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Network Slice Provision Models
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Abstract

Network slicing is an approach to provide separate virtual network based on service requirements, and it's a key feature of the 5G. 3GPP has standardized the specifications for network slicing in the 5GS, but there are still some problems for realization of end-to-end network slices. For complementing the lacks or expanding the usability, several organizations are proceeding standardization. However, the definitions and scopes of network slicing vary to some degree from one organization to another. This document provides classification of provisioning models of network slice for clarifying the differences on the definitions and scopes.

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[1.](#) Introduction and Motivation

Network slicing is an approach to provide separate virtual networks depending on requirements of each service. Network slicing receives attention due to factors such as diversity of services and devices, and it is also a fundamental concept of the 5G for applying networks to such various types of requirements.

In addition, network slicing is expected to enable a business model to provide dedicated logical networks to 3rd parties or vertical customers on-demand, called NSaaS (Network Slice as a Service). For such usage, in network slicing, provision of networks able to guarantee communication characteristics end to end would be required. However, the definitions are not harmonized over several SDOs (Standards Developing Organizations).

This document clarifies provision patterns of network slice, and provides the definitions and scope of network slicing which are available over several organizations. Furthermore, the deliverables would be help for evaluating applicability of existing technologies/ solutions to network slicing.

[1.1.](#) Roles in Network Slice Provisioning

The widespread of system and network virtualization technologies has conducted to new business opportunities, enlarging the offer of IT resources in the form of Network Slices (NS). As a consequence, there is a clear differentiation between the owner of physical resources, the infrastructure operator, and the intermediary that conforms and delivers network services to the final customers, the Virtual Network Operator (VNO).

VNOs aim to exploit the virtualized infrastructures to deliver new and improved services to their customers. However, current NS techniques offer poor support for VNOs to control their resources. It has been considered that the infrastructure operator is

responsible of the reliability of the NS elements but several situations advocate the VNO to gain a finer control on its resources. For instance, dynamic events, such as the identification of new requirements or the detection of incidents within the virtual system, might urge a VNO to quickly reform its virtual infrastructure and resource allocation. However, the interfaces offered by current virtualization platforms do not offer the necessary functions for VNOs to perform the elastic adaptations they require to tackle with their dynamic operation environments.

1.1.1. Definitions in 3GPP on NS Provision Roles

3GPP has defined multiple roles related to 5G networks and network slicing management in [[TS.28.540-3GPP](#)] and they include:

- o Communication Service Customer (CSC): Uses communication services, e.g. end user, tenant, vertical
- o Communication Service Provider (CSP): Provides communication services. Designs, builds and operates its communication services. The CSP provided communication service can be built with or without network slice.
- o Network Operator (NOP): Provides network services. Designs, builds and operates its networks to offer such services.
- o Network Equipment Provider (NEP): Supplies network equipment to network. For sake of simplicity, VNF Supplier is considered here as a type of Network Equipment Provider. This can be provided

also in the form of one or more appropriate VNF(s).

- o Virtualization Infrastructure Service Provider (VISP): Provides virtualized infrastructure services. Designs, builds and operates its virtualization infrastructure(s). Virtualization Infrastructure Service Providers may also offer their virtualized infrastructure services to other types of customers including to Communication Service Providers directly, i.e. without going through the Network Operator.
- o Data Centre Service Provider (DCSP): Provides data centre services. Designs, builds and operates its data centres.
- o NFVI Supplier: Supplies network function virtualization infrastructure to its customers.
- o Hardware Supplier: Supplies hardware.

In case of Network Slice as a Service (NSaaS), the Communication Service Provider (CSP) role can be refined into Network Slice Provider (NSP). The Communication Service Customer (CSC) role can be refined into Network Slice Customer (NSC). A NSC can, in turn, offer its own communication services to its own customers, being thus CSP at the same time.

[1.2.](#) High-level Problem Statement

Beyond their heterogeneity, which can be resolved by software adapters, NS platforms do not offer common methods and functions, so it is difficult for the virtual network controllers used by the VNOs to actually manage and control virtual resources instantiated on different platforms, not even considering different infrastructure operators. Therefore, it is necessary to reach a common definition of the functions that should be offered by underlying platforms to enable such overlay controllers with the possibility of allocate and deallocate resources dynamically and get monitoring data about them.

Such common methods should be offered by all underlying controllers, regardless of being network-oriented (e.g., ODL, ONOS, Ryu) or computing-oriented (e.g., OpenStack, OpenNebula, Eucalyptus).

