Network Slicing Terms and Systems

draft-galis-netslices-revised-problem-statement-01
draft-geng-netslices-architecture-02
draft-netslices-usecases-01
draft-qiang-netslices-gap-analysis-01
draft-flinck-slicing-management-00

Scope of the presentation:

- **What do I mean by network slicing?**
- **What non-IETF work is relevant?**
- **What IETF work is needed?**

On behalf of the 25 draft authors and proponents acknowledged in the last slide

Prof. Alex Galis
University College London
United Kingdom
a.galis@ucl.ac.uk

What do I mean by network slicing?

"It is inefficient and expensive to build a separate infrastructure for each service"

Network Slice – 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 behaviour 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.

→ *A network slice supports at least one type of service.*

→ *A network slice may consist of cross-domain components from separate domains in the same or different administrations, or components applicable to the access network, transport network, core network, and edge networks.*

→ *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.*

What non-IETF work is relevant? **Main SDOs relevant references:**

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

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

ITU-T IMT2020 - Recommendations: 5G Architecture, Management of 5G, Network Softwarisation and Slicing - **(2016 – 2017)**

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

BBF - Requirements / architecture of transport network slicing SD-406: End-to-End Network Slicing **(2017)**

ETSI - NFV priorities for 5G (white paper) **(2017)**

Network Slicing is the Top Emerging Engineering Impactful Problem at IETF.

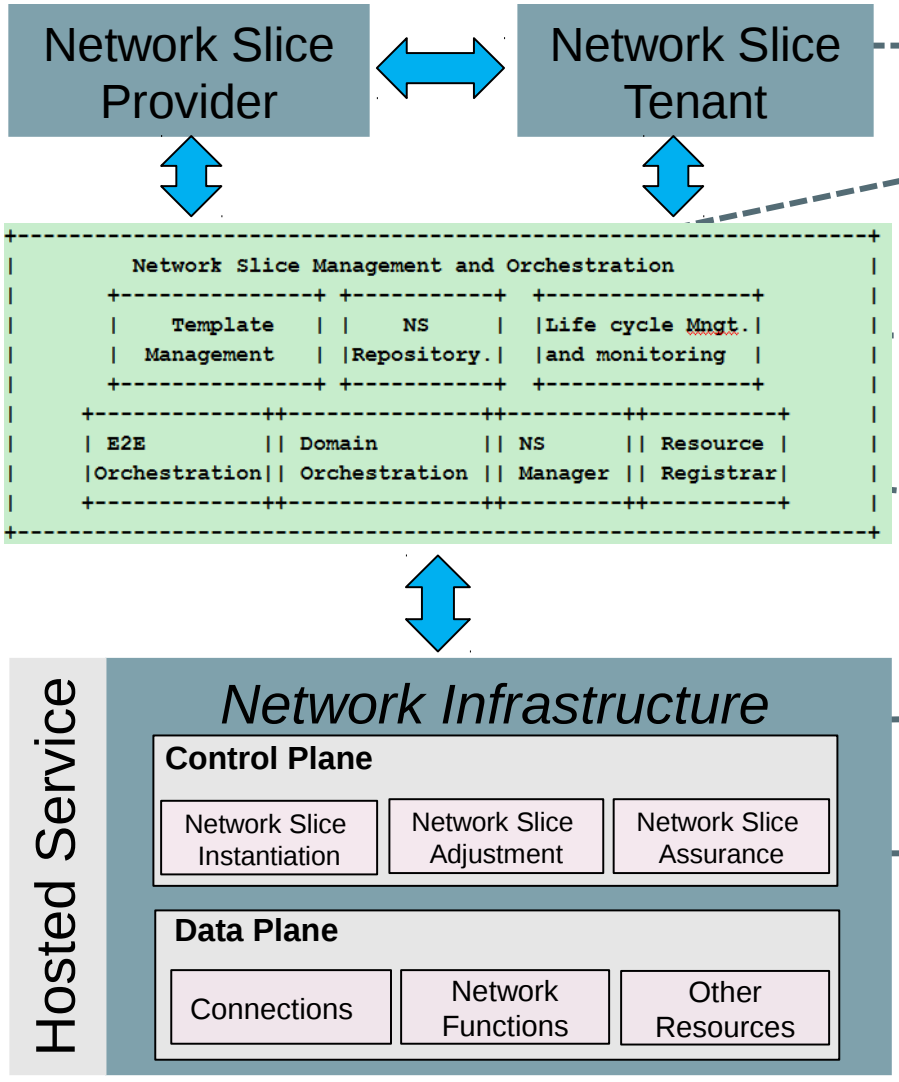
Network Slices – Key Characteristics:

- **is mainly an embedded management concept supporting at least one service at a given time.** It also includes coordination/orchestration of network functions and resources.
- **has dynamic and non-disruptive re-provisioning**.
- **is a dedicated network** part that is built on an infrastructure mainly composed of, but not limited to, connectivity, storage, and computing.
- **is concurrently deployed** with isolation guarantees as logical, independent and self-contained, partitioned network functions and resources on a common infrastructure.
- **is able to dynamically expose**, and possibly negotiate, the parameters that characterize itself. Network slices are configurable and programmable.
- **it is related to an operator** that sees it as a complete network infrastructure and uses part of the network resources to meet stringent resource requirements.
- **supports tenants** that are strongly independent on infrastructure.
- **introduces an additional layer of abstraction** by the creation of logically or physically isolated groups of network resources and (virtual) network functions configurations.

a number of related sub-problems need to be addressed by IETF through new protocols or extensions to existing protocols.

What IETF work is needed?

Network Slicing Reference Architecture



Proposed High Priority Problems to Resolve

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 OAM

- **Network Slice life cycle management**
- **Network Slice Monitoring and Discovery**
- **Autonomic slice management and operation**
- **E2E Network Orchestration**

Performance Guarantee and Isolation

- **Guarantees for network slice isolation**

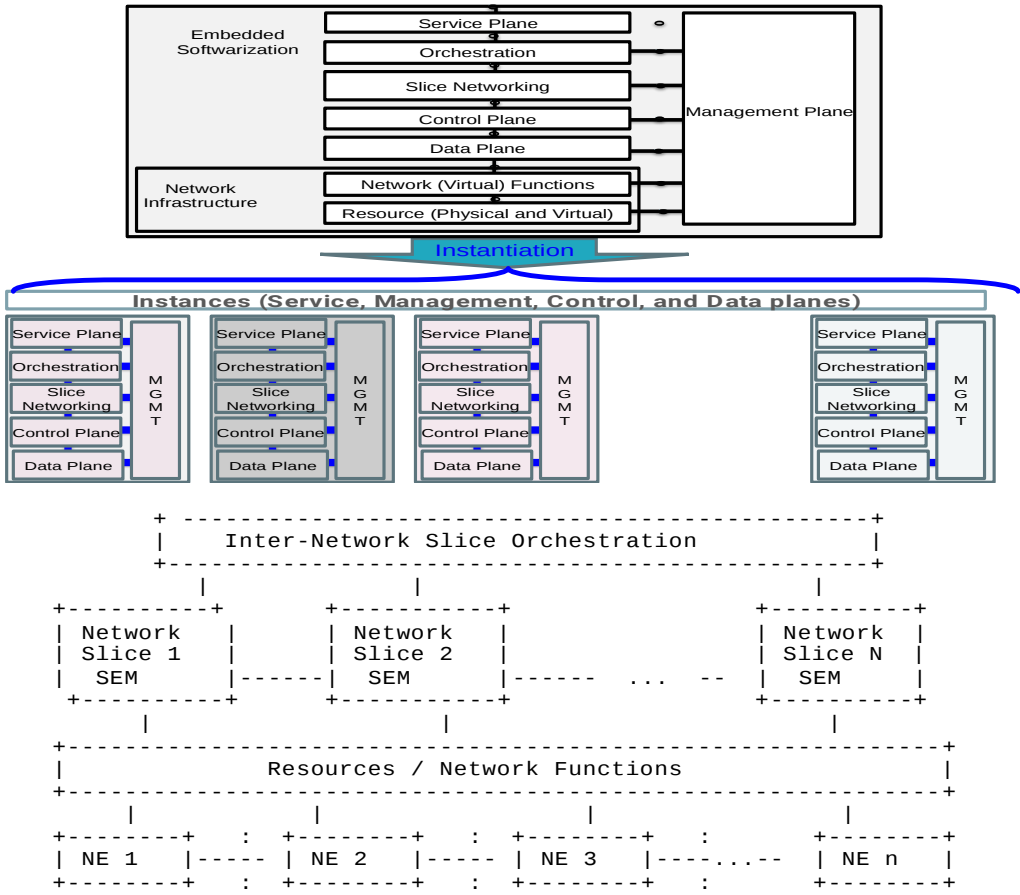
Slicing Resource & Requirement Description

