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Gap Analysis for Network Slicing

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Abstract

This document presents network slicing differenciation from the

non-partition network or from simply particion of connectivity

resources (i.e. VPNs). It lists 17 standardisation gaps related

to four key requirements for network slicing. It presents also an

analysis of existing IETF related working drafts and other SDOs

activities on network slicing.

This gap analysis document aims to provide a basis for future works

in network slicing.

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1. Introduction (Liang, Alex, Slawomir)

Network slicing is an approach of flexible isolation of network

resources and functions for dedicated services, providing certain

level of customization and quality guarantee. It establishes

customized dedicated network upon a common infrastructure for

vertical industries with flexible design of functions, different

performance requirements, system isolation and OAM tools.

Potential requirements need to be investigated [Use Cases] in order to elicit and understand the technical gaps for network-slice enabled networks.

As a differenciation from the non-partition network or from simply partitions of connectivity resources (i.e. VPNs) the followings are identified:

• Network Slice is a network that is build on a infrastructure composed of connectivity, storage and computing (connectivity is only 1/3 part of the infrastructure).

• Each network slice may have its own operator that see this slice as a complete network (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 from infrastructure.

•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 exposur).

• Network slicing would need to be selfmanaged with automated deployment in order to cope with scalability.

• Network slices are configueable and programmable and they have the ability to expose their capabilities and characteristics. The slice protocols and funsctions 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 serources on a common physical infrastructure.

• Network slicing supports dynamic multi-services, multi-tenancy and the means for backing vertical market players (i.e. Health Vertical Sector, Energy Versical Sector, Automotive Vertical Sector, Media and Entertailment Versical Sector, Factory-of-the-Future Vertical Sector, Smart Home Vertical Sector, Smart City Vertical Sector, Additional Specialized Services Vertical Sector)

• Network slicing supports service customization enabled by NFV principles, by particioning of network resource and by configuring the network functions/virtual network functions.

• Network slicing simplifies the provisioning of services, manageability of networks and integration and operational challenges especially for supporting communication services.

• Network operators can exploit network slicing for

* Reducing significantly operations expenditures, allowing also programmability necessary to enrich the offered tailored services.
* Providing the means for network programmability
* Additional business offerings to OTT and other vertical market players without changing the physical infrastructure.

In order to establish a network slice that meets

various customer's demands, the infrastructure owner needs to

understand how these demands map with the available network resources

and accessible capabilities. This also requires end-to-end coverage

and inter-domain operation or negotiation between different network

segments.

Different levels of system abstraction are essential enablers for

network slicing. For instance, the infrastructure owner needs to

understand performance metrics such as bandwidth, latency, isolation

requirements, and traffic forwarding restrictions from slice tenants.

Furthermore, these requirements are expected to map with the

capabilities of a specific network slice with the nature of

flexibility, agility and certain level of customization. Slice

tenants do not worry about the techniques used by the slice provide

for their specific requirements. Meanwhile, the slice provider

provides customized OAM to the tenants under provisioning. Slicing

OAM approach is a fundamental capability to guarantee stable,

effective and reliable services for the vertical industries. It is

also expected to be capable of operations with customized granularity

levels that provides robust management flexibilities.

This document presents the identified standardisation gaps

and investigate potential technical gaps accordingly. To assist

understanding of this document, Section 2 outlines the terminology.

Section 3 presents the standardisation gaps for network slicing.

Section 4~7 illustrates end-to-end consideration, system level

abstractions and OAM concerns. Section 7 summarizes the identified

gaps and demonstrates conclusive analysis.

2. Terminology

2.1. Networking & Servicing Terms

Software-Defined Networking (SDN) - A programmable networks approach that supports the separation of control and forwarding planes via standardized interfaces. It is a of techniques that enables to directly program, orchestrate, control and manage network resources, which facilitates the design, delivery and operation of network services in a dynamic and scalable manner.

Network virtualization - A technology that enables the creation of logically isolated network partitions over shared physical networks so that heterogeneous collections of multiple virtual networks can simultaneously coexist over the shared networks. This includes the aggregation of multiple resources in a provider which appear as a single resource.

Network softwarization - An overall transformation trend for designing, implementing, deploying, managing and maintaining network equipment and/or network components by software programming, exploiting the natures of software such as flexibility and rapidity all along the lifecycle of network equipment/components, for the sake of creating conditions enabling the re-design of network and services architectures, optimizing costs and processes, enabling self-management and bringing added values in network infrastructures.

Software Network - An approach to computer networking that allows network administrators to manage network services through abstraction of higher-level functionality. This is done, for example, by decoupling the system that makes decisions about where traffic is sent (the control plane) from the underlying systems that forward traffic to the selected destination (the data plane).

