Autonomic Slice Networking

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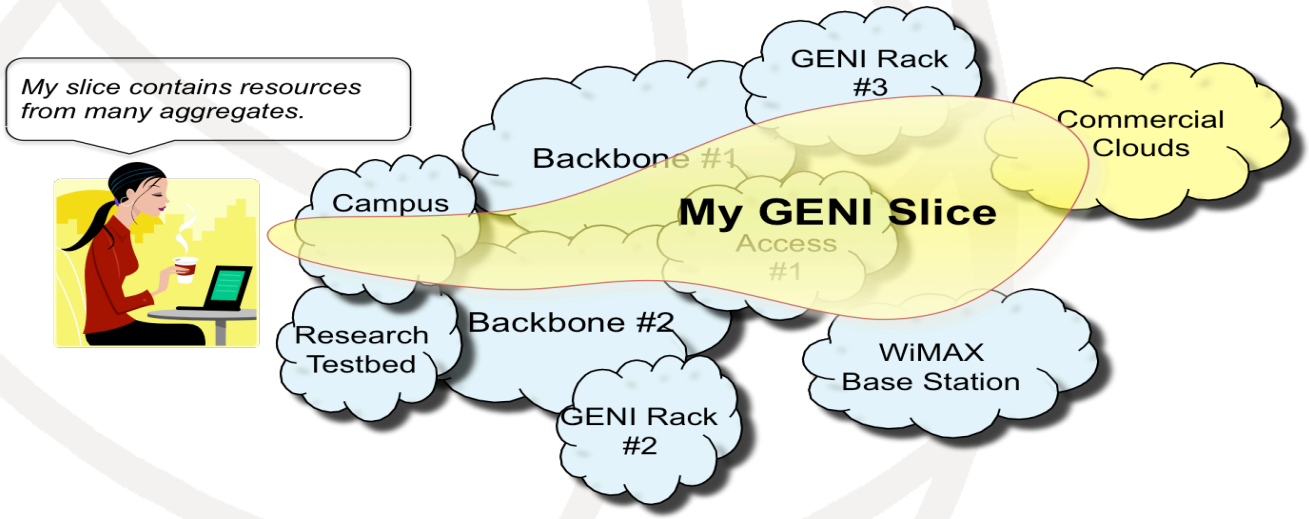
Definitions of Network Slicing (I)

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 the slice.



(*) 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 (II)

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

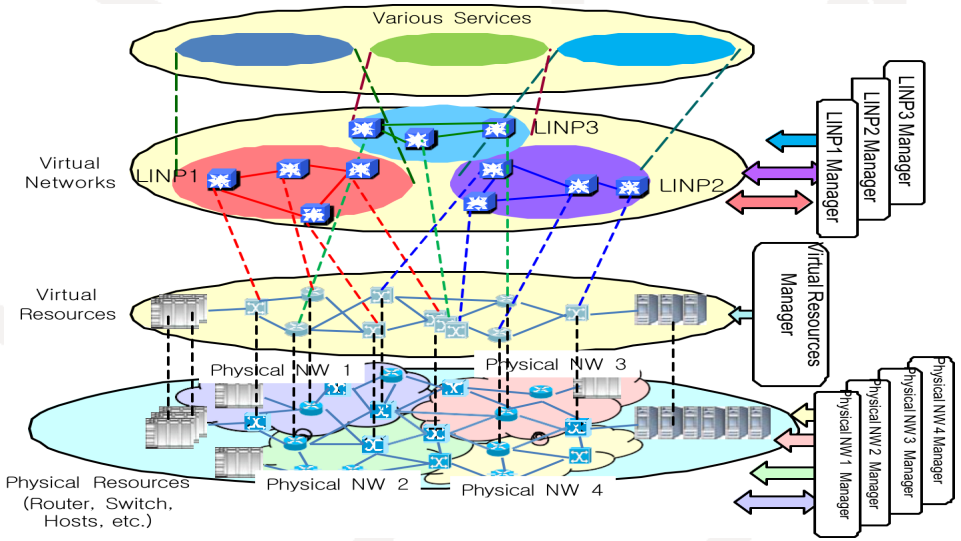
- "Resource allocation to virtual infrastructures or slices of virtual infrastructure."
- "Dynamic creation and management of virtual infrastructures/slices of virtual infrastructure across diverse resources."
- "Dynamic mapping and deployment of a service on a virtual infrastructure/slices of virtual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

