2019 ACM/IEEE Symposium on Architectures for Networking and Communications Systems (ANCS)

Towards A Marketplace for Multi-domain Cloud Network Slicing: Use Cases

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***Abstract*—Dynamic end-to-end cloud network slices following a Slice-as-a-Service (*SaaS*) paradigm offer promising opportunities in support of diverse vertical industries attached to different administrative domains. This paper presents a distributed *Marketplace model* to dynamically create cloud network slices involving different slice resource providers. Portrayed through the lens of three reference use case scenarios, we discuss potential attributes of having a *Marketplace* and the outcomes feeding the use case requirements within a *Slice Marketplace* scope. Effective selection, negotiation, and proper monitoring and enforcement of service level agreements between multiple administrative and technological domains are among the prime challenges towards the realization of a distributed *Marketplace* of federated network and cloud resource providers.**

***Index Terms*—Cloud Network Slicing, Slice-as-a-Service, Marketplace, Multi-domain Network Slicing**

I. INTRODUCTION

A Network Slice (NS) is defined as an independent End-to-End (E2E) logical network running on a shared infrastructure (*i.e.,* compute, storage, connectivity resources) capable of providing a negotiable service quality agreed among its consumers and providers [1]. Slices can be composed of instances of Virtualized Network Functions (VNFs), infrastructure resources (*e.g.,* CPUs, routers, tunnels), and connectivity services spanning multiple administrative domains at the same time and deployed across different networking settings (*i.e.,* access, transport, core). The concept of network slicing conveys the approach to provide isolated slice parts offered by diverse providers based on specific E2E service requirements.

The urge for a dynamic infrastructure sharing business models between multiple operators and service providers to leverage their synergies through shared resource agreements can be facilitated following *SaaS*-like models. A platform that brings together the multi-domain resource providers and tenants of *NS*, with a vision to trade slice parts (*i.e.,* VNFs, storage, bandwidth) through an efficient resource discovery model can ensure dynamic provisioning of E2E slices, as per the requirements of the tenants. Such a *rendezvous* platform is what we refer to as *Marketplace*.

This paper explores a *Marketplace* concept through the lens of a federated cloud network slicing architecture as proposed by the NECOS project [2]. Nicknamed as Lightweight Slice Defined Cloud (LSDC), the NECOS platform aims at addressing limitations of current cloud computing approaches with respect to the ability of trading network slice infrastructure parts involving Telco Service Providers and Edge Clouds [3]. The platform embodies several distinguishing features including a dynamic resource discovery model for grouping sliced resources (*i.e,* compute, storage, connectivity) through a *Marketplace* subsystem. A pricing model enables the interaction between different NECOS stakeholders involving different resource providers, slice owners and tenants specifying particular service and relative cost requirements [4].

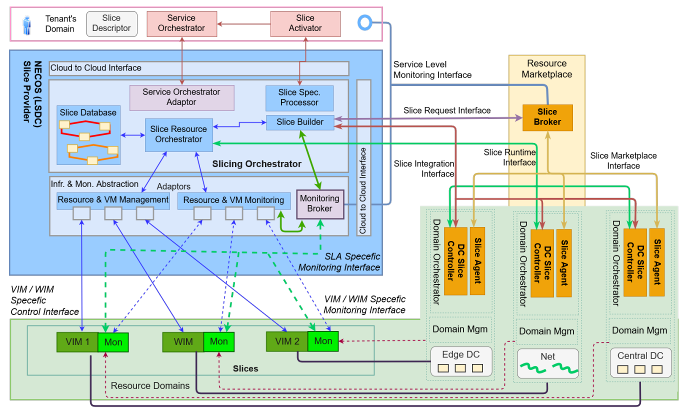

Fig. 1. NECOS platform architecture with a resource Marketplace for multi-domain network slicing.

The idea considering a *Marketplace* has been introduced in different contexts to fulfill the requirements of infrastructure sharing among the participants of Marketplace [5]–[8]. Nevertheless, issues requiring further work include business-to-business and business-to-customer interfaces, pricing models for sharing the components of a slice (or the slice as a whole), and business models for negotiation (*e.g.,* auctions, sharing models, rental opportunities) tailored to the specific use case requirements that adhere to the Service Level Agreements (SLAs).

