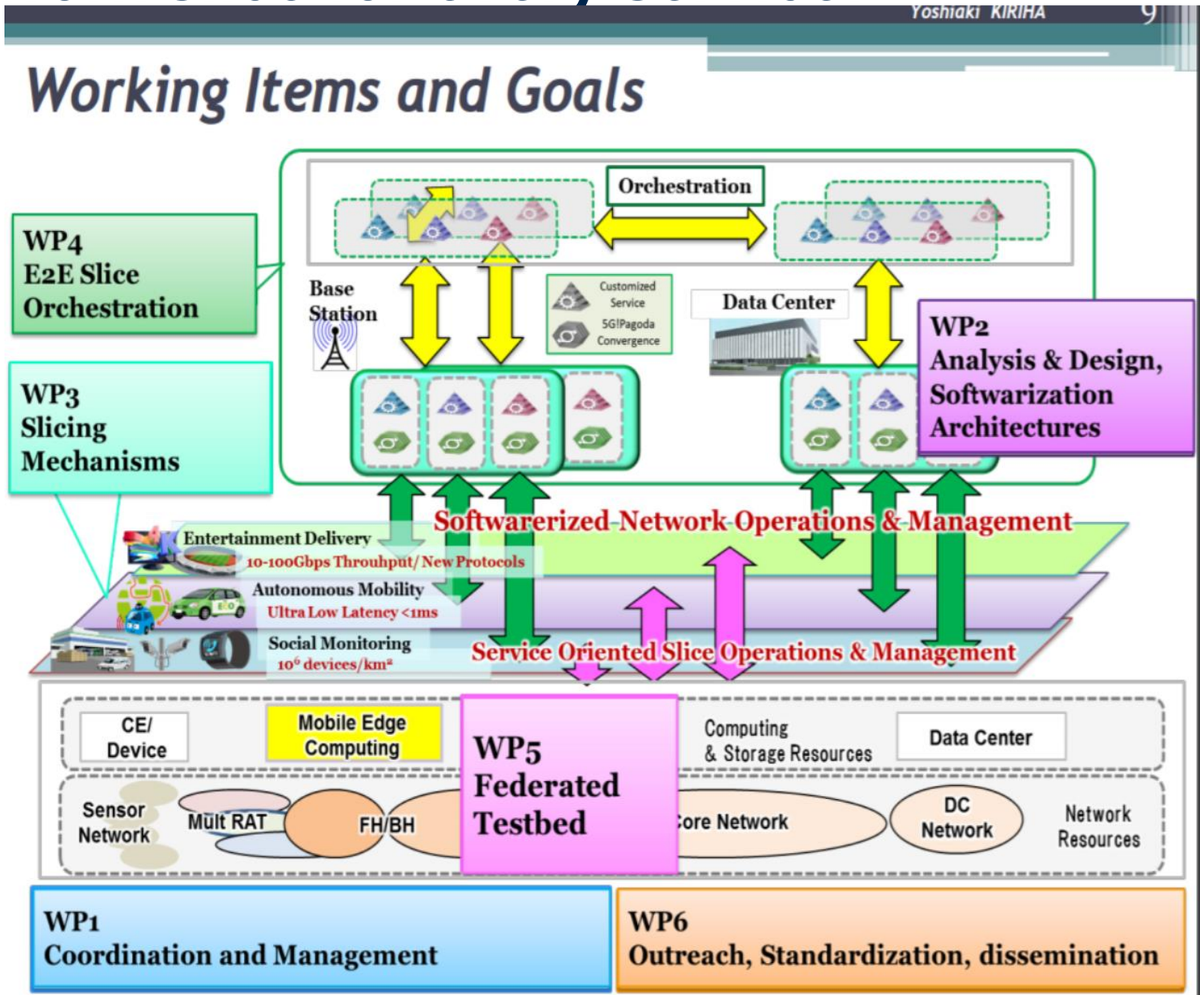
The Top Objectives are
i) the development of a scalable 5G slicing architecture towards supporting specialized network slices composed on multi-vendor network functions, through the development of
ii) a scalable network slice management and orchestration framework for distributed, edge dominated network infrastructures, and convergent software functionality for
iii) lightweight control plane and
iv) data plane programmability and their integration, customization, composition and runtime management towards different markets.

https://www.youtube.com/watch?v=A5_LVYaOhZo

http://www.soumu.go.jp/main_content/000445890.pdf

5G PAGODA – H2020 Project

A network slice for every service!



http://www.soumu.go.jp/main_content/000445890.pdf

5G SLICENET – H2020 Project

Overall Objectives

•SliceNet aims to design, prototype and demonstrate an innovative, verticals-oriented, QoE-driven 5G network slicing framework focusing on cognitive network management and control for end-to-end slicing operation and slice-based/enabled services across multiple operator domains in SDN/NFV-enabled 5G networks. In detail the SliceNet objectives are:

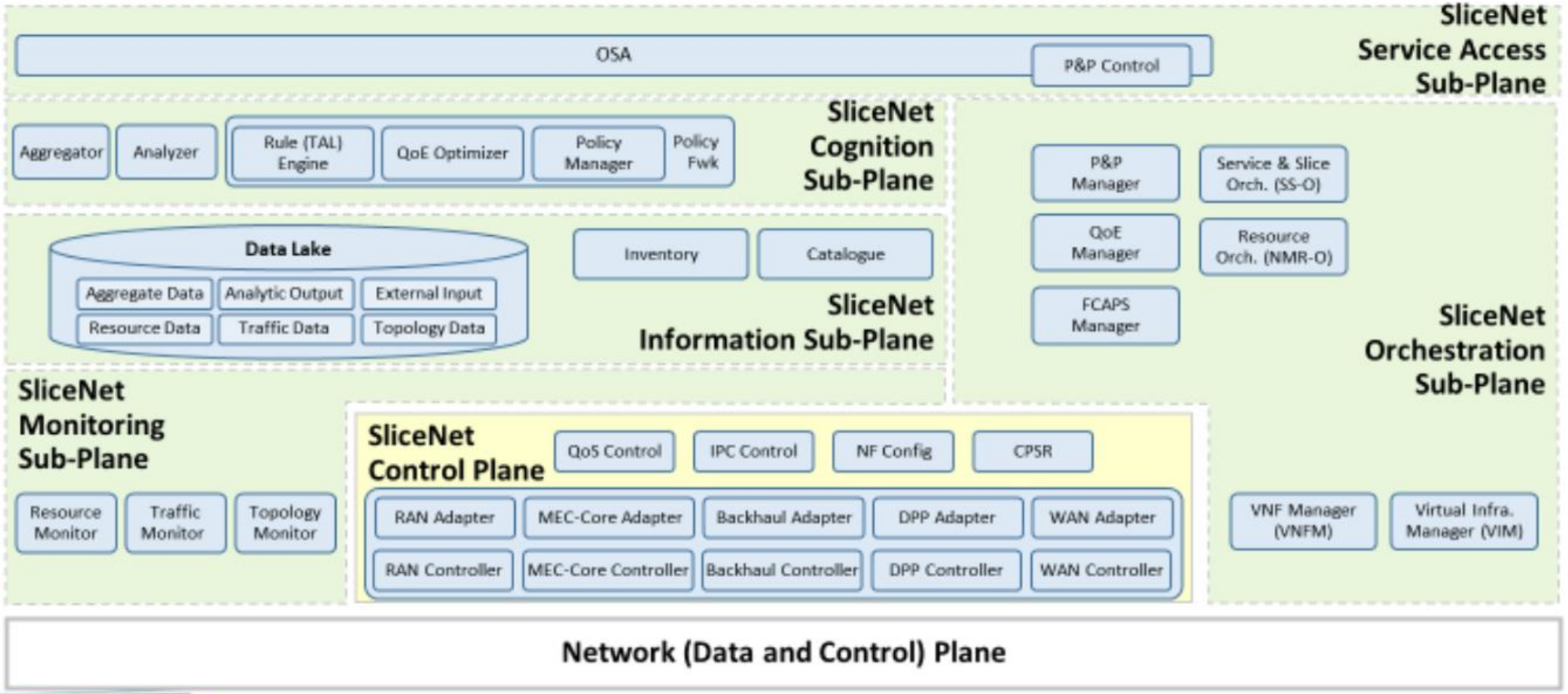
- Achieve an innovative, cognitive, integrated ‘one-stop shop’ 5G slice management framework for vertical businesses and co-designed by vertical sectors
- Enable extensible, end-to-end slice FCAPS management across multiple planes and operator domains
- Establish cognitive, agile QoE management of slices for service assurance of vertical businesses
- Enable slicing-friendly infrastructure and coordinated, true provisioning and control of user-definable slices
- Demonstrate the efficiency and support of the SliceNet framework in delivering slice-based/enabled, diverse 5G use cases for verticals, leverage Phase 1 projects’ results, and contribute key integration results to the Phase 2 demonstration process
- Contribute to the standardisation and helping fill the standards gaps

https://5g-ppp.eu/slicenet/

5G SLICENET – H2020 Project

SliceNet System Architecture

Overall

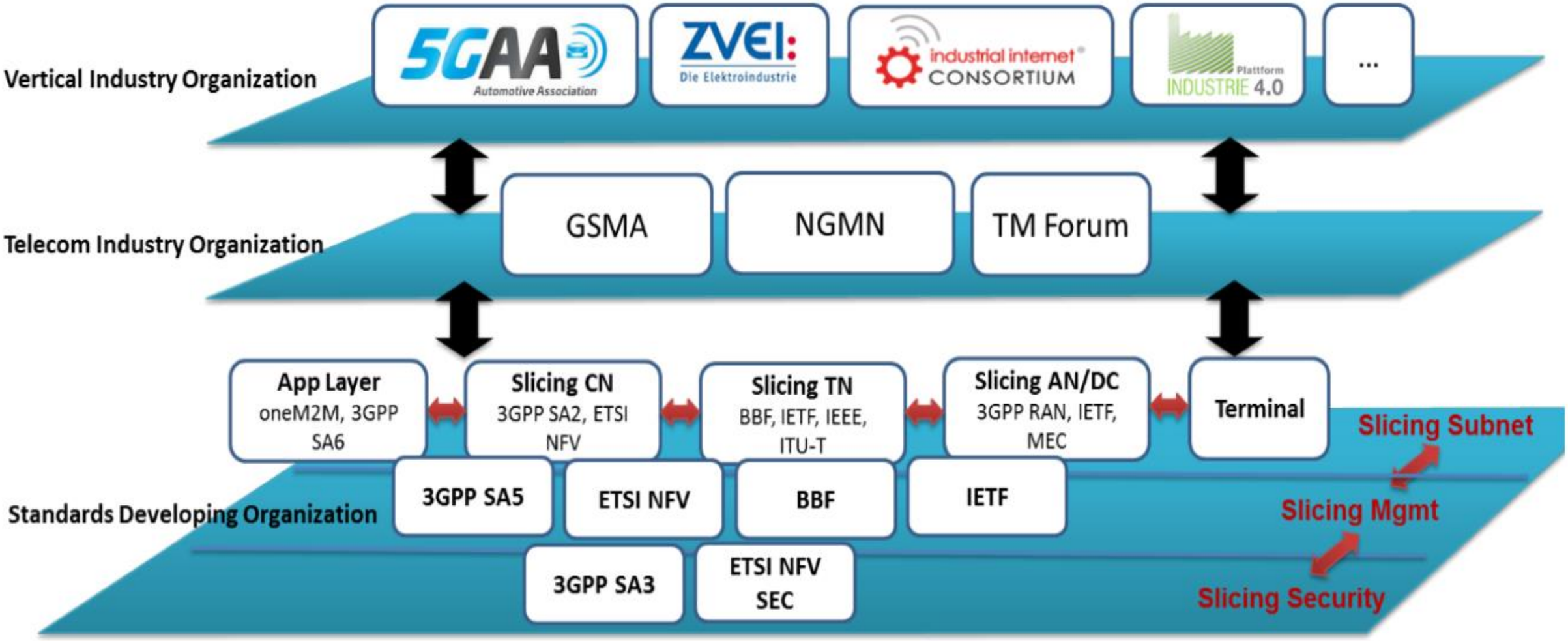


https://5g-ppp.eu/slicenet/

04 Standard Organization Activities

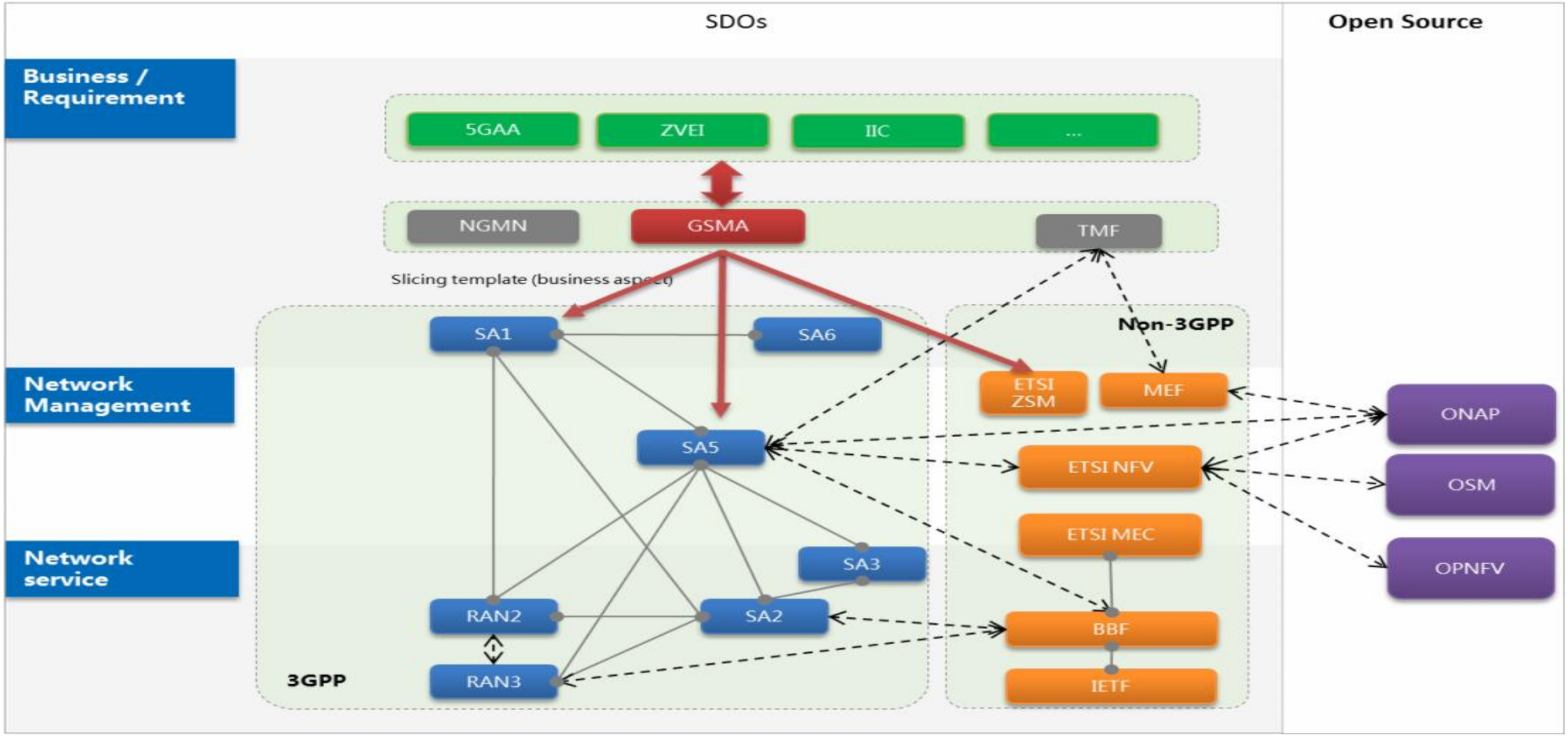
Standardization Landscape

- Network Slicing Relevant Industry Groups and Standards Developing Organisation (SDO)s Landscape.