17 Orchestration capabilities

19 Self-functionality mechanisms

14 Self-functionality infrastructure capabilities

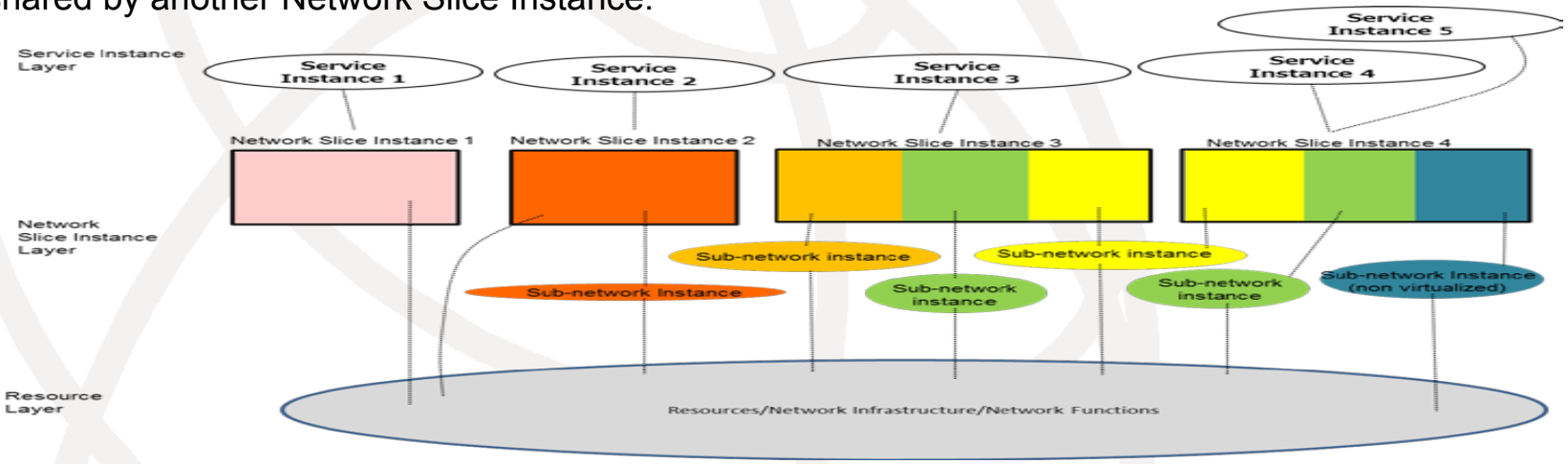
ITU-T Slicing (2011) as defined in [ITU-T Y.3011], [ITUTY.3012] is the basic concept of the Network Softwarization. Slicing allows logically isolated network partitions (LINP) with a slice being considered as a unit of programmable resources such as network, computation and storage.



Definitions of Network Slicing (III)

