5G Architecture Viewpoints

H2020 5G PPP Infrastructure Association

5G PPP 5G Architecture White Paper (July 2016, August 2017)
5G-PPP Cognitive Network Management for 5G White Paper (March 2017)
https://5g-ppp.eu/white-papers/

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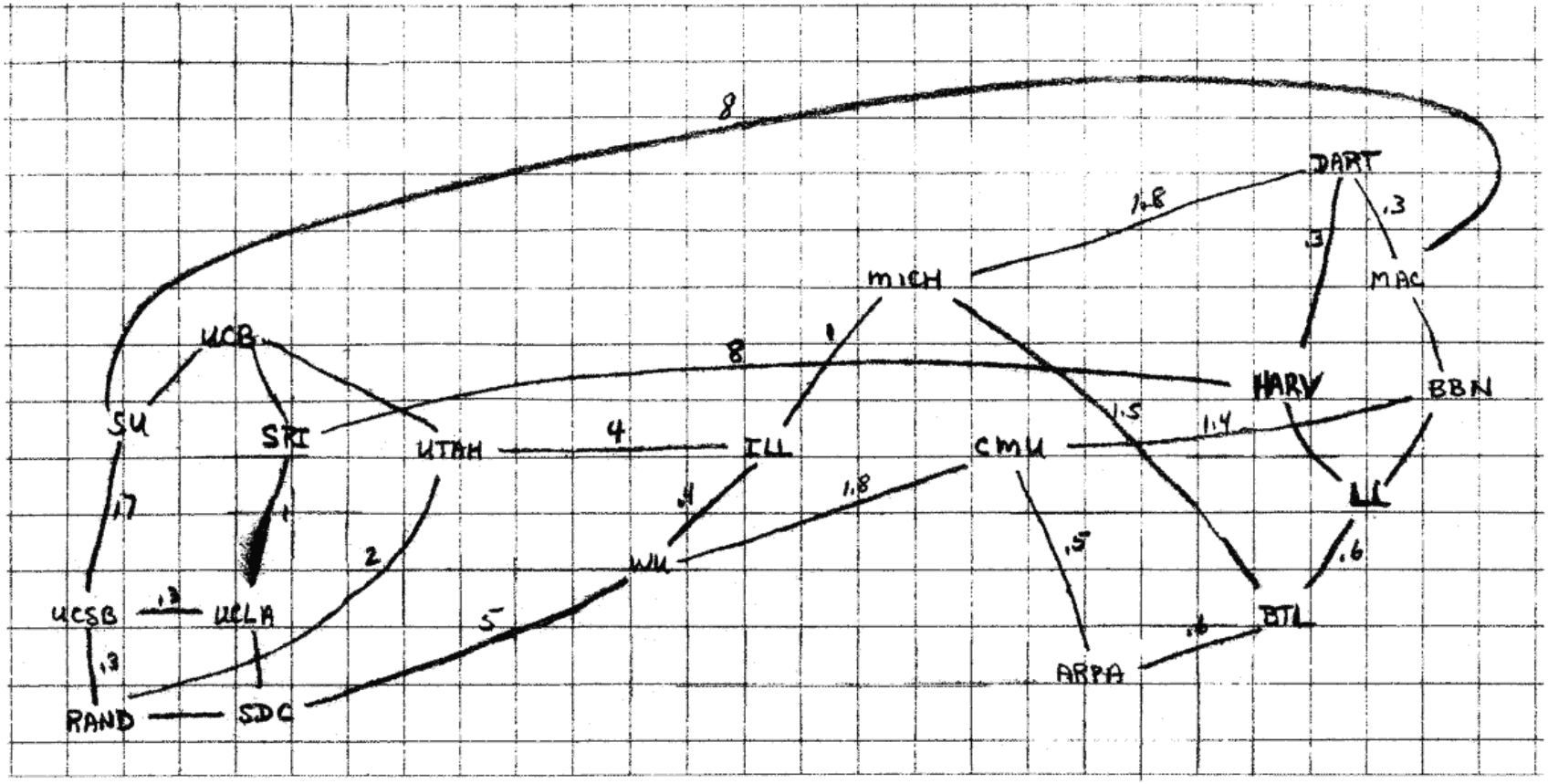
Content

Arpanet Rough sketch by Larry Roberts



5G Networking

5G Networking is driven by

- an **evolution in terms of higher capacity, performance and spectrum access in radio network segments**; and
- an evolution of **native higher flexibility and programmability conversion in all non-radio 5G network segments**: Fronthaul and Backhaul Networks, Access Networks, Aggregation Networks, Core Networks, Mobile Edge Networks, Edge Clouds Software Networks, Software-Defined Cloud Networks, Satellite Networks and IoT Networks.

5G Networking

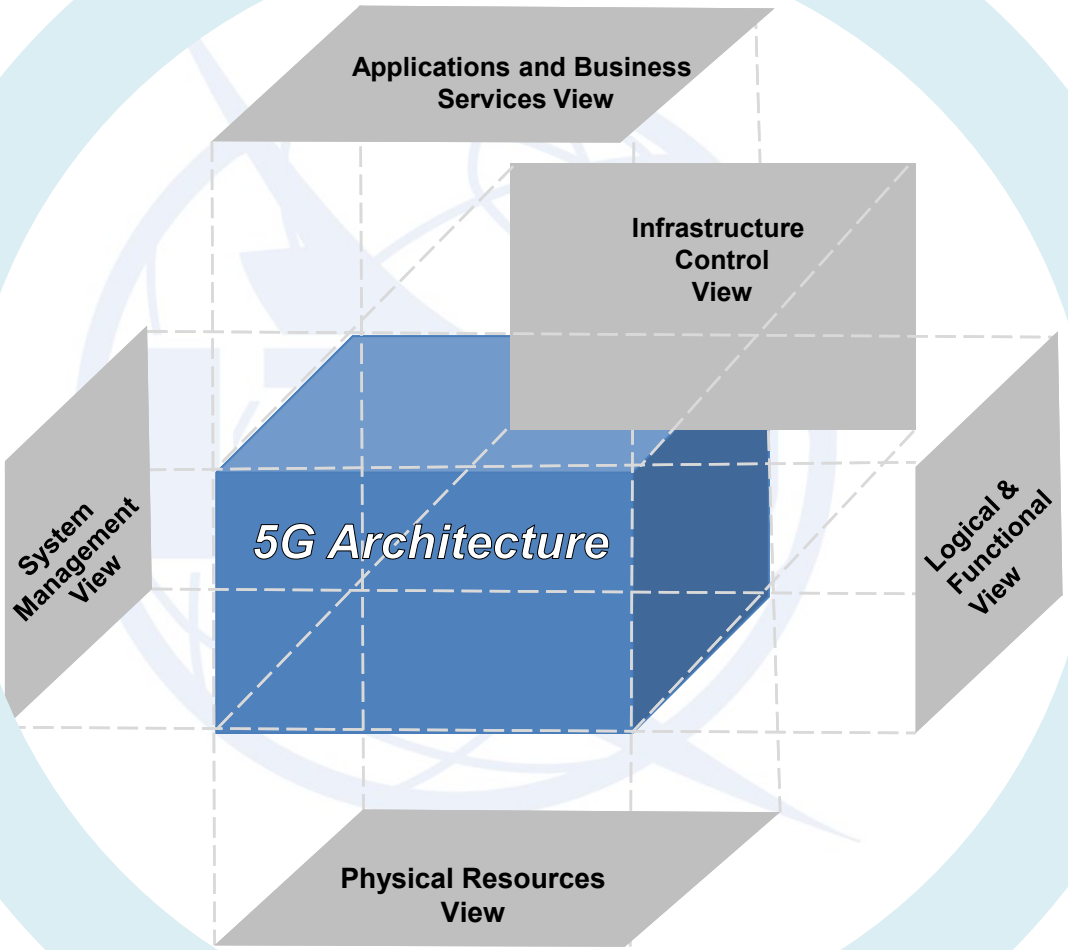
5G Networking is dependent logically and functionally on the followings key separation of concerns:

- **Serving at best high diversity types of communications** (Human & Machines & Devices & Sensors & Edge Systems) with different performance attributes.
- **Separation of concerns between control/management/softwarization/services**
- **Separation of concerns between logical / physical resources functions (i.e. connectivity, compute and storage resources) and network capabilities**
- **A shift in networking and a transition form "network of entities", as in current systems, to "network of (virtual) functions / capabilities**". As such "network (virtual) functions" are units of networking.
- **Network softwarization including network slicing**. Hosting services executions in one (or more) Slices. Network softwarization includes functions for programmability of
  - (1) network devices;
  - (2) network (virtual) functions;
  - (3) network slices;
  - (4) network services and applications;
  - (5) data, control, management planes.
- **Supporting on demand composition of network functions and network capabilities**
- Leveraging **natively Network Softwarization technologies in all network segments and network components.**