Ref: Network Slicing A holistic architectural approach, orchestration and management with applicability in mobile and fixed networks and clouds – prof. Alex Galis

SDO Relationship



Ref: Network Slicing A holistic architectural approach, orchestration and management with applicability in mobile and fixed networks and clouds – prof. Alex Galis

Vertical Industry Organization

- Network Slicing aims to support various vertical industries in the 5G era,
- 5G Automotive Association (5GAA), created in September 2016, aims at a global, cross- industry Organization of companies from the automotive, technology, and telecommunications industries (ICT), working together to develop end-to-end solutions for future mobility and transportation services. In Nov 2017, the first Network Slicing workstream was established in 5GAA WG5
- Manufacturing industry organizations like Zentralverband Elektrotechnik und Elektronikindustrie (ZVEI) and Industrial Internet Consortium (IIC) also started to engage with 5G for next generation smart manufacturing solutions.

Telecom Industry Organization

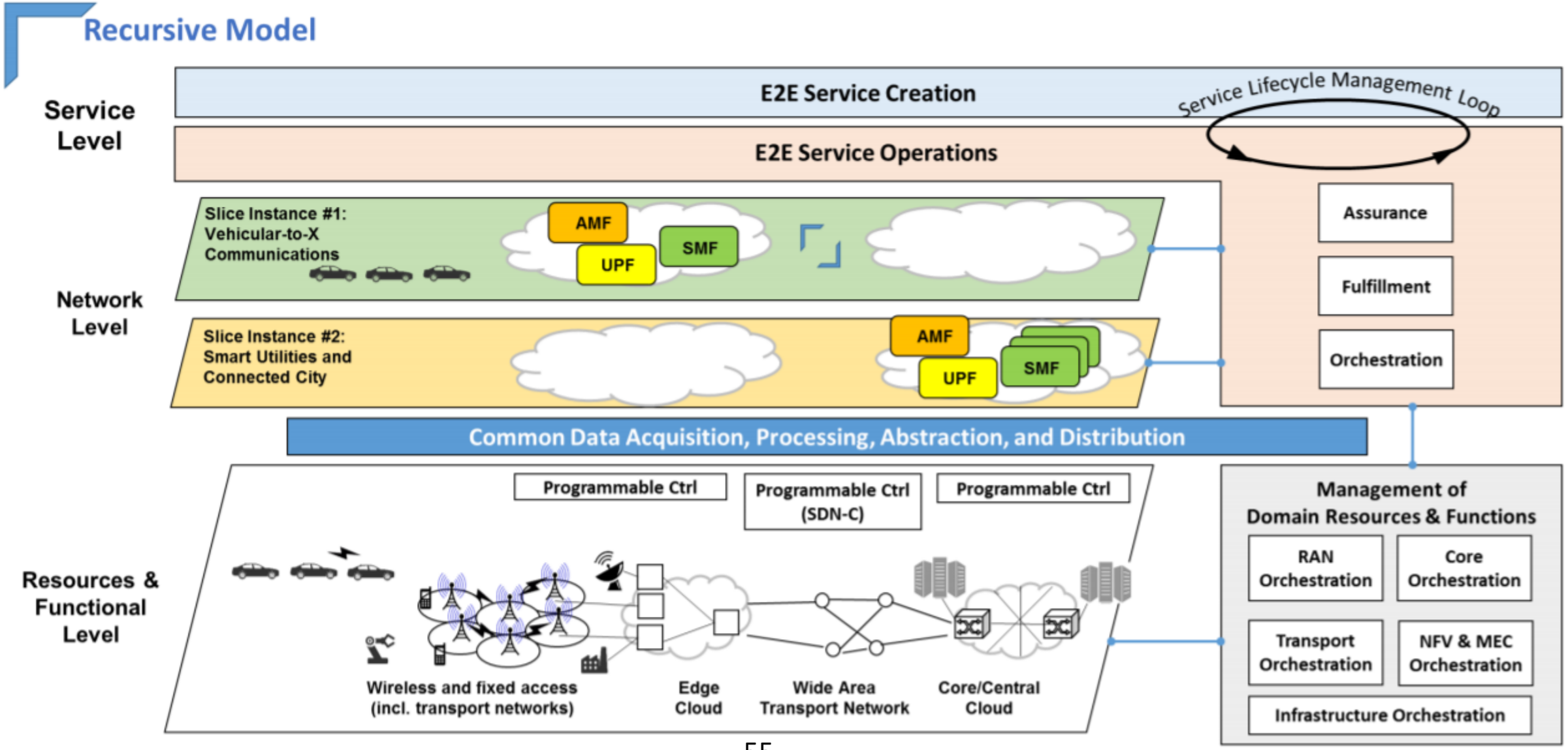
- Telecom Industry Organizations like the GSMA and NGMN (Next Generation Mobile Networks) describe the business drivers, concepts, and high-level requirements of E2E Network Slicing from the operator's point of view. The GSMA has initiated the Network Slicing Taskforce (NEST) project to harmonize slicing definition, identify slice types with distinct characteristics and consolidate parameter and functionality requirements. The NEST aims at generating a Permanent Reference Document (PRD) to guide future Network Slicing standards.
- The NGMN Alliance is developing, consolidating and communicating requirements to ensure that customer needs and expectations on mobile services are fulfilled. The Alliance actively drives global alignment and convergence of technology standards and industry initiatives with the objective to avoid fragmentation and to guarantee industry scale.
- TM Forum ZOOM project has started a workstream to analyze Network Slicing business models and business scenarios of high interest to service providers, vertical industries, and other potential Network Slicing consumers. A number of user stories have been generated, and respective requirements have been derived and mapped to TM Forum Assets.

Standards Developing Organization

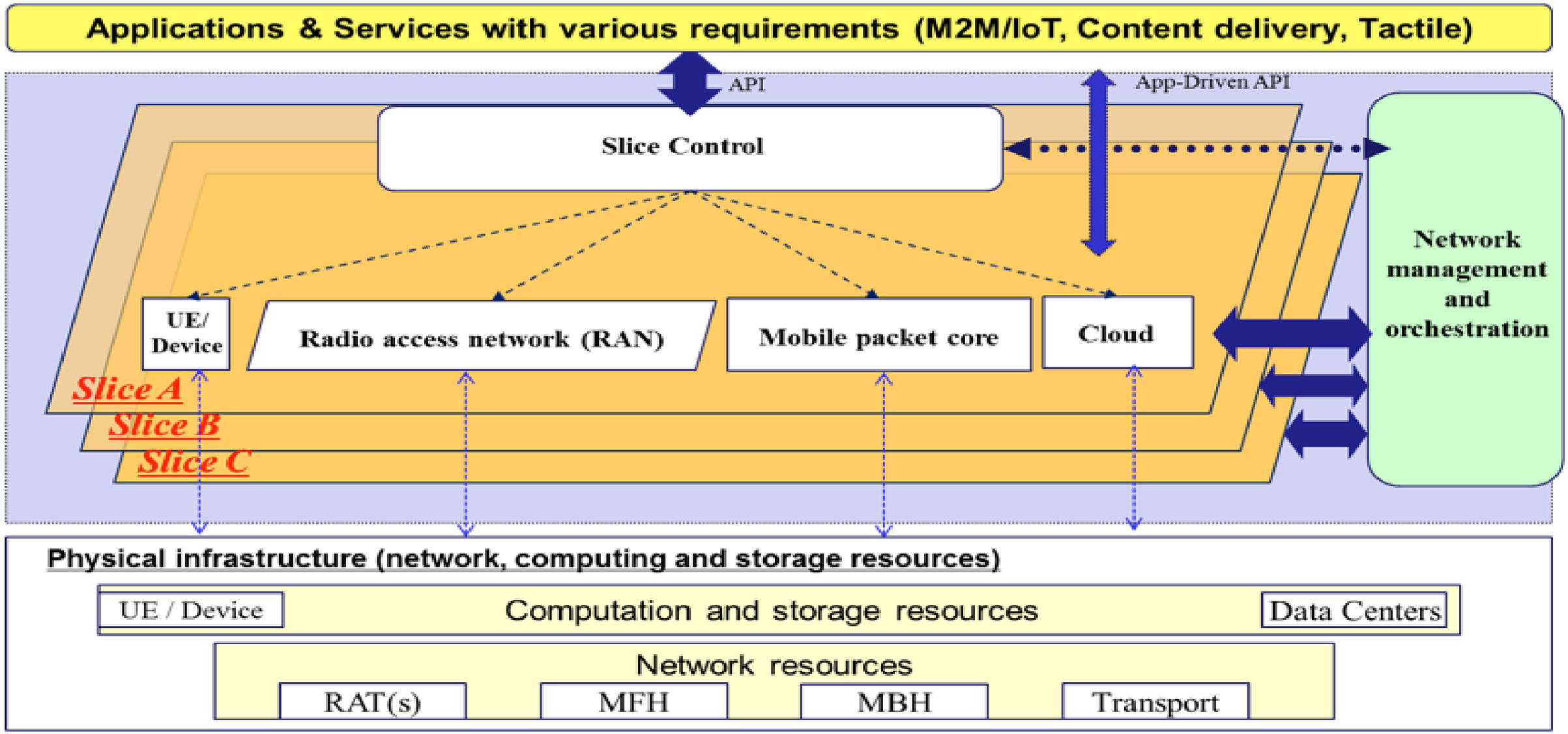
- Various technologies and innovations from different technical domains have substantially contributed to the Network Slicing progress in different Standards Developing Organizations (SDO). Currently, technical specifications of those domains are defined in corresponding SDOs, namely, Radio Access Network (RAN) and Core Network (CN) by 3GPP, Transport Network (TN) by BBF and IETF, etc. ITU-T(GSTR-TN5G), IEEE(NGFI 1914), MEF and other SDOs are working on this topic as well. The major SDOs will be introduced in the following sections.

5G-PPP Software Network Working Group

5G Enhanced Overall System Architecture



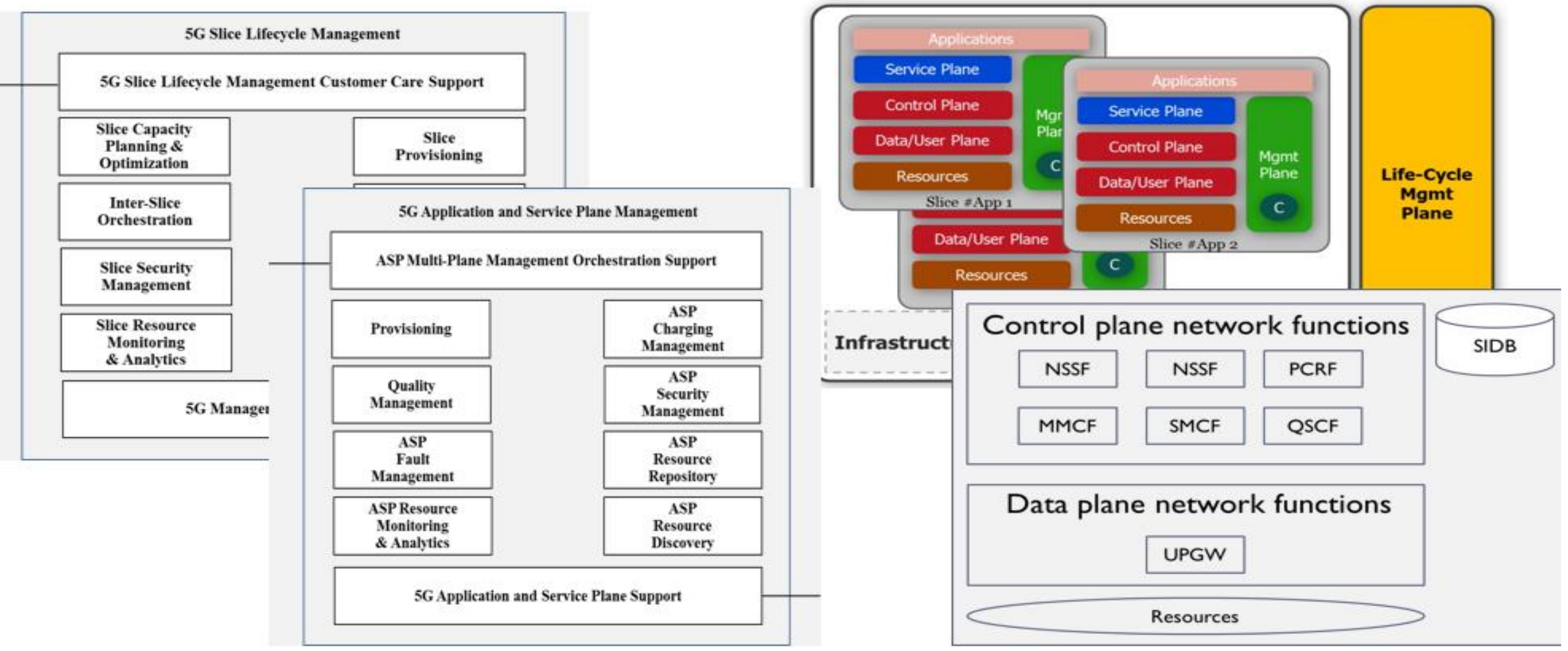
ITU-T IMT2020 Slicing Representation



Ref: Network Slicing A holistic architectural approach, orchestration and management with applicability in mobile and fixed networks and clouds – prof. Alex Galis