Programmable networks - Networks that allow the functionality of some of their network elements to be dynamically programmable. These networks aim to provide easy introduction of new network services by adding dynamic programmability to network devices such as routers, switches, and applications servers. Network Programmability empowers the fast, flexible, and dynamic deployment of new network and management services executed as groups of virtual machines in the data plane, control plane, management plane and service plane in all segments of the network. Dynamic programming refers to executable code that is injected into the execution environments of network elements in order to create the new functionality at run time. The basic approach is to enable trusted third parties (end users, operators, and service providers) to inject application-specific services (in the form of code) into the network. Applications may utilize this network support in terms of optimized network resources and, as such, they are becoming network aware. The behaviour of network resources can then be customized and changed through a standardized programming interface for network control, management and servicing functionality.

Network Segment: includes fixed Access Network (AN), Radio Access

Network (RAN), Transmission Network (TN), Core Network (CN), Edge

Network (EN), central cloud network, edge cloud network, etc.

Service - A piece of software that performs one or more functions and provides one or more APIs to applications or other services of the same or different layers to make use of said functions and returns one or more results. Services can be combined with other services, or called in a certain serialized manner, to create a new service.

Service Instance - An instance of an end-user service or a business service that is realized within or by a network slice. Each service is represented by a service instance. Services and service instances would be provided by the network operator or by third parties.

Administrative domain - A collection of systems and networks operated by a single organization or administrative authority. Infrastructure domain is an administrative domain that provides virtualized infrastructure resources such as compute, network, and storage, or a composition of those resources via a service abstraction to another Administrative Domain, and is responsible for the management and orchestration of those resources.

Multitenancy domain – It refers to set of physical and/or virtual resources in which a single instance of a software runs on a server and serves multiple tenants.

Tenant - A group of users who share a common access with specific privileges to the software instance. A service or an application may be designed to provide every tenant a dedicated share of the instance including its data, configuration, user management, tenant-specific functionality and non-functional properties.

Functional requirement – This is a description of a function, or a feature of a system or its components, capable of solving a certain problem or replying to a certain need/request. The set of functional requirements present a complete description of how a specific system will function, capturing every aspect of how it should work before it is built, including information handling, computation handling, storage handling and connectivity handling.

Functional entity - An entity that comprises an indivisible set of specific capabilities. Functional entities are logical concepts, while groupings of functional entities are used to describe practical, physical implementations.

Interface - A point of interaction between two entities. When the entities are placed at different locations, the interface is usually implemented through a network protocol. If the entities are collocated in the same physical location, the interface can be implemented using a software application programming interface (API), inter-process communication (IPC), or a network protocol.

Reference Point – It is a group of interfaces that would be used for exchange of information and/or controls between two separate (sub)systems which are sharing a boundary. The exchange can be between software, hardware, network devices, network elements, network functions, humans and combinations of these

2.2 Communication Systems Specification Terms

Planes - A plane is a subdivision of the specification of a complete communication system, established to bring together those particular pieces of information relevant to some particular area of concern during the analysis or design of the system. Although separately specified, the planes are not completely independent; key items in each are identified as related to items in the other planes. Each plane substantially uses foundational concepts. However, the planes are sufficiently independent to simplify reasoning about the complete system specification.

Data /Forwarding/ User Plane (FP) - The collection of resources and components across all network devices responsible for forwarding traffic. The set of functions used to transfer data in the stratum or layer under consideration.

Control Plane (CP) - The collection of functions responsible for controlling the operation of one or more network devices plus the functions required to support this control. It instructs network devices with respect to how to process and forward packets. The control plane interacts primarily with the forwarding plane and, to a lesser extent, with the operational plane.

Management & Operational Plane (MP) - The collection of resources responsible for managing the overall operation of individual network devices plus the functions required to support this management. It includes the collection of functions responsible for monitoring, configuring, and maintaining one or more network devices or parts of network devices. The management plane is mostly related to the control plane (it is related less to the forwarding plane).

Orchestration Plane (OP) - An automated arrangement, coordination of complex network systems and functions including middleware for both physical and virtual infrastructures. It is often discussed as having an inherent intelligence or even implicitly autonomic control. Orchestration results in automation with control network systems. Orchestrator is n entity that fulfills orchestration functions. An entity that manages network service lifecycle and coordinates the management of network service life cycle, network function lifecycle and network function infra resources to ensure optimized allocation of the necessary resources and connectivity.

Application Plane (AP) - The collection of applications and services that program network behavior.

2.3 Network Resource Terms

Resource - A physical or virtual (network, compute, storage) component available within a system. Resources can be very simple or fine-grained (e.g., a port or a queue) or complex, comprised of multiple resources (e.g., a network device).

Logical Resource - 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.

Virtual Resource - 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.

Network Function (NF) - A processing function in a network. It includes but is not limited to network nodes functionality, e.g. session management, mobility management, switching, routing functions, which has defined functional behaviour and interfaces. Network functions can be implemented as a network node on a dedicated hardware or as a virtualized software functions. Data, Control, Management, Orchestration planes functions are Network Functions.

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

Network Device (NE) - A component that performs one or more network operations related to packet manipulation and forwarding. This reference model makes no distinction as to whether a network device is physical or virtual. A device can also be considered as a container for resources and can be a resource in itself.