Network Slicing

Integrate Heterogeneous Technologies

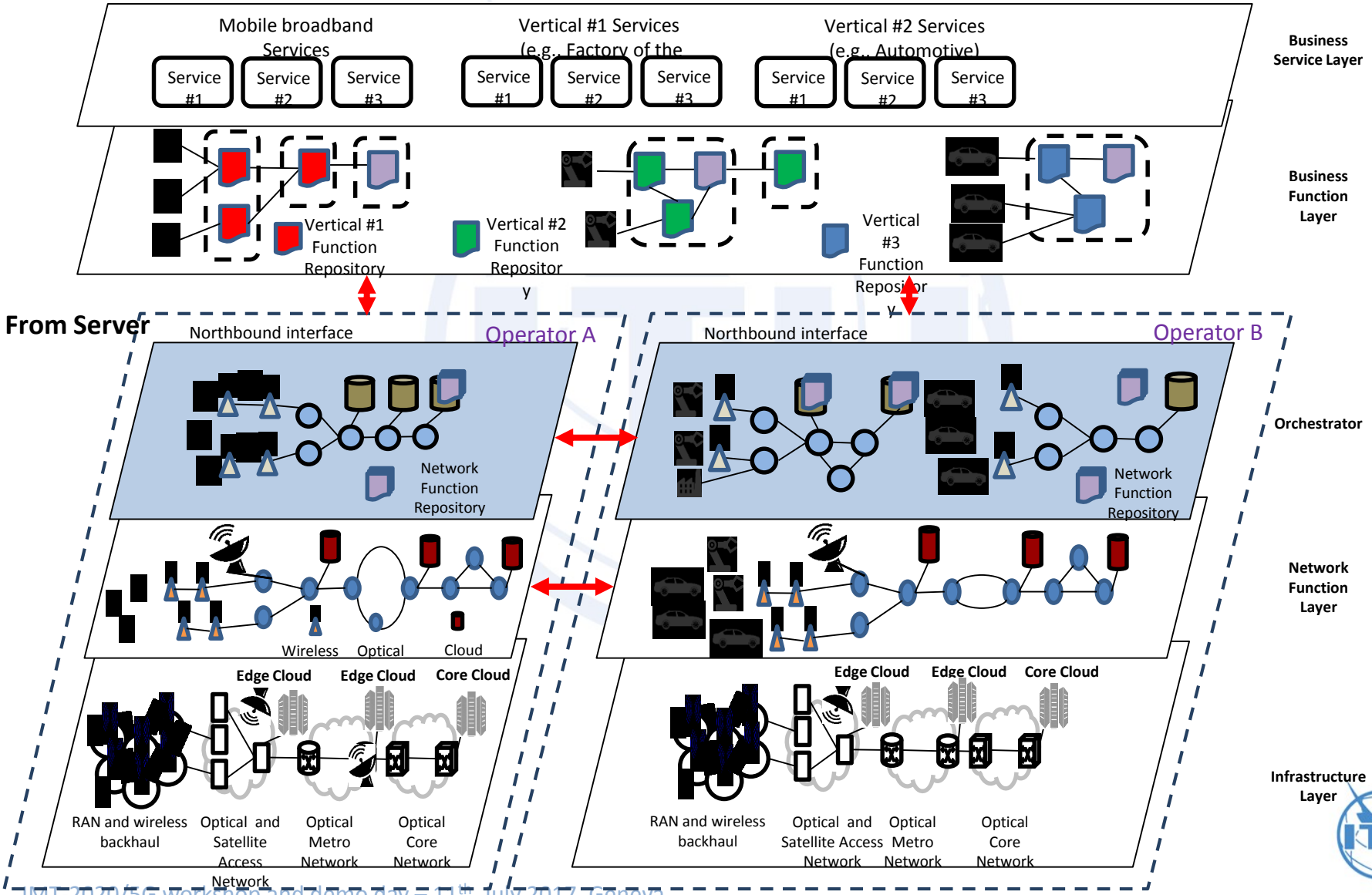
End user and operational services



Integrate Communication and Computation

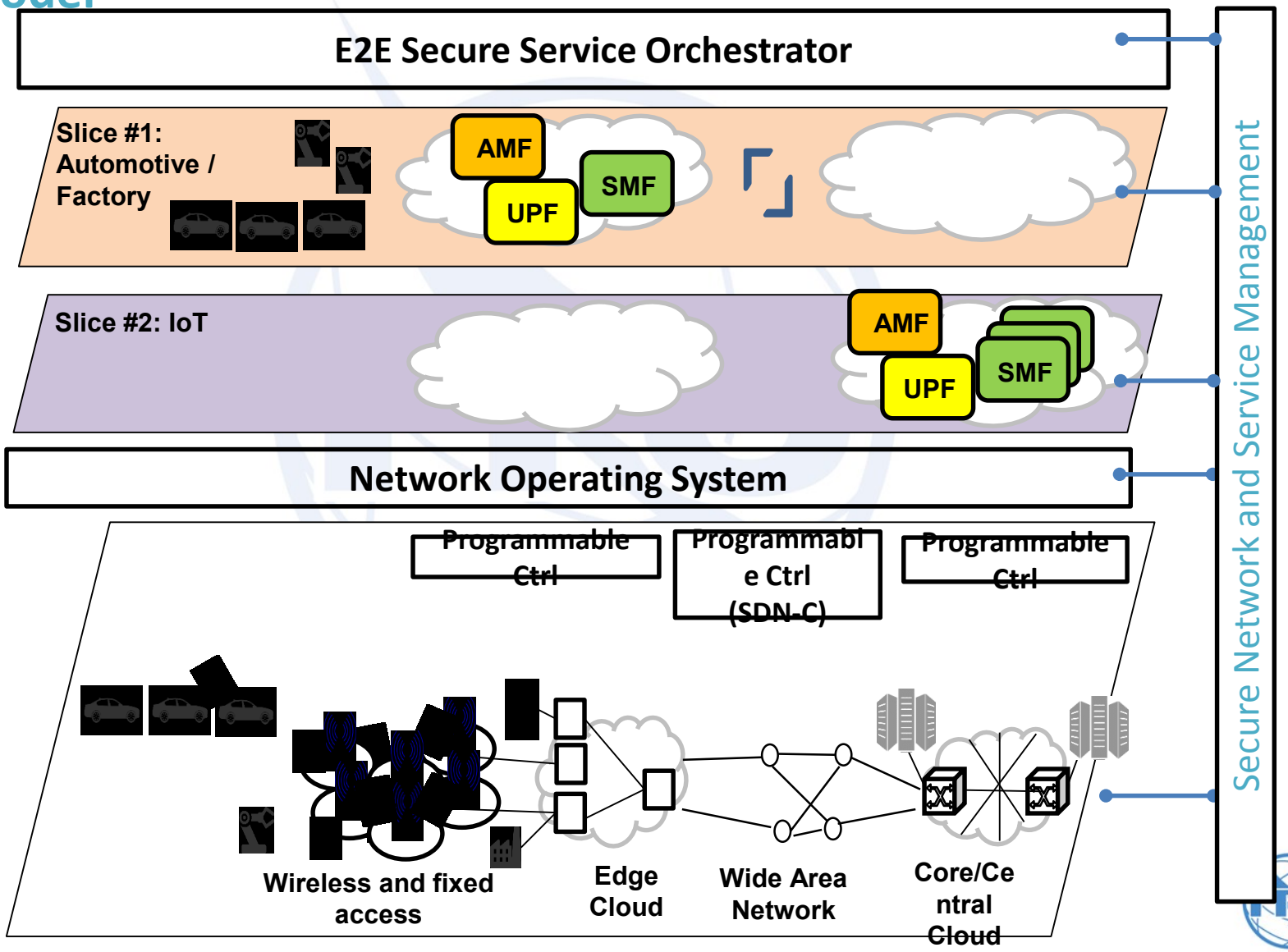
Native Softwarization

5G Networking Functional Layers



5G Architecture

Recursive Model



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5G Networking

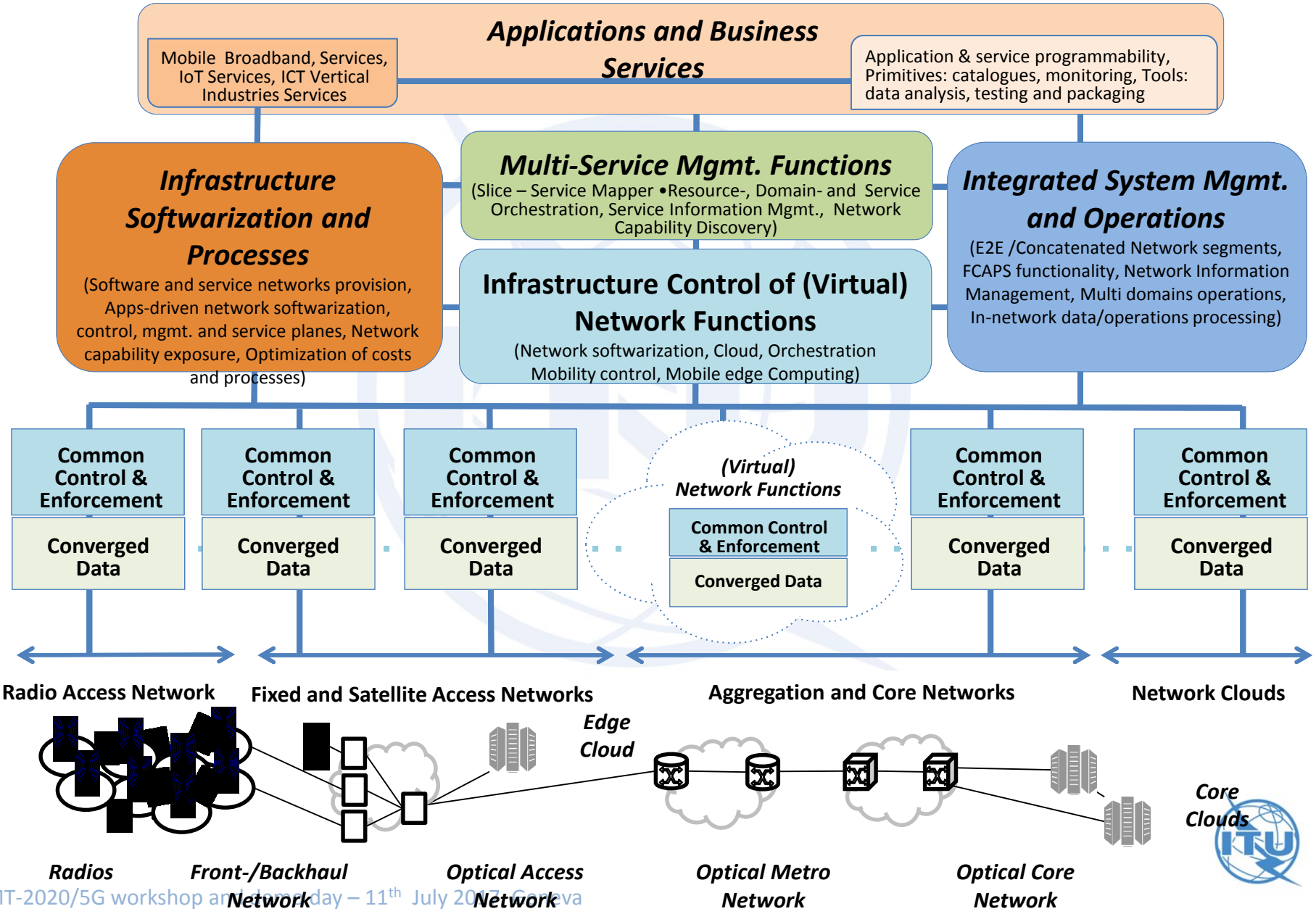
5G Functional Description and Programmability