- **Uniform Reference Model**
- **Slice Templates**
- **Capability exposure and APIs**

Proposed IETF Work Problems (continued): Network Slice Life Cycle Management; E2E Network Orchestration

NS Life Cycle Management: (1) 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.** (2) Template/NS repository **assists life cycle management;** (3) Resource Registrar **manages exposed network infrastructure capabilities;** (4) NS Manager **oversees individual slice** (with capability exposure to NS Tenant).

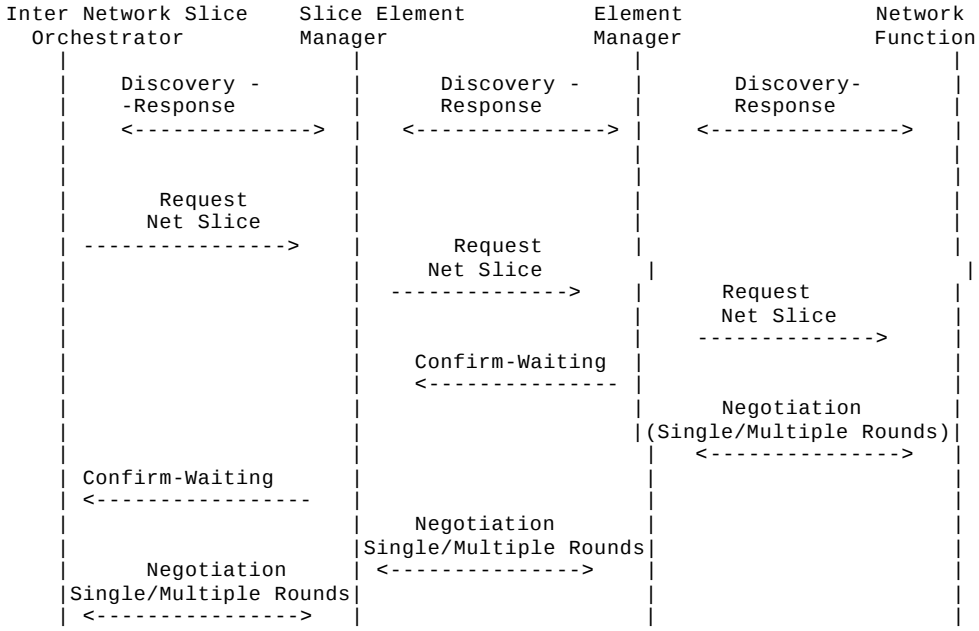
E2E Orchestration (1) **Coordination of any number of inter-related resources** in a number of subordinate domains, and assurance of transactional integrity as part of the triggering process; (2) **Autonomic control of slice life cycle management**, including concatenation of slices in each segment of the infrastructure (in data, control, and management planes); (3) **Autonomic coordination and triggering of slice elasticity and placement**; (4) **Coordination and (re)-configuration of resources** by taking over the control of all the network functions.



Proposed IETF Work Problems (continued): Monitoring and Discovery; Autonomic Slice Management

Monitoring and Discovery: (1) Monitoring Subsystem is responsible for **monitoring continuously the state all components of a NS;** (2) Monitoring Subsystem receives the detailed service monitoring requests with references to resource allocation and Network functions instances in a NS. (3) **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.

Autonomic slice management: (1) Network slice is a dynamic entity with autonomic characteristics of its lifecycle and operations. (2) 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.

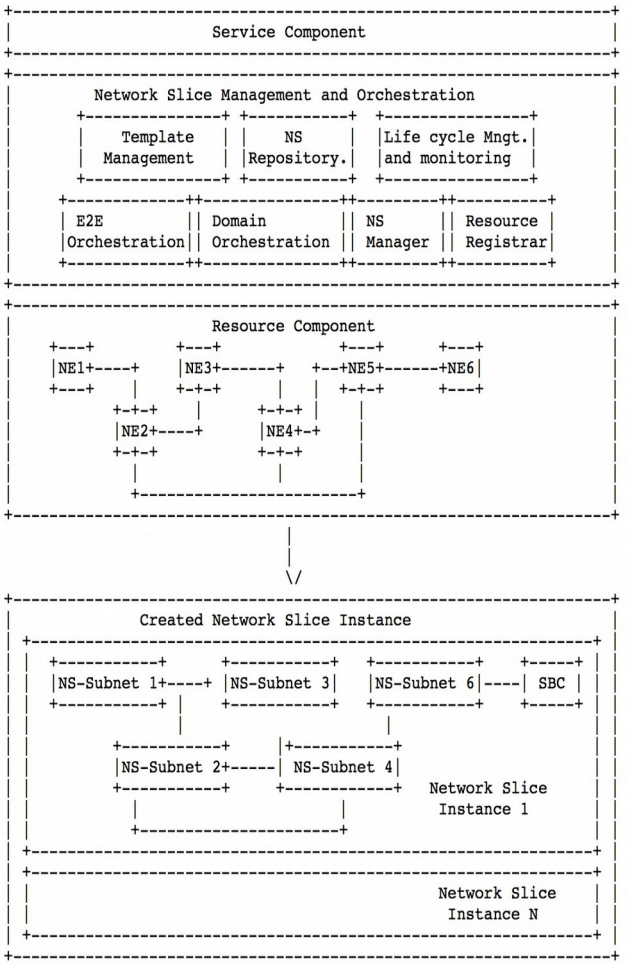


Proposed IETF Work Problems (continued): Service Mapping Single Domain / Cross-Domain; Slice stitching; Guarantees for isolation

Service / data model & mapping : (1) service mapping **enables on-demand processing anywhere in the physically distributed network**, with dynamic and fine granular service (re)-provisioning; (2) It includes a **slice-aware YANG 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: (1) Slice stitching operations are supported by uniform slice descriptors; (2) Efficient stitching/ decomposition (vertically, horizontally, vertically + horizontally).

Guarantees for Isolation: (1) **guaranteed level of service**, according to a negotiated SLA between the customer and the slice provider; (2) 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; (3) **exclusive control and/or management interfaces**, enabling the deployment of different logical network slices over shared resources.