Furthermore, it is also important for those platforms to offer some "PUSH" function to report resource state, avoiding the need for the VNO's controller to "POLL" for such data. A starting point to get proper notifications within current REST APIs could be to consider the protocol proposed by the [[WEBPUSH-WG](#)].

Finally, in order to establish a proper order and allow the coexistence and collaboration of different systems, a common ontology regarding network and system virtualization should be defined and agreed, so different and heterogeneous systems can understand each other without requiring to rely on specific adaptation mechanisms that might break with any update on any side of the relation.

2. Definition of Terms

This section lists definitions and terms related to network slicing. This document refers terms and view points on network slicing in some SDOs, such as 3GPP([[TS.23.501-3GPP](#)], [[TS.28.530-3GPP](#)], [[TS.28.540-3GPP](#)], [[TR.28.801-3GPP](#)]and [[TR.28.804-3GPP](#)]), and NGMN ([[NGMN-5G-White-Paper](#)]). However the scope of this document is not network slicing which is mobile specific but one for general networks, and thus some of definitions in this document may be different from ones of those documents.

Network Slicing: Network slicing indicates a technology, an approach, or a concept to create logical separate networks in

support of services, depending on several requirements, on the same physical resources. This is possible by combinations of several network technologies.

Network Slice (NS): An NS is a logical separate network that provides specific network capabilities and characteristics. In 3GPP definitions, an NS potentially includes both data plane and control plane resources/functions. An NS can have multiple network slice subnets (Radio Access Network/RAN, Transport Network/TN, Core Network/CN, etc.).

Network Slice Instance (NSI): An NSI is a logical network instance composed with required infrastructure resources, including networking (WAN), computing (NFVI) resources, and some include additional network service functions such as firewall or load-

balancer. It is composed of one or more Network Slice Subnet Instances.

Network Slice Subnet: A Network Slice Subnet is a representation of a set of required resources. It is composed and managed as a group of network elements.

Network Slice Subnet Instance (NSSI): An NSSI is a partial logical network instance represented as a network slice instance. It is a minimal unit managed or provided as a network slice. One or more NSSI structure an NSI or an E2E-NSI.

End-to-End Network Slice Instance (E2E-NSI): An E2E-NSI is a virtual network connecting among end points. It is composed of one or multiple NSSIs. This term is original of this document and is used when it should be emphasized that the target NSI provides connectivity from end to end. As an example, for providing an E2E-NSI on the 3GPP 5G network, combining three types of NSIs: RAN-, TRN-, and CN-NSIs would be required.

Transport Network(TN)-NSSI: A set of connections between various network functions (VNF or PNF) with deterministic SLAs. They can be implemented (aka realized) with various technologies (e.g. IP, Optics, FN, Microwave) and various transport (e.g. RSVP, Segment routing, ODU, OCH etc). The overview of NSI composed with TRN-NSSI is shown in [Appendix A](#).

Radio Access Network(RAN)-NSSI: Regardless of RAN deployment (e.g. distributed-RAN, Centralized-RAN or Cloud-RAN, a RAN-NSSI creates a dedicate and logical resource on RAN for each NSI which are completely. The overview of NSI composed with RAN-NSSI is shown in [Appendix A](#).

Core Network(CN)-NSSI: Regardless of Core deployment, a CN-NSI creates a dedicate and logical resource on Core network for each NSI which are completely. The overview of NSI composed with CN-NSSI is shown in [Appendix A](#).

Network Slice as a Service (NSaaS): An NSaaS is a service delivery model in which a third-party provider or a vertical customer hosts NSIs and makes them available to customers. In this model, there

mainly two roles: NS provider and NS tenant.

Network Slice Provider (NS Provider): An NS provider is a person or group that designs and instantiates one or more NSIs/NSSIs, and provides them to NS tenants. In some cases, an NS provider is an infrastructure operator simultaneously. This includes NSI, NSSI, and E2E-NSI providers.

Network Slice Tenant (NS Tenant): An NS tenant is a person or group that rents and occupies NSIs from NS providers.

Network Slice Stakeholder (NS Stakeholder): An NS stakeholder is an actor in network slicing, and has roles of either NS provider or tenant.

Infrastructure Operator: An infrastructure operator is an organization who manages infrastructure networks or data centers for running NSIs. In the most of cases, infrastructure operators are initial NS providers on NSaaS. Also, some of them may be NS tenants simultaneously.

