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**Network Slicing - Revised Problem Statement**  
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Abstract

This document introduces Network Slicing problems and the motivation for new work areas. It represents an initial revision of the Network Slicing problem statement derived from the analysis of the technical gaps in IETF protocols ecosystem. It complements and brings together the efforts being carried out in several other IETF working groups to achieve certain aspects of Network Slicing functions and operations.

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## **[1](#) Introduction**

Network slicing (NS) is an approach of flexible isolation and allocation of network resources and network functions for a network instance, providing high level of customization and quality service guarantee. It transform the networking perspective by abstracting, isolating, orchestrating, softwarizing, and separating logical network components from the underlying physical network supporting the introduction of new network architectures ([\[RFC1958\]](#), [\[RFC3439\]](#), [\[RFC3234\]](#)) and new service delivery [\[5G-ICN\]](#). In general, a particular network slice consists of a union of subsets of (connectivity, storage, computing) resources & (Virtual) Network Functions & Service functions [\[RFC7665\]](#) at the data & control & management planes at a given time that are managed together to provide a logical networking infrastructure in support of a variety of services.

Network slicing enables at a given time the dynamic creation of multiple, parallel sub-networks of different features by flexible isolation of allocated to a slice network resources and network functions and providing high level of customization and quality guarantee.

The management plane allocates the grouping of network resources (whereby network resources can be physical, virtual or a combination thereof), it connects with the physical and virtual network and service functions ([SFC WG]) as appropriate, and it instantiates all of the network and service functions assigned to the slice. On the other hand, for slice operations, the slice control plane functionality that may be operated by slice tenant, takes over the control and governing of all the network resources, network functions, and service functions assigned to the slice. It (re-) configures them as appropriate and as per elasticity needs, in order to provide an end-to-end service. In particular, slice ingress routers are configured so that appropriate traffic is bound to the relevant slice.

Allocation of traffic flows to slices as may be based on simple rules (relying on a subset of the transport coordinate, DSCP/traffic class, or flow label), or may be a more sophisticated one (to be further defined) such as enabling new slice specific constructs in the data plane. Also, the flows to slice allocation rules that are specified for a slice can be changed dynamically, based on some events (e.g. triggered by a service request). The slice control plane is responsible for instructing the involved elements to honor such



needs.

Network operators can use NS to enable different services to receive different treatment and to allow the allocation and release of network resources according to the context and contention policy of the operators. Such an approach using NS would allow significant reduction of the operations expenditure. In addition, there is an enabling link between NS and softwarization. On one hand NS makes possible softwarization, programmability ([RFC7149]), and the innovation necessary to enrich the offered services. On the other hand Network softwarization techniques [IMT2020-2015], [IMT2020-2016] may be used to realise and manage [MANO-2014] network slicing. NS provides the means for the network operators to provide network programmable capabilities to both service providers and other market players without changing their physical infrastructure. NS enables the concurrent deployment of multiple logical, self-contained and independent, shared or partitioned networks on a common infrastructure. Slices may support dynamic multiple services, multi-tenancy, and the integration means for vertical market players (e.g. automotive industry, energy industry, healthcare industry, media and entertainment industry, etc.)

Please refer to [I-D.geng-netslices-architecture] for related terminologies and definitions.

### **1.1 Network Slicing Value Characteristics**

As a differentiation from non-partition networks and those with simple partitions of connectivity resources (e.g. VPNs)/ Virtual Networks/Other abstractions of the data traffic layer, the following key value-added characteristics of Network Slicing and corresponding usage are identified:

- \* Network Slice is a dedicated network that is build on an infrastructure mainly composed of, but not limited to, connectivity, storage and computing.
- \* Each network slice has the ability to dynamically expose and possibly negotiate the parameters that characterize an NS.
- \* Each network slice will have its own operator that sees it as a complete network infrastructure (i.e. router instances, programmability, using any appropriate communication protocol, caches, provide dynamic placement of virtual network functions according to traffic patterns, to use its own controller, finally it can manage its network as its own).
- \* Network slicing support tenants that are strongly independent on infrastructure.
- \* A Network Slicing aware infrastructure allows operators to use part of the network resources to meet stringent resource