MFH: mobile fronthaul

ITU-T IMT2020 Slicing Architecture



IMT2020Architecture Diagrams

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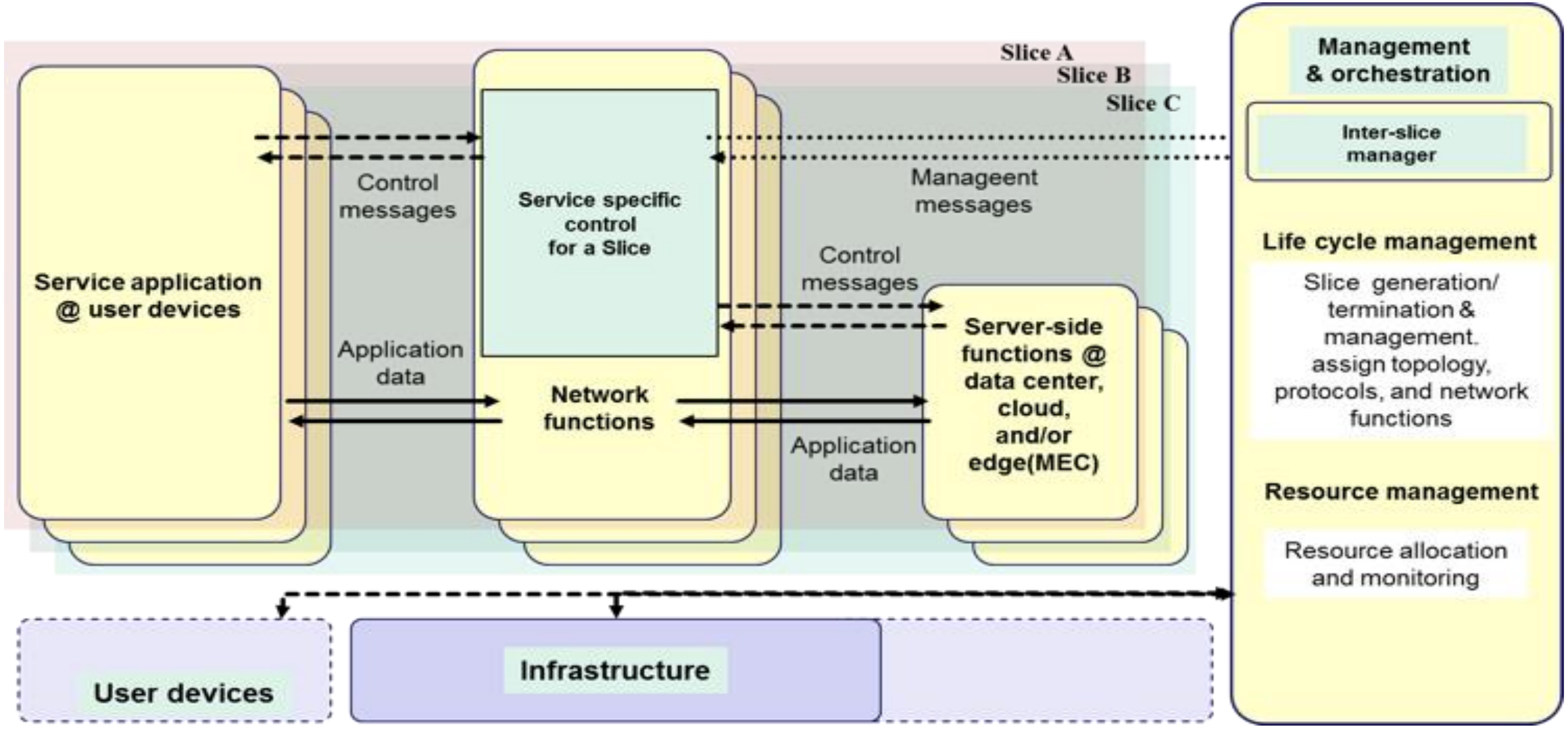
ITU-T IMT2020 Slicing Functional Architecture



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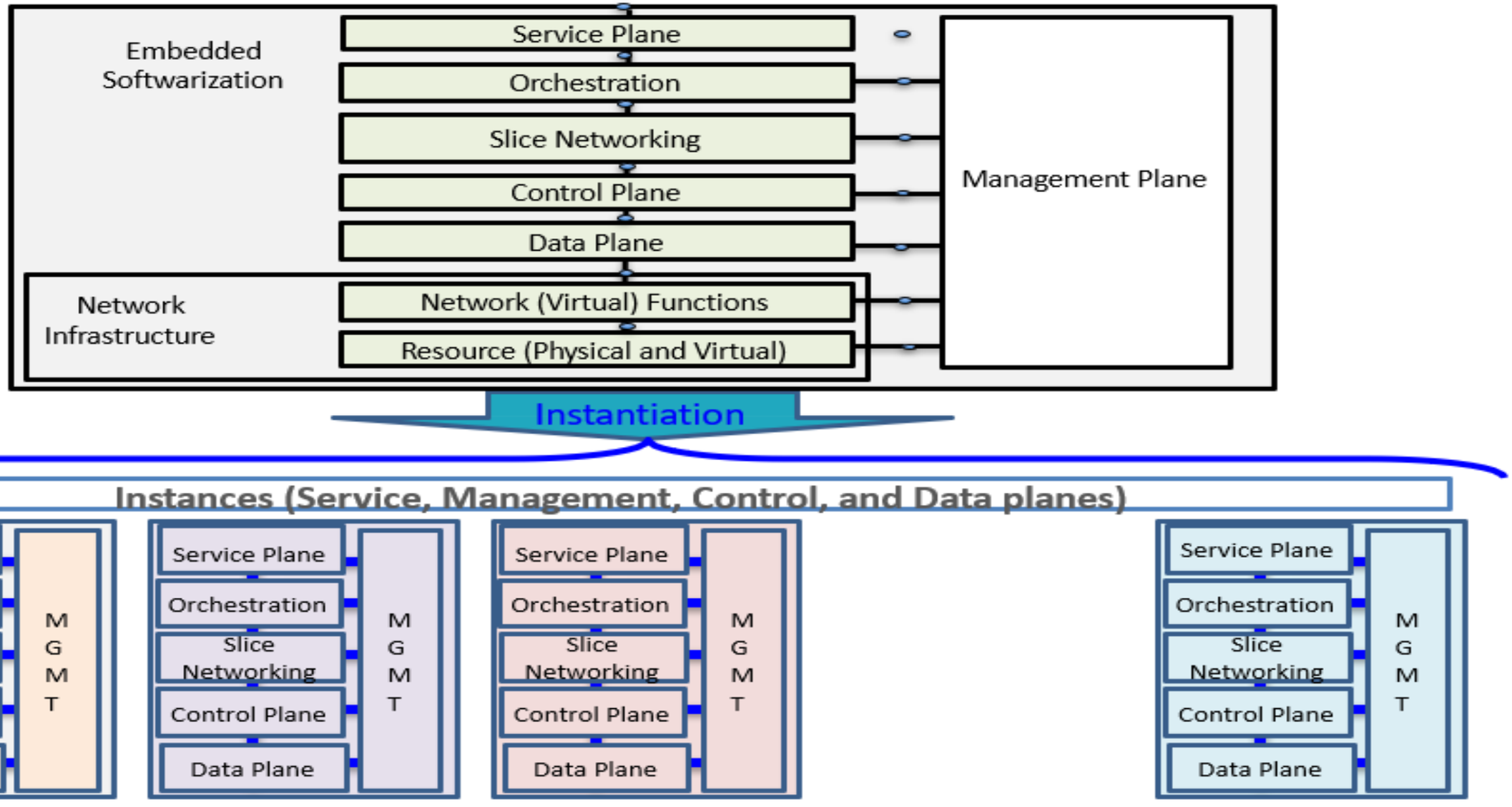
ITU-T IMT2020 Slicing Functional Architecture



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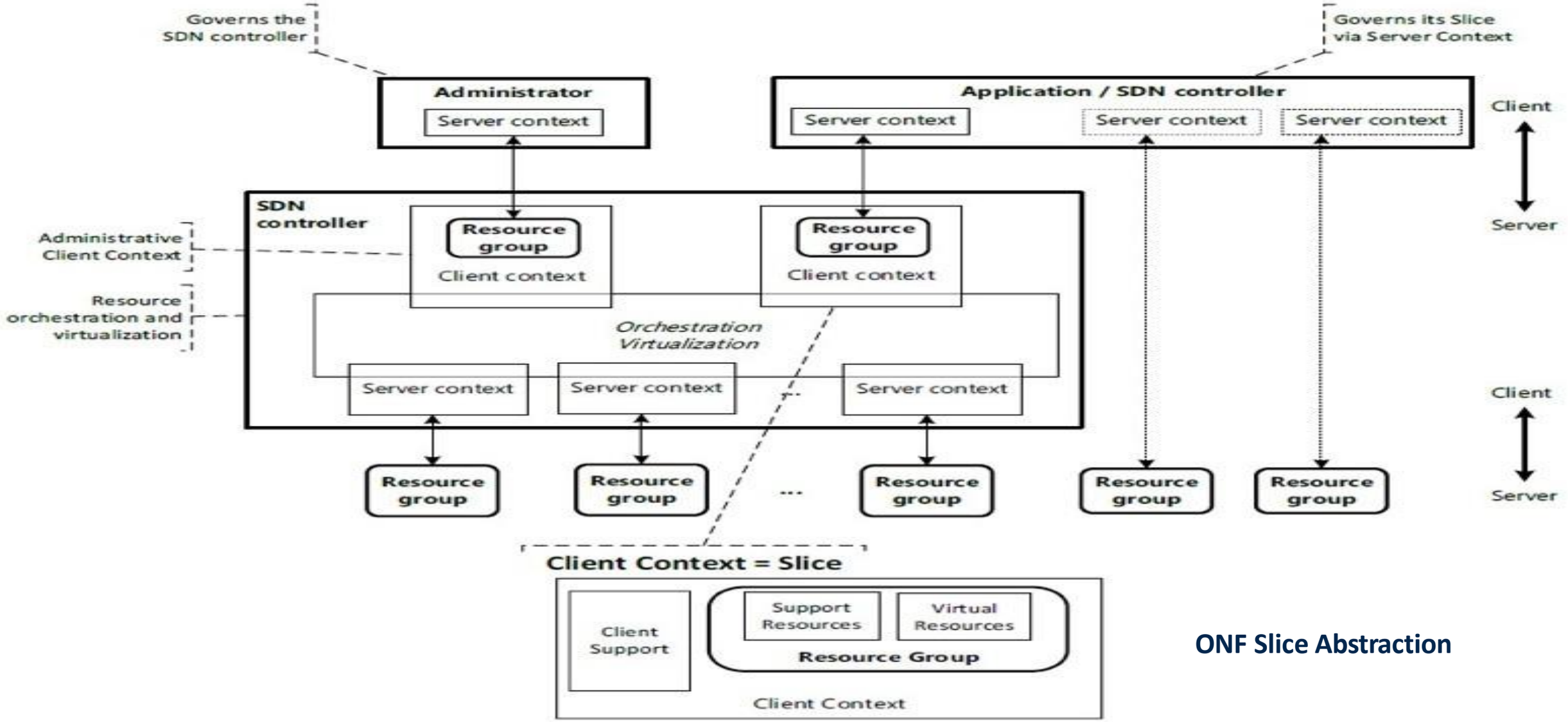
ONF

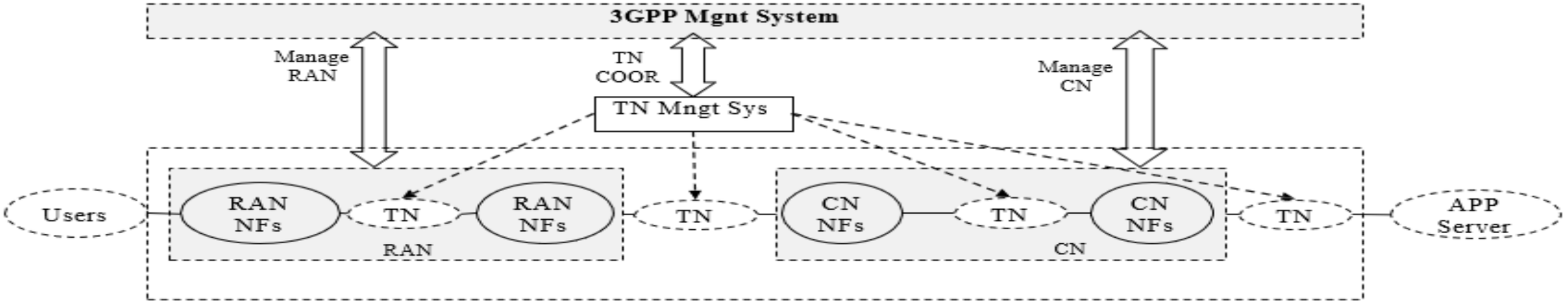


ONF Slice Abstraction

Ref: Network Slicing A holistic architectural approach, orchestration and management with applicability in mobile and fixed networks and clouds – prof. Alex Galis