Vertical Customer: A vertical customer is a organization who provides some communicating services with using NSIs on NSaaS model. In many cases, a vertical customer become the final NS tenant on NSaaS. For example, video gaming companies or vehicle vendors will possibly be vertical customers.

Virtual Network Operator (VNO): A VNO is a person or group that operates virtual networks composed with resources or NSSIs rent from infrastructure operators and provides such virtual networks as NSIs to vertical customers who are final NS tenants. In some cases, infrastructure operators have this role in addition to operating their own infrastructure simultaneously.

Domain: A domain is a group of a network and devices administrated under a policy-based common set of rules and procedures.

Resource: A resource is an element used to create virtual networks. There are several types of resources, i.e., connectivity, computing and storage. The details are described [Section 4.1](#)

Virtual Network: A virtual network is a network running a number of

virtual network functions.

Virtual Network Function (VNF): A virtual network function (VNF) is a network function whose functional software is decoupled from hardware. One or more VNFs run as different software and processes on top of industry-standard high-volume servers, switches and storage, or cloud computing infrastructure. They are capable of implementing network functions traditionally implemented via custom hardware appliances and middleboxes (e.g., router, NAT, firewall, load balancer, etc.).

Network Operation System: A network operation system is an entity or a group of entities for operating network nodes and functions as compositions of infrastructure network. For example, OSS/BSS, orchestrator, and EMS are considered to be network operation systems.

[3.](#) General Requirements for Network Slicing

On network slice operations, capabilities for dynamic instantiation, change, and deletion should be required because an NSI is established based on received orders from tenants in NSaaS. From this aspect, some mechanisms to design a network based on service requirements and to convert those to concrete configurations based on the design would be required.

In addition, each NS has to maintain concrete communication characteristics end to end, and resource reservations on data plane and isolation among NSIs would be required. Isolation is a concept to prevent the reduction of communication quality caused by disturbance from other NSs, and it may have some levels of enforcement, such as hard or soft isolations. In some cases, for providing appropriate communication between client and server, it would be allowed for NS tenants to put their applications as contents server on NSIs by using computing resources.

The required agility of slice operation and granularity of end to end communication quality requested can vary depending on provision model.

[4.](#) Network Slice Structure

This section describes resources used for structuring NSs and the basic structure of E2E-NS.

[4.1.](#) Resources for Structuring Network Slices

A network slice is structured as combinations of the resources it uses. Such resources are mainly categorized into three classes: network/WAN, computing/NFVI, and functionality resources. Variations of each resources are described below. (Note that the lists are not exhaustive.)

Network(WAN) Resources:

- * Connectivity:
 - + (v)Link
 - Bandwidth per link/session
 - Connected area/end points
 - Forwarding route/path (e.g., for traffic engineering, redundancy)
 - Communication Priority (e.g., QoS class)
 - Range of jitter amount
 - + Interface of vNode
 - QoS setting (e.g., Queue size, DSCP remarking, PIR/CIR)
 - Filter setting
 - + vRouter/vSwitch (# Treated as a set of (v)links and interfaces of vNodes.)
- * Multicast support
- * Encryption support
- * Authentication support
- * Metadata conveyance (e.g., subscriber ID)
- * Protocols for slice data plane:
 - + VLAN

- + IPoE (IPv4 or IPv6)

- + MAP-E
- + DS-Lite
- + PPPoE
- + L2TP
- + GRE
- + MPLS
- + VxLAN
- + Geneve
- + GTP-U
- + Segment Routing MPLS
- + Segment Routing IPv6
- + NSH
- + FlexE
- + Other

Computing(NFVI) Resources:

- * (v)CPU core
- * Storage
- * Memory
- * Disk
- * vNIC

- * Connectivity to VNF instances
- * Virtual Deployment Unit:
 - + Virtual Machine (VM)
 - + container

- + micro kernel
- * Resource Deployment Location (i.e., edge DC, central DC, public cloud, ..., etc.)

