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Title:	Network 2030 Challenges and Opportunities in Network Slicing
Purpose:	Call attention to the gaps and fragmentation of standardization of network slicing and put end-to-end multi-domain network slicing into the FG2030 agenda

Contact:	Christian Rothenberg (UNICAMP)	E-mail: chesteve@dca.fee.unicamp.br
Contact:	Luis Miguel Contras Murillo (TELEFONICA)	E-mail: luismiguel.contrerasmurillo@telefonica.com
Contact:	Alex Galis (University College London)	E-mail: a.galis@ucl.ac.uk

Network Slicing Brief Review

Today`s telecommunication industry takes arguably timid approaches on sharing infrastructure assets (e.g, energy, space, antennas, hardware, etc.) or service-specific resource capacity (cf. Mobile Virtual Network Operator - MVNO). As the history of multiplexing gains keeps proving on different fields, future networks shall expect broader approaches to any-layer resource sharing, from virtualized infrastructures to applications and network functions driven by win-win incentives of all stakeholders.

Network slicing, despite not being a new concept [1,2,3], appears as a foundational concept and approach to future network service delivery, with the goal of providing dedicated private networks tailored to the needs of different verticals based on the specific requirements of a diversity of new services such as high definition (HD) video, virtual reality (VR) and V2X applications.

Network Slicing is an end-to-end concept [4,5] covering all network and cloud network segments (access, core, transport, edge). It enables the concurrent deployment of multiple logical, self-contained and independent shared or partitioned network resources and a group of network and service functions on a common infrastructure platform.

Network Slicing (NS) can be defined [7] as *managed 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. Network resources include connectivity, compute, and storage resources.* As per [7], *Network Slices considerably transform the networking perspective by abstracting, isolating, orchestrating, softwarizing, and separating logical network components from the underlying physical network resources and as such they enhance Internet architecture principles.*

The ITU-T [6] defines the concept of LINP composed of multiple virtual resources (i.e., abstraction of physical or logical resources), which is actually a realization of a network slice. ITU-T IMT2010 [9] specifies end-to-end network slicing to provide dedicated logical networks for a customer (or service) in the context of network softwarization.

In a foreseeable future (e.g., 2030), network slicing may have become the norm, realized through diverse operational modes and taking multi-tenancy to an extreme. Such a “deep slicing” vision is broad and deep from both a vertical (multi-layer) perspective as well as an horizontal (end-to-end and multi-domain) view, taking customer/tenant-provider recursivity to an extreme combined with flexible tenant-driven choices on the network protocol stack and actual software instances under its responsibility. However, to realize such a vision, we observe that the current slicing initiatives in standardization and diverging to a large extend, yielding a fragmented landscape that could jeopardize the broadest and deepest realization of network slices.

Standards Development Organizations (SDOs) and some other industrial associations are looking at the network slice concept from different angles and perspectives [16]. From an operator's point of view, there is a risk of fragmenting the conceptual approach to network slices, since small differences can provoke incompatibilities among the different approaches. It is therefore necessary to reach consensus on common terms, definitions, rationale, ideas, and goals to properly normalize the concept of network slicing.

The NGMN Alliance provided a primary description of the network slice concept [8] as mentioned in the introductory section. The NGMN view is that of a 5G slice as a composition of a collection of 5G network functions and specific Radio Access Technology (RAT) settings that are combined for the specific use case or business model while leveraging Network Function Virtualization (NFV) and Software-Defined Networking (SDN) [19] concepts. The network slice concept is organized in a layered manner (NGMN, 2016), differentiating the service instance layer, comprising the end-user of business services; the network slice instance (NSI) layer, as a set of functions forming a complete instantiated logical network; and the Resource layer, consisting of both physical and logical resources. In this layered view, the NSIs can be potentially shared among multiple service instances.

The 3GPP [13] differentiates among network slices and network slice instances. On one hand, a network slice represents a logical network providing specific network capabilities and network characteristics. On the other hand, a network slice instance is defined as a deployed network slice, that is, a specific set of network function instances and associated resources.

