B.1 NFV ISG PoC Report

B.1.1 PoC Project Completion Status

Indicate the PoC Project Status. Can the PoC be considered completed? If this is a multi-stage PoC project, indicate the Reported Stage status and plans for future Project Stages.

- Overall PoC Project Completion Status: Completed

  The demonstration showed how orchestrators are able to obtain the topology information of the SDN controllers at different levels of abstraction. The top SDN controller carried out end-to-end provisioning of optical connections to provide services to end customers, which are connected behind an IP router.

B.1.2 NFV PoC Project Participants

Specify PoC Team; indicate any changes from the NFV ISG PoC Proposal:

- PoC Project Name: Mapping ETSI-NFV onto Multi-Vendor, Multi-Domain Transport SDN
- Network Operators/ Service Providers: Verizon Contact: Vishnu Shukla
- Network Operators/ Service Providers: Telefonica Contact: Victor Lopez
- Research Centre: CTTC Contact: Ricard Vilalta
- Manufacturer A: NEC/ Netcracker Contact: Hiroshi Dempo
- Manufacturer B: ADVA Contact: Konrad Mrówka
- Manufacturer C: Ciena Contact: Lyndon Ong
- Manufacturer D: Coriant Contact: Jonathan Sadler
- Manufacturer E: Infinera Contact: Srini Seetharaman
- Manufacturer F: Juniper Contact: Amy Copley
- Manufacturer G: Sedona Contact: Itay Maor
- Manufacturer H: SM Optics Contact: Francesco Bosisio

B.1.3 Confirmation of PoC Event Occurrence

To be considered complete, the PoC should have been physically demonstrated with evidence provided that the demonstration has taken place.

Provide details on venue and content of PoC demonstration event. Provide pictures and supporting literature where available. Please identify who was present at the demonstration event (optional).

- PoC Demonstration Event Details: OFC2017, Los Angeles, CA, USA

  Arturo Mayoral López de Lerma, CTTC, Spain - E2E Transport API demonstration in hierarchical scenarios

  http://www.ofcconference.org/en-us/home/program-speakers/open-platform-summit/

B.1.4 PoC Goals Status Report

Specify PoC Goals from NFV ISG PoC Proposal (clause A.1.2). Identify any changes from the original NFV ISG PoC Proposal with an explanation as to why the changes were made. Indicate the extent that each goal was met. Provide sufficient information for those not familiar with the PoC goals to understand what has been achieved and/or learned.

- PoC Project Goal #1: __The PoC will demonstrate connectivity services of the SDN-based WAN configured by transport SDN controllers and network devices, referred to as multi-site services in IFA022, ETSI-NFV.
- PoC Project Goal #2: __The PoC will demonstrate interactions between WIM (emulated) and transport SDN controller, which would be applicable to Nf-Vi reference point of the ETSI-NFV MANO framework.
- PoC Project Goal #3: __The PoC will report complemented analysis about the connectivity service for multiple sites, being discussed in IFA022.
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B.1.5 PoC Feedback Received from Third Parties (Optional)

- Where applicable, provide in a free text, feedback received from potential customers, Ecosystem partners, event audience and/or general public.

B.2 NFV PoC Technical Report (Optional)

PoC Teams are encouraged to provide technical details on the results of their PoC using the PoC Scenario Report template below.

In ETSI-NFV, the IFA022 work item studies connectivity service instantiations between different NFVI-PoPs in the context of end-to-end Network Service Life Cycle Management. The use cases are based on scenarios involving multiple sites, hosting NFVI-POPs, which are interconnected over a Wide Area Network (WAN) infrastructure [NFVMAN001]. In this context, a Network Service, which is a composition of Virtual Network Functions, is instantiated across different NFVI-PoPs through the interactions between OSS/BSS, NFVO, WIM/VIM, and Network Controllers. The current IFA022 WI analyses the interactions among OSS/BSS, NFVO, WIM/VIM with reference to the current ETSI-NFV standards specifications, but it also needs examples and references that are external to the ETSI NFV MANO to gain useful insight about the interactions between the Network Controller and underlying WAN infrastructure in order to understand, identify and specify the requirements of the WIM, which may not be obvious within the existing scope of IFA022 in particular and NFV MANO in general. This becomes all the more relevant as the multi-site Network Service composition requirements comes from the MANO components above the WIM. Moreover, the connectivity properties in the underlying transport network may need to be exposed to the NFVO and hence the OSS/BSS via the WIM/VIM.