Functionality Resources:

- * Image:
 - + Data Plane(DP) NF:
 - GateWay(GW) function:
 - o Access Point Type (e.g., for radio, Wi-Fi, and fixed accesses)
 - o Slice Selection Setting
 - o Terminate protocol
 - o Authentication
 - Security Appliance:
 - o IPS (Intrusion Prevention System)
 - o IDS (Intrusion Detection System)
 - o WAF (Web Application Firewall)
 - DPI

- Load Balancer
- TCP Accelerator
- Video Optimizer
- Parental Control
- Mobile DP functions (Ref. 3GPP 5GS)

gNB

UPF

Uplink Classifier

- + Control Plane(CP) NF:
 - DHCP
 - o Fixed IP address allocation
 - o Dynamic IP address allocation
 - o The number of registered devices
 - DNS
 - VoIP (SBC, SIP server)
 - Mobile CP function (Ref. 3GPP 5GS)
 - o AMF (Access and Mobility management Function)
 - o SMF (Session Management Function)
 - o PCF (Policy Control Function)
 - o UDM (Unified Data Management)
 - o NEF (Network Exposure Function)

- * Provided VNF Type (e.g., open source, product of vender#A, ..., etc.)
- * Function location (e.g., edge DC, central DC, Public cloud, etc.)

In terms of security or usability for NS tenants, some abstraction on resource information would be required, however both setting parameters of underlay infrastructure and abstracted information may coexist in these lists.

For abstraction of parameters of underlay networks, some additional protocols or functions (like [[RFC8453](#)]) would be required. Moreover, for providing strict communication qualities, combinations of some technologies may be useful (ref. [[I-D.dong-teas-enhanced-vpn](#)]).

4.2. Basic Network Slice Structure

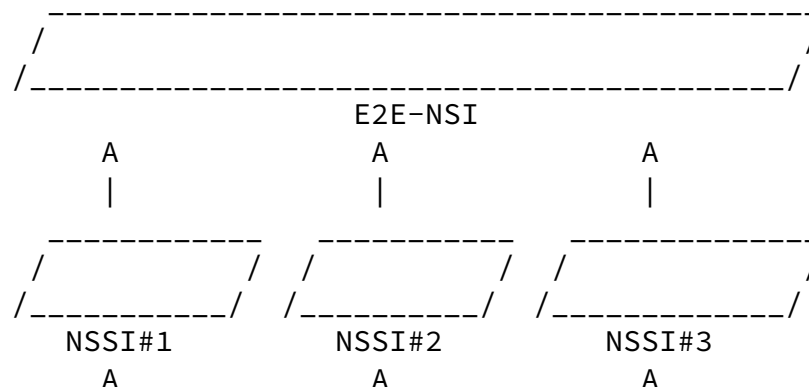
An E2E-NSI is constructed by stitching NSSIs instantiated on each participating domain. This includes the simplest case of a single

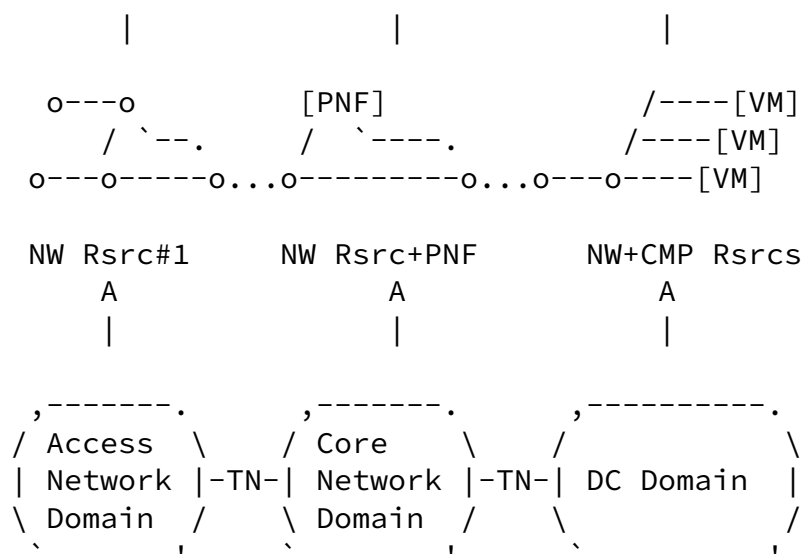
NSSI as an E2E NS. Domain types where some NSSIs are established are described below:

- o Fixed access network
- o Mobile access network
- o Transport network
- o Fixed core network
- o Mobile core network
- o Data center (DC)
 - * Edge DC
 - * Central DC

- o Private network
 - * Enterprise
 - * Factory
 - * Utilities
 - * Farming
 - * Home/SOHO
 - * Other

Figure 1 describes the overview of this structure. Resources in each domain (e.g., access, core networks, and DC) are handled by management entities and constitute an NSSI. An E2E-NSI is established by stitching these NSSIs. Ways to stitch NS-subnets are described in [[I-D.defoy-coms-subnet-interconnection](#)] and [[I-D.homma-nfvrg-slice-gateway](#)].