requirements

- \* Network slicing introduces 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.
- \* Network slicing covers the full life cycle of slices that are managed groups of infrastructure resources, network functions and services (e.g. the network slice components are: service instance, a network functions instance, resources, slice manager and capability exposure).
- \* Network slices are dynamically and non-disruptively reprovisioned
- \* Network slices will need to be self-managed by automated, autonomic and autonomous, systems in order to cope with dynamic requirements, such as scalability or extensibility of an infrastructure (organically growing/shrinking of resources to meet the size of their organizations)
- \* Network slices are configurable and programmable and they have the ability to expose their capabilities and characteristics. The slice protocols and functions are selected according to slice required features. The behaviour of the network slice realized via network slice instance(s).
- \* Network slices are concurrently deployed as multiple logical, self-contained and independent, partitioned network functions and resources on a common physical infrastructure.
- \* Network slicing supports dynamic multi-services, multi-tenancy and the means for backing vertical market players.
- \* Network slicing simplifies the provisioning of services manageability of networks and integration and operational challenges especially for supporting. communication services.
- \* Network slicing offers native service customization enabled by the selection and configuration of network functions for coordinating/orchestration and control of network resource.
- \* Network slicing considerably transforms the networking perspective by abstracting, isolating, orchestrating and separating logical network behaviors from the underlying physical network resources

## **1.2 Network Slicing Work Scope**

The purpose of the NS work in IETF is to develop a set of protocols and/or protocol extensions that enable efficient slice creation, activation / deactivation, composition, elasticity, coordination/orchestration, management, isolation, guaranteed SLA, and safe and secure operations within a connectivity network or network cloud / data centre environment that assumes an IP and/or





MPLS-based underlay.

While there are isolated efforts being carried out in several IETF working groups Network WG [I-D.leeking-actn-problem-statement-03], TEAS WG [[I-D.teas-actn-requirements-04](#)], [I-D.dong-network-slicing-problem-statement], ANIMA WG [I-D.galis-anima-autonomic-slice-networking], [[IETF-Slicing1](#)], [[IETF-Slicing2](#)], [[IETF-Slicing3](#)], [[IETF-Slicing4](#)], [[IETF-Slicing5](#)], [[IETF-Mobility](#)], [IETF-Virtualization], [[IETF-Coding](#)], [[IETF-Anchoring](#)] to achieve certain aspects of network slice functions and operations, there is a clear need to look at the complete life-cycle management characteristics of Network Slicing solutions though the discussions based on the following architectural tenets:

- \* Underlay tenet: support for an IP/MPLS-based underlay data plane.
- \* Governance tenet: a logically centralized authority for network slices in a domain.
- \* Separation tenet: slices may be virtually or physically independent of each other and have an appropriate degree of isolation (note 1) from each other.
- \* Capability exposure tenet: each slice allows third parties to access via dedicated interfaces and /or APIs and /or programming methods information regarding services provided by the slice (e.g., connectivity information, mobility, autonomicity, etc.) within the limits set by the operator or the slice owner.

NS approaches that do not adhere to these tenets are explicitly outside of the scope of the proposed work at IETF.

In pursuit of the solutions described above, there is a need to document an architecture for network slicing within both wide area network and edge/central data center environments.

Elicitation of requirements (examples are [[RFC2119](#)], [[RFC4364](#)]) for both Network Slice control and management planes will be needed, Facilitating the selection, extension, and/or development of the protocols for each of the functional interfaces identified to support the architecture.

Additionally, documentation on the common use-cases for slice validation for 5G is needed, such as mission-critical ultra-low latency communication services; massive-connectivity machine communication services (e.g. smart metering, smart grid and sensor networks); extreme QoS; independent operations and management; independent cost and/or energy optimisation; independent multi-topology routing; multi-tenant operations; new network architecture enablement, etc.



The proposed NS work would be coordinated with other IETF WGs (e.g. TEAS WG, DETNET WG, ANIMA WG, SFC WG, NETCONF WG, SUPA WG, NVO3 WG, DMM WG, Routing Area WG (RTGWG), Network Management Research Group (NMRG) and NFV Research Group (NFVRG)) to ensure that the commonalities and differences in solutions are properly considered. Where suitable protocols, models or methods exist, they will be preferred over creating new ones.