ETSI NFV [11] specifies network operators' perspectives on NFV priorities for 5G, network slicing support with ETSI NFV architecture and an E2E network slicing framework. Another recent development within ETSI Zero Touch Network and Service Management Industry Specification Group (ZSM ISG) is specifically devoted to the standardization of automation technology for network slice management [17]. Within the ETSI Multi-access Edge Computing (MEC) group, a new work item called "MEC support for network slicing" [18] seeks to identify the necessary support for network slicing, evaluating the gaps from MEC features and functions, and identify the new requirements.

The BBF [12] is also approaching network slicing (BBF, 2018) by augmenting the previous management functions by defining new and complementary ones, like Access Network Slice Management (ANSM), Core Network Slice Management (CNSM), and Transport Network Slice Management (TNSM). Each of them is intended to take care of the slice lifecycle management of each particular network slice subinstance (i.e., access, core, or transport).

The IETF is approaching the ideas of network slicing in a fragmented manner itself. The terms slice, slicing (and semantically equivalent ones) appear in multiple drafts [14]. However, a coordinated and focused Working Group to explore candidate uniform framework models, and adequate information models, has not yet been established despite some attempts during the last year.

ONF [10] identifies how to apply SDN to network slicing.

The ITU-T defined in [6] the concept of LINP composed of multiple virtual resources (i.e., abstraction of physical or logical resources), which is actually a realization of a network slice. LINPs are isolated from other LINPs, having their own programmable control plane and data plane. This architectural vision can be seen as an overarching one with the potential to accommodate diverse scoped and engineered forms of network slicing. ITU-T IMT 2020 [14] specifies vertical (service to network resources) and horizontal slicing (concatenation of slices) with independent management of each plane (service, control, data). It presents also a framework for the support of Multiple Network Slicing

Network Slicing Challenges for NETWORK 2030

After the brief review on the ongoing fragmented SDO activities around network slicing, we should highlight that the standardization gap goes hand by hand with a series of key challenges from a provider's perspective on (i) scalability, (ii) arbitration, (iii) slice planning and dimensioning, and (iv) multi-domain [16]. Both business and technical implications can be deemed necessary for such multi-operator slice provisioning context. From the business side, some key implications include: (i) coordination models, (ii) inter-provider SLAs, (iii) pricing schemes, (iv) service specification, and (v) customer facing advertisement. From a technical perspective can be highlighted (i) slice decomposition, (ii) discovery of domains, (iii) common abstraction models, (iv) standard interfaces, protocols, and APIs.

The followings are network and cloud network slicing challenges as applicable to NETWORK 2030:

- Precision Slicing - concurrent deployment of multiple logical, self-contained and independent, shared or partitioned networks on a common infrastructure with guaranties for KPIs (Key Performance Indicators)
- Slice Templates & Methods for the design of slices to different scenarios in Vertical market players (such as the automotive industry, energy industry, healthcare industry, media and entertainment industry, holograms, etc.). This outlines an appropriate slice template definition that may include capability exposure of managed partitions of network resources (i.e. connectivity compute and storage resources), physical and/or virtual network and service functions that can act as an independent connectivity network and/or as a network cloud.
- Native programmability and control of Network Slices; Capability exposure for Network Slicing (allowing openness); with APIs for dynamic slice management and interaction
- Guaranteed Isolation - slice creation and deployment with guarantees for isolation in each of the Data / Control / Management / Service planes. Methods to enable diverse requirements for slicing, including guarantees for the end-to-end QoS of a service within a slice.
- Interaction with the vertical tenants: 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 of vertical tenants.
- Network Slicing Service Mapping - service mapping model binding across network slicing; methods to realize diverse service requirements without re-engineering the infrastructure.
- High level of recursion, namely methods for network slicing segmentation allowing a slicing hierarchy with parent–child relationships
- High Scalability characteristics - 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
- Autonomic slice management and operation, namely self-configuration, self-composition, self-monitoring, self-optimisation, self-elasticity for slices that will be supported as part of the slice protocols.
- Customized security mechanisms 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

Conclusion. Focussing on the network and cloud network slicing challenges would enable the deplorability of expected NETWORK 2030 innovative facilities.

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