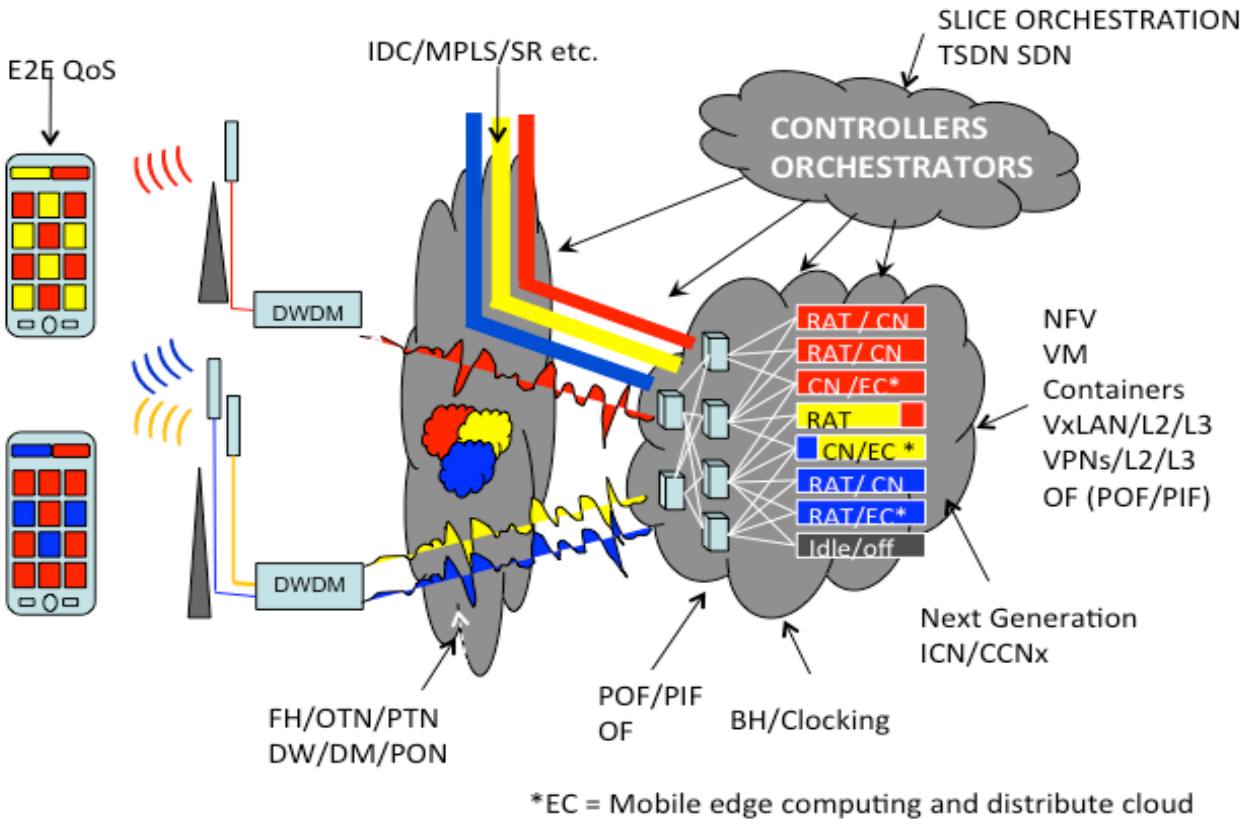
NGMN Slice capabilities (2016) - consist of 3 layers: 1) Service Instance Layer, 2) Network Slice Instance Layer, and 3) Resource layer.

- 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.



Network Service Slices (2016) A **network service slice** is grouping of physical or virtual (network, compute, storage) resources which can act as a sub network and/or cloud and it can accommodate service components and network (virtual) functions. For slice creation, management planes create virtual or physical network functions and connects them as appropriate and instantiate all the network functions assigned to the slice. On the other hand, for slice creation, the slice control takes over the control of all the virtualised network functions and network programmability functions assigned to the slice, and (re-)configure them as appropriate to provide the end-to-end service.

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)

Network Slicing Key Characteristics

- It enables the concurrent deployment of multiple logical, self-contained and independent shared or partitioned networks on a common infrastructure platform. It enables dynamic multi-service support, multi-tenancy and the integration means for vertical market players.
- It is abstracting different physical infrastructures into a logical network that contains shared resources,, and virtual network functions obtained by breaking down single physical equipment into multiple instances, which are isolated from each other.
- In addition virtualization of network functions allow to decouple network node functions from hardware appliances in order to create distinct building blocks that can be flexibly chained to create new communication services.
- The separation of different functions by abstractions simplifies the provisioning of services, manageability of networks and the integration and operational challenges especially for supporting communication services.
- It facilitates the use of the principles of software-defined networks and network function virtualization in order to fulfill the business requirements.
- Network operators / ISP can exploit network slicing for reducing significantly operations expenditures, allowing also programmability and innovation, necessary to enrich the offered services from simple communications services to a wider range of business services.
- It enables Network Operators to offer tailored services and means for network programmability to OTT providers and other market players without changing the physical infrastructure.
- Slice networking is also fully adopted in the context of 5G research, development and standardisation