In view of the above considerations, the objective of this PoC is to demonstrate a connectivity life cycle management with SDN-based Network Controllers over WAN interconnections that are interfaced with the WIM. As shown in Figure 1, the PoC is architecturally configured by a network controller, interfacing with WIM, and Wide Area Network (WAN) infrastructure. The WAN interconnects multiple ETSI-NFV sites. In IFA022, an NFVI-PoP is considered as a site. Based on this PoC, it is expected to gain valuable experiences that will enable us to not only derive the requirements on WIM towards the Network controller but also derive requirements on WIM from/towards the NFV-MANO functional components. By learning a specific SDN controller implementation in this PoC, the capability differences between WIM and Network Controller will be clearer.

For the implementation of the PoC a Transport API [ONFTR522] [ONFTR527] [ONFTAPI], called T-API, shall implement a set of northbound application interfaces of the network controller. Based on select use cases from IFA022, topology and connectivity services shall be implemented and tested. The topology service can be used when WIM explores a set of connectivity end points whose requirements may be specified from OSS\BSS and\or NFVO (e.g. affinity group, location constraint). The topology service can also be used when WIM may collect WAN QoS parameters (e.g. capacity, latency, cost, etc) that shall satisfy the Network service QoS requirements as imposed by the OSS/BSS and\or NFVO. WIM may be asked to collect network QoS parameters via Or-Vi reference point by NFVO. The connectivity service can be initialized when WIM executes path instantiation. Two or more end points given by the WIM are then interconnected with the connectivity service.

In our proposed PoC, a network infrastructure is configured by multiple networks of individual vendors. A domain controller is responsible for the individual ~~a~~ network infrastructure. A multi-domain controller is responsible for end-to-end connectivity of the multi-domain network infrastructure. The multi-domain controller implements the TAPI interface to WIM.

As studied in ETSI-NFV [EVE005], the multi-domain controller can be configured with hierarchical model. There is no WIM-specific specification in ETSI-NFV but, by leveraging this feature, interactions between WIM and Network Controller can be emulated and tested in our PoC. A higher level multi-domain controller emulates as a WIM instance and a lower multi-domain controller works as a Network Controller instance. Transport API (T-API) specification can be used for the reference point between WIM and Network Controller. The PoC will consist of, at the minimum, a carrier lab, where the test-bed will be located hosting at the minimum one multi-domain controller and two domains.

[NFVMAN001] ETSI GS NFV-MAN 001: "Network Functions Virtualisation (NFV); Management and Orchestration"

[NFVEVE005] ETSI GS NFV-EVE005: "Network Functions Virtualisation (NFV); Ecosystem; Report on SDN Usage in NFV Architectural Framework"

[ONFTR522] ONF TR-522 "SDN Architecture for Transport Networks"

[ONFTR527] ONF TR-527 "Functional Requirements for Transport API"

[ONFTAPI] "Repository for Open Transport API Project", https://github.com/OpenNetworkingFoundation/Snowmass-ONFOpenTransport