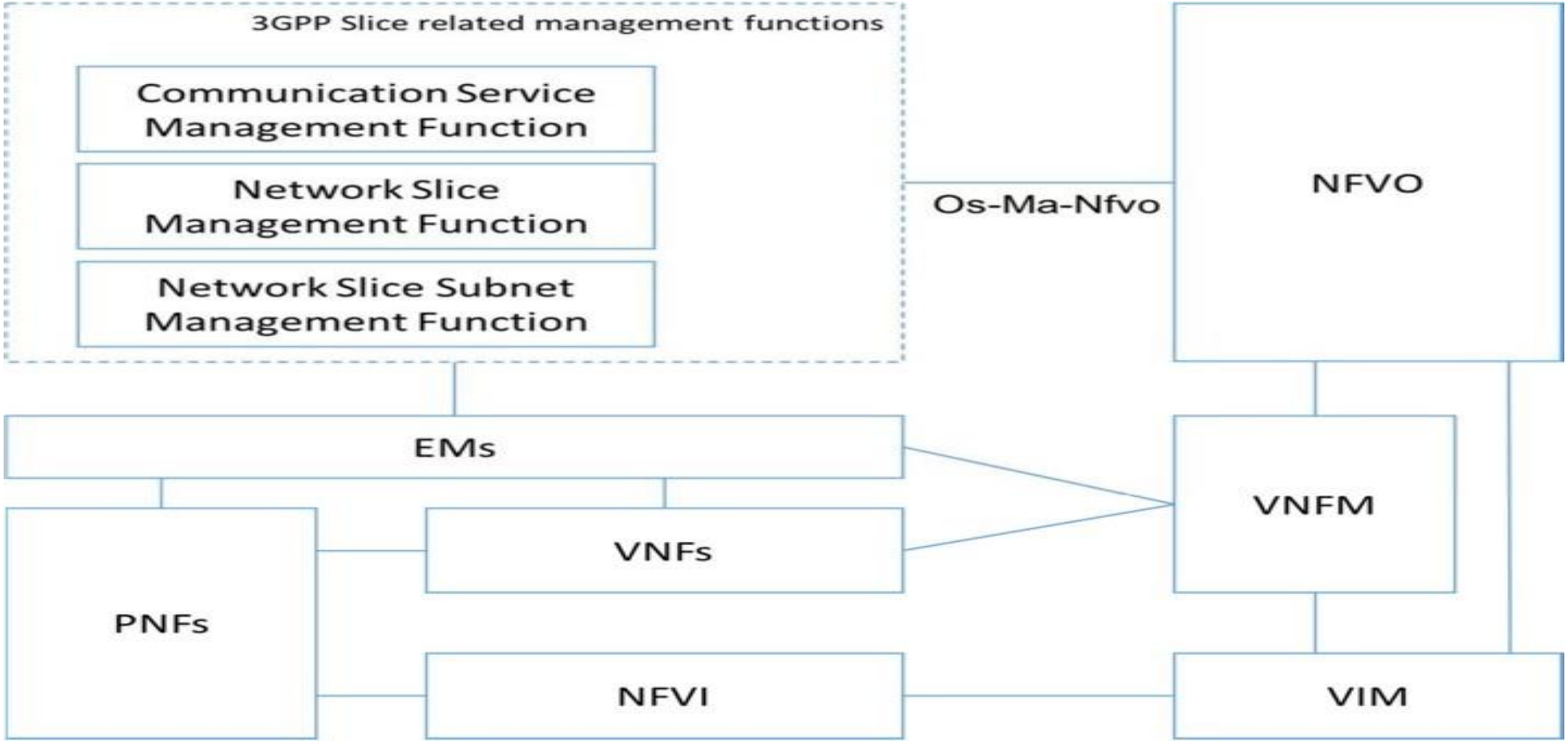
3GPP Network Slicing Intricacies

- Based on Service oriented architecture
- It sees subnet as group of network functions.
- Network Slice subnet instance (NSSI) can be shared or non-shared across different slices (due to 3GPP, functions).
- 2 ways to manage slices:
  - build a service, do not expose slice,
  - offer slice as a service (NSaaS).
- Communication with Non-3GPP (TN and DCSN)



Ref: Network Slicing A holistic architectural approach, orchestration and management with applicability in mobile and fixed networks and clouds – prof. Alex Galis

3GPP Network Slice Management in an NFV Framework



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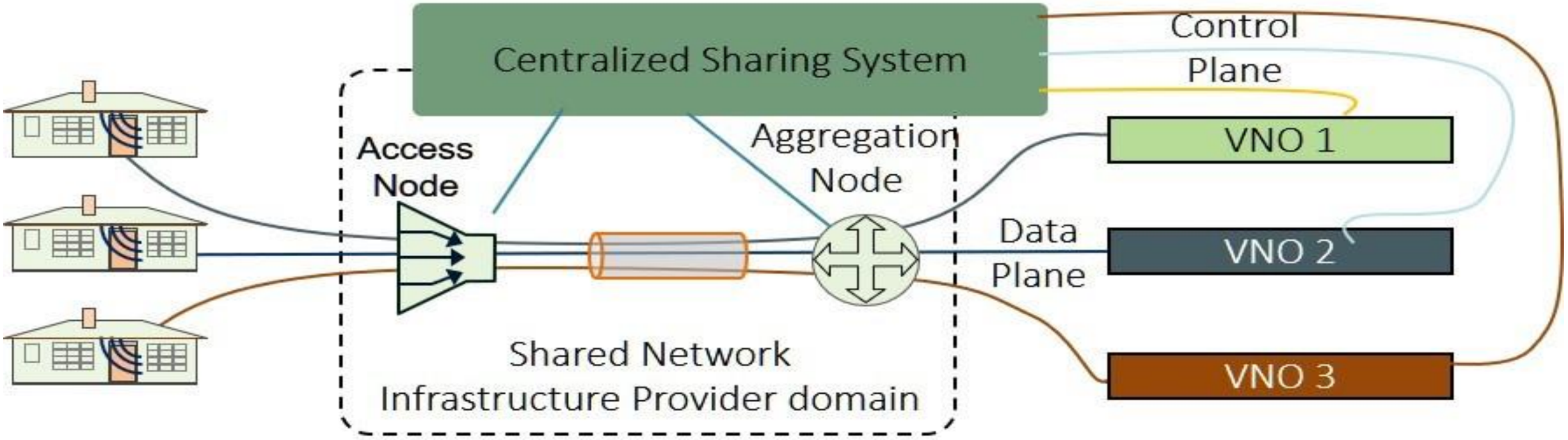
BBF

https://www.broadband-forum.org/projects/5g/work-in-progress

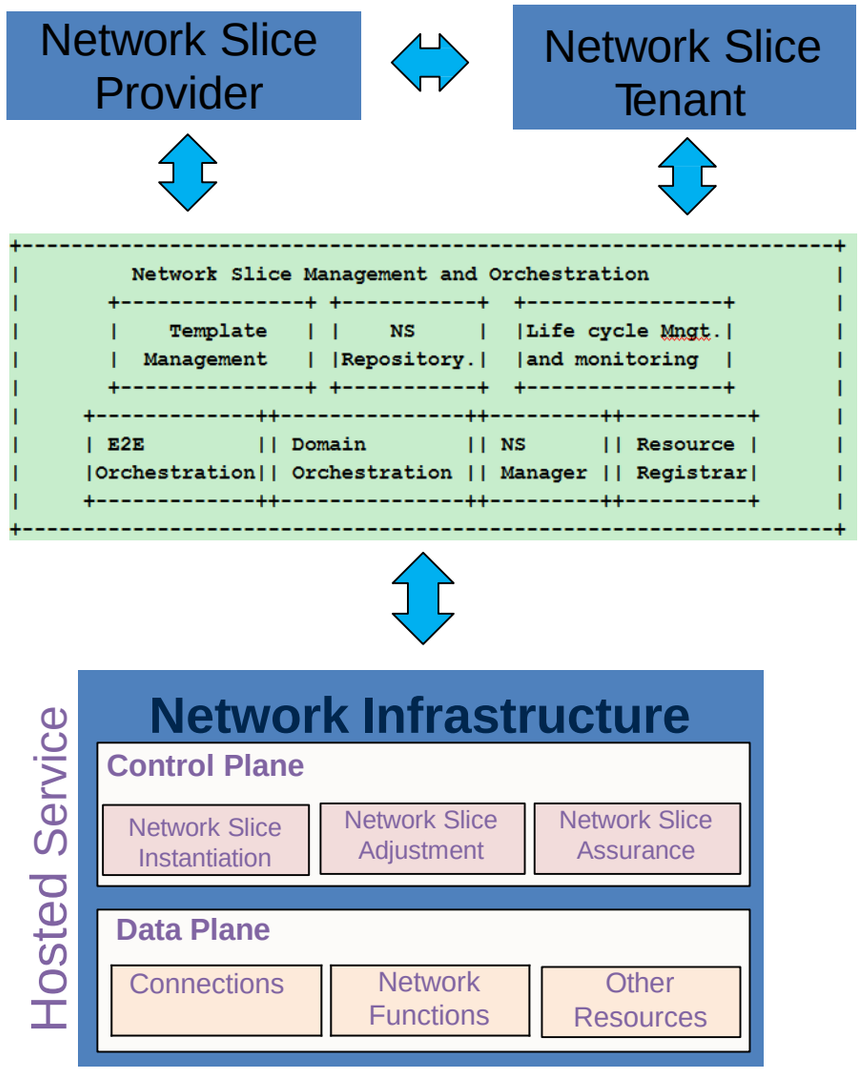
- BBF's main scope in Network Slicing is to clarify the requirements for 5G bearer networks and defines the related TN slicing management architecture. The BBF should establish formal cooperation with 3GPP to facilitate the transmission requirements from 3GPP and coordinate the interface requirements between the 3GPP slicing management system and Bearer slicing management system, including corresponding slicing creation and management processes. The technical definition for a specific interface is not within the scope of the BBF standardization, but they can recommend the potential options.



Ref: Network Slicing A holistic architectural approach, orchestration and management with applicability in mobile and fixed networks and clouds – prof. Alex Galis

IETF - Network Slicing Reference Architecture

- Network Slice Provider (NSP) & Network Slice Tenant (NST)
  - Communicate with NS M&O system via northbou interface
- Network slice management & orchestration
  - Lifecycle mngt to coordinate E2E and Domain Orchestration
  - Template/NS repository to assist life cycle mngt.
  - Resource Registrar to manage exposed network infrastructure capabilities
  - NS Manager to oversee individual slice (capability exposure to NST)
- Network infrastructure owner
  - Control plane for slice instantiation and adjustmen
  - Data plane for guaranteed performance and isolation



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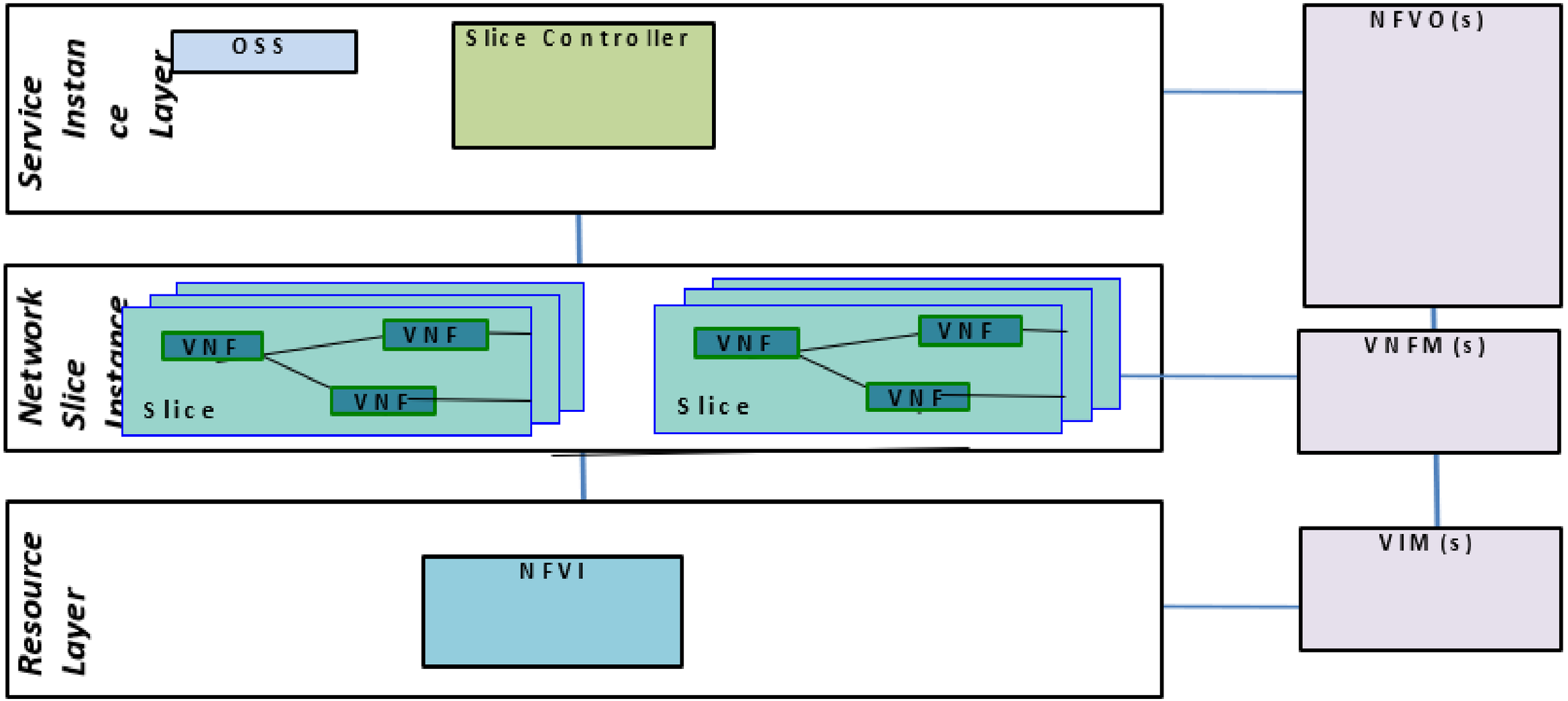
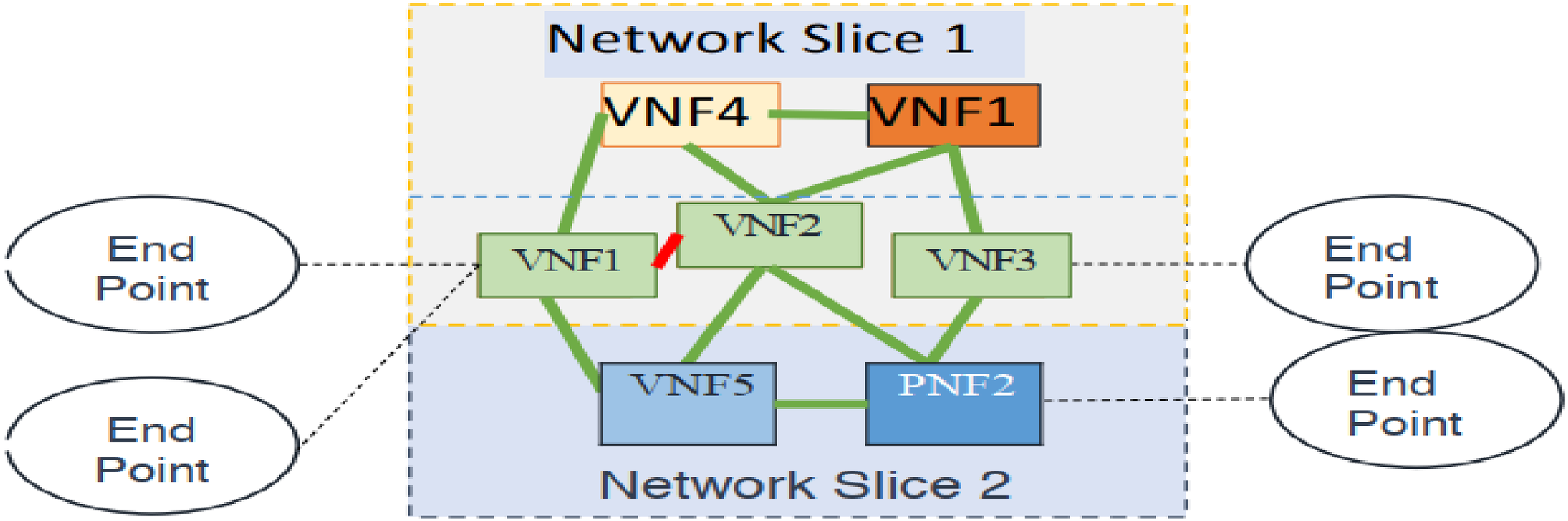
ETSI ISG NFV