As such Slice Networking would considerably transform the networking perspective and enhance Internet architecture **by abstracting, isolating, orchestrating and separating logical network behaviors from the underlying physical network resources.**

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 operations and management
- Independent cost and/or energy optimisation

(Proposal for IETF / ANIMA) A unified Slice definition in the context of Autonomic Networking

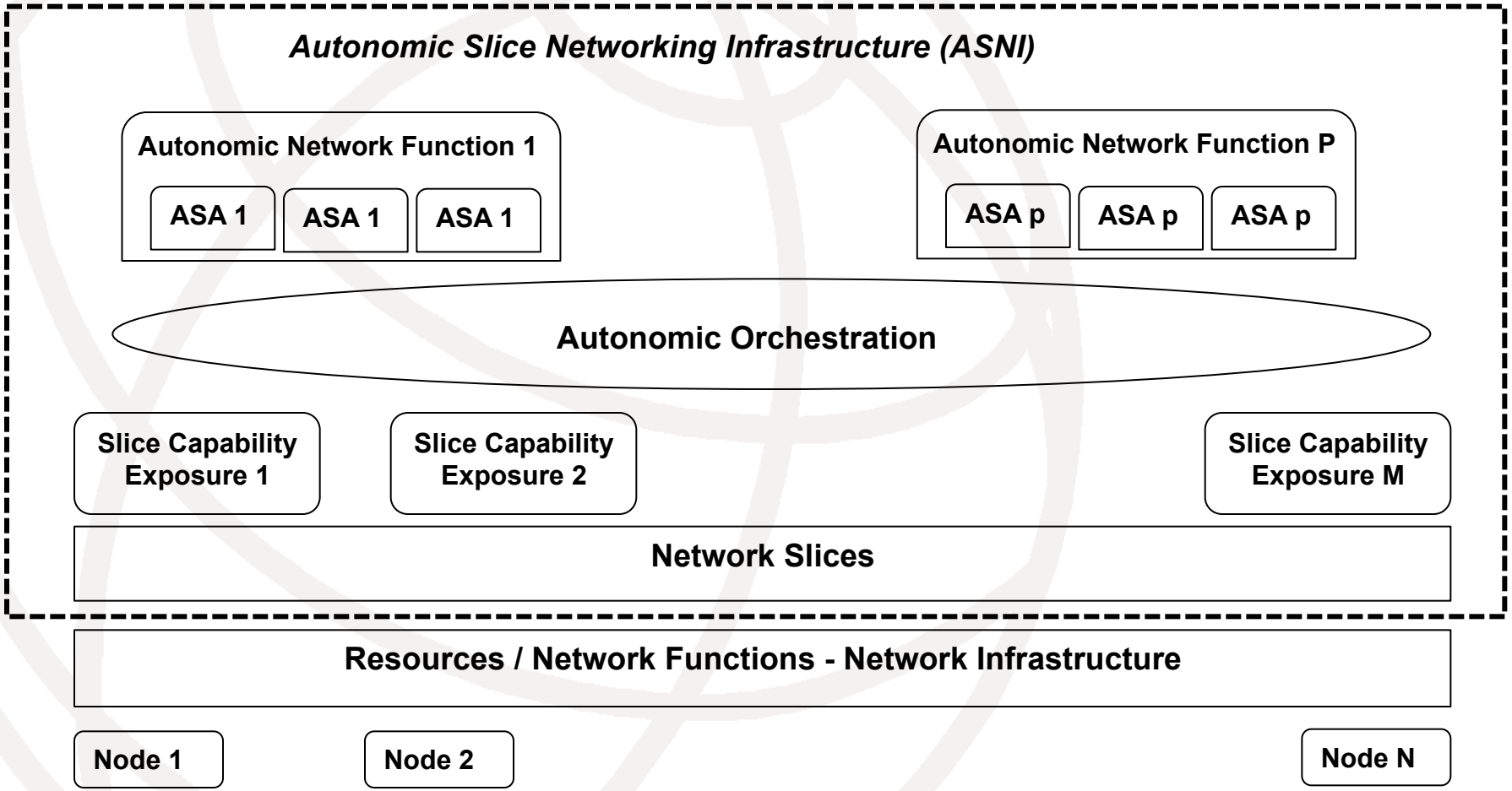
- **The Service Instance component** represents the end-user service or business services which are to be supported. It is an instance of an end-user service or a business service that is realized within or by a Network Slice. Each service is represented by a Service Instance. Services and service instances would be provided by the network operator or by 3rd parties.
- **A Network Slice Instance component** is represented by a set of network functions, and resources to run these network functions, forming a complete instantiated logical network to meet certain network characteristics required by the Service Instance(s). It 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.
- **Resources component** – it includes: (i) *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; (ii) *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.
- **Slice Capability exposure component** is allowing 3rd parties to access / use via APIs information regarding services provided by the slice (e.g. connectivity information, QoS, mobility, autonomicity, etc.) and to dynamically customize the network characteristics for different diverse use cases (e.g. ultra-low latency, ultra- reliability, value-added services for enterprises, etc.) 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.