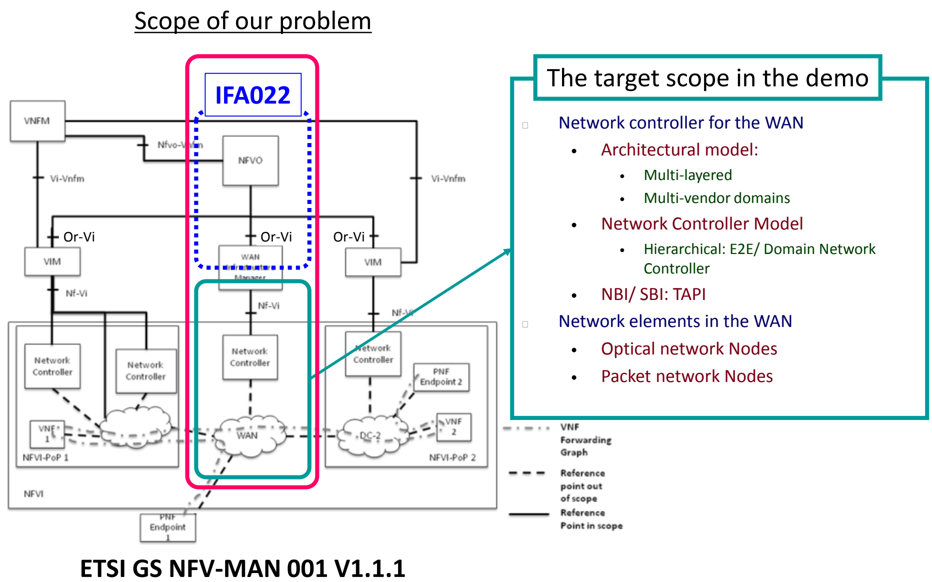

Figure 1 Scope of our demonstration in the PoC

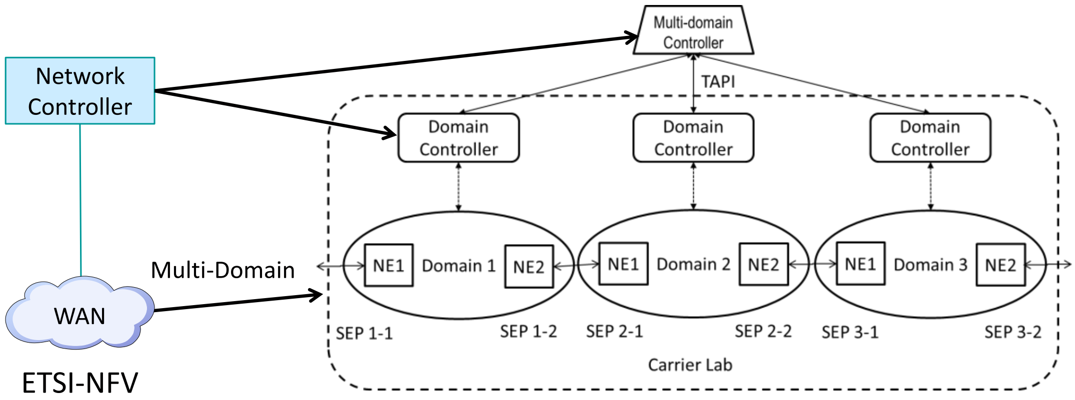

Figure 2 Mapping of the WAN architecture into our PoC model

B.2.1 PoC Scenario Report

Use the table structure below and refer back to the Scenarios in the NFV ISG PoC Proposal (clause A.2.2) and provide information for each of them. Feel free to include additional Scenarios developed during the implementation of the PoC. Do not eliminate Scenarios that were not performed, instead provide a brief status for each with a reason why the scenario was not performed. Do not hesitate to fill multiple instances of the table if several objectives have been demonstrated for each scenario.

Objective Id:	Scenario #1	
Description:	Topology service returns topology network information.	
Pre-conditions	Multi-domain controller needs to discover each domain topology.	
Procedure:	1	A multi-domain controller calls a topology API on each domain controller.
	2	A multi-domain controller gets topology network information elements from each domain controller.
Results Details:	The following APIs were tested and a multi-domain controller got the topology information from each domain controller - Retrieved a collection of topology object - Retrieved a collection of link object in the topologies - Retrieved a collection of node object in the topologies - Retrieved a collection of port object in the node objects	
Lessons Learnt & Recommendations	Network topology information elements can be taken from the underlying network infrastructure configured by multiple vendors' network equipment.	

Objective Id:	Scenario #2	
Description:	Connectivity service in a multi-domain controller installs network configurations into the network infrastructure configured by multiple domains.	
Pre-conditions	There is no connectivity services installed inside the multi-domain network infrastructure.	
Procedure:	1	Based on the retrieved information, multi-domain controller calls connectivity services of each domain controller without specifying path constraints, but allowing each domain controller to perform internal path computation per its local optimization
	2	Each domain controller performs path computation, and configures network elements to instantiate connectivity in each domain.
	3	After the deployment, multi-domain controller retrieves the status of the connectivity on each domain controller.
	4	The connectivity is deleted.
	5	The step#1 to step#4 are a deployment scenario without explicit route. Therefore, do the same procedure from #1 to #4with an explicit route by specifying path constraints
Results Details:	In a single domain, a multi-domain controller - Retrieved service end points (e.g. edge port of the WAN connectivity) - Retrieved connectivity service attributes - Retrieved connection attributes in the connectivity service - Updated connectivity service capacity - Deleted the connectivity service	
Lessons Learnt & Recommendations	It was confirmed that T-API implementation enabled on-demand connectivity setup, control and monitoring across diverse multi-vendor network infrastructure. The connectivity can be configured with/ without specifying path constraints.	