5G Management & Security

5G Network Slicing

Concluding Remarks & Acknowledgement

5G Programmable Architecture



5G Planes

Application and Business Service Plane – It **defines and implements the business processes of the services along specific value chains**.

- A service in the 5G context is a piece of software that performs one or more functions, provides one or more APIs to applications or other services of the same or different planes to make usage of those functions, and returns one or more results.
- Services can be combined with other services, or called in a serialized manner to create a new service.
- An application in the 5G context is a piece of software that utilizes the underlying services to perform a function.
- Application operation can be parameterized, for example, by passing certain arguments at call time, but it is meant to be a standalone piece of software; an App does not offer any interfaces to other applications or services.

Integrated Network Management & Operations Plane -It enables the creation, deactivation, operation, control and coordination (orchestration) of

- Dedicated management functions operating on top of a 5G E2E smart infrastructure;
- The collection of resources required for managing the overall operation and coordination of individual network devices.
- It guarantees the creation the dynamic, configurable, resilient, cost effective software networks

It further includes E2E Network segments management, FCAPS functionality, Monitoring operations, Network Information Management, In-network data and operations processing and Multi-domains management operations.

5G Planes

Multi-Service Orchestration and Management Plane – *The functions and interfaces in this plane are used to set up and manage groups of network instances and/or nodes*.

- More specifically, the setup consists of creating/installing/arranging/deactivation/coordinating NFs and interfaces according to the available physical and virtual resources.
- It also comprises the set of functions associated with the network operations, such as fault management, performance management and configuration management.
- It further includes Slice – Service Mapper functions, Resources, Domain and Service Orchestration functions, Service Information Management functions and Network Capability Discovery functions.
- It also includes the lifecycle management of individual network functions and mobile network instances as a whole. In current mobile networks, this role is often performed by the Operations Support System (OSS). The idea is to enable the creation, operation, and control of multiple dedicated communication service networks running on top of a 5G E2E infrastructure.

Control Plane - *The collection of functions responsible for controlling one or more network functions.*

- Control Plane instructs network devices, network elements, and network functions with respect to processing elementary data units (packets, frames, symbols, bits, etc.) of the user/data/forwarding plane.
- The control of (virtual) network functions include Control of Network (Virtual) functions, Control of Orchestration functions, Control of Mobility functions, Cloud Control functions, Mobile Edge Computing Control functions and adaptors to different enforcement functions.
- The control of (virtual) network functions is generally 5G-applicable, and they are separated from the control and enforcements functions which are network segment-specific. The control plane interacts primarily with the forwarding plane and, to a lesser extent, with the management plane.

Forwarding Plane / Data Plane - *The collection of resources across all network devices responsible for forwarding traffic.*

5G Planes

Infrastructure Softwarization Plane – Enables the **provisioning and operation of software and service networks**. It facilitates the operation of end-to-end heterogeneous networking and distributed cloud platforms, including physical and logical resources and devices. It includes functions for designing, implementing, deploying, managing and maintaining network equipment, network components and/or network services by programming. It further includes functions for the provision of software and service networks, application driven network softwarization, programmability of Software Networks, dynamic deployment of new network and management services (i.e. which could be executed in data, control, management, service plane), network capability exposure, and E2E slice provisioning. It includes functions for dynamic programmability of

(1) network devices;

(2) network (virtual) functions;

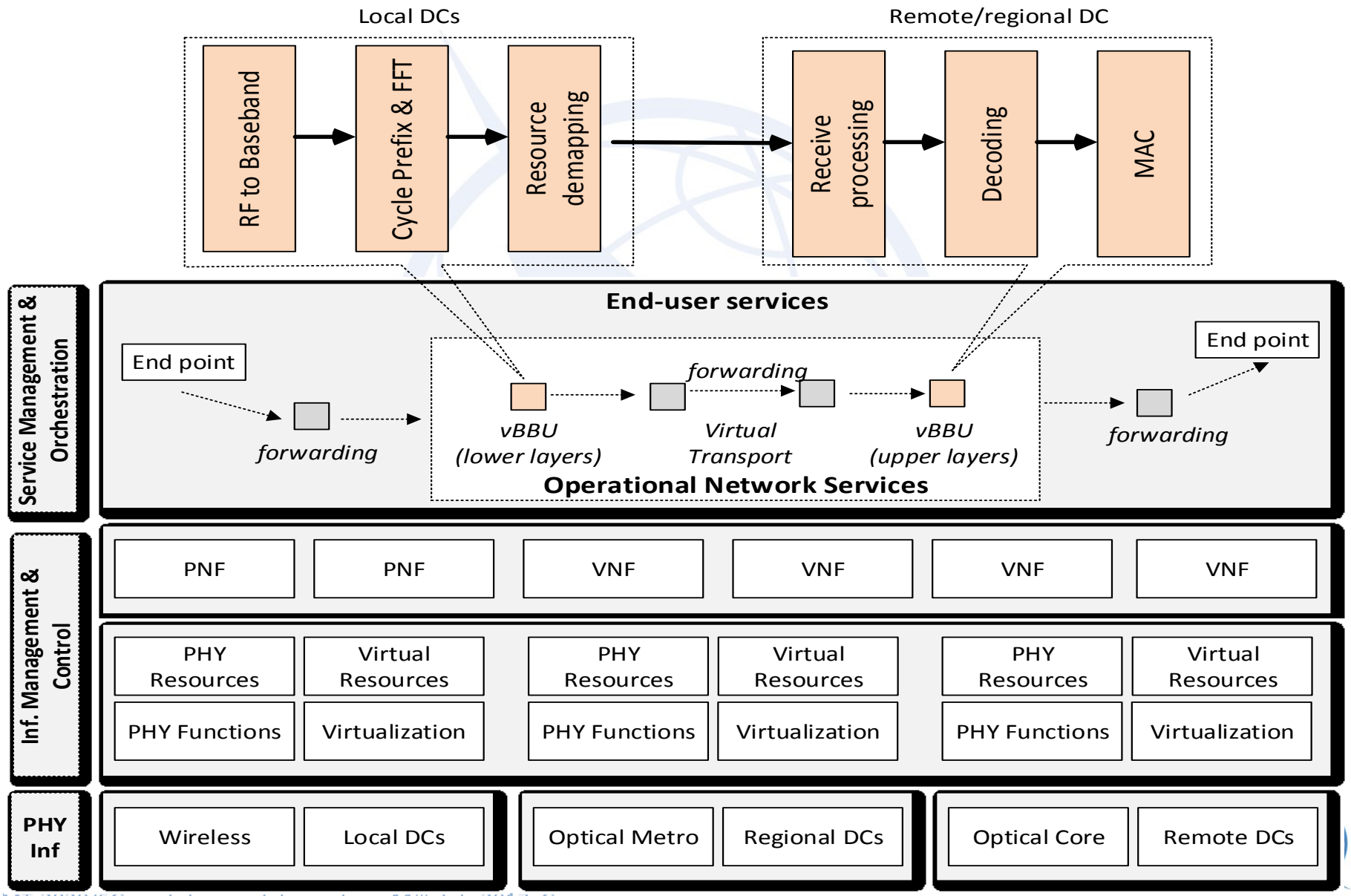
(3) network slices,

(4) network services and applications;

(5) Data, control, management planes.

The software utilize features such as flexibility and rapidity all along the lifecycle of network equipment/components/services, in order to create conditions that enable the re-design of network and services architectures, optimize costs and processes, allow self-management and bring added value to network infrastructures.