Opportunity to integrate Network Slice across almost all the layers in NFV architecture

Ref: Network Slicing A holistic architectural approach, orchestration and management with applicability in mobile and fixed networks and clouds – prof. Alex Galis

ETSI NFV Network Slicing



Network slices with common VNFs

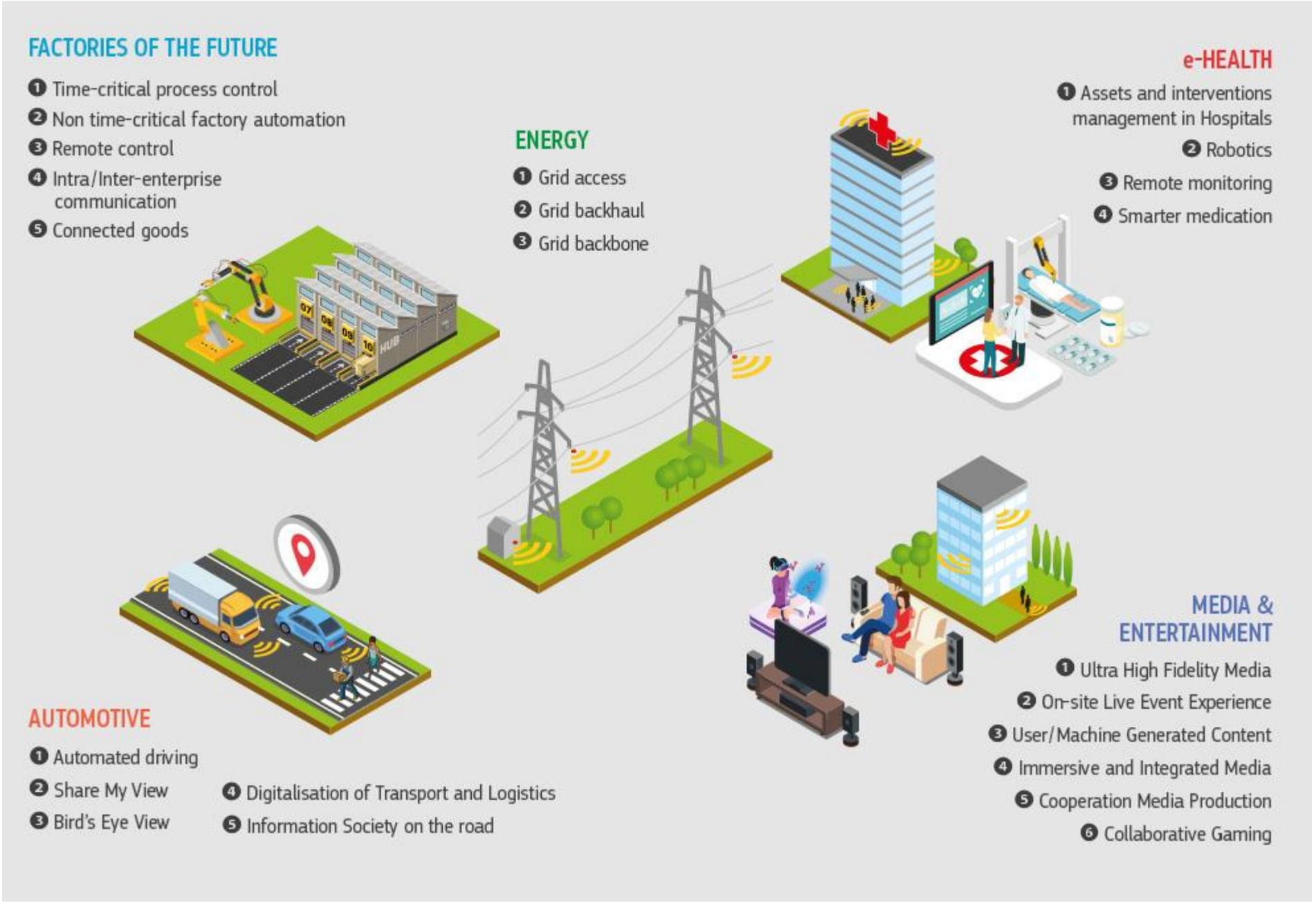
Ref: Network Slicing A holistic architectural approach, orchestration and management with applicability in mobile and fixed networks and clouds – prof. Alex Galis

Summary of SDO efforts

- 3GPP – Valuable platform for slicing (NG-R and 5GC)
- NGMN – Described slicing concept for 5G with IMT2020
- ITU-T Slices work in IMT-2020, SG13 and SG15 – covering management & transport aspects; alignment with 5G.
- ONF, BBF, ETSI-NFV – for SDN and NFV capabilities for slices
- ETSI-NGP – Technology independent holistic approach to slicing
- IETF – focused on fixed network and management. Slices are expected to use existing mature data plane technologies.

05 Vertical Requirements & Use Cases

European 5G vertical industries



AR/VR

- Strong-Interactive VR: Audio-visual interaction
  Audio-visual interaction is characterized by a human being interacting with the environment or people, or controlling an UE, and relying on audio-visual feedback. In order to achieve the VR environments with low motion-to-photon requirements, the 5G network slice should have the capability of motion-to-photon latency in the range of 7-15ms while maintaining the 250Mbps user data rate and motion-to-sound delay less than 20ms.

  During voice conversions, there exists some interactive tasks, 5G Network Slicing is required to have the capability to support 100ms one-way mouth-to-ear low-delay speech coding for interactive conversational services.

  Furthermore, audio components and video components are usually handled separately, so in order to avoid having a negative impact on the user experience, the communication system will also have to cater for the VR audio-video synchronization. The audio-video synchronization thresholds is 5-125ms for audio delayed and 5-45ms for audio advanced.

AR/VR

- Strong-Interactive VR: Low-delay speech and video coding
  Current speech codecs have an inherent coding delay of 20-40ms. In a 4G network, such coding delay is not a problem during a phone call because even a 400ms one-way delay between speakers does not seriously impair an interactive discussion. However, when the speech voice is used in a highly interactive environment, e.g., a multiplayer game or a virtual reality meeting, the requirements on the speech coding delay become tougher to meet, and current coding delays are too high. To support interactivity, the one-way delay for speech should be 10ms (or lower). These scenarios have a critical requirement on transfer bandwidth and delay to guarantee good user experience compared to current video service.

  In order to fulfil the performance requirements of low-delay speech and video coding, the design of the network slice should consider different aspect of video codec, e.g. frame rates, resolution and bandwidth. The higher the frame rate (fps - frames per second) the better the video quality, virtual reality may require the capability of displaying content at frame rates of 120 fps or more.

AR/VR

- Strong-Interactive AR: Use Cases

  Assisting with complex tasks: Use of AR to overlay instructions can speed up fault finding and repairs by utilizing heads up display with connected glasses.

  Connecting remote workers: Allowing remote experts to see exactly what the worker sees and direct them to complete tasks. Enabling a deeper level of assistance and guidance to be conveyed.

  Accelerated Learning: AR training packages can facilitate vastly more effective training. Supervisors are able to mentor and assess capability, resulting in higher-quality work with less mistakes.

Automotive

- Infotainment
  This type of use cases requires direct data exchange between vehicle and application servers via mobile systems. Such services normally focus on providing a more pleasant driving experience both for driver and passengers so they are not safety-critical and can be delivered using mobile broadband (MBB) connectivity.

  Examples include: music, movies, live TV streaming, audio/video conference streaming (office-in-car), online gaming, web browsing.

Automotive

- Telematics
  This type of use case also requires direct data exchange between vehicle and application servers via a mobile system, which are normally provided by automotive manufacturer (or their authorised third-party service provider). Being different from the above category, it provides services to assist the driving experience. Example use cases are navigation provision, remote health monitoring of the vehicle, precise position provisioning, parking slot discovery, automated parking, etc. An automotive manufacturer could also use the connectivity to schedule a control module firmware and software update over mobile system for selected range/type of vehicles.

Automotive

- Road Safety
  These services provide information to the driver about imminent dangers such as red light violation, hazard warning, forward collision warning, intersection collision warning, traffic jam warning, etc. Such information could help the drivers to take remedial actions (e.g. lane changing, deceleration). Being different from the driving experience assistance mentioned in Telematics, these use cases normally are triggered by a specific event (e.g. based on real time road situation detection) and the actions are taken by driver, hence it is not strictly delay-sensitive but it is preferred to be delivered as fast as possible.

https://www.youtube.com/watch?v=hddLbSuZ0Io

Automotive

- Information (Sensor data) Sharing
  Perception of surrounding environment for driving condition analysis is a very crucial aspect to improve driving safety. Real-time information could be exchanged among vehicles, e.g. on-vehicle sensor or information captured by the vehicles like traffic information. Such information could be used for collective perception of environment to avoid potential dangers. One typical use case is “See- Through”, which refers to camera and/or radar data sharing to improve/extend driver’s visibility. For instance, by receiving a video stream captured by the front truck can help the driver behind to make an overtaking decision. Information sharing is also one of the essential factors to enable autonomous driving services mentioned below.

Automotive

- Advanced Driving Service
  Advanced driving services enable semi-automated or fully automated driving.
- Cooperative driving
  Information (on-vehicle sensor data and driving actions like braking and accelerating) can be exchanged among vehicles for cooperative collision avoidance. Another example use case is cooperative lane merging, where vehicles exchange information on their intended trajectories and perform automated lane changing manoeuvres to avoid collisions and to improve traffic flow.

https://www.youtube.com/watch?v=2oJFQnbN5CA

Automotive

- Platooning
  This use case class describes operating a group of vehicles in a closely linked manner so that the vehicles move like a train with virtual strings attached between vehicles. To keep the vehicles as close as possible with safety assurance, the vehicles need to share status information (such as speed, heading) as well as their driving intentions (such as braking, acceleration). By doing this, the overall fuel consumption could be lowered down and the amount of required drivers can also be reduced.

https://www.youtube.com/watch?v=X7vziDnNXEY

Energy

- Smart grid
  Due to the urgent demands of smart grids, an efficient and reliable communication network solution is expected. The backbone network domain is a typical network in which terminals are in the high and extra high voltage area. The terminals of a backhaul network are in the medium voltage area. As for the access network, the end points are in the low voltage area. A large amount of growing demand happens in the medium-voltage and low-voltage domains, which are secondary substations and distributed energy resources, between primary substations and secondary substations. At this moment, there is a lack of energy measurement and communications system between substations. 5G Network Slicing could be an economical and efficient wireless solution compared with a traditional fiber-based communication system.

https://www.youtube.com/watch?v=JwRTpWZReJk&t=157s

Energy

- Micro-grids
  Micro-grids consist of a set of micro-power, load, energy storage and control devices. It could operate in both grid-connected mode and island mode. Micro-grids will play a significant role in the future electricity smart grid architecture and the associated control network. All Micro-grid elements need extensive exchange of signaling between each other. 5G Network Slicing could provide an economical and efficient way to support the communication needs.

Energy

- Smart meters and aggregator gateways
  Future power terminals are expected to supply frequent measurements. This evolution leads to the requirement on future networks to carry short data packages from thousands of users. The data will enable near real-time optimization of sections of the low and medium voltage infrastructures. This optimization will be particularly beneficial for utilities to better serve customers (residential and business) in densely populated areas where 5G Network Slicing is expected to become available first.

https://www.youtube.com/watch?v=_S2UM5T0jW0

Energy

- Electricity traffic scheduling

  -- Power outages as a result cause significant economic damage both to the power company and consumers.