We extend the vision of the *Slice Marketplace* introduced in [4] by considering any slice part beyond physical resources, be composed of compute, storage connectivity in forms of VNFs, routers or WAN, that are tradeable to provide a consolidated LSDC network slicing. This work introduces three relevant use-cases, in which there is a need for: (i) **slice parts negotiation** between slice resource providers spanning across **multiple administrative domains**, and (ii) a consolidated platform following the SaaS model to trade slice parts. We propose extending the NECOS architecture with a missing piece, namely the **Monitoring Broker** as depicted in Figure 1, to enable reliable SLA enforcement. Starting with the identification of a series of functional attributions, including the interaction with Monitoring Broker as an enabling entity for SLA composition and monitoring, an addition contribution of this work is the formulation of a series of open research challenges.

II. A MARKETPLACE FOR NETWORK SLICES

A *Slice Marketplace* can bring the slice resource providers spanning across multiple administrative domains in trading different slice parts with a slice provider for the successful deployment of tenant services. NECOS introduces the idea of a *Marketplace* capable with slice part discovery, negotiation, and selection of resources for facilitating dynamic creation, deployment, and management of E2E network slices. This *Marketplace* platform embodies a brokering mechanism, by introducing the entities of Slice Broker, Slice Agent, and Slice Builder. Within the former, the Slice Broker is the initiating entity of an one round sealed bid auctions process, where the Slice Agents as a part of infrastructure act as bidders, allowing them to follow individual pricing models in order to share/offer their resources. Upon successful completion of the auctions, the Broker communicates back the results, that include alternative instantiations of slice parts, to the Slice Builder; the latter is responsible for the final slice parts selection of the generated slice.

We propose a **Monitoring Broker** to be placed in the *Infrastructure and Monitoring Abstraction* (IMA) subsystem of NECOS to audit the slice parts (e.g., VNFs, WAN, router) through performance profiles (throughput, latency, bandwidth etc.) to maintain SLAs between the NECOS service and resource providers. As shown in Figure 1, the main characteristic of the NECOS Marketplace is to accommodate multi-domain network architectures primarily incorporating federated cloud or data center networks requiring network slice as a service.

III. Motivating Use Cases

We introduce here three use case scenarios highlighting the capabilities of the envisioned Marketplace platform. The first case represents the need for a VNF *Marketplace* for trading VNFs among multiple virtualized Customer Premises Equipment (CPE) central offices and data centers conforming a vCPE network. In the second use case, the envisioned Marketplace allows the trading and the management information exchange for programmable VNF resources spread over a Software-Defined WAN network. The third use case scenario highlights the need for resource negotiation and continuity of virtual connections among multiple operators of Multi-Access Edge Computing Networks (MEC).

A. vCPE: Highly Scalable Multi-domain Slices

On premise vCPE network conforms multiple NFV Infrastructure Points-of-Presence (NFVI-PoP) located at different domains connected over a shared WAN infrastructure (*e.g.,* IP, MPLS, optical network). Such network condition faces the challenge in providing highly scalable services without degrading performance profiles (*e.g.,* throughput, latency, etc), the need for bandwidth negotiation and other network bottlenecks. To reduce the bottlenecks, the *Slice Marketplace* brings the multi-domain VNF providers as-near-as possible to the vCPEs towards optimized geographical distribution and deployment of services.

Marketplace Attributions: *(i)* Provide a platform that selects slice parts based on distributed VNFs, structured and established in NFVI-PoPs across multiple domains through resource negotiation in creating flexible and dynamic slices; *(ii)* Foster distributed negotiation of network Quality of service (QoS) attributes, *i.e.,* bandwidth, for the VNFs spanning across multiple network domains (i.e., branch, central offices, data centers), in this case aggregation, access and core network.

Outcome Opportunities: *(i)* Negotiate Network QoS including VNFs bandwidth requirements with vCPE service provider and CPE vendors in the *Marketplace*. *(ii)* Compute and store status of infrastructure resources (e.g., connectivity bandwidth, hosting domains, execution environment capabilities). *(iii)* Monitor and maintenance of VNF reliability based on performance parameters (*i.e.,* latency, packet loss) following agreed SLAs.