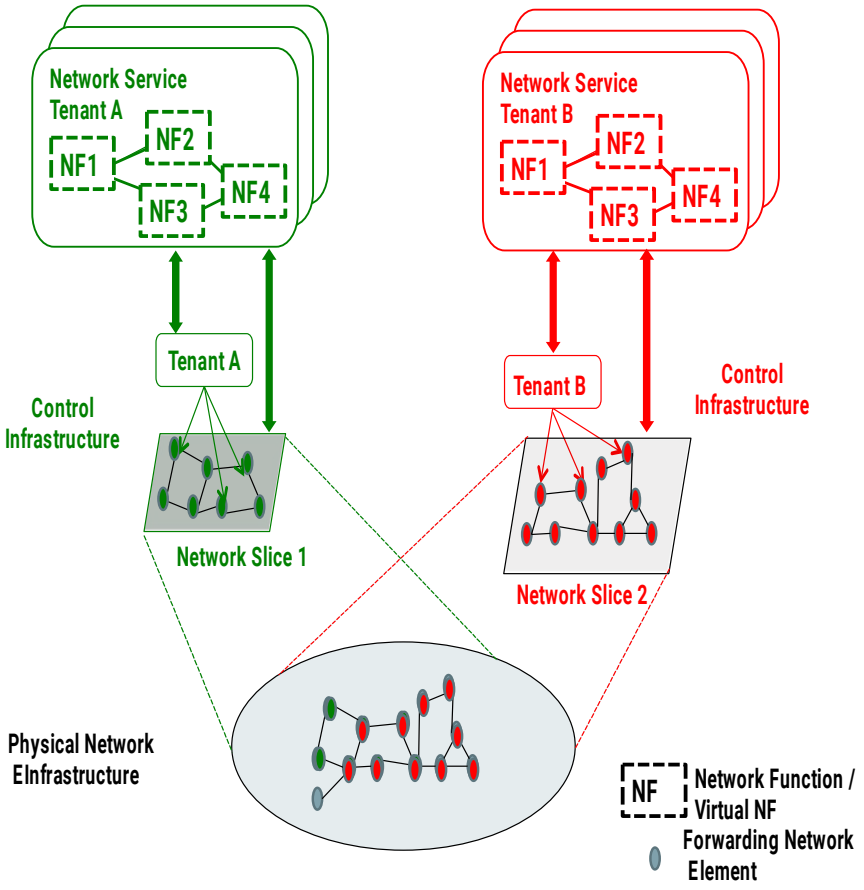


Proposed IETF Work Problems (continued): Uniform Reference Model; Slice Templates; Slice Element Manager and Capability exposure – APIs

Uniform Reference Model: Has (1) Description of all of the functional elements and functional roles required for network slicing; (2) boundaries between the basic network slice operations (creation, management, exposure, consumption); (3) Normalize nomenclature and descriptive / prescriptive definitions.

Slice Templates: Contains (1) Description of Service Instance Components; (2) Description of Network Functions Instance Components; (3) Description of Resource (connectivity, compute, storage); (4) Description connectivity, compute, storage resources; (5) Description of Slice Element Manager and Capability exposure component.

Slice Element Manager & Capability exposure – APIs: Has (1) 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; (2) **Description of the Slice Element Manager** which guarantees a level of service, according to a negotiated SLA between the customer and the slice provider.



Thank you

Network Slicing BoF Proponents - Acknowledgement

Alex Galis
a.gais@ucl.ac.uk
University College London, U.K.

Liang Geng
gengliang@chinamobile.com
China Mobile
Beijing, China

Kiran Makhijani
kiran.makhijani@huawei.com
Huawei Technologies
USA

Cristina Li Qiang
qiangli3@huawei.com
Huawei Technologies
China

Slawomir Kuklinski
slawomir.kuklinski@orange.com
Orange, Poland

Luis Miguel Contreras Murillo
luismiguel.contrerasmurillo@telefonica.com
Telefonica, Spain

Pedro Martinez-Julia
pedro@nict.go.jo
NICT
Tokyo, Japan

Christian Mannweiler
christian.mannweiler@nokia-bell-labs.com
Nokia, Gemany

Anatoly Andriannov
anatoly.andrianov@nokia.com
Nokia, USA

Hannu Flinck
hannu.flinck@nokia-bell-labs.com
Nokia
Finland

Ravi Ravindran
ravi.ravindran@huawei.com
Huawei Technologies
USA

Carlos Jesus Bernardos Cano
cjbc@it.uc3m.es
University Carlos III Madrid, Spain

Cinzia Sartori
cinzia.sartori@nokia-bell-labs.com
Nokia, Gemany

Xavier de Foy
Xavier.Defoy@InterDigital.com
InterDigital Inc.
Canada

Akbar Rahman
Akbar.Rahman@InterDigital.com
InterDigital Inc.
Canada

Jun Qin
qinjun4@huawei.com
Huawei Technologies
China

Jie Dong
jie.dong@huawei.com
Huawei Technologies
China

Stewart Bryan
stewart.bryant@gmail.co
Huawei Technologies
UK

Susan Hares
shares@ndzh.com
Huawei Technologies
USA

Shuping Peng
pengshuping@huawei.co
Huawei Technologies
China

Satoru Matsushima
satoru.matsushima@gmail.com
SoftBank,
Japan

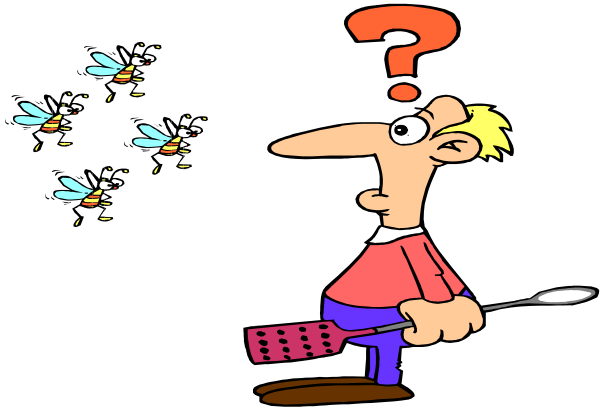
Kevin Smith
Kevin.Smith@vodafone.com
Vodafone,
U.K.

Young Lee
leeyoung@huawei.com
Huawei Technologies
USA

Sheng Jiang
jiangsheng@huawei.comHuawei Technologies
China

IgorBryskin
Igor.Bryskin@huawei.com
Huawei Technologies
USA

Q&A



Spare Slides

What non-IETF work is relevant?

Main SDOs references:

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

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ETSI - NFV priorities for 5G (white paper) **(2017)**

EU 5GPPP projects (2015 - present)

- 15 Large Scale Research projects – all based on Network Slicing (https://5g-ppp.eu);
- White Paper on 5G Architecture centered on network slicing
- White Paper on 5G Autonomic Management Architecture centered on NS

Early references: Programmable Networks research & Federated Testbed research **(1995 -2012)**

GENI Slice (2008): "A GENI slice is the unit of isolation for experiments. A container for resources used in an experiment; A unit of access control

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

Summary - What IETF work is needed?