*Legends

NW Rsrc : Network Resource

CMP Rsrc: Computing Resource

o : virtual/physical node structuring NSI

-- : virtual/physical link structuring NSI

-TN-: Transport Network

[PNF]: Physical Network Function Appliance on NSI

[VM] : Virtual Machine Instance on NSI

Figure 1: Overview of NS Structure

Although it is shown that an NSSI belongs to just only one E2E-NSI in Figure 1, it may be allowed that multiple E2E-NSIs share an NSSI. Some resources may belong to multiple NSSI as well.

In addition, structure on composition of NSI may be recursive. In other words, even though Figure 1 shows a case where NSSIs compose directly an E2E-NSI, in some cases, NSSIs compose an NSI which is a part of an E2E-NSI. The overview is shown in Figure 2. In this

figure, NSI#4 is composed of NSSI#1 and NSSI#2, and it structures E2E-NSI#5 with NSSI#3.

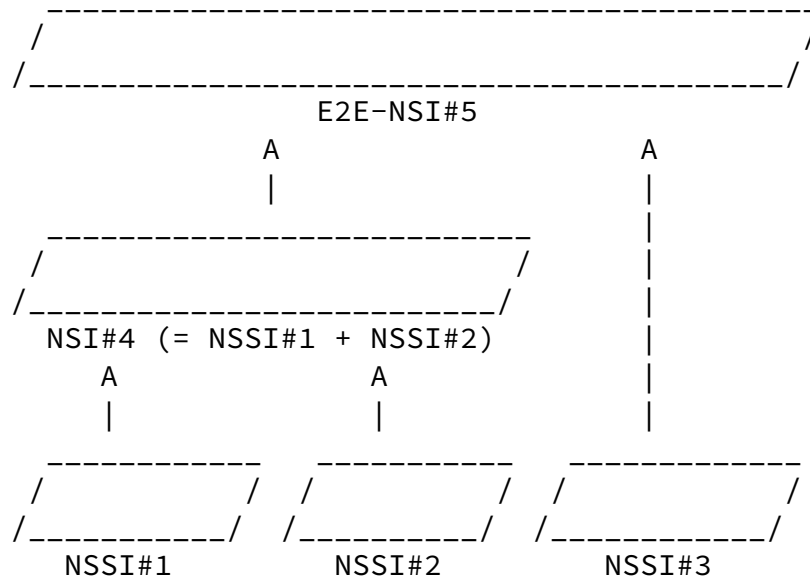


Figure 2: Overview of NS recursive structure

4.3. Stakeholders in the Structuring Network Slices

Potential stakeholders in network slicing are described below:

- o NSSI provider: infrastructure operator
- o Intermediate-NSI provider: infrastructure operator, VNO
- o E2E-NSI provider: infrastructure operator, VNO, service provider
- o NS tenant: infrastructure operator, VNO, service provider, enterprise, mass user
- o End customer: enterprise, mass user, etc.

5. Variations of Network Slice Creation

NSs can be classified according to their creation pattern into two types: ready-made(RM) NS, custom-made(CM), and semi-custom-made(sCM) NS. This section describes the features of these types.

[5.1.](#) Ready-made Network Slice

RM-NS is an NS creation pattern in which an infrastructure operator decides service requirements by itself, and established based on the requirements in advance. NS tenants select one of RM-NSs whose features are closer to their requirements.

This model doesn't need immediacy on designing of NSI and enables to mitigate the difficulty of implementation compared with other models.

[5.2.](#) Custom-made Network Slice

CM-NS is an NS creation pattern in which an NS is established based on an order from a tenant and is provided to it. As examples of usage of CM-NS, an enterprise builds and operates a virtual private network for connecting several bases, or OTT (Over The Top) or other industrial service providers create NSs based on their own requirements and use them as a part of their own services (e.g., connected vehicles/drones, online video games, or remote surgery).

In this model, network operation system would be required to have incorporate intelligence for designing appropriate NSs on-demand.

[5.3.](#) semi-Custom-made Network Slice

sCM-NS is a derivation of a CM-NS. In sCM-NS, an NS provider designs the outline of NSs in advance, and a tenant tunes an NS with deciding some parameters or applications run on resources. For example, an infrastructure operator designs a logical network presenting connectivity, and tenants install their own applications on servers running on the logical network.