Network Element / Entity - A network element is defined as a manageable logical entity uniting one or more network devices. This allows distributed devices to be managed in a unified way using one management system. It means also a facility or equipment used in the provision of a communication service. Such term also includes features, functions, and capabilities that are provided by means of such facility or equipment, including subscriber numbers, databases, signaling systems, and information sufficient for billing and collection or used in the transmission, routing, or other provision of a telecommunications service.

2.4 Slicing Terms - Definition in this draft

Resource Slice - A grouping of physical or virtual (network, compute, storage) resources which. It inherits the characteristics of the resources which are also bound to the capability of the resource. A resource slice could be one of the component of Network Slice, however on its own does not represent fully a Network Slice.

Network slice - 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

• Represented by a set of network functions, virtual network functions and resources at a given time

• Forms a complete instantiated logical network to meet certain network characteristics required by the Service Instance(s).

• Provides network characteristics which are required by a Service Instance.

• May also be shared across multiple Service Instances

(3) Resources component – it includes: Physical, Logical & Virtual resources

• 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.

• 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

• 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 virtual resources of a slice. SEM also exchanges information of virtual resources with other slice element managers via a dedicated resource interface.

• Allow 3rd parties to access via APIs information regarding services provided by the slice (e.g. connectivity information, QoS, mobility, autonomicity, etc.)

• Allow dynamical customization of the network characteristics for different diverse use cases within the limits set of functions by the operator. Network slice enables the operator to create networks customized to provide flexible solutions for different market scenarios, which have diverse requirements, with respect to the functionality, performance and resource separation.

• It includes a description of the structure (and contained components) and configuration of the slice instance.

Network slice template - A complete description of the structure, configuration and the plans/work flows for how to instantiate and control the Network Slice Instance during its life cycle.

Network Slice Instance - An activated network slice. It is created based on network template. A set of managed run-time network functions, and resources to run these network functions, forming a complete instantiated logical network to meet certain network characteristics required by the service instance(s). It provides the network characteristics that are required by a service instance. A network slice instance may also be shared across multiple service instances provided by the network operator. The network slice instance may be composed by none, one or more sub-network instances, which may be shared by another network slice instance.

Network Slice Repository – A repository that in each domain consists of a list of active Network Slices with their identifiers and description. This description defines also the rules that have to be fulfilled in order to access a slice. Network Slice Repository is updated by slice orchestrator. In case of recursive slicing the Network Slice Repository keeps information about all slices that compose a higher level slice but such slice has its own identifier and descriptors.

Slice Border Control – A functional entity that is used for users to slice attachement and in recursive slicing, in which an end-to-end slice is a horizontal combination of per domain slices. It’s role is to expose information about a slice to other slices in order to provide efficent slice connection (i.e. topology information exchange, etc.) and to perform necessary protocol translations.

Slice Selection Function – A functional entity that is used by the end-users in order to attach to a slice. It provides mechanisms related to slice advertisement, on request passes information related to slice attachement to the end-users and optionally authenticate users. In case of lack of an active slice as descibed in user request it may provide slice matching and also trigger the creation of a slice on-demand.

List of Acronyms and Abbeviations

* AN: Access Network
* RAN: Radio Access Network
* TN: Transmission Network
* CN: Core Network
* EN: Edge Network
* CNC: customer network controller
* MDSC: multi-domain service coordinator, could be a hierarchical
  + one
* PNC: physical network controller, each transport network domain
  + has a PNC
* VN: virtual network
* PCC: path computation client, the physical device (normally is the

ingress device of an LSP) which requests for a path computation

service

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT",

"SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this

document are to be interpreted as described in RFC 2119.

Additionally, the key words "MIGHT", "COULD", "MAY WISH TO", "WOULD

PROBABLY", "SHOULD CONSIDER", and "MUST (BUT WE KNOW YOU WON'T)" in

this document are to interpreted as described in RFC 6919.

3. Standards Gaps Analysis in Network Slicing (Satoru, Perdo)

This section provides descriptions for identified standards gaps in Network Slicing as related to 4 key requirements. These 4 requirements are organized according to a general network slice working process: specify the network slicing resource; construct an end-to-end network slice; abstract the end-to-end network slice; and provide OAM operations. These macro requirements can be further broken down into micro requirements described in the use case draft [NS Use Cases].

o Req.1 NS Specification - The management system of both

underlying resources /network functions and overlying resource/network functions provided by consumer or operator, regardless of being automated, human-guided, or human-operated, needs to manage the description of the resources/network functions it has "in stock" and "under its control".

Gap1.1: NS State monitoring - The objective for those systems to have such information is that the resources/network functions will form an important part of their business, and thus they must know "what they have" at every moment, so that, for instance, they are able to "deliver" the requests without incurring into any overutilization of their resources/network functions.

Gap1.2: Uniform Specification - The way resources/network functions are described and specified must be homogeneous and compatible, even among separated domains, providers, and "slicing" platforms. A uniform network slicing template would be needed.

Gap1.3: NS Identity - the goal of slicing identity management and associated security and privacy charactesitics should go beyond slice identity to also include services. The major functionalities may include identifier (ID) assignment to NS, name translation, ID certification, name resolution, and related key distribution management. This is particularly important when these IDs are administered by third parties which are open to service / control / forwarding functions, in which case the requirements of the stake-holders have to be taken into account. NS Identy would be needed in the discovery, negotiation, monitoring and orchestration E2E operations.