### **1.3 Notes**

- (1) This issue requires efficient interaction between an upper layer in the hierarchy and a lower layer for QoS guarantees and for most of the operations on slicing.

## **2. Network Slicing - Selected Problems and Work Areas**

The goal of this proposed work is to develop one or more protocol specifications (or extensions to existing protocols) to address specific slicing problems that are not met by the existing tools. The following problems were selected according to the analysis of the technical gaps in IETF protocols ecosystem. Each problem is associated with one identified IETF gap ([draft-qiang-netslices-gap-analysis-01](#)). In addition an initial priority level is attached to each problem. [(\*\*\*) high priority, (\*\*) medium priority and (\*) low priority]. The proposed WG charter would include at least the high priority problems.

### **2.1 Global Issues - Problems (GP)**

#### **2.1.1 Problem GI1: Uniform Reference Model (\*\*\*)**

Related Identified IETF Gap: "A detailed specification of Network Slicing Specification".

Uniform Reference Model for Network Slicing (Architecture document):

- \* Description of all of the functional elements required for network slicing.
- \* Description of shared non-sliced network parts. Establishes the boundaries to the basic network slice operations (creation, management, exposure, consumption).
- \* Describes the minimum functional roles derived from basic network slice operations including infrastructure owner (creation, exposure, management), slice operator (exposure, management, consumption), slice customer (management, consumption). Describe the interactions between infrastructure owner <-> slice operator, slice operator <-> slice operator, slice operator <-> slice customer.



- \* Additionally, this working area will normalize nomenclature and definitions for Network Slicing.

Short explanation: A uniform definition and architecture of Network slicing is presented in the NS Architecture draft. A Network slice is a managed group of subsets of resources, network functions/network virtual functions at the data, control, management/orchestration planes and services at a given time. Network slice is programmable and has the ability to expose its capabilities. The behaviour of the network slice realized via network slice instance(s).

- (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
  - a. Represented by a set of network functions, virtual network functions and resources at a given time
  - b. Forms a complete instantiated logical network to meet certain network characteristics required by the Service Instance(s).
  - c. Provides network characteristics which are required by a Service Instance.
  - d. May also be shared across multiple Service Instances
- (3) Resources component - it includes: Physical, Logical & Virtual resources
  - a. 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.
  - b. 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 (SEM) and Capability exposure component
  - a. Slice Element Manager (SEM) is instantiated in each Network Slice and it manages all access permissions and all interaction between a Network Slice and external functions (i.e. other Network Slices, Orchestrators, etc). Each SEM converts requirements from orchestrator into virtual resources and manages

Consolidation and versification of the above definition is required. New protocols are needed for the creation, for discovery and for orchestrating network slicing.

### **2.1.2 Problem GI2: Requirements for operations and interactions (\*\*)**



Related Identified IETF Gap: "A detailed specification of Network Slicing Specification".

Review common scenarios 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.

Short explanation: Review of the functional and non- functional NS requirements is needed to ensure that resource utilization is maximized and infrastructure costs are minimized as services will need to operate over a union of shared network infrastructures, as against the traditional monolithic model operated either as dedicated network or as an overlay.

### **2.1.3 Problem GI3: Slice Templates (\*\*\*)**

Related Identified IETF Gap: "A detailed specification of Network Slicing Specification".

Design the slices to different scenarios [[ChinaCom-2009](#)], [GENI-2009], [[IMT2020-2016bis](#)], [[NGMN-2016](#)], [[NGS-3GPP-2016](#)], [[ONF-2016](#)]]; Outlines an appropriate slice template definition that may include capability exposure of managed partitions of network resources (i.e. connectivity ([[CPP](#)]), 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.

Short explanation: A network slice template based on uniform reference model would enable the creation of a network slice instance. A template defines an abstraction of the overall network resources and functions requirement for a particular network slice instance. Different templates can also be regarded as definitions of individual network slice types. Besides the reference model for network resources and functions, each template has a complete description of the structure, configuration and the plans/work flows for how a certain type of network slice instance should be instantiated and managed during its life cycle.

There should be a clear definition of the level of abstraction of the network slice template according to the arrangement and specification of network slice life cycle management system. A valid network slice instance profile created based on specific network slice template is going to be decomposed into configuration profiles to certain OAM domains for the purpose of network slice instance creation.