[6.](#) Network Slice Provision Models

This document classifies NS provision models into three categories defined in the following section. The capabilities which NS tenants can have on management of NSs would vary depending on the selected provision model.

[6.1.](#) Categorization of NS Provision Models

The provision models are categorized into three models: SaaS (Software as a Service) -like Model, PaaS (Platform as a Service) -like Model, and IaaS (Infrastructure as a Service) -like Model.

[6.1.1.](#) SaaS-like Model

In SaaS-like Model, underlay infrastructure is hidden from tenants, and tenants can receive desired communication environment without deep knowledge about network and servers. An NS tenant decides attribute values of its NS, such as bandwidth or latency, based on their requirements, and NS providers design and create NSIs which fulfill the values.

NS tenants need not to grasp detailed configurations in underlay networks in this model. However, it may not be possible to provide strictly desired NS to tenants because of abstraction of configurable parameters. Moreover, it may cause complexity on designing NS catalog due to quantities of selected attributes.

[6.1.2.](#) PaaS-like Model

In PaaS-like Model, an NS is represented with several components such as nodes and connectivities among them. An NS tenant can design and customize its desired NS with combining such components. NS providers breakdown the NS designed by the NS tenant to concrete configurations of their infrastructure, and create/change NSSIs by inputting the configurations. An NS tenant is also able to incorporate its own functions or applications into its NSI by using computing resources provided from NS providers.

This model potentially has high customizability of NS rather than SaaS-like model, but needs NS tenants to have some knowledge about network management. In terms of designing NS, the tenants provide outline of their NSs, and thus it would make creation of concrete configurations be easier.

[6.1.3.](#) IaaS-like Model

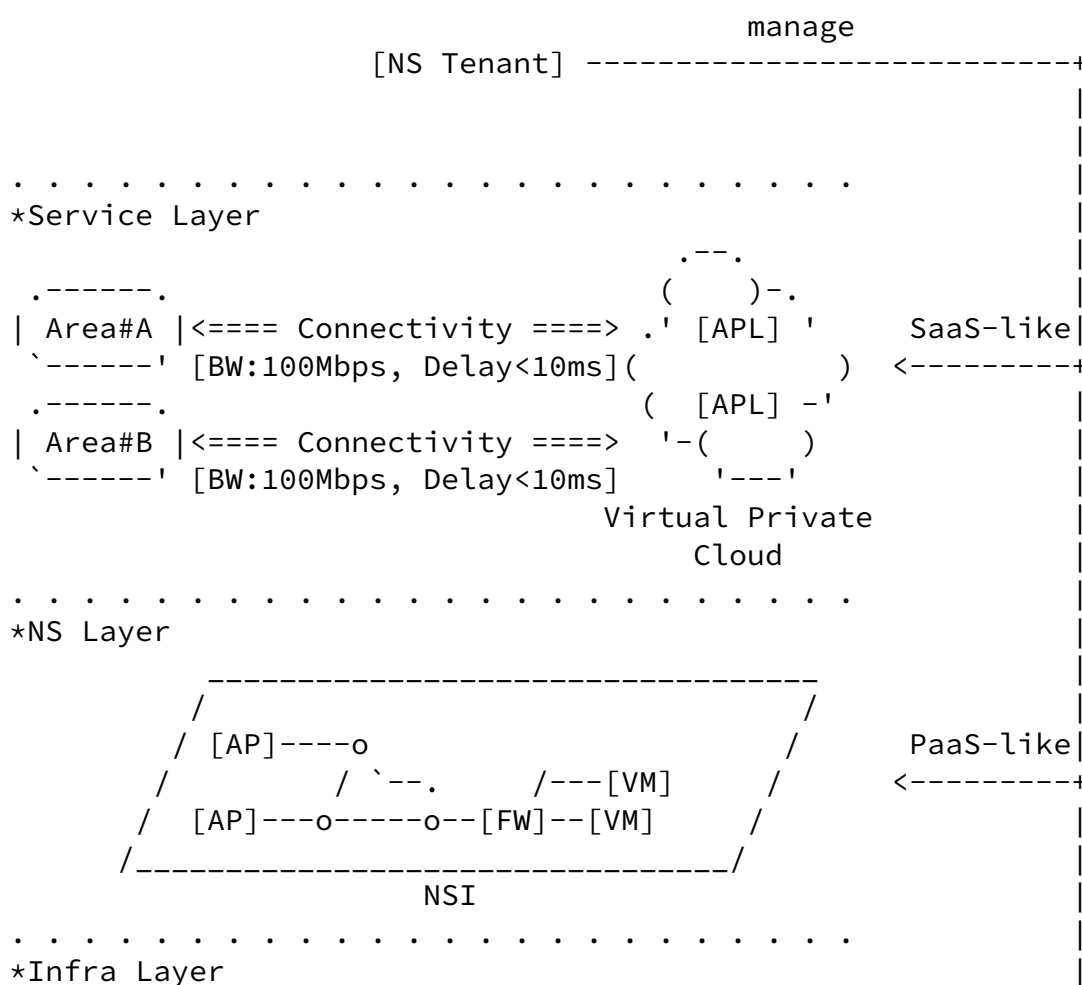
In IaaS-like model, an NS is represented with concrete configurations of underlay infrastructure. NS tenants are able to structure or change their desired NS by controlling infrastructure resources directly.