5G Programmable Hardware



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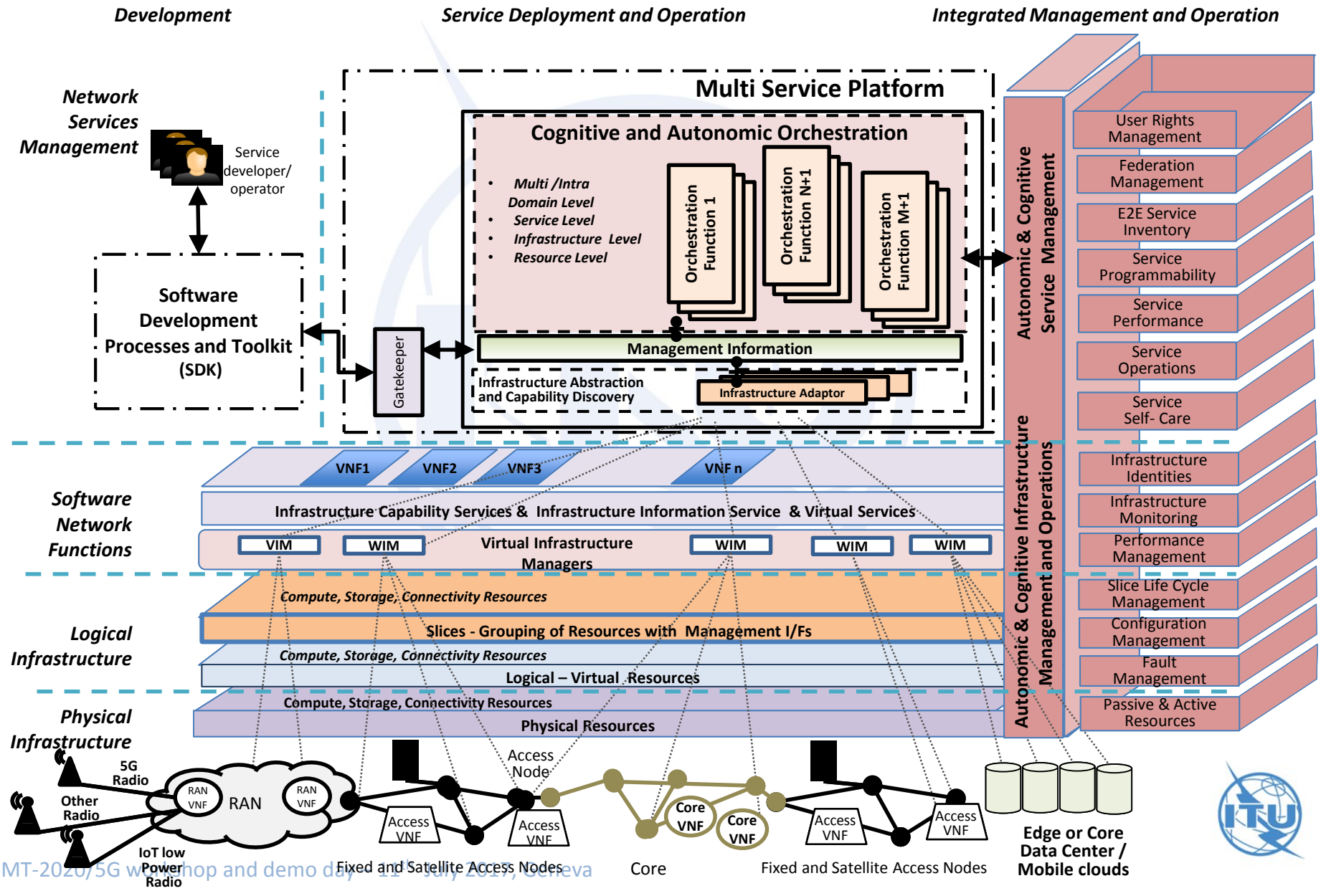
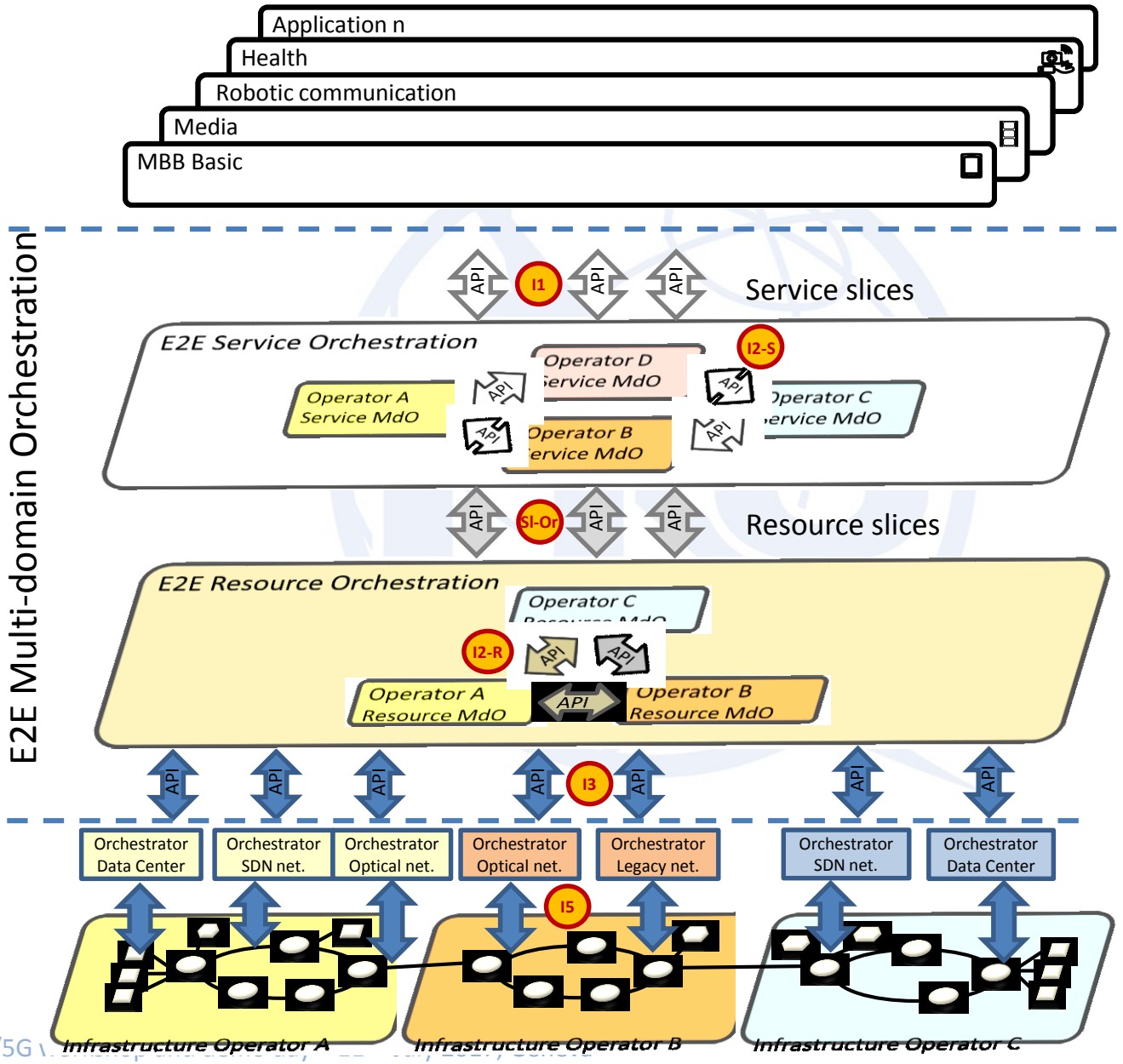
5G Management and Orchestration



