

Multi-domain Software Defined Network: exploring possibilities

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1. Introduction

Software Defined Networking [1] is a rapidly evolving concept in the networking community. SDN technologies and in particular OpenFlow protocol [2] can be used effectively to provide the environment for clouds, networking test-beds, campus networks and generally all applications that require fast adaptability (security, traffic engineering, Network-as-a-Service) and programmability. Service Providers in general and NRENs in particular are also experimenting with the integration of SDN/OpenFlow based technologies in the core of both their network and cloud facilities.

One of the SDN/OpenFlow hot topics is currently dealing with the adoption of SDN/OpenFlow multi-domain solutions, with the idea of enabling research and end-users communities with large scale trials on top of which they can deploy their services. Nevertheless, current SDN solutions do not naturally support multi-domain environments. Several initiatives have recently start working on it (e.g. FELIX [3] or the FI-PPP XIFI project [4]) trying to provide a smart solution to the SDN/OpenFlow multi-domain panorama.

GN3plus JRA2T1 group task aims to research on the utilization of the SDN in the multi-domain environment, based on a twofold approach consisting of the federated slice (slice-oriented) and provisioning connections

(connection-oriented). Connection-oriented multi-domain SDN concept puts the emphasis on providing circuits (connections) in the federated / multi-domain environment utilizing SDN and OpenFlow protocol in particular. Slice-oriented multi-domain SDN concept is focused on the definition of mechanisms in which distributed slices of networking resources can be created and used among many different SDN domains [5][6]. Such mechanisms should allow to create federated test-beds or datacenters which can be perceived as one logical domain enabling easier control of the resources (e.g. FP7 NOVI project [7]).

2. Connection-oriented multi-domain SDN

One of the most interesting topics which needs to be investigated is how to setup a multi-domain connection (path) leveraging the SDN/OpenFlow capabilities in heterogeneous environments. OpenFlow introduced very flexible traffic differentiation by allowing packet forwarding using much more parameters than traditional approach. The flexibility provided by OpenFlow enables circuits to be established in numerous forms – from pure Layer 1 connections (port-port), through Layer 2 and Layer 3 (IP address space) to Layer 4 TCP/UDP ports. However, since not every domain has to be OpenFlow/SDN-enabled, optional SDN/OpenFlow-specific parameters need to be passed in a way, which won't disable possibility to setup a circuit in non-SDN domains.

For a connection-oriented case NSI Connection Service [8] (from the Network Services Framework [10]), responsible for the setup of the circuits in the federated / distributed environment, has been chosen as a promising solution among others because of its technology agnostic's approach [9]. The most recent specification of this service (v2.0) introduced new data model elements, which enables extensions of the base functionalities without integration into core elements of the protocol. One of the most important features, from this considerations point of view, is existence of so called 'any'¹ attribute in NSI messages, which semantic meaning depends on defined namespace instead of pre-defined assumptions [11].

Possibilities of the SDN/OpenFlow integration with the NSI are presented in the following subsections.

2.1. Using STP definition for a connection setup

By utilizing newest STP definition², it is possible to code into the 'LabelType' attribute [12] information regarding e.g. range of VLANs, L3 IP subnet/range or even L4 TCP/UDP ports available on the interface. In that way appropriate STP ports can be chosen to transport network traffic with specific network parameters (characteristics). The schema of 'Reserve' connection request remains untouched and for a connection reservation process basic NSI service types (P2P, ETS or EVST) can be used providing compatibility with the non-SDN domains [14].

2.2. Extending 'reserve' request by an OpenFlow/SDN-specific attributes

In the second version of NSI-CS new definition of the 'Reserve' request has been proposed in order to enable possibility to transport additional (technology- or domain-specific) parameters within the protocol message [13]. SDN/OpenFlow-specific information can be passed in the form of new base service type or by defining new optional namespace in the request.

- **New service base type:** Protocol defines three base service types which characterize properties of the multi-domain connection [14]. However, there is a possibility to define another service (placed in the 'any' attribute), which based on the agreement between domains agents, can be provided to the customers. In order to provide SDN/OpenFlow-specific connection new service type can be proposed. It should extend one of the service base type (e.g. Ethernet VLAN Service Type) by a layer 3 or/and layer 4 fields to enable setup of more granular flow-based connections.
- **New OpenFlow/SDN-specific namespace:** Despite service-specific attributes, 'Reserve' request possess property called 'anyAttribute' which has been added in order to be able to cope with any

¹According to the specification 'ANY' attribute "provides a flexible mechanism allowing additional elements to be provided such as the service specific attributes specified by 'serviceType'. Additional use of this element field is beyond the current scope of this NSI specification, but may be used in the future to extend the existing protocol without requiring a schema change" [11].

²Service Termination Point (STP) represents the logical/virtual ports of the domain. Ingress and egress traffic is transported through these ports and between them NSI connection is setup. Definition of the STP (despite of location, device serial number, physical port etc.) also contains information regarding network resources present on that port. [12]

domain/technology-specific extensions without a need of modification of protocol core. Custom SDN namespace might enable flexible approach to the management of network resources and enable use of connection-related SDN apps (e.g. custom statistics monitoring, packet inspection, resiliency or load balancing etc.) or suggest a quality of service of the circuit. Domains that do not support this extension(s) should silently ignore them, instead of dropping the whole request. As one of the NSI's basic service types [14] still can be used in the connection request, circuits via non-SDN domains can be easily established.

3. Slice-oriented multi-domain SDN: A centralized approach

Slice-oriented solution primary objective aims to enable the creation of sets of federated resources across several domains. Such multi-domain federation entails (i) the SDN domains slices creation and (ii) E2E multi-domain connectivity among such slices to build the multi-domain federation.