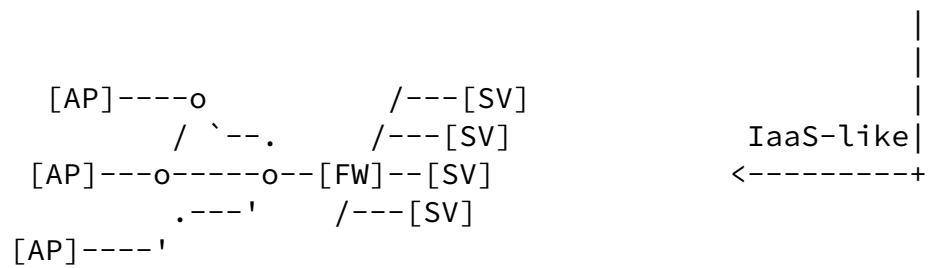
This model potentially has high customizability of NS rather than

other models, but needs NS tenants to have deep knowledge about network and server operation. Also, NS providers need not to recognize NSs on their infrastructure because NS tenants directly manage their NS. Meanwhile, in terms of security and prevention of disturbances among NSs, some limitations on expositions of resources to tenants would be needed.

[6.2.](#) Mapping of NS Provision Models and Infrastructure Layering

An example of mapping of each NS provision model is shown in Figure 3.





*Legends

- o : virtual/physical node
- : virtual/physical link
- [AP] : Access point
- [APL]: Application owned by NS Tenant
- [FW] : Firewall Function
- [VM] : Virtual Machine Instance on Sever
- [SV] : Server as Infrastructure

Figure 3: Mapping of NS provision models

In some cases, NSIs provided based on IaaS- or PaaS-like models are coordinated to a form of SaaS-like model by an NS broker , and the NS broker or by the tenant, becoming a NS provider in a recursive manner. For example, a vertical customer sends its high-level requirements to an NS broker create an appropriate NSI with resources provided by infrastructure operators.

[6.3.](#) Configurable Parameters/Attributes for NS

In the NS creating procedure, configuration parameters are decided based on requirements which the intended service has. Such service requirements are expressible in the following attribute values.

o Attributes for Network Resource

- * bandwidth
- * latency

- * jitter
- * packet loss rate
- * reliability (e.g., MTBF, MTTF)
- o Attributes for Functionalities Resources
 - * function type (e.g., security, parental control)
 - * throughput
 - * packet error rate
 - * availability

Configurable parameters of components in underlay infrastructure will vary depending on the implementation and structure. Controlled resource types are described in [Section 4.1](#).

[6.4](#). Capability of NS Tenant on each Provision Model

Capability of NS tenants on NS management would vary depending on the NS provision model. This section describes clarification about such capability in each model.

[6.4.1](#). Capability in SaaS-like Model

In SaaS-like Model, an NS is represented for a tenant with attributes values listed in [Section 6.3](#). In other words, an NS tenant never know the concrete configurations of components in underlay infrastructure.

An NS tenant chooses a value from the range presented by the NS provider in each attribute. The NS provider creates or changes a NS by configuraing components in underlay infrastructures based on the decided attribute values.

In terms of telemetry for assurance of service qualities on a NS, a tenant can obtain telemetry information with unit of NSI, and never know ones of underlay components structuring the NS.