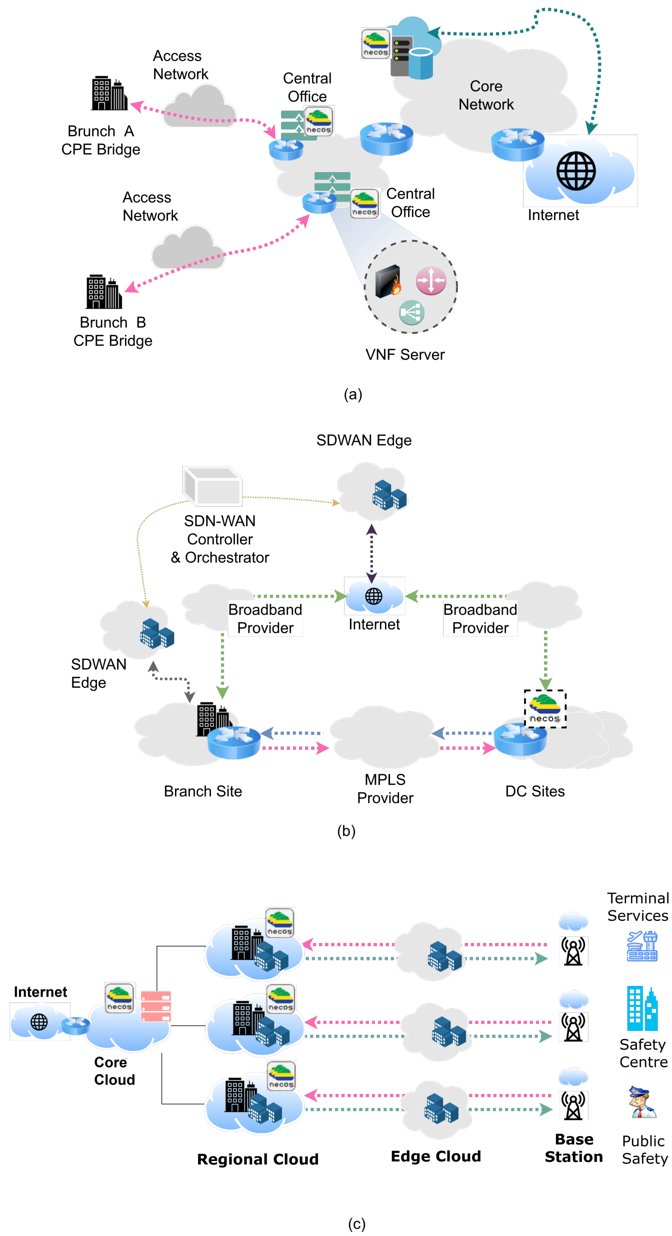

Fig. 2. Multi-administrative domain networks with positioning of NECOS Marketplace model for resource trading (a) vCPE, (b) SD-WAN, and (c) MEC Network.

B. SD-WAN: Customized Multi-domain Connectivity Slices

Whether SD-WAN is deployed over the public Internet and or with mixing MPLS or through a private cloud network, it introduces customization of network connectivity bt delivering specific network service demands. Trading of SD-WAN slices can be performed among increasing number of vendors based on the type of connectivity requirements between SD-WAN edges and DC. Negotiation and monitoring the VNF network profiles across multiple WAN connections is a critical challenge for SD-WAN slice Marketplace.

Marketplace Attributions: *(i)* To perform distributed bandwidth negotiation for multiple domains. The slice descriptor will carry the VNFs structure and bandwidth requirements for interconnecting the edge-DC and will compose the main factors for local and distributed bandwidth negotiation. *(ii)* Bandwidth management, compute and store link usage information (*e.g.,* occupancy) for consistent auditing purposes. *(iii)* SLA-oriented customization of on-demand/automatic resource reconfiguration.

Outcome Opportunities: *(i)* Negotiate VNFs bandwidth requirements at different levels of connectivity. *(ii)* Select links interconnecting the VNFs to meet connectivity requirements of the slices. *(iii)* Tight monitoring to realize the SLA in managing associated QoS capabilities (*e.g.,* throughput, latency, frame loss ratio) across multiple domains connected over the WAN.

C. MEC: Multi-Access Edge Computing

MEC brings real-time network capacities (*e.g.,* enhanced throughput) on the NS table allowing guaranteed maximum utilization of infrastructure resources (*e.g.,* radio network). Requisition of a MEC slice, if deployed on top of platforms implemented by different vendors and multi-operator networks, requires efficient utilization of the network resources with enhanced quality of experience for the end users.

