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Network Slicing - Introductory Document and 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 silo 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) refers to the managed partitions of physical and/or virtual network resources, network physical/virtual and service functions [RFC7665] 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.

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 ([RFC1958], [RFC3439], [RFC3234]).

The management plane creates 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 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, ingress routers are configured so that appropriate traffic is bound to the relevant slice. Identification means for the traffic may be simple (relying on a subset of the transport coordinate, DSCP/traffic class, or flow label), or identification may be a more sophisticated one (to be further defined). Also, the traffic capacity that is 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 NS makes possible softwarization, programmability ([RFC7149]), and the innovation necessary to enrich the offered services. 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 OTT 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.)

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:

o Underlay tenet: support for an IP/MPLS-based underlay data plane the transport network used to carry that underlay.

o Governance tenet: a logically centralized authority for network slices in a domain.

o Separation tenet: slices may be independent of each other and have an appropriate degree of isolation (note 1) from each other.

o Capability exposure tenet: each slice allows third parties to access via dedicated interfaces and /or APIs information regarding services provided by the slice (e.g., connectivity information, mobility, autonomicity, etc.) within the limits set by the operator.

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 data center environments.

Elicitation of requirements ([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; 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.

1.1. 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. Suggested 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.

o 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 (creation, management, exposure, consumption).
Describes the minimum functional and non-functional roles derived from basic network slice operations including infrastructure owner (creation, exposure, management), slice operator (exposure, management, consumption), slice user (management, consumption). Describe the interactions between infrastructure owner -- slice operator, slice operator -- slice operator, slice operator -- slice user. Additionally, this working area will normalize nomenclature and definitions for Network Slicing.

o 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.

o Slice Templates: 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.

o Network Slice capabilities (where some prioritization may be needed) 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 enable diverse requirements for NS including 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: namely 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 algorithms.

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

* Capability exposure (e.g. openness) for NS; plus APIs for slices.

* Programmability and control of Network Slices.

o Network slice operations (again some prioritization may be needed) are expected to be:

* 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.

* Autonomic slice management and operation: namely self-configuration, self-composition, self-monitoring, self-optimisation, self-elasticity are carried as part of the slice protocols.

* 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 ([GUERZONI-2016], [KARL-2016]).

* Service Mapping: having dynamic and Automatic Mapping of Services to slices; YANG models for slices.

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

o Efficient enablers and methods for integration of above capabilities and operations.

2.1. Notes

(2) Protection refers to the related mechanisms so that events within one slice, such as congestion, do not have a negative impact on another slice.

(3) Elasticity refers to the mechanisms and triggers for the growth /shrinkage of network resources, and/or network and service functions.

(4) 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.

(5) 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.

(6) 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. Documents

The following are the proposed / expected / resulting documents with priority (I) or (II) (we note that revised prioritization may be needed):

o (I) Agreed work plan

o (I) NS Architecture document
  - Slice template and reference model to IESG (Informational)

o (I) NS Exposure Interface specification and Data model
  - Slice life-cycle management model and NS Exposure Interface specification to IESG (Informational)
  - YANG data model for slicing.

o (I) Service Requirement to Network Capability Mapping Data Model
  - Requirements for both NS control and management planes.
  - Common use-cases for slice validation for 5G.

o (I) Four dimensional efficient slice isolation with guarantees for isolation in each of the Data/ Control/ Management/ Service planes.

o (II) Methods to enable diverse requirements for NS including guarantee for the end-to-end QoS of a slice.

o (I) End-to-end coordination and orchestration of slices.

o (II) Customized security mechanisms per slice.

o (I) Slice stitching / composition: enablers for efficient stitch / composition / decomposition of slices vertically, horizontally and vertically + horizontally. This item covers considerations related to interconnecting slices that are bond the same administrative domain or interconnecting multi-administrative domain.

4. Security Considerations

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

5. IANA Considerations

This document requests no IANA actions.

6. Acknowledgements

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