Problems grouped by Requirements ⊔ Gaps

Identified Requirement : "Network Slicing OAM"

- **Problem : Network Slice life cycle management**
- **Problem : Network Slice Monitoring and Discovery**
- **Problem : Autonomic slice management and operation**
- **Problem : E2E Network Orchestration**

Identified Requirement : "Cross-Domain Coordination"

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

Identified requirement : "Performance Guarantee and Isolation"

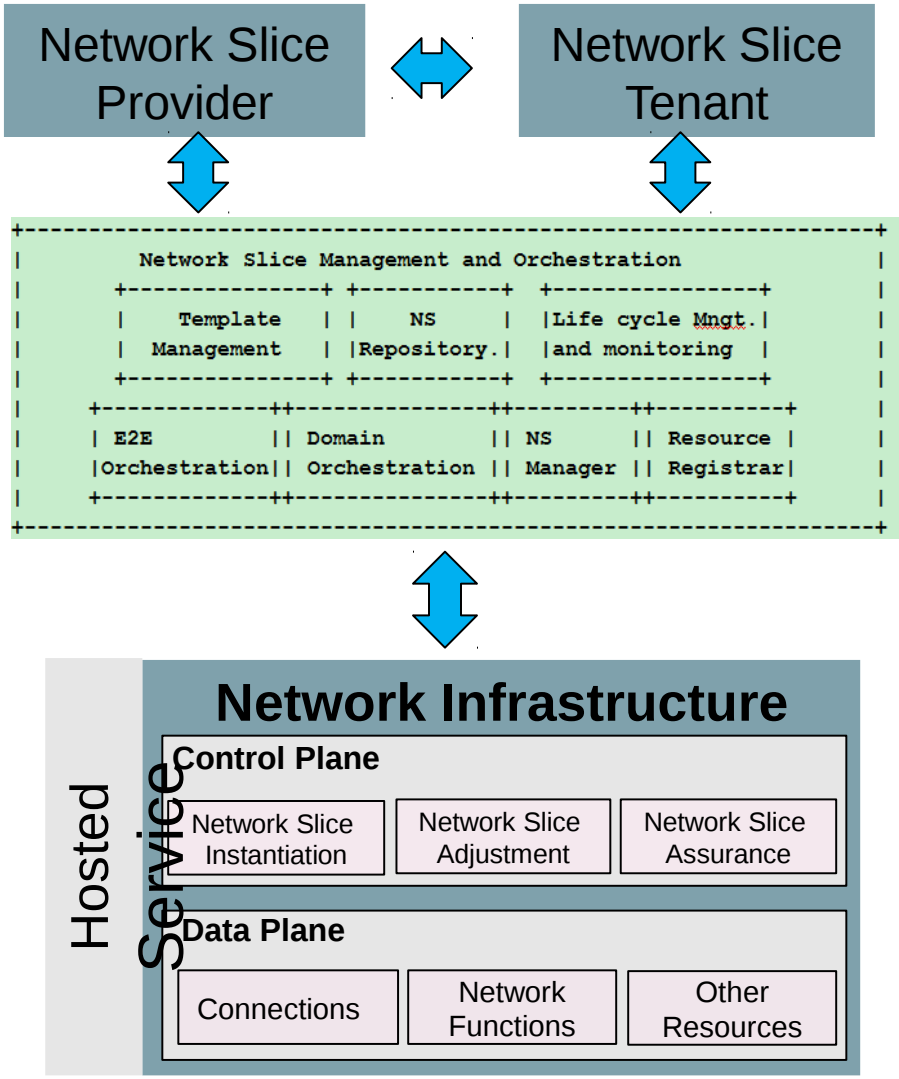
- **Problem : Guarantees for network slice isolation**

Identified Requirement : "Slicing Resource & Requirement Description"

- **Problem : Uniform Reference Model**
- **Problem : Slice Templates**
- **Problem : Capability exposure and APIs**

Network Slicing Reference Architecture

- Network Slice Provider (NSP) & Network Slice Tenant (NST)
  - Communicate with NS M&O system via northbound 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 adjustment
  - Data plane for guaranteed performance and isolation



Network Slice Provider (NSP), Network Slice Tenant (NST), Network infrastructure owner (NIO) Interaction

- NIO <=> NSP:
  - + NIO offers the physical infrastructure to NSP, and NSP creates and manages the "slice" of network resources.
  - + NSP interacts vertically to request and instantiate (embed) composite network services onto the underlying physical infrastructures.
  - + NSP can possibly act as NIO.

- NSP <=> NST:
  - + NSP offers the individual objects/resources obtained after slicing the physical infrastructure to the NST.
  - + NST requests to the NSP the necessary CRUD (Create, Retrieve, Update, Delete) operations on its own Network Slices.

- NSP <=> NSP:
  - + Allows inter-provider tasks (e.g. migration of resources or whole slices among providers.
  - + Organizes the interoperability levels among Network Slices managed by different providers.
  - + Facilitates the recursive slicing, so a new NSP slices the resources offered by other NSP.

- NIO <=> NIO:
  - + Horizontal communication between owners to coordinate the required interactions among physical infrastructure resources, and/or the migration of whole slices among different NIOs.
  - + It may be common for NIO to provide network infrastructures to NSP in an old-fashion way where no network slicing is concerned.

However, a NIO may become a double role of NIO+NSP once it provides NSaaS.

Operators' View of Network Slicing

- Different roles in network slicing
  - Network Infrastructure Owner (NIO)

  Owns the physical infrastructure and lease them operators. NIO becomes an NSP is it lease the infrastructure in network slicing fashion.

  - Network Slice Provider (NSP)

  Provides network slice to NST. Typical NSPs include NIO and telecommunication service providers.

  - Network Slice Tenant (NST)

  Purchases network slice from a NSP. Typical examples of NST includes virtual operator, application provides etc.

Uniform reference model & template

Slice as a union of subsets of resources & VNFs 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 Functions Instance component

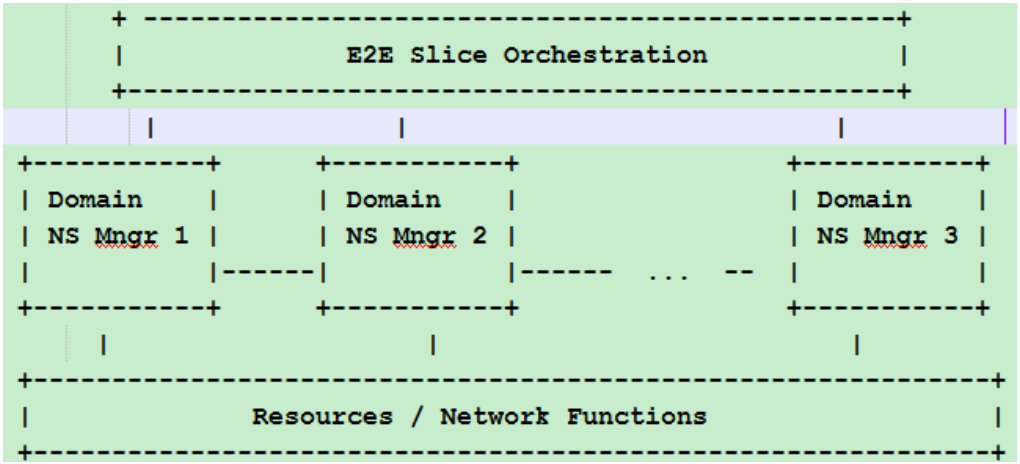
- represented by a set of network functions, and resources
- forms a complete instantiated logical network to meet certain network characteristics required by the Service Instance(s).
- provides network characteristics which are required by a Service Instance.
- may also be shared across multiple Service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

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

- *Physical & Logical resou*rces - 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 Element Manager & 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.