  -- By means of fiber and Wi-Fi, which results in high latency and low level of reliability.

  -- 5G URLLC Network Slicing could play an important part in fault location and fault isolation by transmitting critical monitored data, controlling signals among feeders, bar switches and automation control servers.

  -- Furthermore, by building a precise map of power consumption it is possible to improve the traffic scheduling and production.

Industry 4.0 Manufacturing

- Augmented reality https://www.youtube.com/watch?v=Xmpe1uYTDgI
  Augmented reality optimally supports shop floor workers, for instance, in tasks like: monitoring of processes and production flows, step-by-step instructions for specific tasks (e.g. in manual assembly workplaces), ad-hoc support from a remote expert (e.g. maintenance or service tasks). It is expected that the AR devices have minimum capabilities and that complex functions are executed at the edge cloud.
- Control-to-control (C2C)
  Control-to-control (C2C) communication refers to the communication between different industrial controllers. For higher flexibility it is expected that this communication is wireless. Depending on the concrete scenarios, these C2C systems typically have very challenging requirements on the communication service.

Industry 4.0 Manufacturing

- Motion control
  Motion control controls moving and/or rotating parts of machines. Wireless communication is well suited for the control of components, which move and/or rotate.
- Mobile robots and mobile platforms
  Mobile robots and mobile platforms perform activities like assistance in work steps and transport of goods, materials and other objects and can have a large mobility within the industrial environment.
- Mobile Control Panels with Safety Functions
  Mobile control panels with safety functions are devices for the interaction between people and production machinery as well as for the interaction with moving devices, e.g. for configuring, monitoring, debugging, controlling and maintaining machines, robots, cranes or complete production lines. Optionally these panels are equipped with an emergency stop button.

Industry 4.0 Manufacturing

- Closed-loop control
  Closed-loop control in which several sensors are installed in a plant and each sensor performs continuous measurements. The measurement data is transported to a controller, which takes a decision to set actuators.
- Process monitoring
  Process monitoring in which several sensors are installed in the plant to give insight into process or environmental conditions or inventory of material. The data is transported to displays for observation and/or to databases for registration and trending.
- Plant asset management
  Plant asset management that is required to keep a plant running. It is essential that the assets, such as pumps, valves, heaters, instruments, etc., are maintained. Timely recognition of any degradation and continuous self-diagnosis of components are used to support and plan maintenance. Remote software updates enhance and adapt the components to changing conditions and advances in technology.

Internet of Things for Low Power Wide Area Applications

- Asset Tracking and monitoring
  Being able to track and monitor assets is a very attractive use case because it allows to optimize the operational aspects, which differs depending on the type of asset. There are available examples of assets tracking that range from suitcases to pallets or containers.
- Waste management
  To minimize both costs and the impact on the environment, city administrations are looking to make waste collection smarter. Sensing when residential bins require to be collected improves operational cost. In addition, there could be a variety of sensors installed in bins, like for detecting the emission of gasses or fire.
- Smart parking
  Sensors are used to collect data about the occupancy of each parking space are becoming a very prominent use case for IoT. This solution not only improves traffic congestion, but it can also improve revenue collection where parking is paid for and improve usage of parking spaces where drivers can be directed to a free space.

Smart Cities

- Intelligent lighting
  Intelligent lighting refers to lighting networks in which, for instance, lights can be turned on in a formation on-demand. In addition, maintenance gains can be improved through regular status reports. However, the gains are expected to be relatively low. Therefore, the bundling with other services is needed, e.g. for monitoring, reporting, and coordination tasks as well potential sites for small cells or roadside units (for V2X services).
- Public safety
  Public safety networks open new opportunities to detect and fight crime. Examples could be secure and reliable communication networks for security service and law enforcement as well as the real-time analysis of data coming from different sources like cameras, sensors, etc.

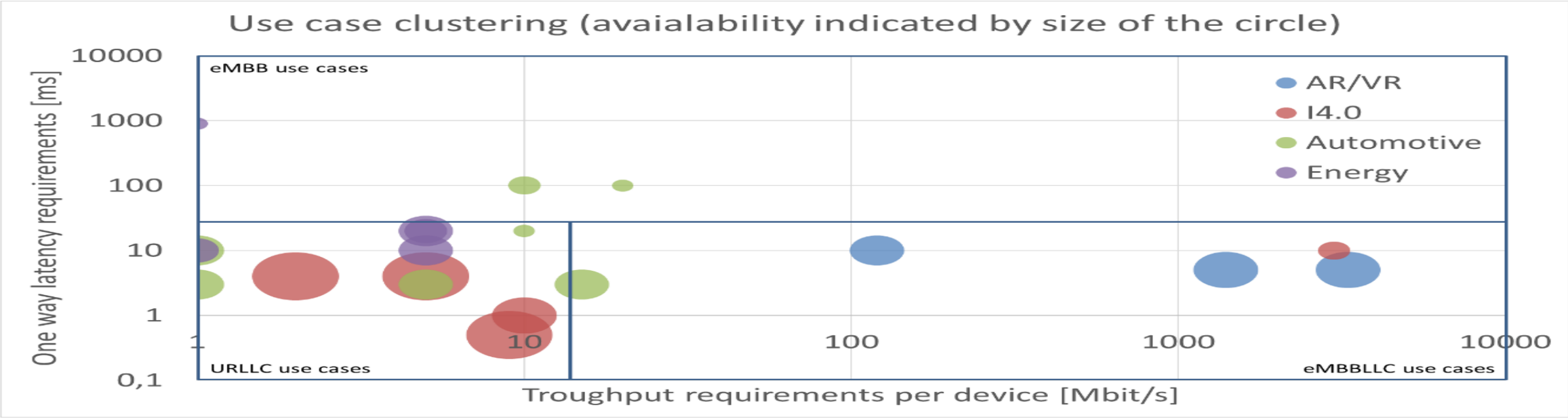
Smart Cities

- Emergency service management
  Emergency service management is about efficient and target-oriented communication in disaster (natural as well as man-made) scenarios. Herby, warnings to the people as well as communication to non-human entities (e.g. shutting down elevators, etc.) is envisioned.

06 Industry Recommendations & Requirements Analysis

Use Case Clustering

- Future use cases are normally clustered based on their performance requirements into:
  - Enhanced mobile broadband (eMBB)
  - Ultra-reliable low latency communications (URLLC)
  - Massive machine type communications (mMTC)



Ref: Network Slicing Use Case Requirements - GSMA

Performance Requirements

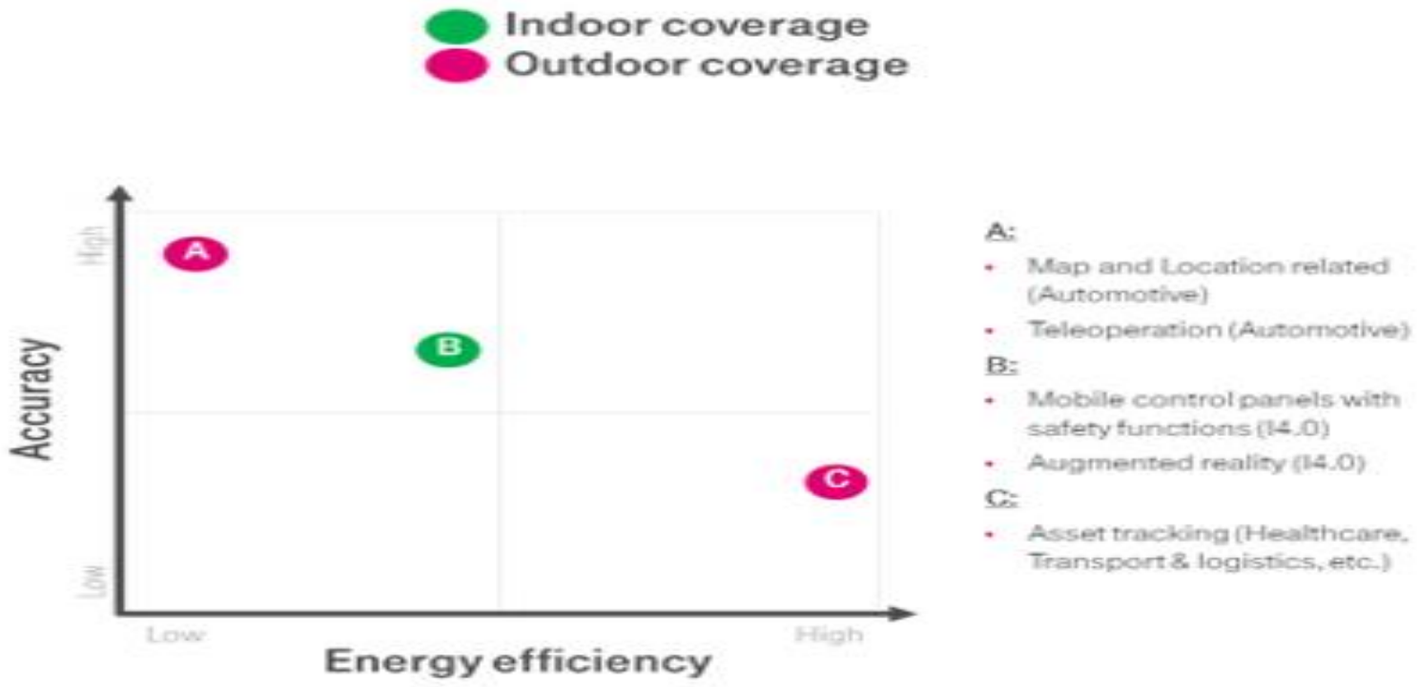
- Very tight synchronization
  Some use cases have stringent requirements in terms of synchronicity of communication devices. Examples are cooperative driving use cases from the automotive industry or motion-control and control-to-control use cases from the Industry 4.0 vertical. For the latter ones, values of smaller than 1 microsecond are required.
- Cyclic traffic
  Some applications rely on cyclic/deterministic traffic. Cyclic traffic is traffic with very regular traffic patterns, e.g. inter-packet delay (X).

Functional Requirements

- Security
  Security leaks may cause damage. Requirements may be very different from industry to industry. For instance, the method to provide secure connectivity for millions of low-cost sensors could be very different to the mechanisms used to provide security for public safety services. Appropriate technical solutions should be defined to meet these requirements and comply with the requirements and solutions defined by 3GPP.
- Isolation
  Degree of resource sharing that could be tolerated by the industry partner. Some customers may not mind to share network resource with other customers, but would require isolation for the computing resource. Sensitivity or criticality of the processes used by some customers may on the other hand lead to the requirement to only want to share the physical site like base stations, but use dedicated spectrum. Network Slicing should be able to be configured with different levels of isolation to satisfy the customers' needs.

Functional Requirements

- Positioning
  Many use cases have a strong demand for the capability of positioning (geo-localization) devices. Different customers may have different requirements in terms of accuracy, energy efficiency, indoor/outdoor support, and cost, etc. For some of the use cases, positioning techniques will have to work reliably under challenging conditions, e.g. deep indoors.



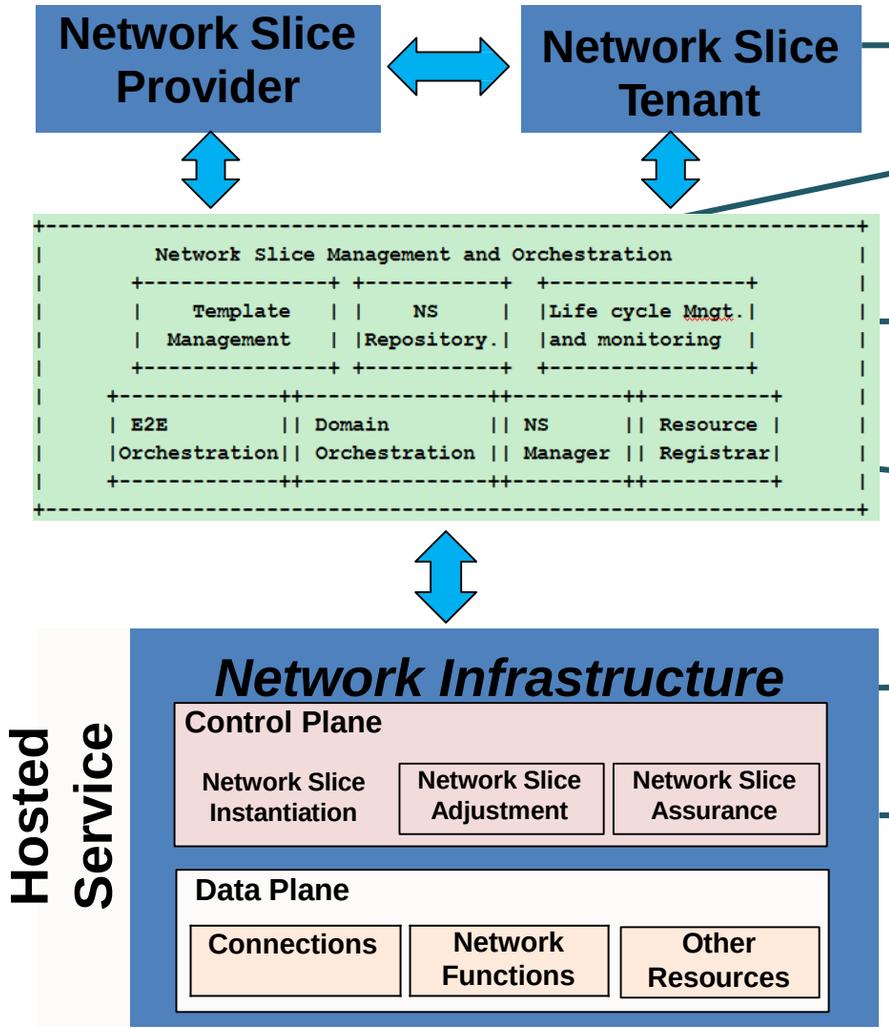
Ref: Network Slicing Use Case Requirements - GSMA

Functional Requirements

- Delay tolerance
  To support certain vertical industry use cases, mobile system should be able to provide guaranteed SLA that is agreed with the customers. For instance, certain traffic flows should reach the end user within certain latency boundary. At the same time, there are use cases that are less sensitive to delay variations giving the mobile system some level of flexibility in scheduling traffic. For instance, in automotive industry, (non-critical) software/firmware update could be deprioritized and delivered when traffic is low such as during off-peak hours.
- Predictive QoS
  Predictive QoS is an important feature allowing operators to inform the service in advance about a quality drop. Predictive QoS can be applied to various KPIs, e.g. coverage, throughput, latency, etc.