Gap1.4: NS capability exposure - It’s role is to expose information and characteristics about a slice to other slices in order to provide efficent slice connection (i.e. topology information exchange, etc.) and to perform necessary protocol translations.

Gap1.5 NS APIs- Elaboration of NS programmable interworking methods, APIs and capabilities should include:

* A level of abstraction sufficient both for NS operations and for customization of the capability provided by the interfaces
* Modelling for the virtual/abstracted resource/network functions in a multiple-technology environment
* Support for programming for operation velocity
* Methods for automatic and/or autonomic operations
* Provisioning of classified NS functional elements suitable for a range of system developers such as supplication service providers, network service providers, and network management operator

o Req.2: E2E Network Slicing - Network users in relation to network

slicing are entities that operate some set of physical, logical,

virtual, or, in general, abstracted resources that are not owned

directly by them. This means that they will have providers, that

can be different and separated, but they still require to offer a

coherent service to their customers, which are naturally expecting

this entity to be seen as only one entity.

Gap2.1: Cross Provider Domins- It is fundamental for network slices, in the form they are delivered to such operators, to be able to cross provider domains and thus effectively form the required end-to-end infrastructure.

Gap2.2: NS Repository – Repository is needed that in each domain consists of a list of active Network Slices with their identifiers and description. This description defines also the rules that have to be fulfilled in order to access a slice. Network Slice Repository is updated by slice orchestrator. In case of recursive slicing the Network Slice Repository keeps information about all slices that compose a higher level slice but such slice has its own identifier and descriptors.

Gap2.3: Composition / Stitching of slices – Efficient methods for E2E composition / decomposition of network slices need to elaborated.

Gap2.4: E2E QoS - Analysis of QoS requirements of current networks mostly focus on QoS per network segment. An end-to-end (i.e. from a user device to another corresponding user device) QoS framework should be considered in the design of solutions for E2E Slicing.

Gap2.4: End-to-end reference model for scalable operation -

Since Ns may be highly virtualized systems they would include an enormous number of instances and reactions are not easy to extrapolate from current physical systems. The resource and network function handling must be the essential part of the scalable and novel operations, which potentially improves conventional network operations and, possibly even up to the level of supporting disaster recovery, by using softwarized network resiliency and recovery of /with the virtualized systems both in a single domain and in multiple domains. An appropriate end-to-end reference model should be elaborated for efficient and scalable operations.

o Req.3 NS Domain-Abstraction To complement the previous

requirement, it is important for network slices to be aware but

independent of the domain to which they belong.

Gap3.1 This implies that NS are abstracted from any specific

domain, so operators can change their behavior without requiring to

reconfigure all individual parts and pieces of the overall system.

Gap3.2: Common abstration model for resources and network functions-There is no common model that can provide abstraction of

various capabilities supported by physical resources/ network functions across all network segments that constitute end-to-end scope. The granularity of the current abstraction model may not be sufficient to support various approaches to satisfy end-to-end quality requirements of the application, while minimizing impact on utilization of networks. Elaboration of an appropriate NS abstraction model is needed 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.

Gap3.3: Network Slicing Configuration - Network Slicing would need the ability to expose their capabilities and characteristics. Such ability includes the configuration of slice protocols and network functions which are changing or ajusted according to slice required features.

Gap3.4 - Signalling to reduce end-to-end complexity - There are various signalling procedures that contribute to the end-to-end connectivity establishment involving all domains network components and network devices. Besides the transport delay through the network components, signalling which is basically accompanied in the beginning of each new session or transmission may have more serious impacts on total end-to-end latency and complexity. More efficient signalling protocols should be elaborated to cope with the limitations on the information exchange systems between and withing existing domains and network segments.

o Req.4 OAM Operations with Customized Granularity; Different

network slice users (operators, customers) will have different

requirements. On one end of the spectrum we have those operators

that will require a finalized service that they will simply

commercialize. On the other end we have those operators that need

(or want) to fine-tune all the low-level aspects of the network

resources that form their system or service. Moreover, in the

middle there is plenty of room for variations.

Gap4.1: Operation Granularity Levels -The underlying network layers must offer different levels of granularity for the management of their resources and network functions, that the upper layer operators can choose according to their needs and objectives.

Gap4.2 Elasticity - It is envisioned that NS would efficiently

supports a diversified set of application requirements across end-to-end paths with varied QoS requirements. Each slice should provide an isolated environment to efficiently accommodate individual applications meeting specific QoS requirements. The slice should be capable of dynamically adjusting resources and network functions configuration to meet the application requirements.

Gap4.3: Self-management capability - Network slicing would need to be self-managed with automated deployment in order to cope in a costefective way with scalability and heterogiety.

Gap4.4: Service Customization - Network slicing would need to support service customization enabled by NFV principles, by particioning of network resource and by configuring the network functions/virtual network functions.