Requirements

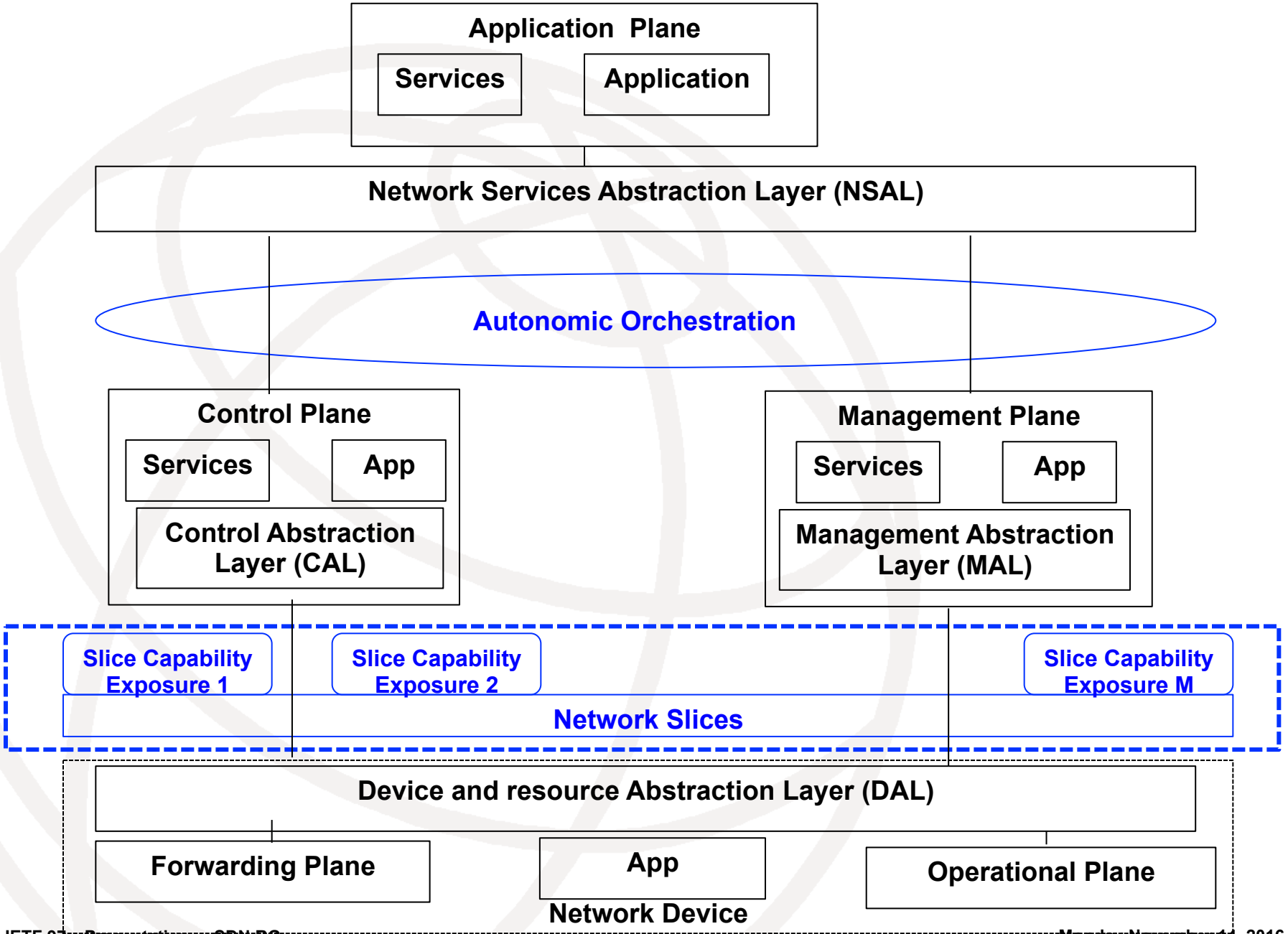
- ***Slice creation***: management plane create virtual or physical network functions and connects them as appropriate and instantiate them in the slice.
- ***The instance of slice management then takes over the management and operations*** of all the (virtualised) network functions and network programmability functions assigned to the slice, and (re-)configure them as appropriate to provide the end-to-end service.
- ***A complete slice is composed of*** not only various network functions which are based on virtual machines at C-RAN and C-Core, but also transport network resources which can be assigned to the slice at radio access/transport network. Different future businesses require different throughput, delay and mobility, and some businesses need very high throughput or/and low delay. Transport network shall provide QoS isolation, flexible network operation and management, and improve network utilization among different business.
- ***QoS Isolation*****:** Although traditional VPN technology can provide physical network resource isolation across multiple network segments, it is deemed far less capable of supporting QoS hard isolation, which means QoS isolation on forwarding plane requires better coordination with management plane.
- ***Independent Management Plane***: Like above, network isolation is not sufficient, a flexible and more importantly a management plane per instance is required to operate on a slice independently and autonomously within the constraints of resources allocated to the slice.
- Another flexibility requirement is that an ***operator can deploy their new business application or a service in network slice*** with low cost and high speed, and ensure that it does not affect existing of business applications adversely.