07 Network Slicing Challenges

Network Slicing Reference Architecture



Challenges

Cross-Domain Coordination

- Service/data model & mapping in a single domain and Cross-Domain Coordination
- Slice stitching / composition in a single domain and Cross-Domain Coordination

Network Slicing Management

- Uniform Network Slice life cycle management
- Network Slice Monitoring and Discovery
- Autonomic slice management and operation
- E2E Network Orchestration
- Realisation of NS Characteristics

Performance Guarantee and Isolation

- Guarantees for network slice isolation

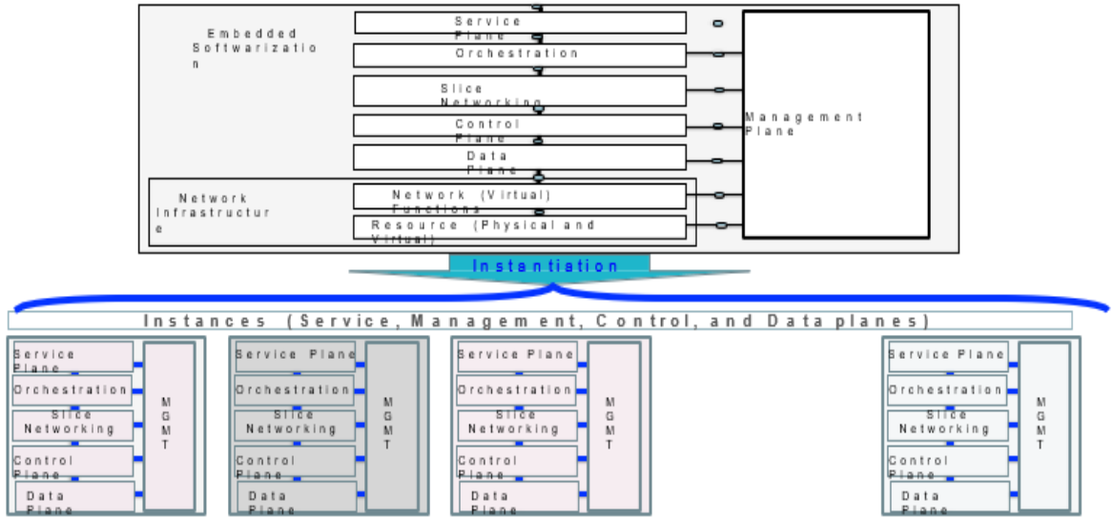
Slicing Resource & Requirement

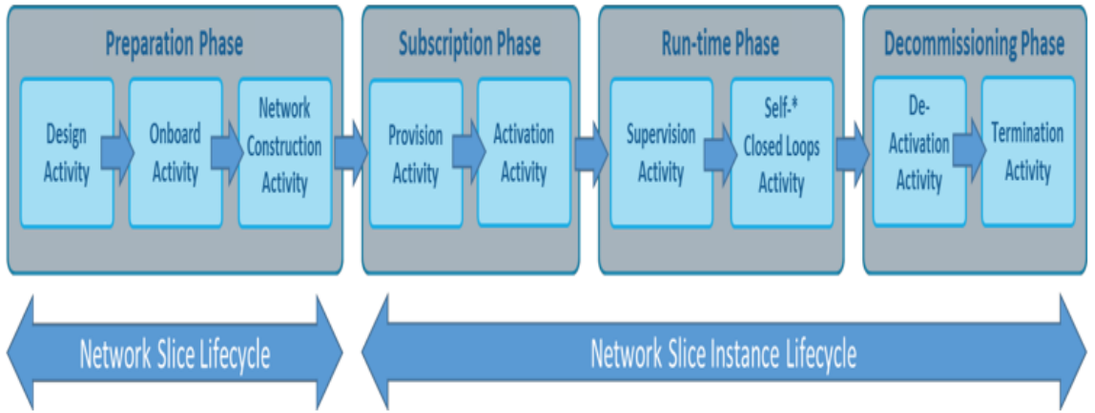
- Capability exposure and APIs

Ref: Network Slicing A holistic architectural approach, orchestration and management with applicability in mobile and fixed networks and clouds – prof. Alex Galis

Life Cycle Management

- **The management plane creates the grouping of network resources** (physical virtual, or a combination thereof), it **connects with the physical and virtual network and service functions**, and it **instantiates all of the network and service functions assigned to the slice**.
- Template/NS repository **assists life cycle management.**
- Resource Register **manages exposed network infrastructure capabilities.**
- NS Manager **oversees individual slice** (with capability exposure to NS Tenant).





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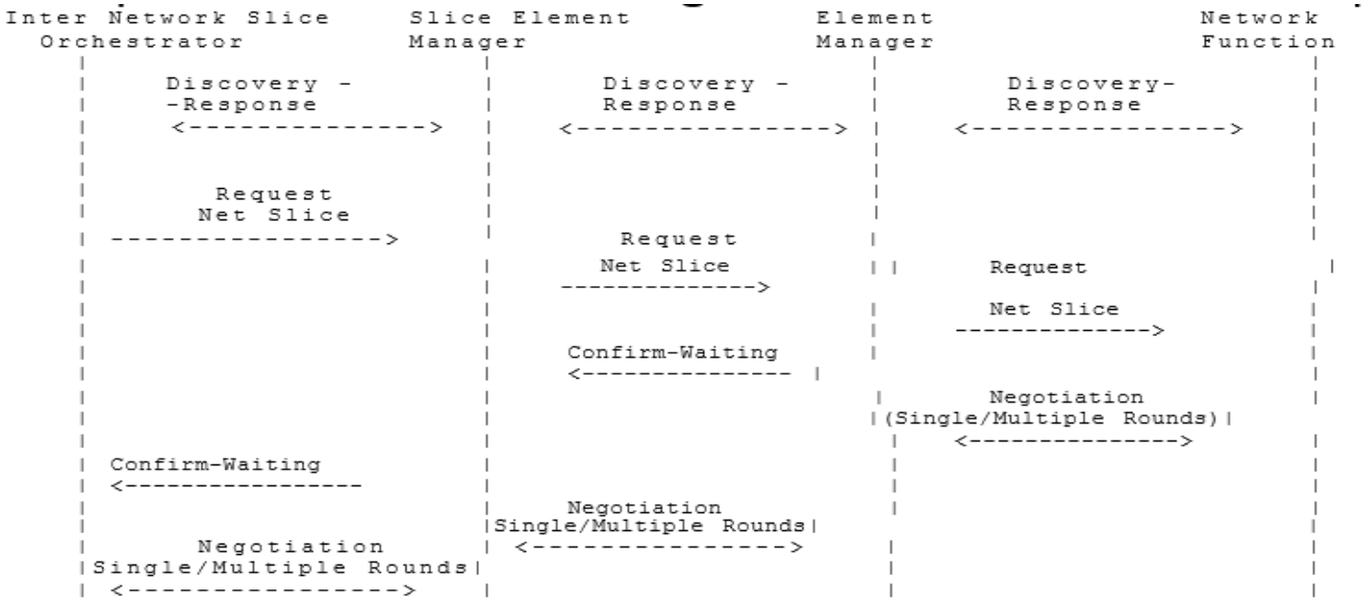
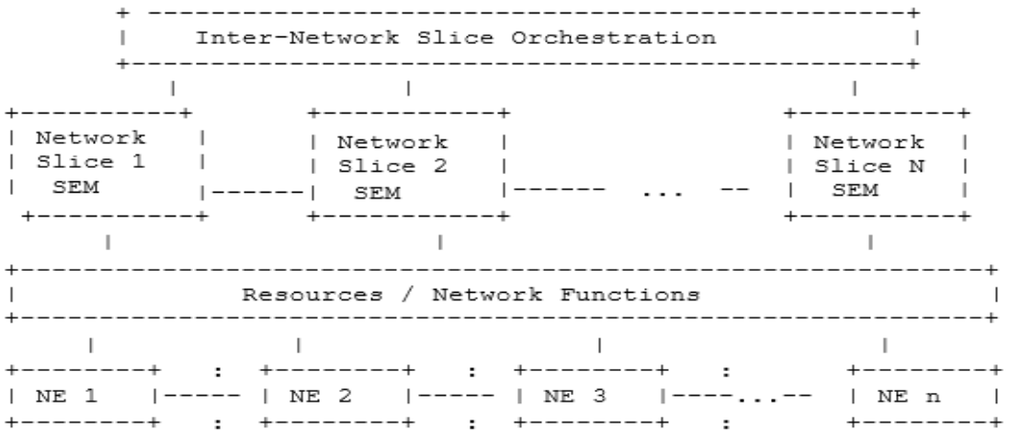
E2E Network Orchestration

- **Coordination of any number of inter-related resources** in a number of subordinate domains, and assurance of transactional integrity as part of the triggering process.
- **Autonomic control of slice life cycle management**, including concatenation of slices in each segment of the infrastructure (in data, control, and management planes).
- **Autonomic coordination and triggering of slice elasticity and placement**.
- **Coordination and (re)-configuration of resources** by taking over the control of all the network functions.

Monitoring and Discovery

- Monitoring Subsystem is responsible for **monitoring continuously the state all components of a NS**;
- Monitoring Subsystem receives the detailed service monitoring requests with references to resource allocation and Network functions instances in a NS.
- **Discovery and monitoring probes are needed of all NS components** and NS itself and for dynamic discovery of service with function instances and their capability.





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Autonomic Slice Management

- Network slice is a dynamic entity with autonomic characteristics of its lifecycle and operations.
- The problem of allocation of resources between slices combined with real-time optimization of slice operations can only be solved by continuous autonomic monitoring of slice performance and making continuous autonomic adaptations of the resources allocated to them.

Service Mapping Single Domain / Cross-Domain

- Service mapping **enables on-demand processing anywhere in the physically distributed network**, with dynamic and fine granular service (re)-provisioning;
- It includes a **slice-aware information** model based on **necessary connectivity, storage, compute resources, network functions, capabilities exposed and service elements**.

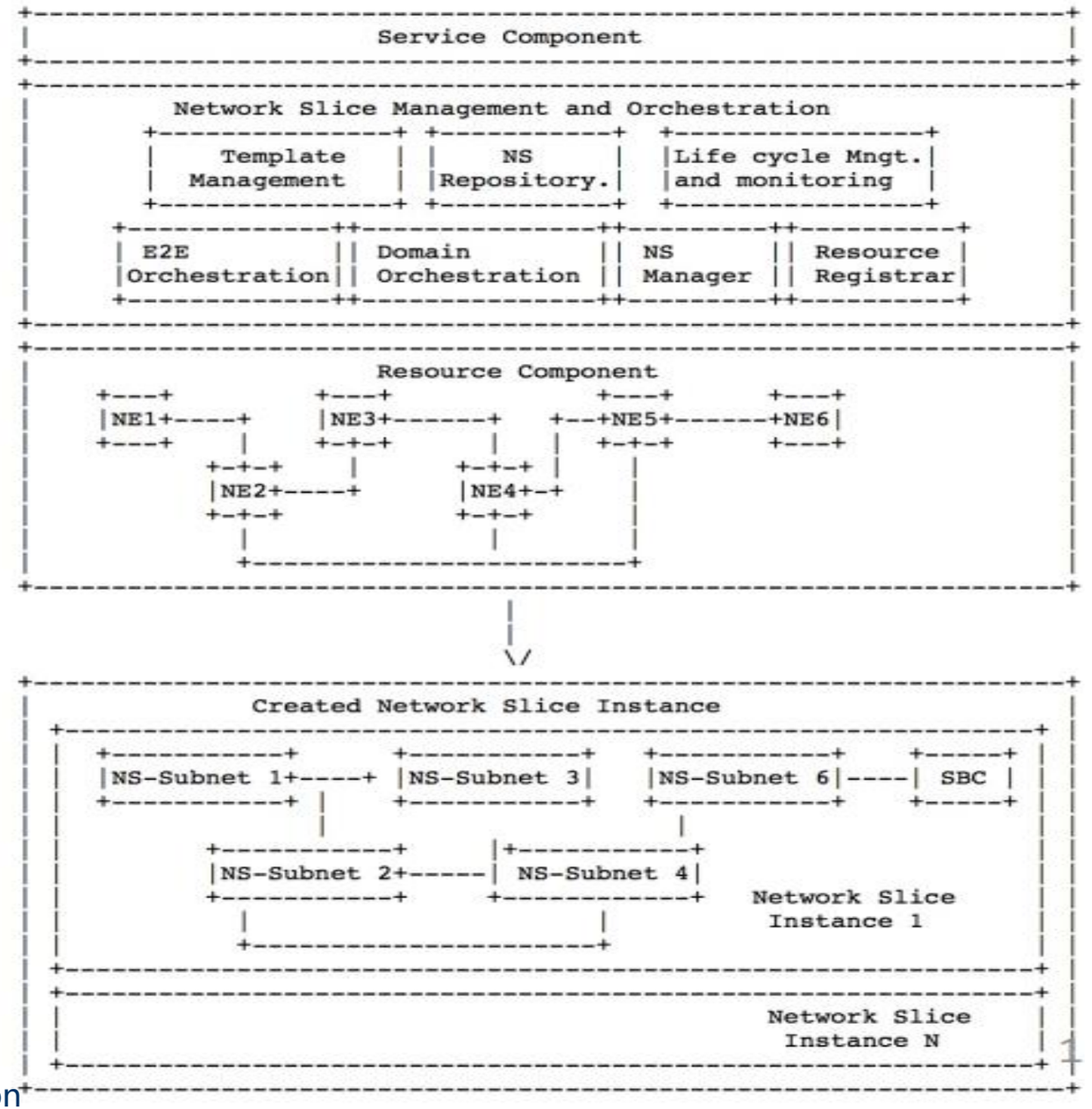
Slice Stitching

The stitching of slices is an operation that **modifies functionality of an existing slice by adding and merging functions of another slice** (i.e. enhancing control plane properties be functions defined in another slice template). Stitching of slices is used to enrich slice services:

- Slice stitching operations are supported by uniform slice descriptors.
- Efficient stitching/ decomposition (vertically, horizontally, vertically + horizontally).