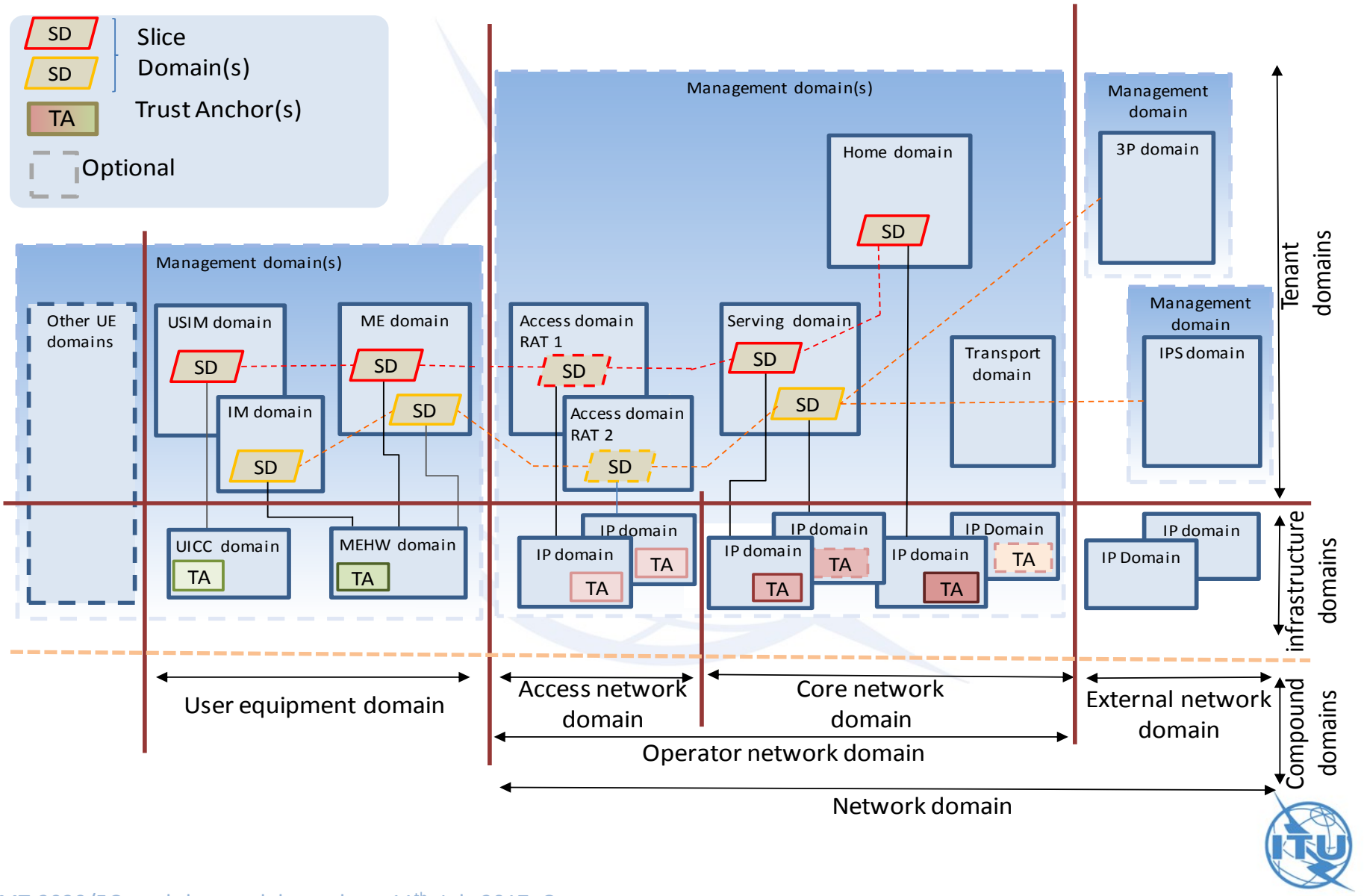
E2E Multi-Domain



Infrastructure programmability

Resource Domains

5G Security Domains



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5G Network Slicing

Concluding Remarks & Acknowledgement

Definitions of Network Slicing & References (I)

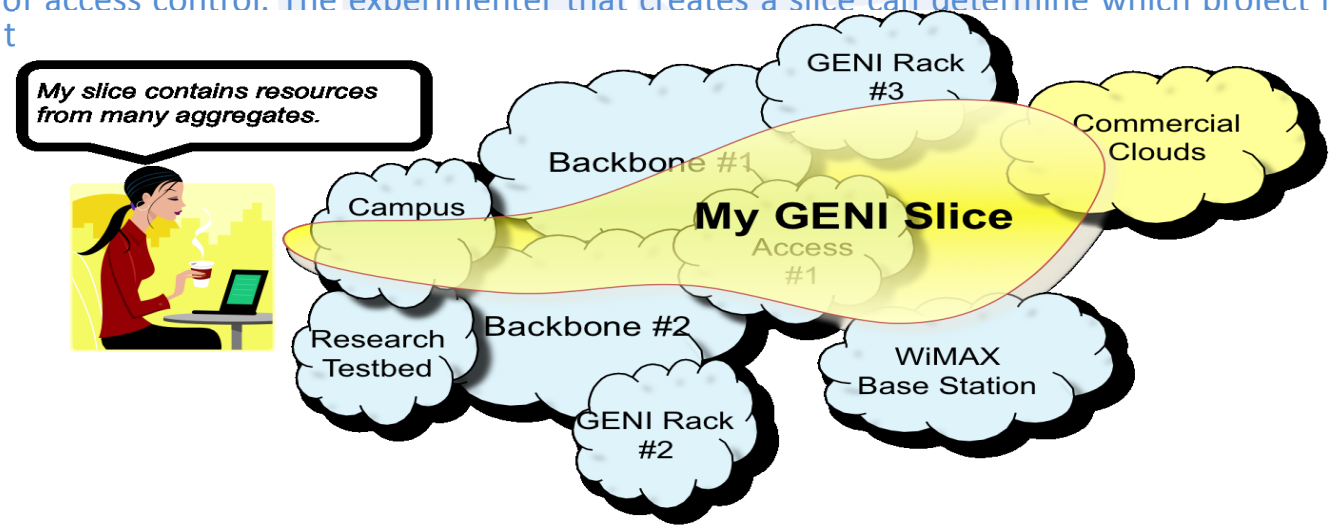
I - Slicing Resources:

Active / Programmable Networks research: node operating systems & resource control frameworks (1995 -2005) (*)

Federated Testbed research : Planet Lab USA (2002), PlanetLab EU (2005), OneLab EU (2007), PlanetLab Japan (2005), OpenLab EU (2012)

GENI Slice (2008): "GENI is a shared network testbed i.e. multiple experimenters may be running multiple experiments at the same time. A GENI slice is:

- The unit of isolation for experiments.
- A container for resources used in an experiment. GENI experimenters add GENI resources (compute resources, network links, etc.) to slices and run experiments that use these resources.
- A unit of access control. The experimenter that creates a slice can determine which project members have access t



(*) Galis, A., Denazis, S., Brou, C., Klein, C. (ed) –"Programmable Networks for IP Service Deployment" ISBN 1-58053-745-6, pp 450, June 2004, Artech House Books, http://www.artechhouse.com/International/Books/Programmable-Networks-for-IP-Service-Deployment-1017.aspx

Definitions of Network Slicing & References(II)

I - Slicing Resources:

Slice capabilities (**2009**) "Management and Service-aware Networking Architectures (MANA) for Future Internet" – A. Galis et all - Invited paper IEEE 2009 Fourth International Conference on Communications and Networking in China (ChinaCom09) 26-28 August 2009, Xi'an, China, http://www.chinacom.org/2009/index.html

3 Slices Capabilities

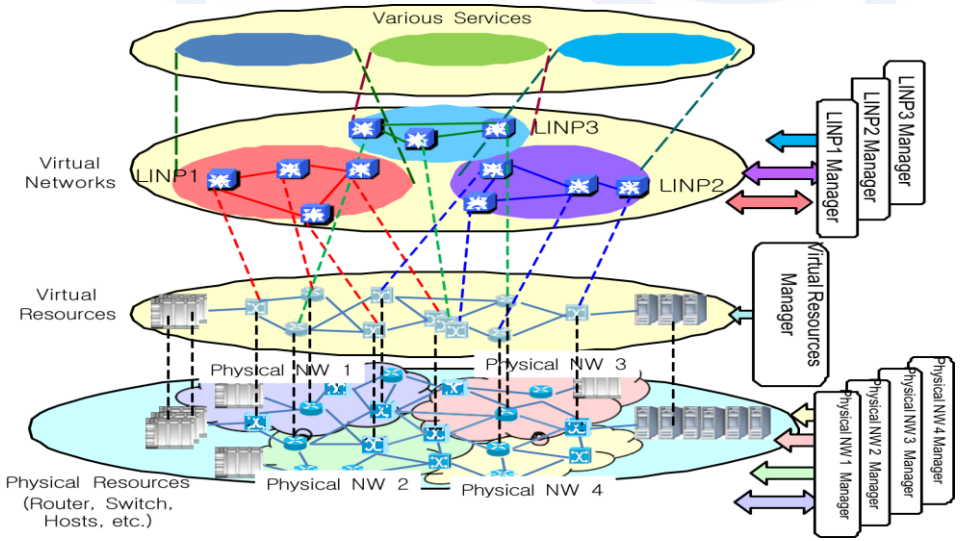
- "Resource allocation to virtual infrastructures or slices of virtual infrastructure."
- "Dynamic creation and management of virtual infrastructures/slices of virtual infrastructure across diverse resources."
- "Dynamic mapping and deployment of a service on a virtual infrastructure/slices of virtual infrastructure."

17 Orchestration capabilities

19 Self-functionality mechanisms

14 Self-functionality infrastructure capabilities

ITU-T Slicing (2011) as defined in [ITU-T Y.3011], [ITUTY.3012] is the basic concept of the Network Softwarization. Slicing allows logically isolated network partitions (LINP) with a slice being considered as a unit of programmable resources such as network, computation and storage.

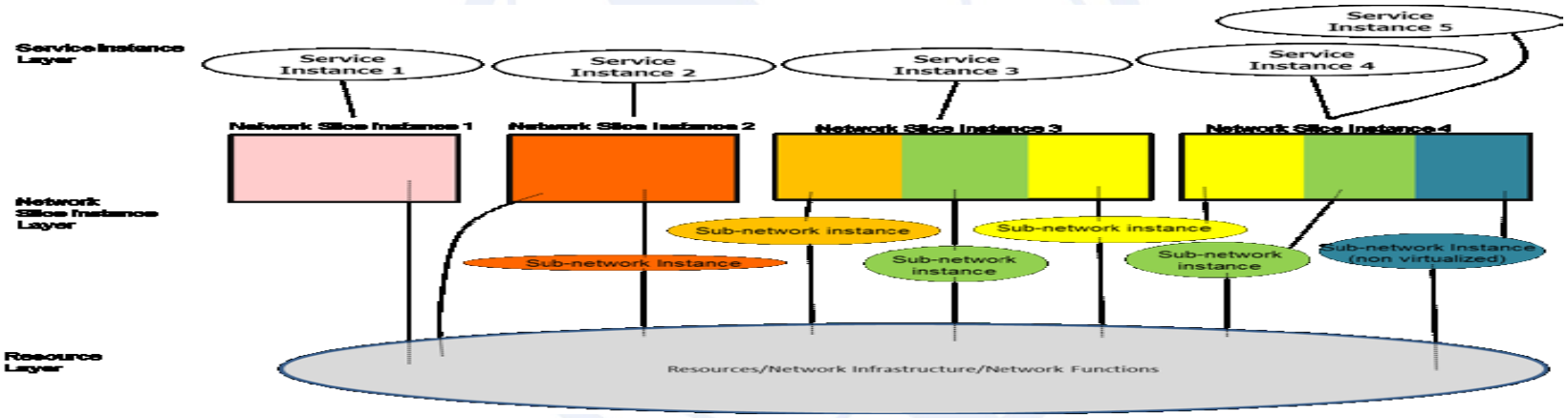


Definitions of Network Slicing & References(III)

II- Network Slicing :

NGMN Slice capabilities (2016) - consist of 3 layers: 1) Service Instance Layer, 2) Network Slice Instance Layer, and 3) Resource layer.