Definitions of Network Slicing & References (I)

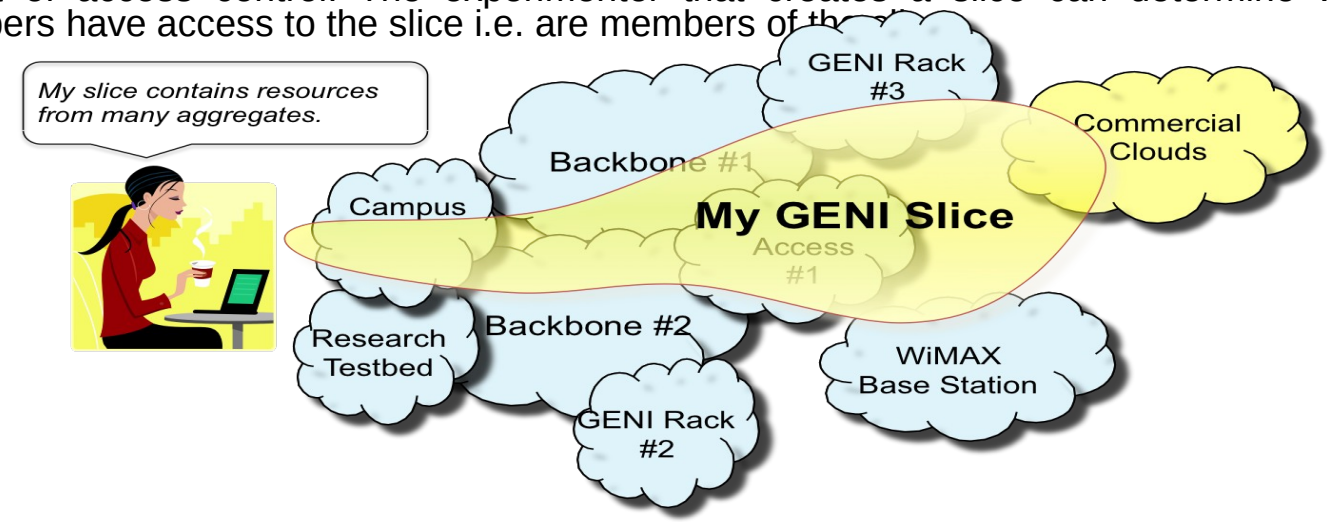
I - Slicing Resources:

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 to the slice i.e. are members of th



(*) 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

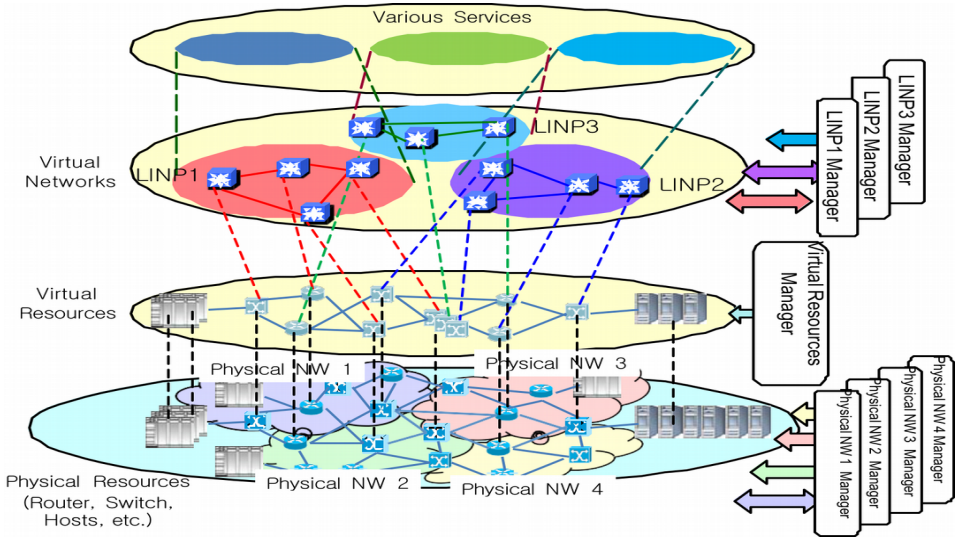
- "Resource allocation to virtual infrastructures or slices of virtual infrastructure."
- "Dynamic creation and management of virtual infrastructures/slices of virtual infrastructure across diverse resources."
- "Dynamic mapping and deployment of a service on a virtual infrastructure/slices of virtual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

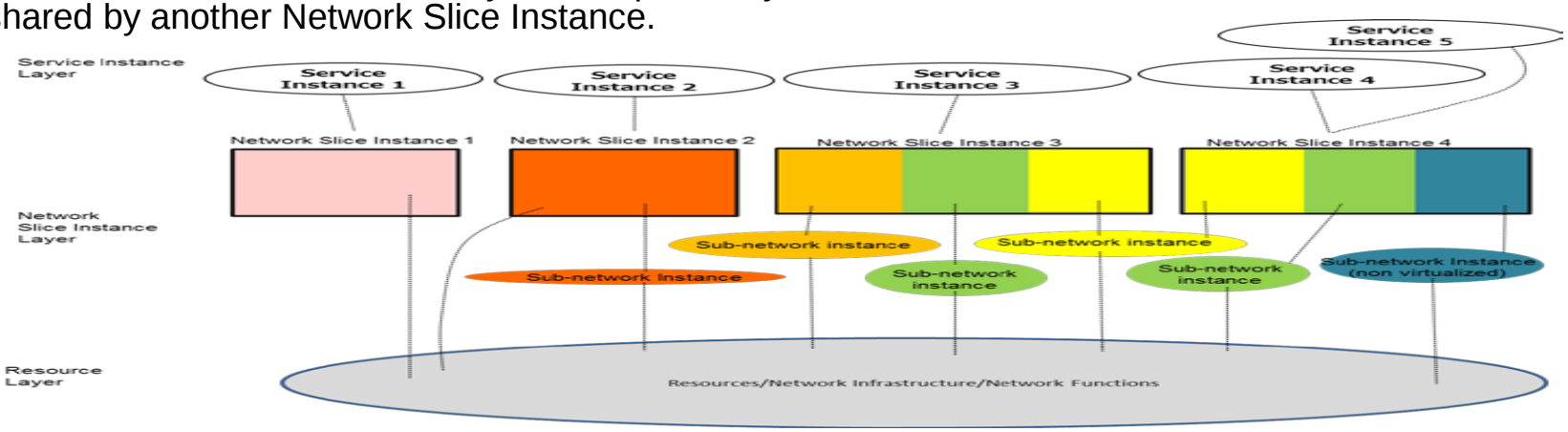


Definitions of Network Slicing & References(III)

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 TR23.799 Study Item "Network Slicing' **2016**