Objective Id:	Scenario #3	
Description:	Interactions between WIM and Network Controller by leveraging hierarchical multi-domain controllers. As described, our multi-domain controller can be configured with a hierarchical model shown in Figure 3. By leveraging this feature, a higher level multi-domain controller works as an emulated WIM instance and a lower multi-domain controller works as a Network Controller instance.	
Pre-conditions	There is no connectivity services installed inside the multi-domain network infrastructure.	
Procedure:	1	The mid-level multi-domain controller, shown as the 2^{nd} level multi-domain controller in the Figure 4, retrieves domain controllers to get topology information elements.
	2	The emulated WIM (=the top-level multi-domain controller) retrieves mid-level multi-domain to get topology information elements. Other domain controllers are retrieved if they are hosted by the top-level multi-domain controller.
	3	Based on the retrieved information and internal knowledge of the inter-domain links, the path computation service in the ~~the~~ emulated WIM (=the top-level multi-domain controller) is used to determine end-to-end path characteristics.
	4	Then the emulated WIM (=the top-level multi-domain controller) uses connectivity service API with the associated Service End-Points to the Domain Controllers along the end-to-end path
	5	The mid-level multi-domain controller uses connectivity service API to instantiate the requested connectivity.
	6	Domain controllers interfaced with the top-level and mid-level multi-domain controllers configures their network elements to instantiate the requested connectivity.
Results Details:	In multiple domains, the emulated WIM (=the top-level multi-domain controller) - Retrieved service end points (e.g. edge port of the WAN connectivity) - Retrieved connectivity service attributes - Retrieved connection attributes in the connectivity service - Updated connectivity service capacity - Deleted the connectivity service	
Lessons Learnt & Recommendations	It is confirmed that T-API implementation deployed in a hierarchical SDN controllers' tree enables real-time orchestration of on-demand connectivity setup, control and monitoring across diverse multi-layer, multi-vendor, multi-carrier networks.	