- The Service Instance Layer represents the services (end-user service or business services) which are to be supported. Each service is represented by a Service Instance. Typically services can be provided by the network operator or by 3rd parties.
- A Network Slice Instance provides the network characteristics which are required by a Service Instance. A Network Slice Instance may also be shared across multiple Service Instances provided by the network operator.
- The Network Slice Instance may be composed by none, one or more Sub-network Instances, which may be shared by another Network Slice Instance.



3GPP SA2 23.799 Study Item "Network Slicing' **2016** ; SA5 TR 28.801Study Item "Network Slicing **2017**

ONF Recommendation TR-526 "Applying SDN architecture to Network Slicing" **2016**

IETF Draft draft-gdmb-netslices-intro-and-ps-02 2016- 2017

EU 5GPPP

- **15 Large Scale Research projects – all based on Network Slicing** (https://5g-ppp.eu) **(2015- 2018+)**
- **White Paper on 5G Architecture centered on network slicing** (https://5g-ppp.eu/wp-content/uploads/2014/02/5G-PPP-5G-Architecture-WP-July-2016.pdf) **(2016)**

Definitions of Network Slicing & References(III)

Slice as a union of subsets of resources & NFVs at a given time

(1) The Service Instance component

- represents the end-user service or business services.
- an instance of an end-user service or a business service that is realized within or by a NS.
- would be provided by the network operator or by 3rd parties.

(2) A Network Slice Instance component

- represented by a set of network functions, and resources
- forms a complete instantiated logical network to meet certain network characteristics required by the Service Instance(s).
- provides network characteristics which are required by a Service Instance.
- may also be shared across multiple Service Instances

(3) Resources component – it includes: *Physical, Logical & Virtual resources*

- *Physical & Logical resources* - An independently manageable partition of a physical resource, which inherits the same characteristics as the physical resource and whose capability is bound to the capability of the physical resource. It is dedicated to a Network Function or shared between a set of Network Functions;
- *Virtual resources* - An abstraction of a physical or logical resource, which may have different characteristics from that resource, and whose capability may not be bound to the capability of that resource.

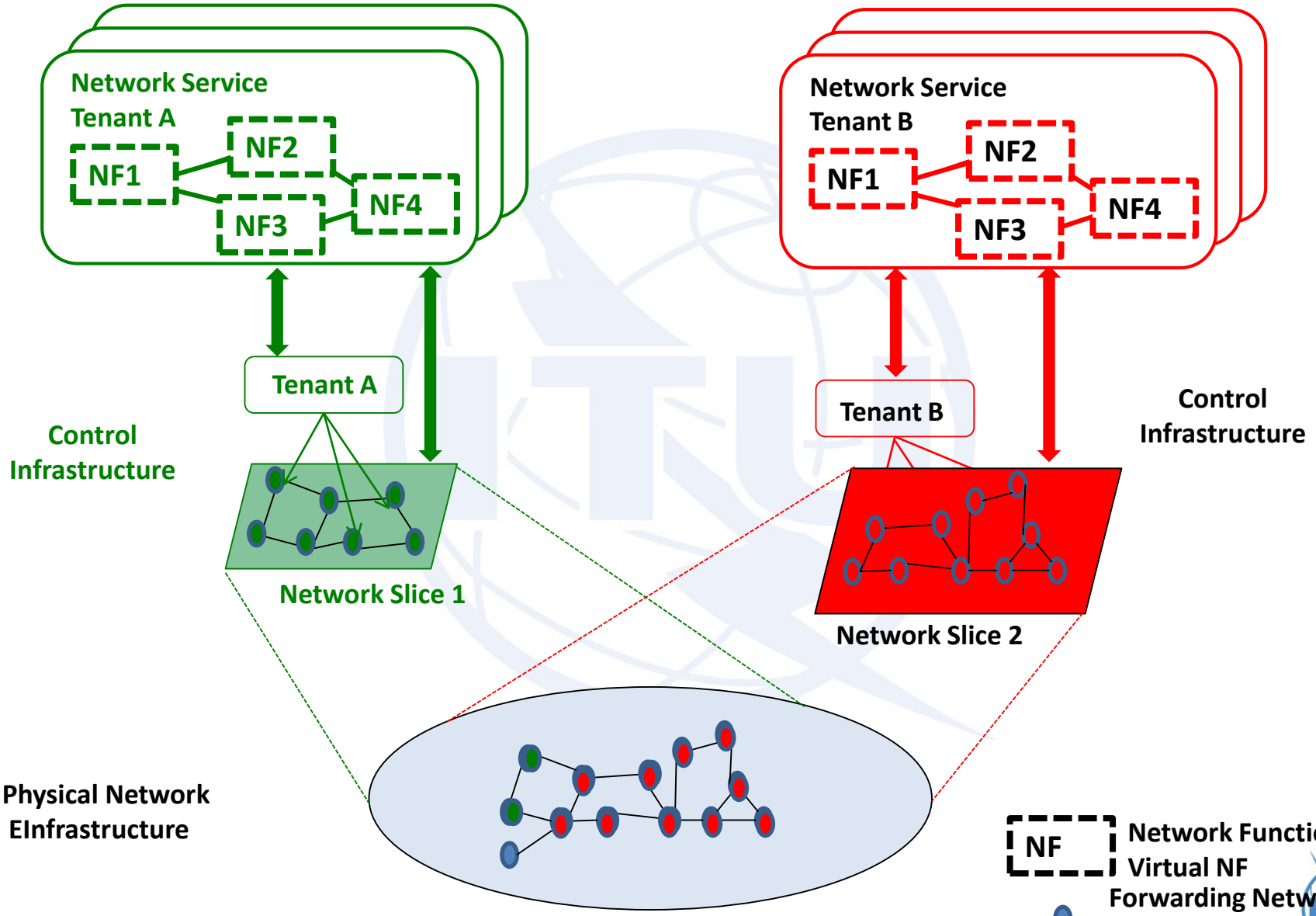
(4) Slice Capability exposure component

- allow 3rd parties to access via APIs information regarding services provided by the slice (e.g. connectivity information, QoS, mobility, autonomicity, etc.)
- allow to dynamically customize the network characteristics for different diverse use cases within the limits set of functions by the operator.
- it includes a description of the structure (and contained components) and configuration of the slice instance.

NS Scenarios

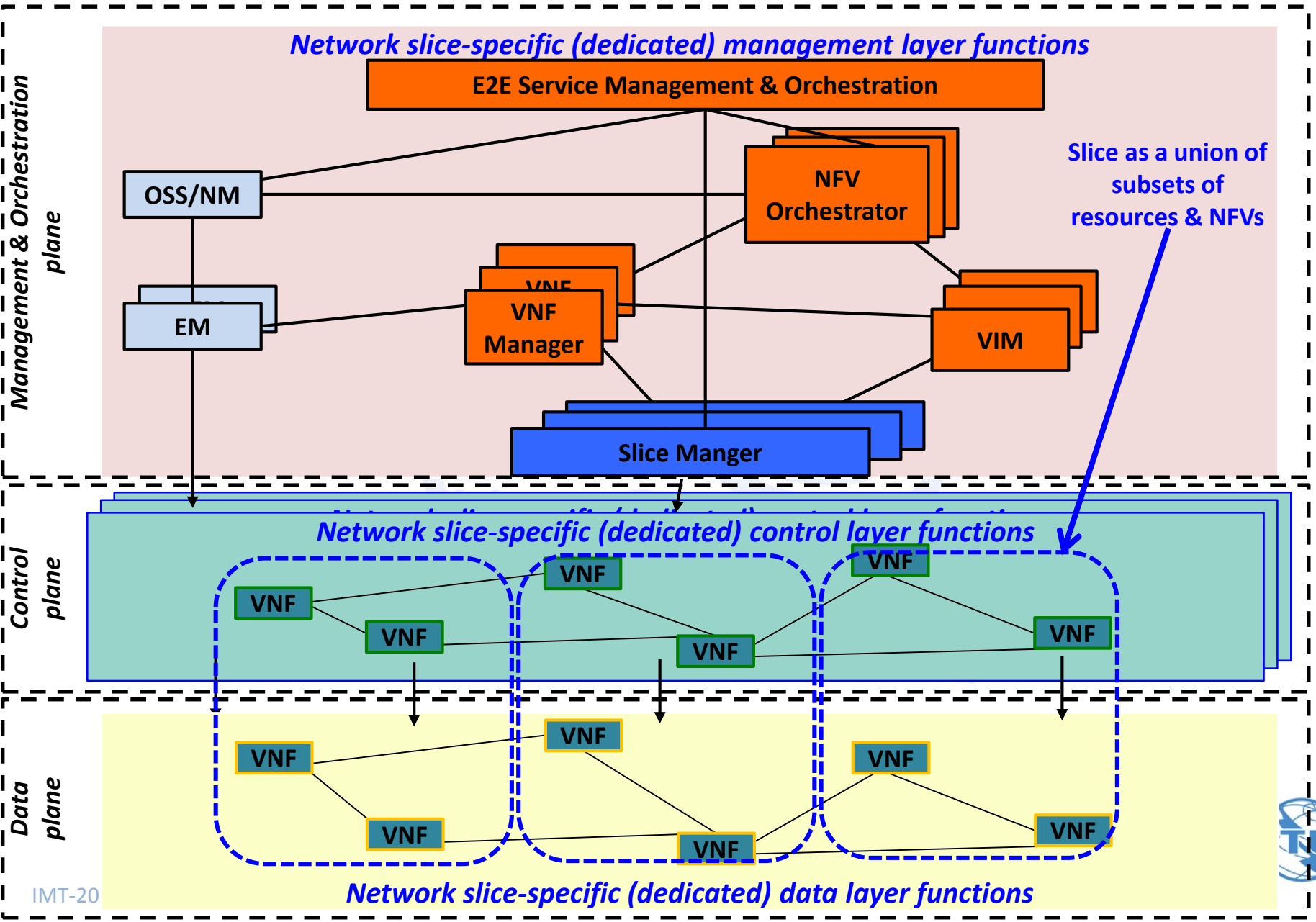
- Mission-critical Ultra low latency communication
- Massive-connectivity machine communication (e.g. Smart metering, Smart grid and sensor networks)
- Extreme QoS
- Independent QoS isolation design
- Independent operations and management
- Independent autonomic management functionality
- Independent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