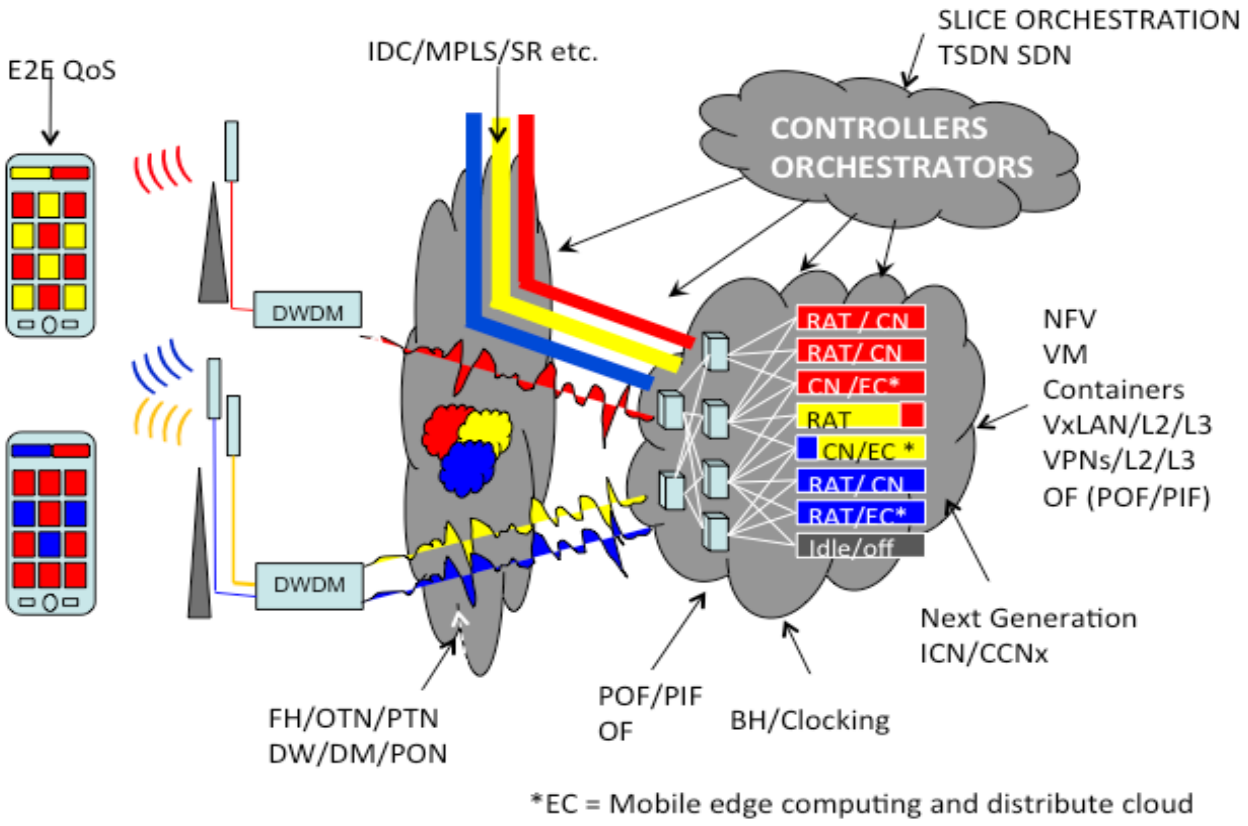
ONF Recommendation TR-526 "Applying SDN architecture to Network Slicing" **2016**