The creation of a specific network slice template strictly relies on the exposed network capabilities. The network slice life cycle





management system should not allow a template with parameters exceeding the capabilities to be created.

## **2.2 Network Slice Capabilities - Problems (NSC)**

### **2.2.1 Problem NSC1: Guarantees for isolation (\*\*\*)**

Related Identified IETF Gap: "Slicing specific extension on Isolation".

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.

Short explanation: Network slices MUST support multi-tenancy, ensuring that isolation and performance guarantees are provided at the data, control, management and service planes. This involves the following:

- \* A network slice SHOULD provide a guaranteed level of service, according to a negotiated SLA between the customer and the slice provider
- \* Slices 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).
- \* Slices MUST be isolated at data level, even if sharing resources. Security and privacy mechanisms should be in place to ensure this.
- \* A network slice SHOULD be provided with exclusive control and/or management interfaces (depending on the type of network slice), enabling the deployment of different logical network slices over shared resources.

### **2.2.2 Problem NSC2: Fulfilling diverse requirements (\*)**

Related Identified IETF Gap: "A detailed specification of Network Slicing Specification".

Methods to enable diverse requirements for NS including guarantee for the end-to-end QoS of service in a slice.

Short explanation: The main goal of fulfilling NS requirements is to ensure that service operators can utilize or benefit from Network Slicing through multi-tenancy, enabling different customized infrastructures for different group of services across different network segments and operating them independently. It includes the tasks that go into determining the needs or conditions to meet for NS systems, taking account of the possibly conflicting requirements of



the various stakeholders and a prioritisation of requirements. New protocols are needed for interoperability between diverse type of network slices which are fulfilling diverse requirements

### **2.2.3 Problem NSC3: Efficiency in slicing (\*)**

Related Identified IETF Gap: "A detailed specification of Network Slicing Specification".

Specifying policies and methods to realize diverse requirements without re-engineering the infrastructure.

Short explanation: This item is deployment-specific and cannot be promised as a problem to be solved entirely by protocols. An underlying infrastructure will always be needed to be reengineered and maintained to support up-to-date technologies and emerging requirements (including instantiating new service functions or withdrawing service functions, adding new nodes to absorb for traffic, ...). It is a local decision to figure out whether many services will be bound to the same slice, how many slices are to be instantiated and so on. Exposing standard interfaces to capture requirements will help to rationale the use of resources and how the requirements are fulfilled, however it is a challenge to guarantee in an absolute manner that slicing allows "diverse requirements without re-engineering the infrastructure".

### **2.2.4 Problem NSC4: Slice Recursion (\*\*)**

Related Identified IETF Gap: "A detailed specification of Network Slicing Specification".

Short explanation: Recursion is a property of some functional blocks: a larger functional block can be created by aggregating a number of a smaller functional block and interconnecting them with a specific topology. As such recursive network slice definition is defined as the ability to build a new network slice out of existing network slice (s). A certain resource or network function /virtual network function could scale recursively, meaning that a certain pattern could replace part of itself. This leads to a more elastic network slice definition, where a network slice template, describing the functionality, can be filled by a specific pattern or implementation, depending on the required performance, required QoS or available infrastructure.

New protocols are needed for use of network slice template segmentation allowing a slicing hierarchy with parent - child relationships.



### **2.2.5 Problem NSC5: Customized security mechanisms per slice (\*)**

Related Identified IETF Gap: "Mechanisms for customized granularity OAM (Operations, Administration, and Maintenance)".

Short explanation: Customized securing mechanisms will be needed on a per slice basis. This may be provided by enabling dedicated service functions. For such cases, SFC techniques can be used here. Soliciting distinct SFs per slice can be provided with existing tools. I don't see a new problem out there.

This may be provided by configuring dedicated policies in a given security service function. In such case, I2NSF techniques can be used to interact with a given service function.

Traffic isolation may be needed for some services. Legacy tools can be used. I'm not sure if there is specific work specific to slicing other than making sure that appropriate flows are grafted to the appropriate slice and no data leaking between slices is to happen.

### **2.2.6 Problem NSC6: flexibility and efficiency trade-offs (\*)**

Related Identified IETF Gap: "A detailed specification of Network Slicing Specification".