NS Representation

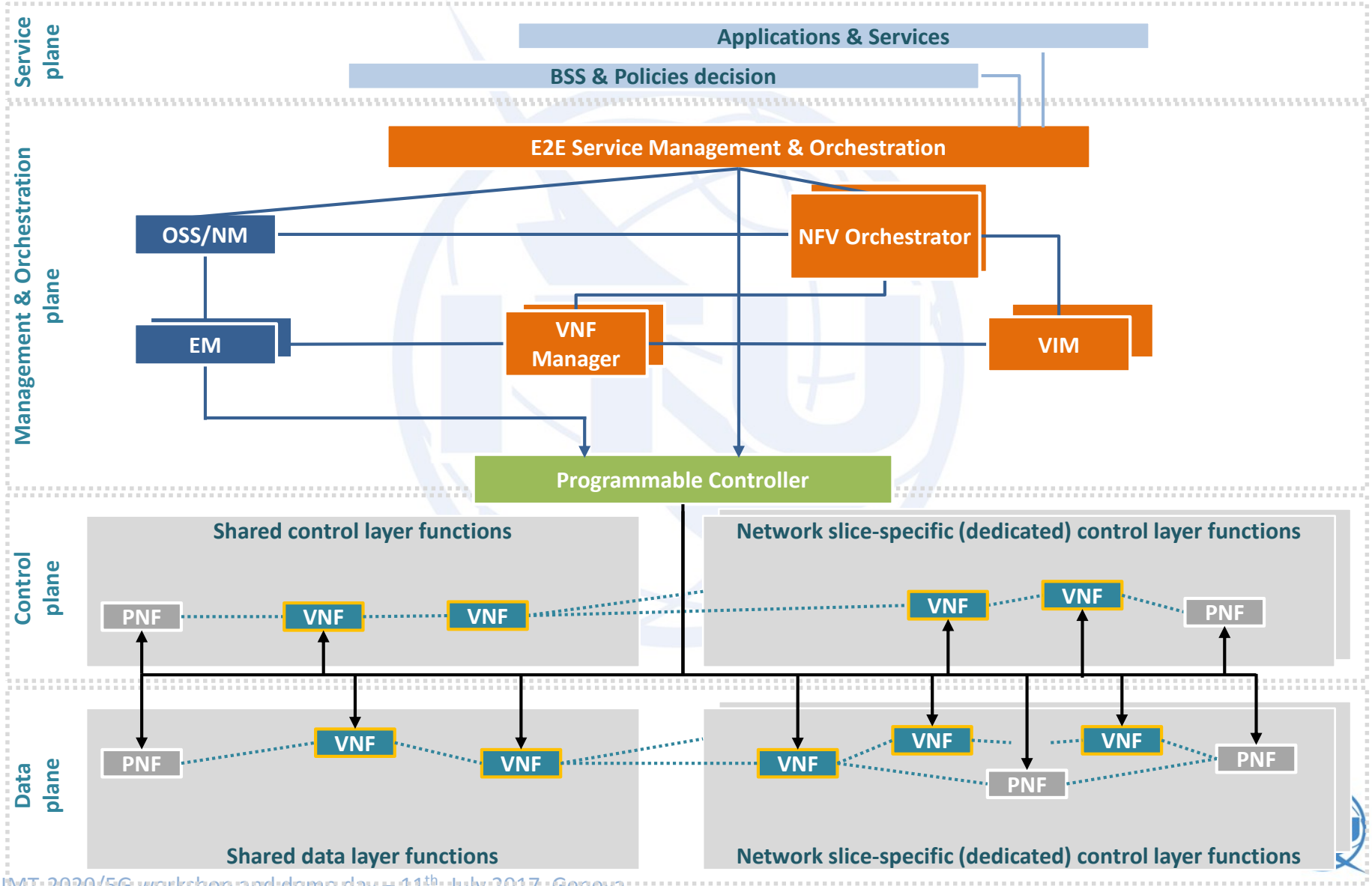


Revisited ETSI NFV Framework

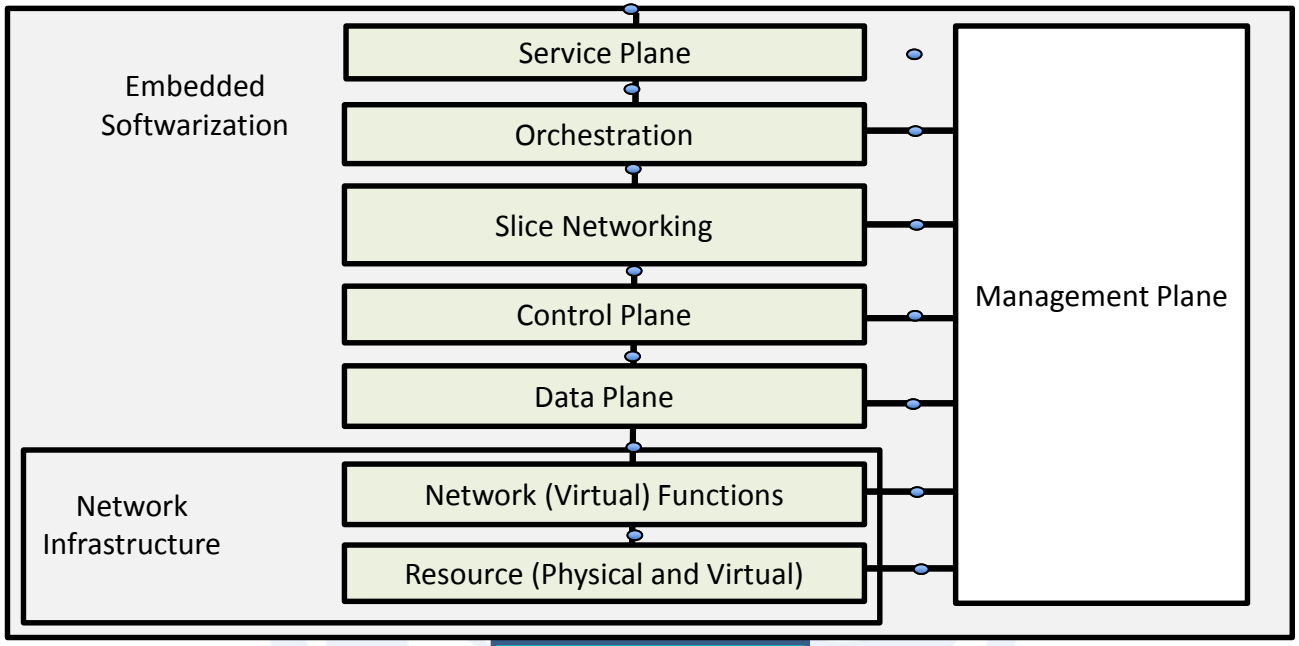
Opportunity to integrate Network Slice across almost all the layers in NFV architecture