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)**

C-RAN Virtualization & Slicing under Software Control

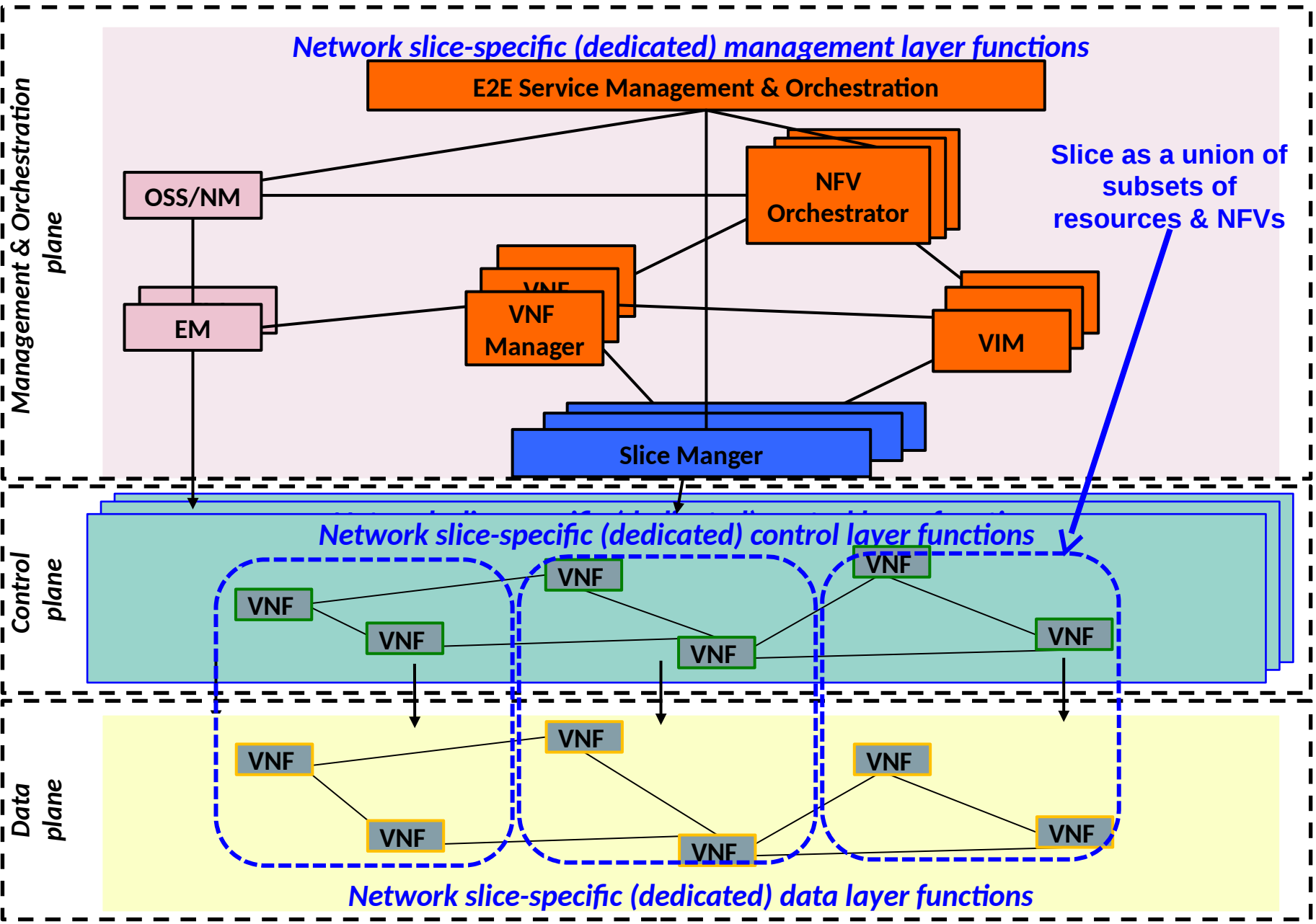


Example of 5G C-RAN network slicing

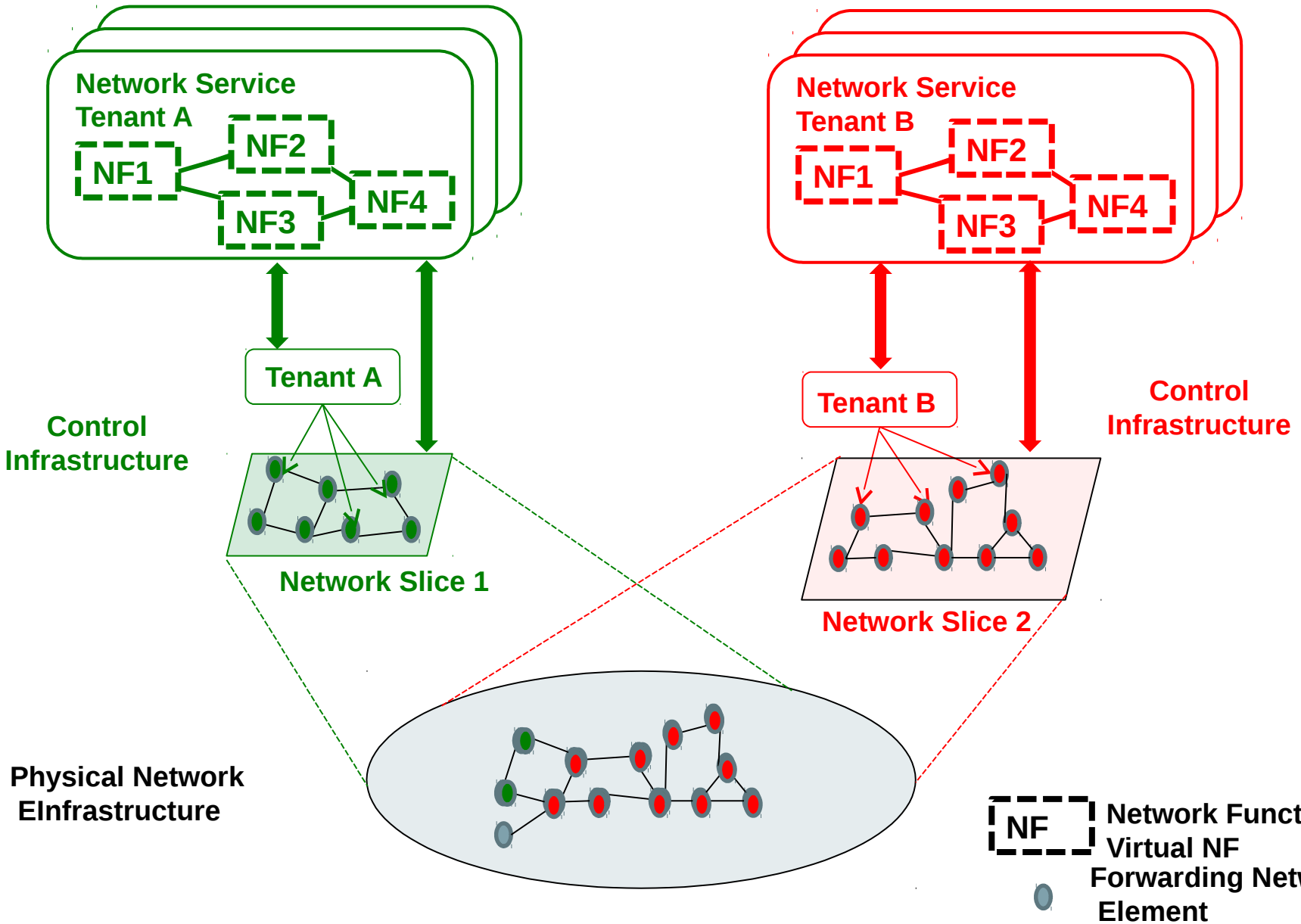
(Report of Gap Analysis – Focus group on IMT-2020– Nov 15 T13-SG13-151130-TD-PLEN-0208!!MSW-E.docx)

Revisited ETSI NFV Framework

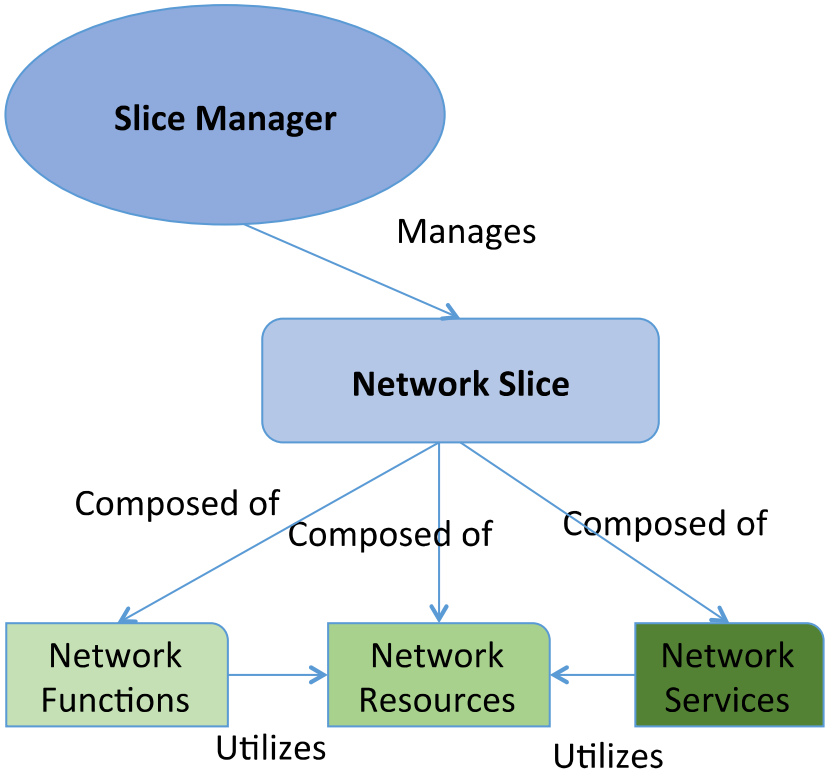
Opportunity to integrate Network Slice across almost all the layers in NFV architecture