Guarantees for Isolation

- **Guaranteed level of service**, according to a negotiated SLA between the customer and the slice provider.
- NS must be isolated at service level (e.g., one slice must not impact on the level of service of the other slides even if sharing resources); **isolated at data / control / management level**, even if sharing resources.
- **Exclusive control and / or management interfaces**, enabling the deployment of different logical network slices over shared resources



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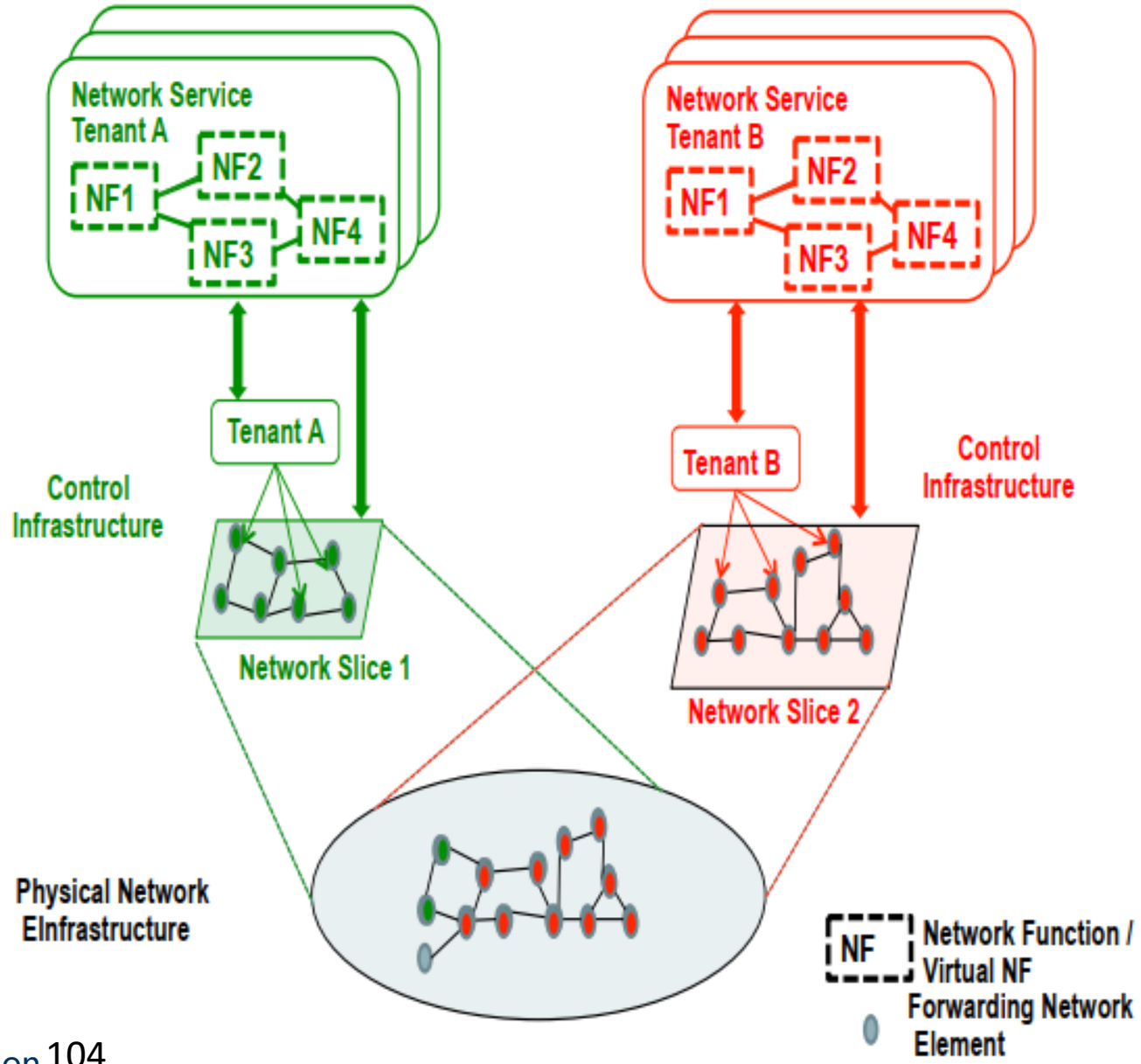
Uniform Reference Model

- Description of all of the functional elements and functional roles required for network slicing.
- Boundaries between the basic network slice operations (creation, management, exposure, consumption).
- Normalize nomenclature and descriptive / prescriptive definitions.



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Slice Templates

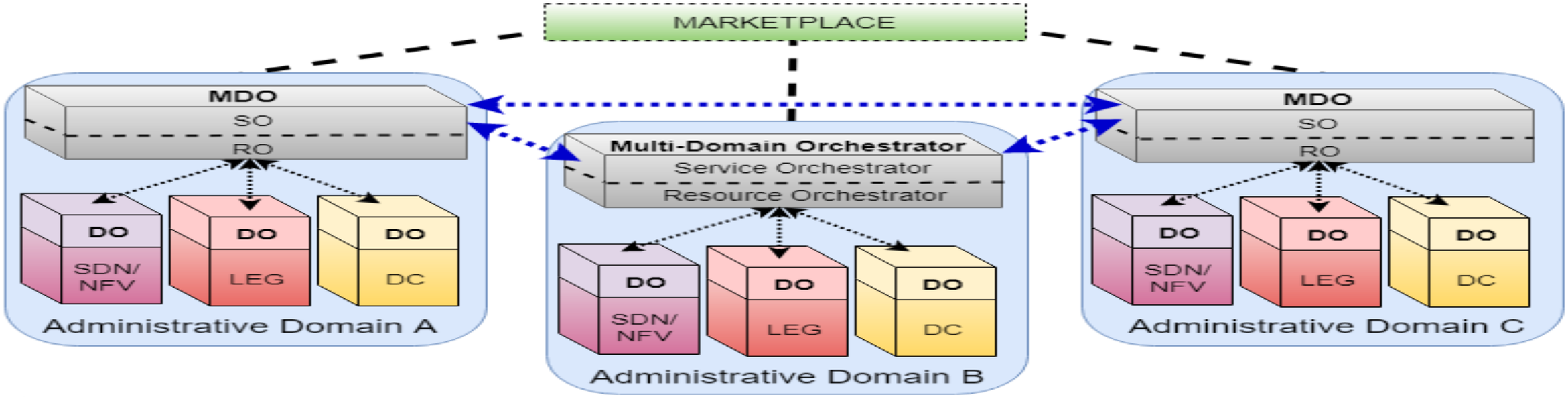
- Description of Service Instance Components.
- Description of Network Functions Instance Components.
- Description of Resource (connectivity, compute, storage).
- Description connectivity, compute, storage resources.
- Description of Slice Element Manager and Capability exposure component.

Slice Element Manager and Capability Exposure – APIs

- Description of exclusive control and/or management interfaces and capabilities exposed for a network slice, enabling the deployment of different logical network slices over shared resources.
- Description of the Slice Element Manager which guarantees a level of service, according to a negotiated SLA between the customer and the slice provider.

Realizing Network Slicing Capabilities

- **Network Slicing Service Mapping**: creating an efficient service mapping model binding across network slicing; specifying policies and methods to realize diverse service requirements without re-engineering the infrastructure
- **Network Slicing Recursion**: Recursion, namely methods for NS segmentation allowing a slicing hierarchy with parent–child relationships
- **Customized security per slice**: In any shared infrastructure, security is a key element to guarantee proper operation, and especially a fair share of resources to each user including Resource isolation and allocation policy at different levels and Isolation of network service management for multiple tenants.
- **E2E Precision Slicing** (E2E Network Slices with guaranteed QoS / KPIs)- E2E multiple logical, self-contained and independent, shared or partitioned networks on a common infrastructure with guaranties for QoS characteristics and /or KPIs (Key Performance Indicators).



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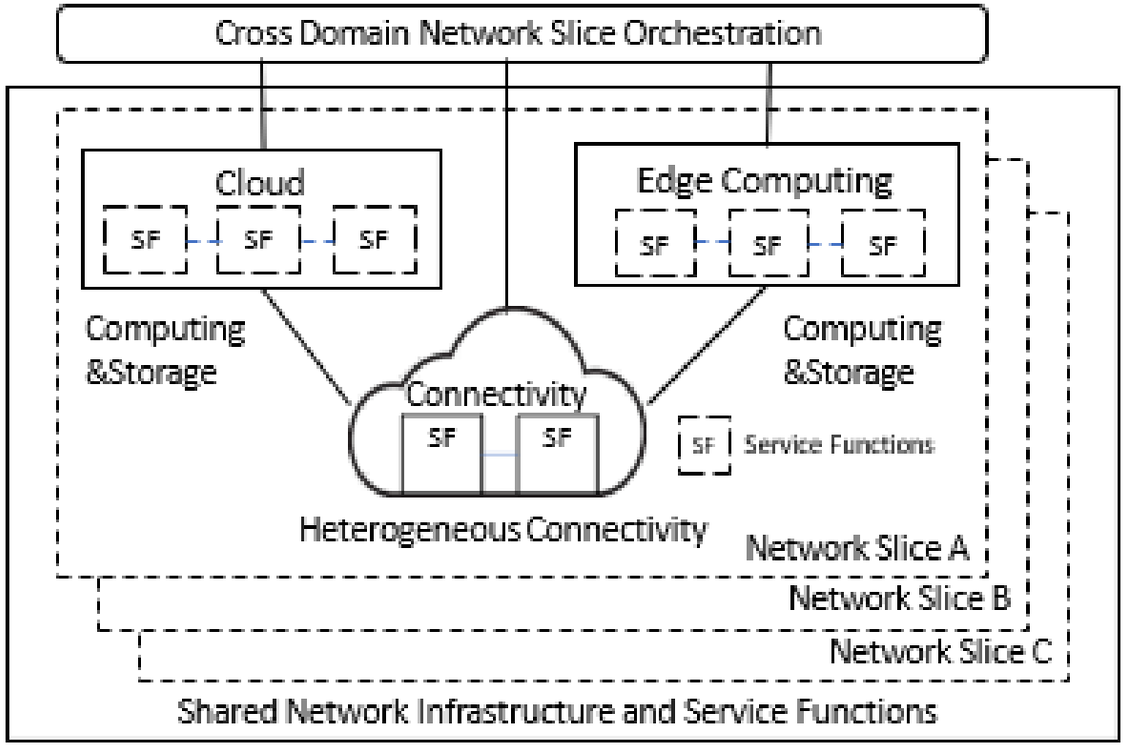
Realizing Network Slicing Capabilities

- **Network Slices Reliability**: Maintaining the reliability of a network slice instance, which is being terminated, or after resource changes
- **Flexible Radio Access Network (RAN) slicing**: RAN slicing targeting flexible customization and multiplexing over disaggregated RAN infrastructures agreement (SLA) with a tenant.
- **Per-tenant Policy Management**: In a multi-tenant, multi-slice end-to-end hosting and networking scenario, closed-loop automation requires both per-tenant policies, as well as the network operator's own. Per- tenant policies would be set to limit compute, storage and network resource usage, block the execution of unauthorized operations, trigger actions including scaling, healing, and topology reconfiguration to meet the service-level agreement (SLA) with a tenant
- **Network Slicing Scalability**: Scalability: In order to partition network resources in a scalable manner, it is required to clearly define to what extent slice customers can be accommodated or not on a given slice. The application of different SLAs on the offered capabilities of management, control and customization of slices will directly impact the scalability issue.

Realizing Network Slicing Capabilities

- **Uniform Slice lifecycle management :** Slice lifecycle management including creation, activation/deactivation, protection, elasticity, extensibility, safety, and sizing of the slicing model per network and per network cloud for slices in access, core and transport networks; for slices in data centres/clouds.
- **Network Slicing Optimization:** namely methods for automatic selection of network resources for NS; global resource views; global energy views; Network Slice deployment based on global resource and energy efficiency.
- **Network Slicing Dimensioning:** Over-dimensioning has been the normal way in the past for avoiding any kind of congestion. With slicing the traffic sources and destinations become much less predictable, if at all. Appropriate planning, dimensioning and enforcement are needed to make sustainable the transition to this new form of service.



Deployment and Economic

- **Deployment Options**: There are architectural, engineering, performance, flexibility and service agility without disruption challenges in terms support of many next-generation services in a NS enable infrastructure. In terms of deployment options an operator could deploy a single multi-service network, with a shared physical layer supporting a shared functional layer. Alternatively, the operator could deploy separate physical sub-networks, each with their own physical resource layer and functional layer on top of that; Or the operator could deploy discrete virtual networks, built on one shared physical resource layer, with multiple functional layers dedicated to each application or service type.
- **Economy of Scale in Slicing:** The benefits of slicing grow as the number of service types that you are trying to launch grows. In addition significant investment is needed in automation to be able to do this at scale, otherwise the complexity and operational challenges are likely to mount up. It's key that the rest of the organization gears up to support this ambition – development, delivery, marketing, operations and so on - otherwise the operator won't be able to exploit the technology commercially.

Deployment and Economic

- **Service Diversity:** the key challenge is how to support and operate different kind of services with very distinct needs onto the same infrastructure. One practical approach is to position segregated services on specialized partitions, designed and optimized for the type of service to be provided.
- **Vertical Customers:** Interaction with the vertical customers: Proper abstractions and templates have to be defined for ensuring the provision of a consistent service portfolio and their integration with the internal network management and orchestration.

參考資料

[1] Network Slicing A holistic architectural approach, orchestration and management with applicability in mobile and fixed networks and clouds – prof. Alex Galis

[2] Network Slicing Use Case Requirements - GSMA

[3] An Introduction to Network Slicing - GSMA

[4] Network slicing in 5G - Hans J. Einsiedler