Gap4.5: Multi-servicees/Multi-tenancy - Network slicing would need to support dynamic multi-services, multi-tenancy and the means for backing vertical market players (i.e. Health Vertical Sector, Energy Versical Sector, Automotive Vertical Sector, Media and Entertailment Versical Sector, Factory-of-the-Future Vertical Sector, Smart Home Vertical Sector, Smart City Vertical Sector, Additional Specialized Services Vertical Sector)

Gap4.6: Network Slincing Isolation - Guarantees for isolation in each of the Data /Control /Management /Service planes are needed. Enablers for safe, secure and efficient multi-tenancy in slices.

4. Network Slicing Resource Specification (Sue, Luis)

TBD

5. End-to-End Network Slicing (Cristina)

5.1. Description

The end-to-end network slicing requirement refers to the inter-

operation/negotiation between network segments or domains, which

includes

o Network slice resource/network functions negotiation: for example, a tenant requests for a network slice with at most 10 ms end-to-end delay. Different network segments/domains should negotiate to reach an

agreement like- RAN provides at most 2 ms service, TN domain I

provides at most 4ms service, TN domain II provides 2 ms service

and CN provides at most 2 ms service;

o Configuration negotiation: such as VLAN ID, remote IP address,

physical port ID, etc.;

o Other inter-operations/negotiations: for example, RAN needs to

notify TN about the information of newly attached eNodeB when user

moves.

From terminal to server, an end-to-end network slice will involve

different network segments such as RAN, TN, CN, etc. Even within the

same network segment, there always involve multiple domains due to

geographic isolation, administrative isolation and other reasons.

There are two ways to enable an end-to-end network slice: based on a

common platform or based on inter-operation/negotiation.

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If all of the involved network segments and domains belong to the

same operator or the same operator union, the common platform

solution may be work. In this case, all of the network segments and

domains only need to communicate with the common platform, and follow

the coordination management of this common platform. Whilst the most

common case is that the involved network segments and domains belong

to different operators/vendors/administrative regions, and there does

not exist a common platform. Consequently, the cross-network segment

and cross-domain inter-operation/negotiation (i.e., end-to-end

network slicing) will be essential throughout the whole lifecycle.

5. Related Work

There are some related works studies the inter-operation/negotiation

between different entities. This subsection will briefly review

these related work to provide a basis for the gap analysis.

5.1. IETF Autonomic Networking Integrated Model and Approach (ANIMA)

Autonomic Networking Integrated Model and Approach (ANIMA) WG

provides a series of tools for distribued and automatic management,

which includes: Generic Autonomic Signaling Protocol (GRASP) ,

Autonomic Networking Infrastructure (ANI), etc.

GRASP [ANIMA-GRASP] is a protocol for the negotiation between ASAs

(Autonomic Service Agent). In GRASP, ASAs could be considered as

"APPs" installed on a device. Different ASAs fulfil different

management tasks such as parameter configuration, service delivery,

etc. Based on GRASP, the same purpose ASAs that installed on

different devices are able to inter-operate and negotiate with each

other. Network slicing could make use of GRASP for the coordination

among devices in the underlying infrustracture layer, as well as the

coordination among different domain managers. However, the security

issue incured by cross-domain usage should be fixed in GRASP.

ANI [ANI] is a technical packet consisting of BootStrap (for

authentication, domain certification distribution, etc.), ACP (a

separate control plane), and GRASP (for control message

coordination). ANI could be used to construct the management tunnel

among devices in uderlying infrustrature layer. While the network

slicing and cross-domain oriented extensions are necessary.

5.2. IETF Abstraction and Control of Traffic Engineered Networks (ACTN)

ACTN [TEAS-ACTN] is an information model proposed to TEAS WG, which

enables the multi-domain coordination in transport network. As a

end-to-end network slicing solution, ACTN is unable to provide the

cross-network segment and the corss-operator negoation/inter-

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operation, as well as the negoation/inter-operation across different

administration domains within an operator. In ACTN, each physical

transport network domain is under the control of a PNC as shown in

Figure 1. Based on a MDSC, multiple PNCs coordinate with each other.

Although the MDSC may be a hierarchical structure, the hierarchical

MDSC still could be regarded as a logical common platform. As

section 4.1 discussed, such common platform solution has a strict

presumption that is all of the PNCs belong to the same administration

region, the same operator or the same operator union. The biggest

factor that prevents ACTN from being directly applied to network

slicing is that, ACTN and network slicing have totally differnet

management modes. ACTN is path-oriented (i.e., LSP technique based),

whilst network slicing is resource-oriented. Take the scenario shown

in Figure 2 as an example, there are two LSPs: LSP1 (A->C->D, 20G)

and LSP2 (B->C->D, 20G). If the coming data of Node A becomes to

10G, and the coming data of Node B becomes to 30G. Then, the path-

oriented management has to re-configure these two LSPs (i.e., LSP1

and LSP2). While from the resource-oriented management perspective,

the C->D part does not need any change. In summary,

+-------+ +-------+ +-------+

| CNC-A | | CNC-B | | CNC-C |

+---+---+ +---+---+ +---+---+

| | |

+-------\ |CMI /------+

\ | /

+---------+----------+

| (Hierarchical)MDSC |

+---------+----------+

/ | \

+-------+ |MPI +---------+

| | |

+---+---+ +-------+ +----+--+

| PNC | | PNC | | PNC |

+-------+ +-------+ +-------+

Figure 1: A Three-tier ACTN Control Hierarchy

o In-device resource: ACTN only abstracts the topology and link

features, it has no idea about the features of network device,

such as the number of ports, the bandwith of each port, the

forwarding capciity, etc.

o L2 resource negotiation: ACTN does not provide the L2 resource

negotiation among devices.