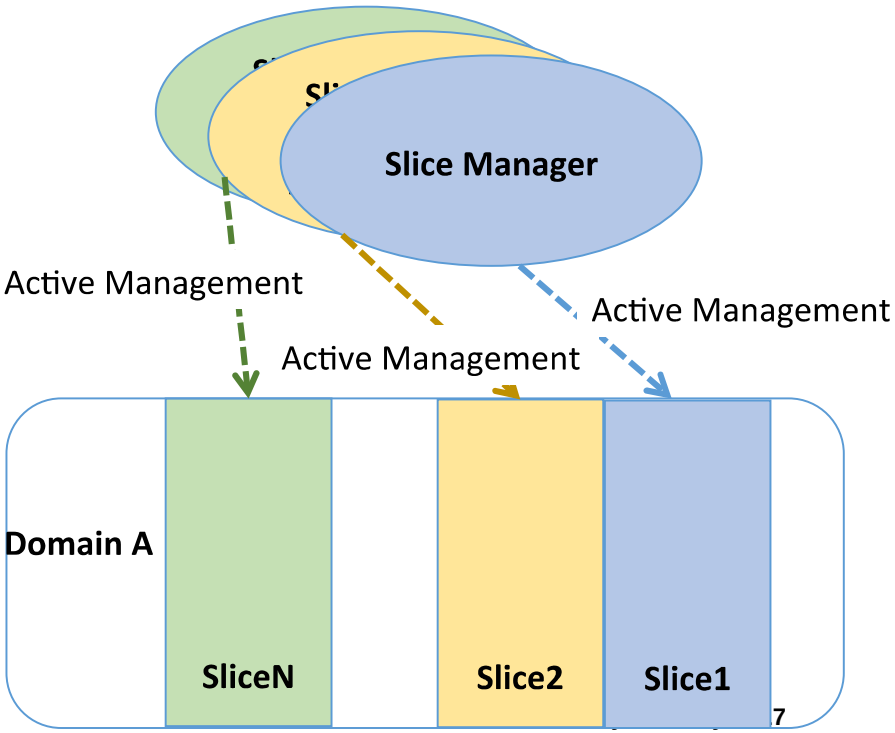


Network Slice Representation



Network Slicing Models



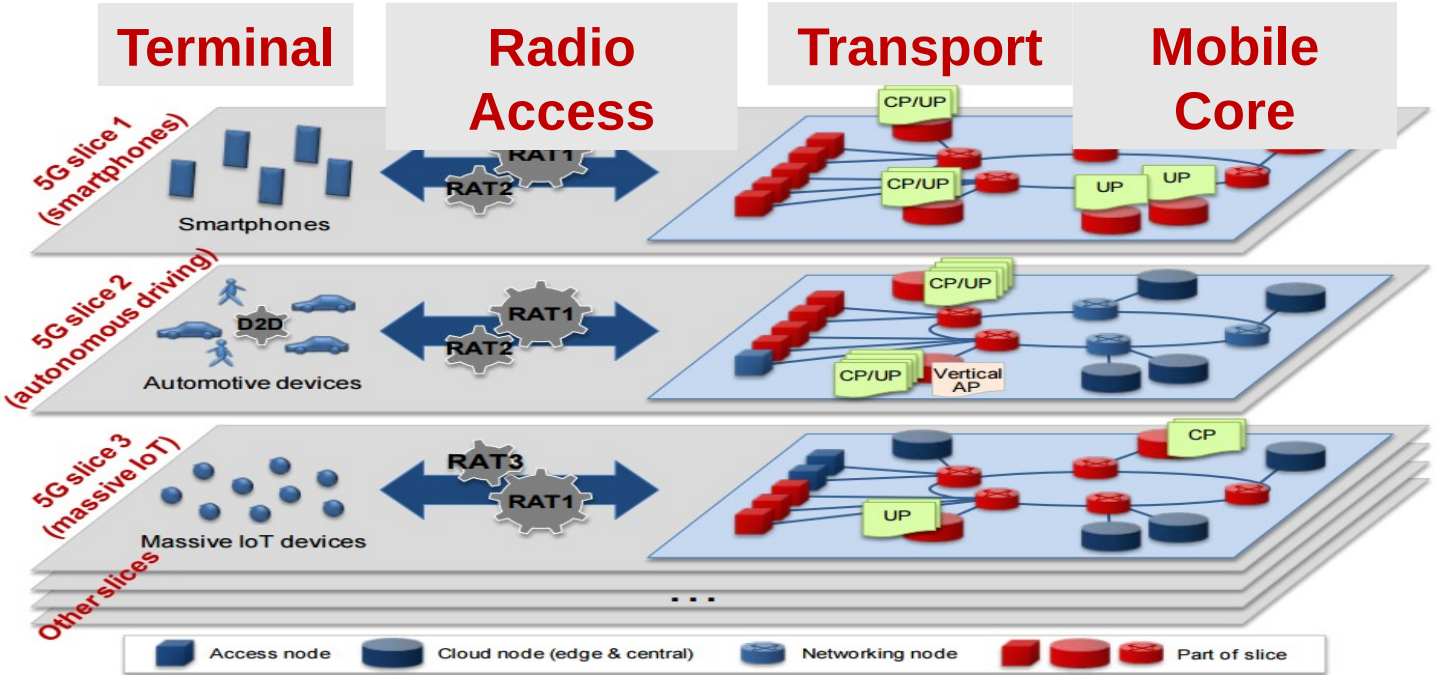


Network Slice Usage Scenarios

- 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 optimisation
- Independent multi-topology routing
- Sharing Infrastructure: Enablers for sharing infrastructure safely and efficiently (Multi-tenant)

Use Case of Network Slicing

- End-to-End Network Slicing of 5G



-- from NGMN 5G white paper

- Transport network is considered as part of 5G E2E network slice
  - Coordination with mobile world is needed to identify the

Network Slicing Work Items @ IETF

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

(2) Slice Templates: capability exposure + managed partitions of network resources, compute and storage resources), physical and/or virtual network and service functions

(3) 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.

(4) Network Slice capabilities are expected to be:

- Four-dimensional efficient slice creation with **guarantees for isolation in each of the Data /Control/Management /Service planes.**
- Enablers for **safe, secure and efficient multi-tenancy in slices**.
- Methods to **guarantee for the end-to-end QoS of service in a slice**.
- Efficiency in slicing: specifying policies and methods to realize diverse requirements without re-engineering the infrastructure.
- Recursion: namely methods for **NS segmentation allowing a slicing hierarchy** with parent - child relationships.
- **Customized security mechanisms** per slice.
- Methods and policies to manage the **trade-offs between flexibility and efficiency in slicing**.
- 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 environment; NS interconnection.

Network Slicing Work Items @IETF (cntd)

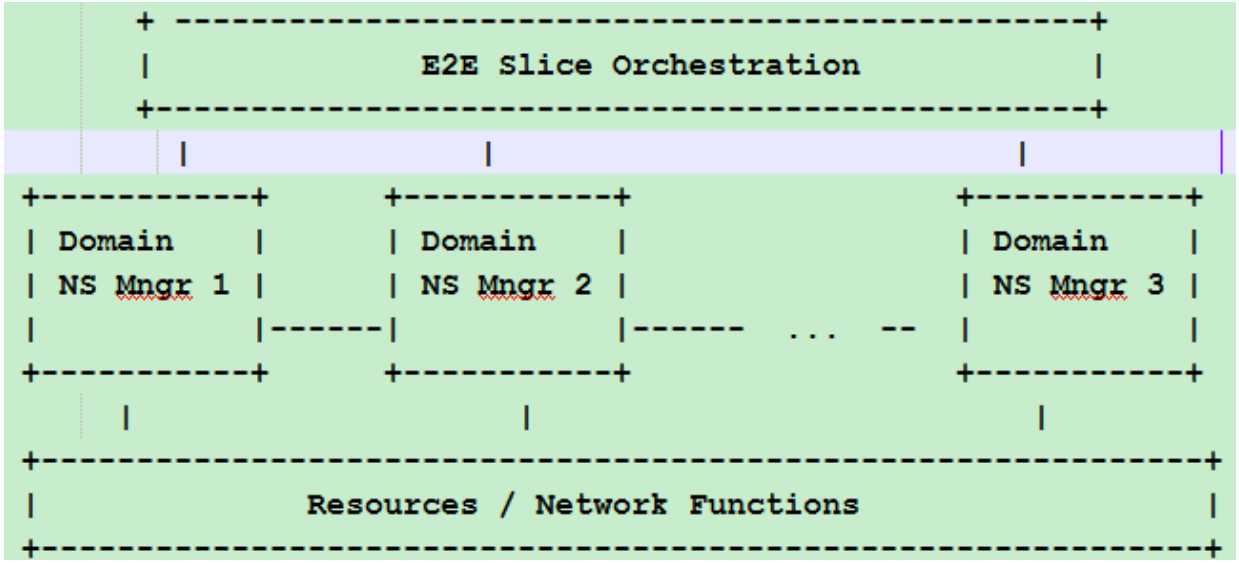
(5) Network slice operations :

- **Slice life cycle management** including creation, activation / deactivation, protection, elasticity, extensibility, safety, sizing and scalability of the slicing model per network and per network cloud: slices in access, core and transport networks; slices in data centres, slices in edge clouds.
- **Autonomic slice management and operation**: namely self-configuration self-composition, self-monitoring, self-optimisation, self-elasticity are carried as part of the slice protocols.
- **E2E Slice stitching / composition**: 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.
- **End-to-end network segments and network clouds orchestration of slices**
- **Service Mapping**: having dynamic and Automatic Mapping of Services to slices; YANG models for slices.

(**6)** Describe the enablers and methods for the above mentioned capabilities and operations from **different viewpoints on slices** (e.g. slice's owner towards user, towards the physical infrastructure owner)

(7) Efficient enablers and **methods for integration of above capabilities and operations**.

Network Slicing Reference Architecture



- **Life cycle management**
  - Triggered by Life cycle mngt. function
  - coordinated by E2E Slice orchestration and distributed to domain slice orchestration
- **Network Slice Instance Management**
  - Created network slice is seen as a “service” offered to NST from a NSP view, certain provisioning will be exposed to NST by Network Slice Manager.
  - NST have certain level of slice OAM capability via network slice manager
  - Further ETSI MANO consideration addressed in draft-flinck-slicing-management-00 will be incorporated in future update