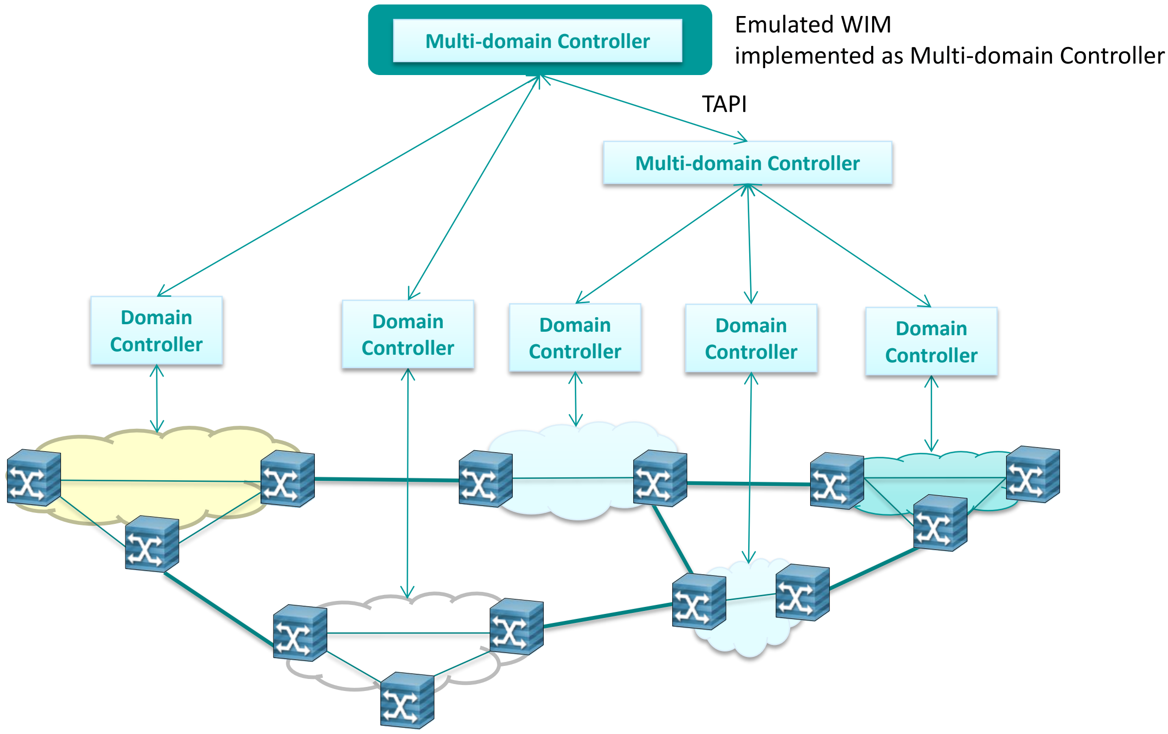

Figure 5 A PoC model for interactions between WIM and Network Controller

B.2.2 PoC Contribution to NFV ISG

Use the table below to list any contributions to the NFV ISG resulting from this PoC Project.

Contribution	WG/EG	Work Item (WI)	Comments
NFVIFA(16)000834r6	IFA	ETSI GR NFV-IFA 022	Accepted as Use Case#1 in IFA022. In the contribution, a use case is discussed in the context of the E2E Enterprise vCPE (EvCPE) network service orchestration. The overall model focuses on two NFVI-PoPs located at two different sites connected over a shared WAN infrastructure (e.g. IP/MPLS, optical network, etc.).
NFVIFA(16)0001240r1	IFA	ETSI GR NFV-IFA 022	Noted. This contribution described an overview of WIM and Network Controller, as well as references for this topic. In the context, WIM was introduced as an SDN Controller Application.
NFVIFA(16)0001489r3	IFA	ETSI GR NFV-IFA 022	Accepted in IFA022 Derived from the discussion in NFVIFA(16)0001240r1, the contribution proposed management architecture and activities. Referring to IFA005 and IFA013, the contribution discussed the interactions among OSS/BSS, NFVO, VIM, WIM and Network Controller for WAN. It also discussed related information elements defined in ETSI-NFV.
NFVIFA(17)000080r3	IFA	ETSI GR NFV-IFA 022	Accepted in IFA022. The contribution analysed Or-Vi reference point [MAN001] on WIM. Referring to IFA005, it also analysed the roles of WIM, and some information elements regarding to NFVI-PoP and WAN connectivity between the connected two sites.
NFVIFA(17)000341	IFA	ETSI GR NFV-IFA 022	Proposed for NFV#18 The objective of this analysis is to describe the instantiation procedures written in the step 2, use case 2 while referring to references [NFVIFA005], [NFVIFA013], [NFVIFA014]. In order to decide the allocation of the Virtual Links requested by OSS/BSS, NFVO needs to find the NSD to be deployed, determine the location of NFVI-PoPs, and check available network resources while working with WIM/ Network Controller.

B.2.3 Gaps identified in NFV standardization

Use the table below to indicate Gaps in standardization identified by this PoC Team including which forum(s) would be most relevant to work on closing the gap(s).Where applicable, outline any action(s) the NFV ISG should take.

Gap Identified	Forum (NFV ISG, Other)	Affected WG/EG	WI/Document Ref	Gap details and Status
WIM	NFV ISG,	IFA	ETSI GR NFV-IFA 022	WIM as a part of MANO component but the capability has not specified in ETSI-NFV. Nf-Vi reference point connecting to Network Controller is also not specified in the community. In multi-site services, NFVO has NsVirtualLinkDesc IE in the Network Service Deployment Flavour (NsDf) IE. "connectivityType" and "virtualLinkDf" are the attributes/ contents related to the WAN infrastructure. On the other hand, NFVO need to the current network status information to decide the resource deployment. NFVO, for example, needs to have topology and connectivity information used in the WAN infrastructure. Due to the scope defined in IFA022, Nf-Vi reference point between Network Controller and WAN cannot be discussed in ETSI-NFV.
		EVE	ETSI GS NFV-EVE 005	
	ONF Transport SDN	Optical Transport Working Group	TR-508 Functional Requirements for Transport API	
			TR-522 SDN Architecture for Transport Networks	
	OIF/ONF	SDN T-API Interop Demo	Executive Overview SDN Transport API Interoperability Demonstration	
			SDN Transport API Interoperability Demonstration	

B.2.4 PoC Suggested Action Items

- Provide suggested Action Items and/or further work required from the NFV ISG and/or external forums.