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o network perspective coordination: ACTN manages the network from

the perspective of LSP, it does not cover the coordination among

LSP tunnels.

20G->10G +---+

---------->+ A +----+20G->10G

+---+ |

+--->+---+ 40G +---+

| C +----->+ D |

+--->+---+ +---+

20G->30G +---+ |

---------->+ B +----+20G->30G

+---+

Figure 2: A Comparison Example

5. 3. IETF Path Computation Element Communication Protocol (PCEP)

Path Computation Element (PCE) [RFC4655]separates the path

computation function from physical devices and provides the

centralized path computation for a domain as shown in Figure 3. PCE

is a key functional module that can be embedded into various

management systems. For example, [PCE-ACTN] studies the

applicability of PCE for ACTN, [PCE-SDN] extends PCE communication

Protocol (PCEP) for the hierarchical SDN control system, etc.

+------------+ +------------+

| | Inter-PCE | |

| PCE <------------------> PCE |

| | Request/Response | |

+-^----------+ +------------+

|

|Request/

|Response

|

+-v------+ +--------+ +--------+

Service |Head-End| Signaling |Adjacent| Signaling |Adjacent|

--------> Node <-----------> Node <-----------> Node |

Request +--------+ Protocol +--------+ Protocol +--------+

Figure 3: Multiple PCE Path Computation with Inter-PCE Communication

In general, PCEs coordinate with each other based on PCEP. PCEP

operates over TCP, only one PECP session can exist between a pair of

PCEP peers at one time [RFC5440]. This constraint makes PCEP

unsuitable for network slicing, since there always are multiple

isolated network slices need cross-domain or cross-network segment

negotiation/inter-operation at one time. Moreover, the function of

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PECP is far less than the application requirements of network

slicing. PECP provides limited messages such as the PCE request/

response messages, specific event notification message (e.g., PCE

gets overloaded), error message, etc. None of these messages covers

the network slicing provision negotiation.

5.3 Network Slicing in other SDOs

Open Network Fundation (ONF) has developed a recommendation on applying SDN architecture to Network Slicing [ONF-2016].

3GPP is studying the network slicing focussing on radio networks and core networks and it issued an architecture for Next Generation System [NGS-3GPP-2016] September 2016.

ITU-T IMT 2020 and ITU-T SG13 is studying network sofwarisation inclusife of network slicing and it has issues a number of recommendations: Gap Analysis [IMT2020-2015], Network Softwarisation [IMT2020-2016], Terms [IMT2020-2016bis]

NGMN is studieng the network slicing from the mobile network point of view. I has issued a number of recommendations [NGMN-2015], [NGMN-2016]

5.7. Other Potential Solutions

15 Large Scale European Research projects are now developing technology for 5G Networks and all researching Network Slicing (https://5g-ppp.eu) – More info to be added

White Paper on 5G Architecture centered on network slicing (https://5g-ppp.eu/wp-content/uploads/2014/02/5G-PPP-5G-Architecture-WP-July-2016.pdf) (2016) - More info to be added

5G Exchange (5GEx) [5GEx] is a 5G-PPP project which aims to enable

cross-domain orchestration of services over multiple administrations

or over multi-domain single administration networks. The main

infrastructure considered in 5GEx is the NFV/SDN compatible software

defined infrastructure, which will limit the scope of network

slicing [5GEX], [5GEx Architecture].

5G SONATA is a project of a 5G-PPP project aiming at service programmability and orchestration in a single domain [5G SONATA].

[suggested sections]

5.4 NVo3 and VPNs, TE, RSVP-TE etc...

5.5 Segment routing

5.6 Deterministic Networking

5.7 Flex Ethernet

5.6 Summary of Gaps in Related Work

The technologies in the above section can only partially meet the requirements of network slicing.

* Several technologies meet all network slicing requirements within the scope of a single administrative domain that has full visibility but fail to do so across multi-topology domain.
* None of the approaches are efficient in explicitly negotiating resources across multiple-domains, while hiding internal details at the same time.
* While some solutions that have data plane capabilities lack in corresponding control plane as well as autonomous management aspects of a network slice by a slice operator.
* Some of the use cases mentioned in [NS-USECASE], require their own data plane or control plane over the abstracted topology.