Methods and policies to manage the trade-offs between flexibility and efficiency in slicing.

Short explanation: Mechanisms SHOULD be in place to allow different levels of flexibility when providing network slices: from the ones that provided greater levels of flexibility in the provided resources and services that compound the slice, allowing to dynamically change/scale/migrate it over time within a negotiated range, to the ones that ensure the efficiency of the use of the resources at the cost of a smaller degree of flexibility.

### **2.2.7 Problem NSC7: Optimisation (\*\*)**

Related Identified IETF Gap: "non-overlay OAM solution".

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; Mapping protocols.

Short explanation: NS optimization includes methods which enable that resources utilization is monitored and maximize, that infrastructure operational costs are minimized and that QoS are managed and



maximized at the time of creation of network slice instance and well as during NS operation.

#### **2.2.8 Problem NSC8: Monitoring and Discovery (\*\*)**

Related Identified IETF Gap: "Mechanisms for dynamic discovery of service with function instances and their capabilities".

Monitoring status and behaviour of NS in a single and/or multi-domain environment; NS interconnection.

Short explanation: A Network slice is a managed group of subsets of resources, network functions / network virtual functions at the data, control, management/orchestration planes and services at a given time. Monitoring of slices interacts with and it is part of the NS Lifecycle management to aiming at reporting the performance of the running NS. As input, the Monitoring Subsystem receives the detailed service monitoring requests with references to resource allocation and Network functions instances in a NS. The Monitoring Subsystem is responsible for the monitoring continuously the state all 4 components of a NS (Service Instance component, Network Slice Instance component, Resources component). New protocols are needed for discovery and monitoring probes of all NS components and NS itself itself and for dynamic discovery of service with function instances and their capability.

#### **2.2.9 Problem NSC9: Capability exposure and APIs (\*\*\*)**

Related Identified IETF Gap: "A detailed specification of Network Slicing Specification".

Capability exposure for NS; plus APIs for slices

Short explanation: To exploit the flexibility offered by network slices their users (customers, overlying operators) would need to know the features offered by both individual resources and complete slices. This means that there must be interfaces to deliver such information to the entity that needs it, but that will be also transitively delivered to the following chains of the slicing structure towards the final users.

To this sense, there are two specific interfaces that must be defined to address such function:

- \* The bottom-up interface, offered by underlying resource providers to resource consumers (operators) of any layer.
- \* The top-down interface, offered by overlying operators to lower level providers.





On the one hand, the first interface will, obviously, enable slice operators to access the slices owned by underlying providers and manage the resources they have been assigned in them. On the other hand, the second interface will enable lower layers to know details about the resources managed by overlying operators and the requirements they impose to the overlying network slices.

In this respect, both interfaces will emphasize the relation among the original resources, as well as the links from them to the resulting resources. This forms the main key of their management operations.

#### **2.2.10 Problem NSC10: Programmability of Operations of Network Slices** (\*\*)

Related Identified IETF Gap: "Mechanisms for customized granularity OAM (Operations, Administration, and Maintenance)".

Short explanation: Network slice operations consist of all operations related to life cycle management of a slice and its optimized operation. Slice instance lifecycle management includes all operations related to slice instance creation, activation, update and deactivation. All these operations are automated and driven by appropriate policies. A slice instance is created according to a slice template and related policies. A unique identifier is assigned to each slice after its creation and a list of active slice instances are stored in slice repository. Several slice types are predefined which describe their functions as access, core, transport, data center and edge cloud slices. As example to each slice instance a Slice Priority parameter is assigned which describe the way of handling of slice degradation in case of lack of resources that can be allocated to slices. The parameter is also used in emergency situations in which there is a need to release resources from existing slices and to allocate them to newly created slices that are used for emergency situation handling.

The end-to-end slice can be a composition of per administrative or technological domain slices that are created according to their local templates. The process of slice creation can be recursive. The slice level are split between slice operator and slice tenant. The slice tenant obtains information about slices related KPIs and is expressing his reconfiguration wills as intents (high level policies), which are implemented in an automated manner by slice control and management planes. The slice operator is responsible for slice lifecycle and slice FCAPS handling. During operations of slice the slice resources are allocated in a dynamic way in order to provide required performance but in an economical way.