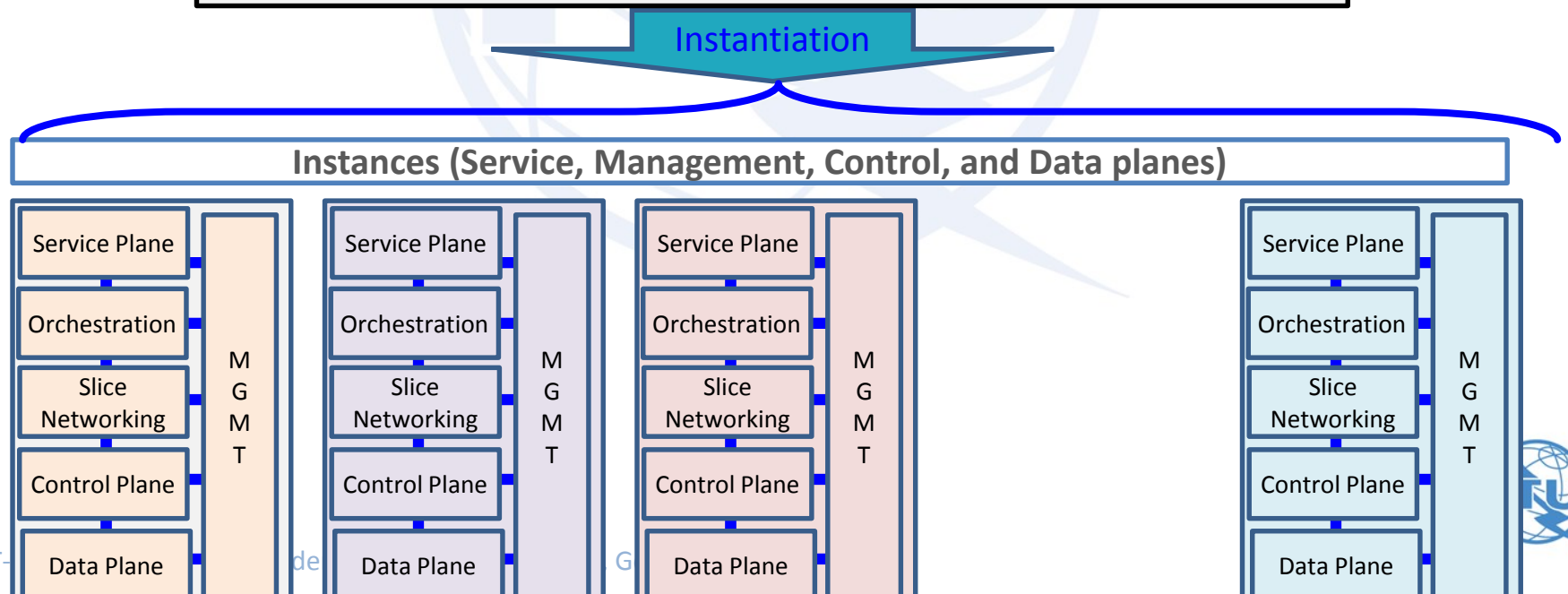


5G Networking



Network Slice Life Cycle Management





NS Management & Operations

(1) **Uniform Reference NFV Model for Network Slicing (Architecture document)**: Describes all of the functional elements and instances of a network slice in NFV. Describes shared non-sliced network parts. Establishes the boundaries to the basic network slice operations

(2) **Review common scenarios / Use Cases** from the requirements for operations and interactions point of view. Describes the roles (owner, operator, user) which are played by entities with single /multiple entities playing different roles.

(3) Network Slice capabilities in NFV environment :

- Enablers for **safe, secure and efficient multi-tenancy in slices**.
- Methods to **guarantee/manage for the end-to-end QoS of service in a slice**.
- Recursion: methods for **NS segmentation allowing a slicing hierarchy** with parent - child relationships.
- Optimisation: **Mapping algorithms & methods for network resources automatic selection for NS ;** global resource view formed; global energy view formed; Network Slice deployed based on global resource and energy efficiency.
- **Monitoring status and behaviour of N**S in a single and/or muti-domain NFV environment.

5) Network slice operations in an NFV environment:

- **Slice life cycle management** including creation, activation / deactivation, protection, elasticity, extensibility, safety, sizing and scalability of the slicing model per network and per network clouds.
- **Slice management and operation**: namely configuration, composition, monitoring, optimisation, elasticity are carried as part of the slice protocols.
- **E2E Slice stitching / composition in an NFV environment**: having enablers and methods for efficient stitching /composition/ decomposition of slices:
  - vertically (service + management + control planes) and/or
  - horizontally (between different domains part of access, core, edge segments) and /or
  - vertically + horizontally.

NS Key Characteristics - No1 Engineering Priority in 5G

"The service cannot provide optimal experience on a best-effort network"; "It is inefficient and expensive to build a separate infrastructure for each service"

- **NS is mainly an in-band management concept in support of a service which is coordinating/orchestrating network functions and resources at a given time.**
- **NS is a dedicated network that is build on an infrastructure mainly composed of, but not limited to, connectivity, storage and computing. Network slices are concurrently deployed as multiple logical, self-contained and independent, partitioned network functions and resources on a common physical infrastructure in order to support well at least one service.**
- **NS has the ability to dynamically expose and possibly negotiate the parameters that characterize an network slice. Network slices are configurable and programmable.**
- **NS has its own operator that sees it as a complete network infrastructure and to use part of the network resources to meet stringent resource requirements.**
- **NS is supporting tenant(s) that are strongly independent on infrastructure.**
- **NS is introducing an additional layer of abstraction by the creation of logically or physically isolated groups of network resources and network function/virtual network functions configurations separating its behavior from the underlying physical network**
- **NS is dynamically and non-disruptively reprovisioned.**

Content

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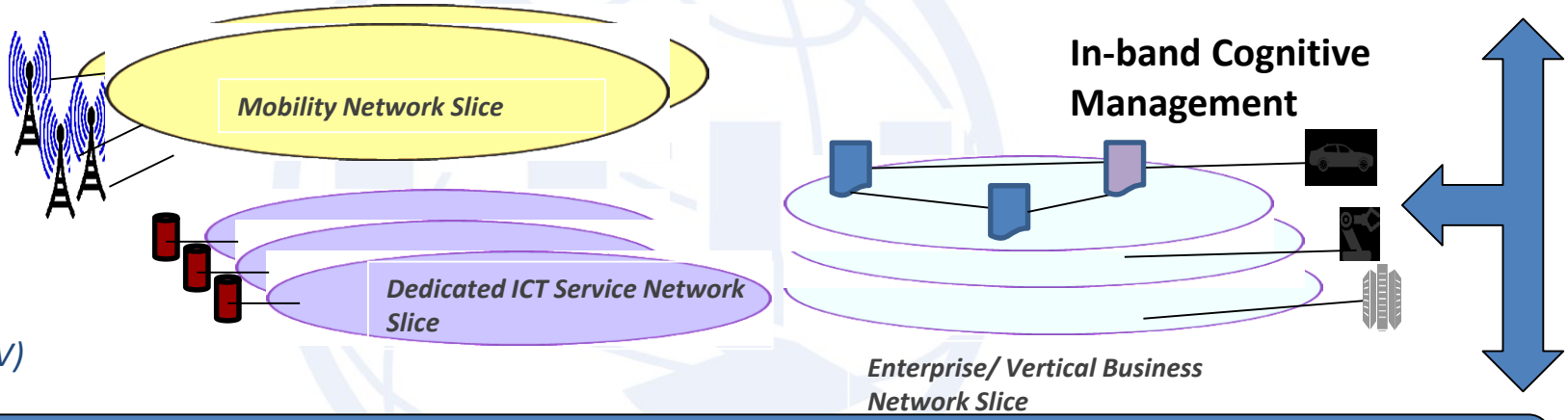
Concluding Remarks & Acknowledgement

5G Architecture – Concluding Remarks

- Dynamically adapting the network to meet future demands requires
- Creating the dynamic, configurable, resilient, cost effective network
- A programmable network operating system with simple interface to the network (smart network fabric)
- Transition from network devises to network functions and virtual network functions with inbound management

E2N Multi-Domain Orchestration
E2D coordination, conflict resolution, multi-domain information exchange

Service Adapted Network Slices
Enabled by Network Function Virtualization (NFV)



Smart Network Fabric: E2E Multi-Domain Network Operating System Facilities
Network Abstraction, Allocate (virtual) network resources, Maintain network state, Ensure network Reliability in a multi domain environment

Smart Cloud & Network Fabric
Enabled by Programmability Including SDN

5G Networking – Summary

- Slice support (configuration mode selection, adaptation)
- Decomposition and reutilization of functional blocks
- Flexible placement of virtual network functions
- Deployment and management of cloud facilities resources
- Muti-Domain Orchestration and Life Cycle Management
- Network programmability for multi-domain control management and orchestration
- Security as a service
- Multi- tenancy support
- Open access
- Closed control loops
- Self Management of Network (Virtual) functions
- Virtualization of Network Functions
- Service and Network Programmability
- Hosting services executions in one (or more) Slices
- Enforce required capability/capacity/security/elasticity/ adaptability/ flexibility "where and when needed
- Supporting on demand composition of network functions and network capabilities
- Network OS facilities

Applications, Services, Management, Orchestration & Control, Softwarization

- Slice support (slice awareness)
- Control/user plane split
- NFV support (possibly limited)
- C-RAN/D-RAN functional splits
- Tight Interworking of LTE and new radio interfaces for the 5G RAN
- Multi-connectivity
- Enhanced/new network access functions
- CN/RAN split
- New RAT for higher frequencies up to 100 GHz (e.g., access, handovers etc)
- Support for mm-wave standalone and non-standalone operation
- PHY numerology (TTI, waveform, coding, etc)
- Security as a service

Access

- Fixed-Mobile Convergence
- Slice support
- SDN & NFV support
- Heterogeneous fixed and wireless access technologies
- Flexible optical transport in the metro domain
- Compute and storage hardware available in aggregation nodes
- Central, regional and edge clouds, cloudlets
- Functional splits can vary from D-RAN to C-RAN
- Control and user plane split
- New fronthaul
- Security as a service

Transport

- Slice support
- SDN support and full exploitation of NFV
- Control and user plane split
- Fixed Mobile Convergence
- CN/RAN split
- Security as a service

Core Network

- Slice support
- Security as a service
- Service support and programmability
- Virtialization of Network Functions

Mobile Edge Computing, Edge Networks

- Slice support
- Security as a service
- Service support and programmability

Satellite Networks

Acknowledgement

5G PPP Infrastructure Association

- 5G PPP 5G Architecture White Paper (July 2016, August 2017)
- 5G-PPP Cognitive Network Management for 5G White Paper (March 2017)
- https://5g-ppp.eu/white-papers/

5GPPP EU Research Projects

- 5GEx – "5G Multi-Domain Exchange" https://5g-ppp.eu/5gex/
- 5G SONATA – "Service Programming and Orchestration for Virtualized Software Networks in 5G" https://5gppp.eu/sonata/.

Confucius

“Ability will never catch up with the demand for it.”