6. Network Slicing-Domain Abstraction (Kiran, Jie)

End to end resource awareness is a key differentiating aspect of network slicing. It is also important for a network slice to be isolated from other slices and is generally achieved through network abstraction technolgoies such as virtual private networks (VPN) and other overlays (NVO3). VPNs essentially are private networks of enterprises by connecting remote sites. It is only the partial goal of network slice domain that determines reachability. Ther are 2 issues with VPNs

1. An end-end VPN tunnel competes with other traffic in the network and end to end network resource policies cannot be guaranteed.
2. The reachability and resource reservation protocols are not tightly integrated and often solutions require centralized PCE-P like methods.

Network slices partition the infrastructure across multiple domains. Many slicing scenarios are at the scale of public internet such as V2X, mMTC, mission critical services etc. The resources allocated shall not compete with other traffic, yet having the flexibility to scale allocate/deallocate resources on-demand. In comparison of network virtualization technologies, the notion of abstraction in slicing shall allow support several control planes (one per slice instance).

The abstraction in slicing should be able to logically express or represent resource requirements from different domains running different technologies.

7. OAM Operation with Customized Granularity (Med, Christian)

7.1. Description

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

o 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.

o Administration: refer to activities to keep track of resources

within the network and how they are used.

o 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:

o 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:

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\* 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 a

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

slices. 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.

o Ability to automatically discover the underlying service functions

and the slices they are involved in or they belong to.

o 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.

7.2. Analysis

The reader may refer to [RFC7276] for an overview about available OAM

tools. These technology-specific tools can be reused in the context

of network slicing. Providers that deploy network slicing

capabilities should be able to select whatever OAM technology-

specific feature that would be address their needs. No gap that

would legitimate specific requirements has been identified so far.

[I-D.ooamdt-rtgwg-ooam-header] specifies a generic OAM header that

can be used if overlay technologies are enabled. Obviously, this

effort can be reused in the context of network slicing when overlay

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techniques are in use. Nevertheless, for slice designs that do not

assume an overlay technology, OAM packets must be able to fly over

the appropriate slice and for a given service/customer. This is

possible by reusing some existing tools if and only if no specific

fields are required (e.g., carry a slice identifier).

SFC WG [SFCWG] is chartered to define SFC-specific OAM. Extensions

that will be specified by the SFC WG will be reused in the context of

netslices. Nevertheless, the current charter of the WG does not

imply work on the automated discovery of SF instances and their

capabilities, nor the automatic discovery of control elements. An

additional specification effort is therefore required in this area.

8. Gap Summary (Alex, All)

The following table is a summary of the gaps identified previously in

this document.

+----------------+--------------------------------------------------+

| Requirements | Gaps |

+----------------+--------------------------------------------------+

| Network |1. Mechanism for NS state anf monitoring state |

| Slicing |2. Mechanisms for uniform specification |

| Specification |3. Mechanism and framework for NS Identity |

| |4. Mecahnims for capability exposure |

| |5. Mechanisms for interworking |

+----------------+--------------------------------------------------+

| End-to-End |1. Mechanism for secure corss-network segment and |

| Network | cross-domain network slicing provision |

| Slicing | negotiation/inter-operation |

| |2.Mechanisms for network slicing E2E repository |

| |3.Mechanisms for E2E NS composition /decomposition|

| |4.Mechanisms for E2E NS scalable operations |

+----------------+--------------------------------------------------+

| Network |1.Mechanisms and models for NS abstractions |

| Slicing-Domain |2.Common model for resources / network functions |

| Abstraction |3.Mechanisms for Network slicing configuration |

| |4.Mechanisms to reduce end-to-end complexity |

+----------------+--------------------------------------------------+

| OAM Operation |1. Mechanism for dynamic discovery of service |

| with | function instances and their capabilities; |

| Customized | Mechanism for dynamic discovery of instantiated |

| Granularity | nest slices; Mechanism for customized net |

| | slices OAM operations when overlay techniques |

| | are not in use. |

| |2. Mechanisms for elasticity |

| |3. Mechanisms for self-management |

| |4. Mechanisms for service customization |

| |5. Mechanisms for multi-servicees/Multi-tenancy |

| |6. Mechanisms for Network Slices Isolation |

+----------------+--------------------------------------------------+

Table 1: Gap Summary

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9. Security Considerations

This document analyzes the standardization work on network slicing in

different WGs. As no solution proposed in this document, no security

concern raised.

10. IANA Considerations

There is no IANA action required by this document.

11. Acknowledgements

12. Informative References

[ANI] "A Reference Model for Autonomic Networking",

<https://datatracker.ietf.org/doc/draft-ietf-anima-

reference-model/?include\_text=1>.

[ANIMA-GRASP]

"A Generic Autonomic Signaling Protocol (GRASP)",

<https://datatracker.ietf.org/doc/draft-ietf-anima-

grasp/>.

[5GEx] "5G Exchange (5GEx) - Multi-domain Orchestration for

Software Defined Infrastructures",

<https://www.researchgate.net/

publication/296486303\_5G\_Exchange\_5GEx\_-\_Multi-domain\_Orch

estration\_for\_Software\_Defined\_Infrastructures>.