Each network slice exhibits following features: protection (note 2), elasticity (note 3), extensibility (note 4) and safety (note 5).

## **2.3 Network Slice Operations - Problems (NS0)**

### **2.3.1 Problem NS01: Slice life cycle management (\*\*\*)**

Related Identified IETF Gap: "non-overlay OAM solution".

Slice life cycle management including creation, activation / deactivation, protection (note 2), elasticity (note 3), extensibility (note 4), safety (note 5), 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.

Short explanation: Network slicing enables the operator to create logically partitioned networks at a given time customized to provide optimized services for different market scenarios. These scenarios demand diverse requirements in terms of service characteristics, required customized network and virtual network functionality (at the data, control, management planes), required network resources, performance, isolation, elasticity and QoS issues. A network slice is created only with the necessary network functions and network resources at a given time. They are gathered from a complete set of resources and network /virtual network functions and orchestrated for the particular services and purposes.

New protocols are needed for realising full Slice life cycle management at two distinct levels:

- (1) "network slice life-cycle management level" (i.e. the series of state of functional activities through which a network slice passes: creation, operation, deletion) and
- (2) "network slice instances level" (activated network slice level).

Functions for creating and managing network slice instances and the functions instantiated in the network slice instance are mapped to respective framework level.

### **2.3.2 Problem NS02: Autonomic slice management and operation (\*\*)**

Related Identified IETF Gap: "non-overlay OAM solution".

It includes self-configuration, self-composition, self-monitoring, self-optimisation, self-elasticity are carried as part of the slice protocols.



Short explanation: Network slice is a dynamic entity which lifecycle and operations should be automated. There are 3 main reasons of this automation:

- (1) There is an expectation that the number of slice instances can be huge what rises the problem of management scalability if it is performed in a classical, manual way.
- (2) Network slice instances can be created on demand by the end-users or verticals. They may play a role of slice instance administrator (making some reconfigurations or monitoring slice performance. It is however not expected that such administrator will have required experience and tools related to slice instance management. They can express some high-level requests that has to be translated into low level operations
- (3) Multiple network slice instances have to share common resources in economical way but with preserving required performance indicators. The problem of allocation of resources between slices combined with real-time optimization of slice operations can be only solved by continuous monitoring of slice performance and making continuous adaptations of resources allocated to them.

The mentioned reasons call for autonomic management which part should be autonomic management of each slice and autonomic management of resources that are allocated to slices. The autonomic operations at the slice instance level comprise of self-configuration, self-composition, efficient self-monitoring, self-healing and real-time optimization (self-optimisation) as a part of the autonomic management framework.

### **2.3.3 Problem NS03 - Slice stitching / composition (\*\*\*)**

Related Identified IETF Gap: "non-overlay OAM solution".

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.

Short explanation: Slice stitching. The network slice has to provide end-to-end communication and services. In some cases such end-to-end network slice instance can be created directly but in multi-domain environment the end-to slice will be a composition of slices of different domains in the each network segments (i.e. access, core, edge, transport, etc.). In such a case the domain slices will be created and maintained using domain specific slice templates and use



domain specific operations and all the domain slicing will be stitched together horizontally. The operation is supported by appropriate descriptions of domain slices, exchange of slice related policies between domains. Slice stitching operations are supported by uniform slice descriptors and appropriate matching of them. Each slices has appropriate set of mechanisms (slice border control functions) that support horizontal stitching of slices.

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

Slices will be recursively used as components in software architectures. This means that several slices will be able to be used together to build a "composite network service" that inherits the capabilities of the original slices. The recursive property means that both slices and derived composite services can be again "split" into pieces to form new slices. The straight result of this aspect is that complex services are highly simplified by "stitching" slices and/or part of them, achieving the actual complexity by exploiting layering, which is the de-facto standard composition capability typically mapped into network architectures, but also by exploiting the abstraction levels offered by network service composability.

However, to hide such complexity and thus achieve the intended abstraction, the network architecture (and slicing reference model) must include, adopt, and promote the deployment of the necessary mechanisms and functions that support slice stitching and network service composability.

#### **2.3.4 Problem NS04: E2E Network Orchestration (\*\*\*)**

Related Identified IETF Gap: "non-overlay OAM solution (Operations, Administration, and Maintenance) solution".