- ***Programmability*****:** Operator not only can slice a common physical infrastructure into different logical networks to meet all kinds of new business requirements, but also can use SDN based technology to improve the overall network utilization. By providing a flexible programmable interface; the 3rd party can develop and deploy new network business rapidly. Further, if a network slicing can run with its own slice controller, this network slicing will get more granular control capability [I-D.ietf-anima-autonomic-control-plane] to retrieve slice status, and issuing slicing flow table, statistics fetch etc.
- ***Life cycle self-management***: It includes creation, operations, re- configuration, composition, decomposition, deletion of slices. It would be performed automatically, without human intervention and based on a governance configurable model of the operators. As such protocols for slice set-up /operations /(de)composition / deletion must also work completely automatically. Self-management (i.e. self-configuration, self-composition, self-monitoring, self-optimisation, self-elasticity) is carried as part of the slice protocol characterization.
- ***Extensibility*****:** Since the Autonomic Slice Networking Infrastructure is a relatively new concept, it is likely that changes in the way of operation will happen over time. As such new networking functions will be introduced later, which allow changes to the way the slices operate.
- ***Transport network shall provide*** QoS isolation, flexible network operation and management, and improve network utilization among different business.
- The flexibility behind the slice concept needs to address **QoS guarantee on the transport network** and enable network openness.