Several services are involved to accomplish previous stated two fold step process, namely, a connection management service, an slicing management service (to create and handle the slices) and at least, also a Data-Center management service to manage the storage and computing capabilities assigned to each slice. This proposal aims to leverage most up-to-dated services for the SDN multi-domain framework. For multi-domain connectivity purposes, NSI service has been chosen as described in the previous sections.

While provisioning several services across multiple domains, a centralized approach enables to keep an overall updated status of the connection management as well as services' life-cycle. Such centralized approach relies on an orchestrator that acts as management platform and coordinates services while yet delegating the execution of operations locally to each of the domain. This approach smartly fits as a solution to provide with E2E multi-domain SDN resources federation. All in all, such orchestrator can be seen as the entity that solves the gap between users (applications) and network, making use of several mechanisms (services). OpenNaaS [15] management platform system brings up important features and capabilities which makes it a smart option to such orchestrator.

3.1. Orchestrator + NSI + SDN

In the complete slice-based scenario, the NSI management system manages the Network Services Agent (NSA). Hence, each domain's network provider must announce to the NSA the STPs (Service Termination Points) that it will manage, and the Transfer Function that determines the connectivity between them. Moreover, depending on the slicing mechanism we can, at the moment of the creation of the slice, specify which subset of the STPs belongs to that slice, or just use single STPs and let the slicing mechanism slice the traffic inside the domain.

Independent of the slicing mechanism inside each domain, the RP-NSA should aggregate the NSI messages of the P-NSA (Provider NSA) agents of each slice/domain.

The slicing mechanism should provide the client isolation on the network as well as defining the desired virtual topology that the client has requested; this can be done per domain, or per cosmos (whole set of domains). It should provide client isolation such that two clients are not able to interact between them (unless agreed by both). Technologies achieving such objectives are e.g. FlowVisor [16] or VeRTIGO [17].

The Data Center management system manages the computational capabilities assigned to each client slice.

Finally, the Orchestrator act as management integrating and coordinating previous management systems as services, in order to provide E2E multi-domain sliced-based services (virtual topologies, client isolation, and computational nodes). Figure 1 shows the integrated view of the proposed multi-domain SDN management framework.

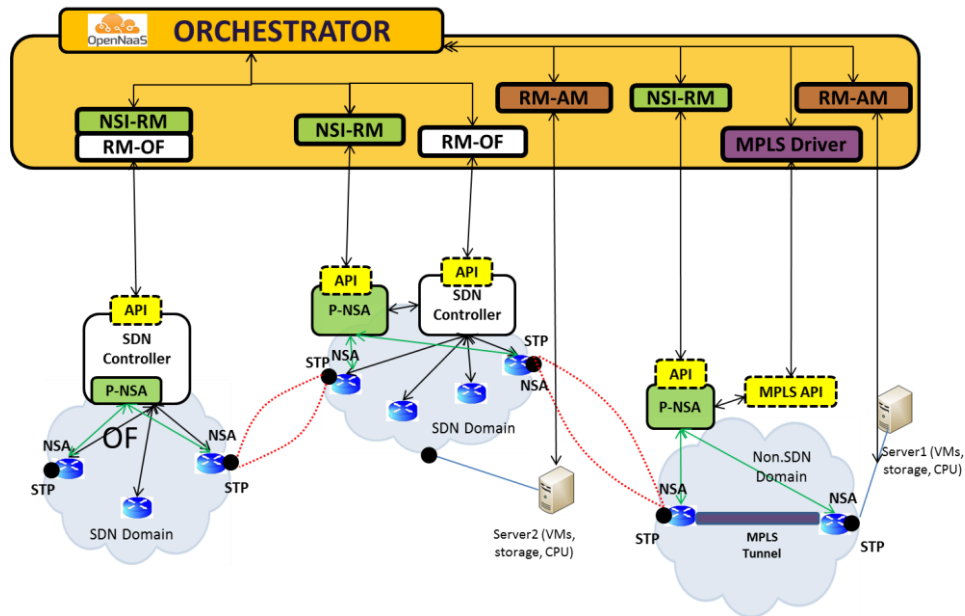


Figure 1 Multi-domain SDN management framework

4. Summary

Solutions proposed by GÉANT JRA2T1 group can fill a gap in the nowadays studies regarding multi-domain network environment with the use of novel SDN concept. Research on multi-domain subject has been divided into two areas of interest: connection-oriented and slice-oriented. For a connection-oriented case NSI-CS has been chosen as a promising multi-domain protocol. Moreover three possible solutions of integration NSI with the SDN/OpenFlow has been proposed: based on STP definition, new service type and custom namespace, where the latest looks promising as a potential overall solution. For a novel slice-oriented case, enabled by SDN/OpenFlow concept, new architecture has been described. Above studies can be a starting point for a further development process as well as can introduce changes in the multi-domain networking protocol in the form of NSI-CS. GN3plus was started in 2013 and further results are expected till Q2 2014.

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Eduardo Jacob (EHU) got in 1991 a BSc in Industrial Engineering and a MSc. in Industrial Communications and Electronics from the University of the Basque Country (UPV/EHU). He spent 2 years in a public R&D in Telecommunications enterprise which is nowadays Tecnalía. Later he spent some years as IT director in the private sector before returning to the Faculty of Engineering of Bilbao getting his PhD in ICT in 2001. He is assistant professor at the same Faculty, where is acting as Head of the Communications Engineering Department. He also leads the I2T research lab. He is the promoter and coordinator of the EHU OpenFlow Enabled Facility. His interests are related to application of the Software Defined Networks to support advanced applications, privacy and security in end to end communications systems for sensors.

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