[5GEx Architecture]

"Guerzoni, R., Vaishnavi, I., Perez-Caparros, D., Galis, A.,

et al Analysis of End-to-End Multi Domain Management and

Orchestration Frameworks for Software Defined

Infrastructures - an Architectural Survey", June 2016,

<onlinelibrary.eiley.com/10.1002/ett.3084/pdf>.

[5G SONATA]

“5G Service Programability”

"Karl, H., Peuster, M, Galis, A., et al DevOps for Network

Function Virtualization - An Architectural Approach", July

2016,

<http://onlinelibrary.wiley.com/doi/10.1002/ett.3084/full>.

[5G PPP]

“White Paper on 5G Architecture centered on network slicing”

<https://5g-ppp.eu/wp-content/uploads/2014/02/5G-PPP-5G-Architecture-WP-July-2016.pdf>

[I-D.ooamdt-rtgwg-ooam-header]

Mirsky, G., Kumar, N., Kumar, D., Chen, M., Yizhou, L.,

and D. Dolson, "OAM Header for use in Overlay Networks",

draft-ooamdt-rtgwg-ooam-header-03 (work in progress),

March 2017.

[PCE-ACTN]

"Applicability of Path Computation Element (PCE) for

Abstraction and Control of TE Networks (ACTN)",

<https://datatracker.ietf.org/doc/draft-dhody-pce-

applicability-actn/?include\_text=1>.

[PCE-SDN] "PCE Hierarchical SDNs",

<https://datatracker.ietf.org/doc/draft-chen-pce-h-sdns/>.

[RFC4655] Farrel, A., Vasseur, J., and J. Ash, "A Path Computation

Element (PCE)-Based Architecture", RFC 4655,

DOI 10.17487/RFC4655, August 2006,

<http://www.rfc-editor.org/info/rfc4655>.

Qiang, et al. Expires November 18, 2017 [Page 12]

Internet-Draft Network slicing May 2017

[RFC5440] Vasseur, JP., Ed. and JL. Le Roux, Ed., "Path Computation

Element (PCE) Communication Protocol (PCEP)", RFC 5440,

DOI 10.17487/RFC5440, March 2009,

<http://www.rfc-editor.org/info/rfc5440>.

[RFC6291] Andersson, L., van Helvoort, H., Bonica, R., Romascanu,

D., and S. Mansfield, "Guidelines for the Use of the "OAM"

Acronym in the IETF", BCP 161, RFC 6291,

DOI 10.17487/RFC6291, June 2011,

<http://www.rfc-editor.org/info/rfc6291>.

[RFC7276] Mizrahi, T., Sprecher, N., Bellagamba, E., and Y.

Weingarten, "An Overview of Operations, Administration,

and Maintenance (OAM) Tools", RFC 7276,

DOI 10.17487/RFC7276, June 2014,

<http://www.rfc-editor.org/info/rfc7276>.

[SFCWG] "Service Function Chaining (sfc)",

<https://datatracker.ietf.org/wg/sfc/about/>.

[TEAS-ACTN]

"Information Model for Abstraction and Control of TE

Networks (ACTN)", <https://datatracker.ietf.org/doc/html/

draft-ietf-teas-actn-info-model>.

[NS Use Cases]

“Network Slicing Use Cases: Network Customization for different services”

<draft-makhijani-netslices-usecase-customization-02>

[ONF-2016]

"Paul, M, Schallen, S., Betts, M., Hood, D., Shirazipor,

M., Lopes, D., Kaippallimalit, J., - Open Network

Fundation document "Applying SDN Architecture to 5G

Slicing", Open Network Fundation, April 2016,

<https://www.opennetworking.org/images/stories/downloads/

sdn-resources/technical-reports/

Applying\_SDN\_Architecture\_to\_5G\_Slicing\_TR-526.pdf>.

[NGS-3GPP-2016]

"Study on Architecture for Next Generation System - latest

version v1.0.2", September 2016,

<http://www.3gpp.org/ftp/tsg\_sa/WG2\_Arch/Latest\_SA2\_Specs/

Latest\_draft\_S2\_Specs>.

[IMT2020-2015]

"Report on Gap Analysis", ITU-T FG IMT2020, December

2015, <http://www.itu.int/en/ITU-T/focusgroups/imt-

2020/Pages/default.aspx>.

[IMT2020-2016]

"Draft Technical Report Application of network

softwarization to IMT-2020 (O-041)", ITU-T FG IMT2020,

December 2016, <http://www.itu.int/en/ITU-T/focusgroups/

imt-2020/Pages/default.aspx>.

[IMT2020-2016bis]

"Draft Terms and definitions for IMT-2020 in ITU-T

(O-040)", ITU-T FG IMT2020, December 2016,

<http://www.itu.int/en/ITU-T/focusgroups/imt-2020/Pages/

default.aspx>.

[NGMN-2015]

"5G White Paper", 2015

<https://www.ngmn.org/5g-white-paper.html>.

[NGMN-2016]

"Description of Network Slicing Concept", Jan 2016

<https://www.ngmn.org/uploads/media/160113\_Network\_Slicing\_v1\_0.pdf>.

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