Autonomic Slice Networking – Reference Model

- **"Autonomic Slice Networking Infrastructure" (ASNI)** - It consists of a number of autonomic nodes resources, which interact directly with each other. Those autonomic nodes resources provide a common set of capabilities across a network slices. The ASNI provides functions like naming, addressing, negotiation, synchronization, discovery and messaging.
- **Autonomic network functions** typically span several slices in the network. The atomic entities of an autonomic function are called the **"Autonomic Service Agents" (ASA**), which are instantiated on slices.

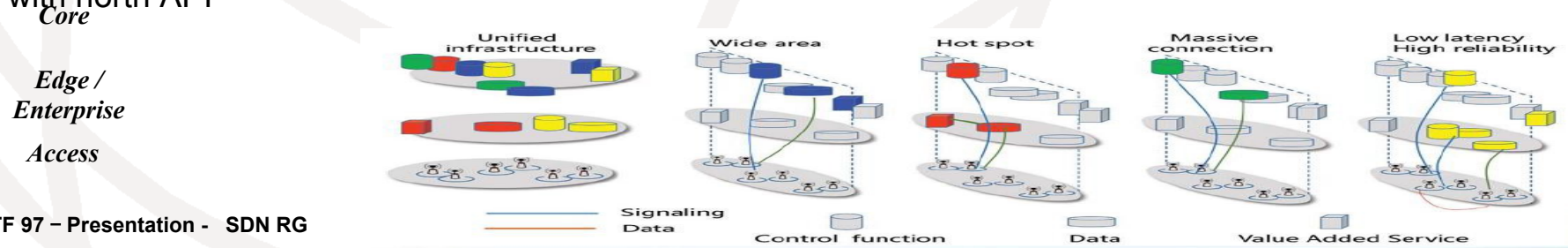


Revisited SDN Layer Architecture (rfc7426) – Reference Model



Advanced Network Slicing Work Items and Issues

- Reference Models (Autonomic Slice Networking; Revisited SDN Layered Architecture)
- Identify and select the slice in device, access and core part
- Design guarantee the end-to-end QoS of a slice
- Shared non-sliced network parts
- Isolation of slices (levels of impact on other slices; common control functions)
- Slice protection (i.e. providing related slice protection mechanisms so that events within one slice, such as congestion, do not have a negative impact on another slice)
- Efficiency in slicing (realise diverse requirements without re-engineering the infrastructure)
- Design the slices to different scenarios; an appropriate slice template definition
- Effective Autonomic slice management (self-configuration, self-composition, self-monitoring, self-optimisation, self-elasticity are carried as part of the slice protocols)
- Enablers for efficien stich/composition/decomposition of slices vertically (service + management + control planes) and/or horizontally (between different domains of edge, access, core segments)
- E2E slice life-cycle management
- Autonomically management and orchestration on network service slices
- Dynamic Mapping of Services to slices
- Enablers for sharing infrastructure safely and efficiently (Multi-tenant)
- Four dimensional efficient isolation in Data/Control/Management/Service planes
- Automation: Created flexibly + Slice resource modified easily according to service requirement + Useless slice deleted promptly
- Global optimisation - Network resources automatic acquisition, global resource view formed; Network Slice deployed based on global resource; Mapping algorithms
- Autonomic E2E orchestration of slices
- Infrastructure openness to use fully controlled network slices (Service openness enable program services with north API



Concluding Remarks

- Autonomic Slice Networking is introduced to SDN RG
- Initial draft <draft-galis-anima-autonomic-slice-networking-01>
- Invitation to participate in the Slice Networking related SDN drafts related to
  - reference model,
  - control plane,
  - management plane,
  - signaling protocol,
  - control loops,
  - terms and concepts