End-to-end network segments orchestration of slices ([[GUERZONI-2016](#)], [[KARL-2016](#)]).

Short explanation: Network service composition has demonstrated to be highly beneficial for both operators and final users [GRAMMATIKOU-2012]. It allows the formation of large number of different services, which will be specialized to the particular needs of a user or a specific situation. However, the current network architecture is far from being ideal to implement such function.

One of the keys of network slicing is the flexibility it adds to the





network and the resulting "de-ossification" of network resources. Thus, this environment is much more optimal to allow the proliferation of network service composition, but it means that some sort of specific requirements must be pushed towards the architecture that supports the general slicing.

First, a proper composable network service model needs network resources to be compatible, regardless of the domain to which they pertain. Then they must be homogeneously described, so a user can actually understand their individual capabilities and "draw" the service they want to build by combining them. Finally, the resources living among separated network slices must be "connectable" to each other. This means that they must cross the domain of their providers/owners in order to reach their destination.

New protocols are needed for full end to end orchestration between the layers, from the IP layer and up.

#### **2.3.5 Problem NS05: Service Mapping in a single domain and Cross-Domain Coordination (\*\*\*)**

Related Identified IETF Gap: "Companion YANG data model for network slicing - single domain and Cross-Domain Coordination".

Having dynamic and Automatic Mapping of Services to slices; YANG models for slices.

Short Description: The main goal of the service mapping framework is to enable on-demand processing anywhere in the physically distributed network, with dynamic and fine granular service (re-)provisioning, which can hide significant part of the resource management complexity from service providers and users, hence allowing them to focus on service and application innovation. It include a slice-aware YANG information model based on necessary connectivity, storage, compute resources, network functions, capabilities exposed and service elements in a single domain as well as Cross-Domain Coordination. As such the service mapping participates in management of the network slices.

#### **2.3.6 Problem NS06: Roles in Network Slicing (\*)**

Related Identified IETF Gap: "Detailed specification of Network Slicing Specification".

Enablers and methods for the above mentioned capabilities and operations from different viewpoints on slices (note 6).

Short explanation: Several viewpoints emerge from the global and



wide interaction among the Network Infrastructure Owner (NIO), Network Slice Provider (NSP), and Network Slice Tenant(NST), and they must be treated by network slicing to ensure their use cases are correctly covered. They are:

- 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.

Any NSP can become a NST if it uses specific network slice instance for a particular service, or it purchase NSaaS from another NSP.

#### **2.3.7 Problem NS07: Efficient enablers and methods for integration (\*)**

Related Identified IETF Gap: "non-overlay OAM solution".

Efficient enablers and methods for integration of above capabilities



and operations.

Short explanation: In order to enable the above required capabilities and operation for network slicing, well defined reference points among the involved actors and entities are required, as well as the proper interface definitions ensuring interoperability of all involved pieces. Some examples of the required reference points/interfaces include:

Customer/Vertical (user of the slice) - Network Slice Provider. The user of the slice SHOULD be able to specify the characteristics of the slice and provide it in a suitable/understandable format to the NSP. A proper information model is needed to convey the customer slice requirements. And the model might need to support different levels of abstraction, to support different use cases.

Network Slice Provider - Network Slice Provider / Network Slice Operator / Network Service Provider. The slice provider MUST be able to request resources to compose a slice to other slice providers, slice operator or service operators. The interface needs to support recursiveness and different levels of abstraction (the request might involve resources or services).

Inter-domain interactions at different levels. Another way of composing a slice is by interaction of players at the same level (peering, instead of recursive), by delegating the request to other providers/operators. This type of interaction can take place at different levels (resource, network service, etc), and therefore would impose different requirements. In all cases, security issues are key due to the inter-operator nature.

## **2.4 Notes**

- (1) Protection refers to the related mechanisms so that events within one slice, such as congestion, do not have a negative impact on another slice.
- (2) Elasticity refers to the mechanisms and triggers for the growth/shrinkage of network resources, and/or network and service functions.
- (3) Extensibility refers to the ability to expand a NS with additional functionality and/or characteristics, or through the modification of existing functionality/characteristics, while minimizing impact to existing functions.
- (4) Safety refers to the conditions of being protected against



different types and the consequences of failure, error harm or any other event, which could be considered non-desirable.