The PoC was originally derived from Use Case#1 described in the IFA022 WI regarding multi-site connectivity services, IFA022. In the context, the PoC team designed an underlying WAN infrastructure with their transport SDN features, and demonstrated how their SDN-based network infrastructure can be leveraged in the given scope by bringing together their diversified specialities of multiple SDOs, service providers/ vendors and research organization. As described in the identified gap, the current scope in IFA022 is limited so the outcomes in this PoC would be helpful. In our PoC activity, the T-API specified in OIF/ONF is applied as a solution for the Nf-Vi reference point, and the interoperability has been confirmed in this PoC. ETSI-NFV, therefore, leverage our outcomes when ETSI-NFV studies the multi-site services as a whole.

In the future direction of ETSI-NFV, the multi-site service with WAN connectivity has been recognised as one of the NFV key features for realizing 5G [5G]. The topic also relates closely to network slices and End-to-end Service Management. The PoC team, therefore, suggests NFV ISG should not limit their scope within a site but expand their scope to have better multi-site view.

[5G] “Network Operator Perspectives on NFV priorities for 5G”, ETSI-NFV

B.2.5 Any Additional messages the PoC Team wishes to convey to the NFV ISG as a whole?

- Provide any feedback in a free text format to the NFV ISG. Please indicate whether the team wishes any specific message to be published or publically quoted.

Architecturally, SDN controllers can be placed in a hierarchical model [NFVEVE005] and the top-level SDN controller should interact with external components through its NBI. In our PoC model, T-API was used as a solution for the NBI between the SDN controllers. The solution can also be a solution of Nf-Vi reference point for Network Controller for WAN infrastructure in ETSI-NFV.

According to the clause of "5.6.3 Roles and responsibilities" [NFVMAN001], the WIM should be responsible for the following aspects related to the NFVI connectivity services:

• *Path computation based on quality assurance factors such as jitter, RTT, delay & bandwidth calendaring.*

• *Establish connectivity over the physical network (e.g. set of MPLS tunnels).*

• *Provide a northbound interface to the higher layers, e.g. NFVO, to provide connectivity services between NFVI-PoPs or to physical network functions.*

• *Invoke the underlying NFVI network southbound interfaces, whether they are Network Controllers or Network Functions, to construct the service within the domain.*

As we demonstrated, the 1st and 2nd aspects have been implemented as common SDN controller services in our PoC. By leveraging the common services, shown in Figure 6, the top-level SDN controller can be extended for capabilities for WIM component. The 3rd aspect, which relates to Or-Vi reference point, needs to be cleared in IFA022 in order to clarify the rest of the WIM capabilities. The 4th aspect can be covered by our lower multi-domain or domain controllers. The SDN controller has capabilities to construct the network service within the domain.

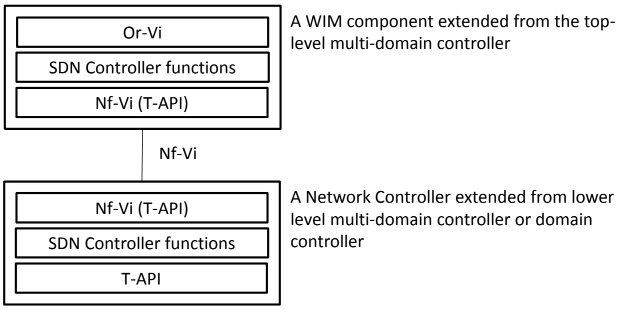

Figure 6 WIM and SDN-based Network Controller

B.2.6 Any Additional messages the PoC Team wishes to convey to Network Operators and Service Providers?

- Are there any specific requests/messages that the team would like to convey to Network Operators and Service Providers?

It was a great experience to work with members from service providers, research organization and vendors at the same place. We all appreciate Verizon, Telefonica and ETSI-NFV for providing and supporting this opportunity.