Marketplace Attributions: *(i)* This *Marketplace* aiming for providing a negotiation platform for VNFs performance metrics (*e.g.,* throughput bandwidth) and MEC application situated and distributed across multiple edge clouds in connecting the NFVI-PoPs. *(ii)* Mechanisms to select links interconnecting the VNFs to meet service requirements of the MEC slice. *(iii)* Tight monitoring to realize the SLA in managing associated QoS capabilities (*e.g.,* throughput, latency, frame loss ratio) of VNFs across multiple edge clouds. *(iv)* Platform to negotiate dynamic adjustments in the target edge to maintain SLA standards.

Outcome Opportunities: *(i)* Negotiate Network QoS aligned with MEC application requirements across different MEC edge vendors in the *Marketplace*. *(ii)* Compute and store current infrastructure resource state (throughput, capabilities, domains, edge environments) for joint optimization of VNFs, *(iii)* Classification and grouping of negotiated VNF reliability based on performance parameters (*i.e.,* throughput, packet loss) and MEC application capabilities (network condition, big data) following agreed SLAs.

IV. CHALLENGES

Slice Negotiation – from the need of clear business-to-business and business-to-customer interfaces (e.g., 5GEx project[1]), a *Slice Marketplace* must establish opportunities for the realization of different network slicing business models among its players (e.g., auctions, sharing models, rental opportunities).

SLA Composition – in a *Slice Marketplace* means are needed to realize multiparty agreements detaining shared responsibilities, for instance, ensuring slice parts established in a multi-domain setting. Such agreements must be transparent and explicitly open to be audited by its counterparts (*a priori*, in run-time and *a posteriori*).

Slice Provenance – resources composing the slice parts (*i.e.,* VNFs, routes, tunnels) must present guaranteed and/or predictable behaviour (*e.g.,* performance, fault tolerance, scalability) fulfilled by reliable providers, which must be assured by the *Slice Marketplace*.

V. IMPLEMENTATION WORK

Efficient selection and negotiation of appropriate slice parts will lead to transparent SLA monitoring in the slice lifecycle within the *Marketplace*. Triggering events upon violations of confirmed SLAs between the service provider and multi-administrative resource providers requires the recording, the maintenance and the sharing of slice behavior information across multiple domains.

Having a monitoring broker in the NECOS IMA component (see Fig. 1) and implementing the proposed *Marketplace* for the NECOS consortium will contribute to fostering reliable trading of slice resources. The proposed *Monitoring Broker* integrates two new interfaces connecting the slice broker and slice providers, respectively defined as a service level monitoring interface and a SLA specific monitoring interface, with the already existing NECOS marketplace to ensure reliability and provenance of the platform. Upon establishment of guaranteed slice provenance, the *Monitoring Broker* can audit the created NSs for the proper enforcement of SLAs across multiple providers and verticals.

A Distributed Ledger Technology (DLT) can suffice for the required decentralization of slice database. We aim to tackle the previous mentioned challenges and implement the marketplace design. A planned prototype implementation of one of the above use cases evolves around integrating blockchain based *Smart Contract* model among the service and infrastructure providers of NSs (cf. [9], [10]).

Among enabling technologies serving distinct purposes, Hyperledger projects (e.g., Sawtooth [11] and Fabric [12]) are among the reference candidate platforms for implementing such envisioned Marketplace model. We broadly classify the functions of smart contracts in two categories, maintaining the status of slice resources and assuring information sensitivity. The heavily sensitive domain specific information (*i.e.,* cost model, resource description and location) sets deployed off-chain wherein, contract information, such as resource types, transaction of adding updating new resources/domains are deployed on-chain and shared throughout multiple administrative domains.

Blockchain smart contracts turn a distributed partnership into a programmable software instance. With the embodiment of the *Slice Marketplace* by DLTs, different administrative domains can partner via smart contracts designed to track the negotiation and maintenance of offered slice parts, monitor slice instance profiles, and trigger events upon contract violations. Analyzing such event logs, slice providers can categorize the resource provider profiles and perform trading actions and billing for the slice parts associated with the tenants' services.

[1]http://www.5gex.eu/

Acknowedgements

This work was supported by the H2020 4th EU-BR Collaborative Call, under the grant agreement no. 777067 (NECOS - Novel Enablers for Cloud Slicing), funded by the European Commission and the Brazilian Ministry of Science, Technology, Innovation, and Communication (MCTIC) through RNP and CTIC.

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