6.4.2. Capability in PaaS-like Model

In PaaS-like model, an NS is represented with NF nodes and their connectivities. An NS tenant can indicate functionalities of NF nodes and thier locations. Also, the tenant decides attribute values of connectivities. An NS provider creates or changes an NSI by configuring underlay nodes and links depending on the indication of the tenant. An NS tenant is also able to deploy its own NF as software with provided computing resources.

In terms of telemetry, an NS tenant can obtain telemetry information of NF nodes and connectivities structuring an NS, in addition to whole of NSI.

6.4.3. Capability in IaaS-like Model

In IaaS-like Model, an NS is represented with configurations of (virtual) nodes and (virtual) links connecting the nodes. An NS tenant is able to configure nodes and links in underlay infrastructure. In short, an NS tenant directly design detailed NS and manages it. In addition, an NS tenant inserts its own functions or applications in the NS with using computing resources.

In terms of telemetry, an NS tenant can obtain telemetry information of nodes and links in addition of whole of NSI.

7. Security Considerations

In NSaaS, parts of controls of infrastructures are opened to externals, and thus some mechanisms, such as authentication for APIs, to prevent illegal access would be required.

Other considerations are TBD

8. IANA Considerations

This memo includes no request to IANA.

9. Acknowledgement

The author would like to thank Toru Okugawa for his kind review and valuable feedback.

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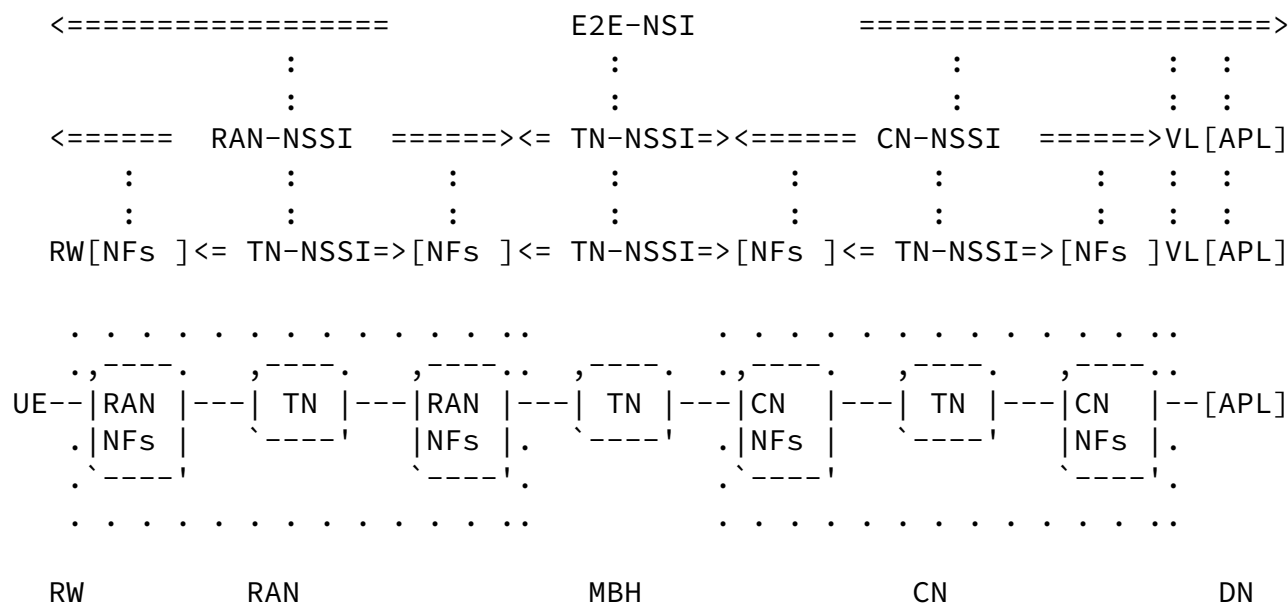
Appendix A. NS Structure in the 3GPP 5GS

The overview of structure of NS in the 3GPP 5GS is shown in Figure 4. The terms are described in the 3GPP documents (e.g., [TS.23.501-3GPP] and [TS.28.530-3GPP]).

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*Legends

UE: User Equipment
 RAN: Radio Access Network
 CN: Core Network
 DN: Data Network
 TN: Transport Network
 MBH: Mobile Backhaul
 RW: Radio Wave
 NF: Network Function
 APL: Application Server

Figure 4: Overview of Structure of NS in 3GPP 5G

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