- (5) Multiple viewpoints on slices: I) viewpoint of the slice's owner towards user: from this viewpoint a slice is defined as a means to "split" physical or virtual infrastructure elements to "service" smaller portions. This action would be recursively done from the owner of the initial and physical infrastructure element to the users. II) viewpoint of from the user towards the physical infrastructure owner. From this viewpoint a slice is viewed just as a set of resources that must be managed (requests to a provider, listed, changed, returned to the provider, etc.). This viewpoint emphasizes those issues that would be used in the SLA definition of a slice.

### **3. OAM Operation with Customized Granularity**

In accordance with [[RFC6291](#)], OAM is used to denote the following:

- \* Operations: refer to activities that are undertaken to keep the network and the services it deliver up and running. It includes monitoring the underlying resources and identifying problems.
- \* Administration: refer to activities to keep track of resources within the network and how they are used.
- \* Maintenance: refer to activities to facilitate repairs and upgrades. Maintenance also involves corrective and preventive measures to make the managed network run more effectively, e.g., adjusting configuration and parameters.

As per [[RFC6291](#)], NetSlices provisioning operations are not considered as part of OAM. Provisioning operations are discussed in other sections. Maintaining automatically-provisioned slices within a network raises the following requirements:

- \* Ability to run OAM activities on a provider's customized granularity level. In other words, ability to run OAM activities at any level of granularity that a service provider see fit. In particular:
  - An operator must be able to execute OAM tasks on a per slice basis.
  - These tasks can cover the "whole" slice within a domain or portion of that slice (for troubleshooting purposes, for example).
  - For example, OAM tasks can consist in tracing resources that are bound to a given slice, tracing resources that are invoked when forwarding a given flow bound to a given





- network slice, assessing whether flow isolation characteristics are in conformance with the NS Resource Specification, or assessing the compliance of the allocated slice resource against flow/customer requirements.
- An operator must be able to enable differentiated failure detect and repair features for a specific/subset of network. For example, a given slice may require fast detect and repair mechanisms (e.g., as a function of the nature of the traffic (pattern) forwarded through the NS), while others may not be engineered with such means.
- When a given slice is shared among multiple services/customers, an operator must be able to execute (per-slice) OAM tasks for a particular service or customer.
- \* Ability to automatically discover the underlying service functions and the slices they are involved in or they belong to.
- \* Ability to dynamically discover the set of NetSlices that are enabled within a network. Such dynamic discovery capability facilitates the detection of any mismatch between the view maintained by the control plane and the actual network configuration. When mismatches are detected, corrective actions must be undertaken accordingly.

#### **4 Summary**

The following is a summary of the selected higher priority problems based on previous analysis in this document:

(I) Identified IETF Gap: "A detailed specification of Network Slicing Specification"; Requirement: Network Slicing Specification.

- \* Problem GI1: Uniform Reference Model
- \* Problem GI3: Slice Templates
- \* Problem NSC9: Capability exposure and APIs

(II) Identified IETF Gap: "A companion YANG data model for Network Slicing"; Requirement: Network Slicing Specification.

- \* Problem NS05: Service Mapping in a single domain and Cross-Domain Coordination.

(III) Identified IETF Gap: "Slicing specific extension on Isolation (Performance Guarantee and Isolation-PGI"; Requirement: Performance Guarantee and Isolation.

- \* Problem NSC1: Guarantees for isolation.



(IV) Identified IETF Gap: "Mechanisms for dynamic discovery of service with function instances and their capabilities"; Requirement: Network Slicing OAM.

- \* Problem NSC8: Monitoring and Discovery

(V) Identified IETF Gap: "non-overlay OAM (Operations, Administration, and Maintenance) solution"; Requirement: Network Slicing OAM.

- \* Problem NS01: Slice life cycle management
- \* Problem NS04: E2E Network Orchestration

(VI) Identified IETF Gap: "Mechanisms for customized granularity OAM (Operations, Administration, and Maintenance)"; Requirement: Network Slicing OAM.

- \* Problem NS02: Autonomic slice management and operation
- \* Problem NS03: Slice stitching / composition

## **5 Security Considerations**

Security will be a major part of the design of network slicing.

## **6 IANA Considerations**

This document requests no IANA actions.

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