TELECOM INFRA PROJECT

CANDI First Experimental Demonstration

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Disclaimer

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1. Story of CANDI's roadmap

1.1. The final goal of CANDI

The goals of CANDI is to realize "Flexible feature allocation on IP & Optical network" , "Achieve efficient IP & Optical network" and "Provide inputs for OOPT sub-working group"

Following CANDIs goal, CANDI is taking below direction to reach the goals.

1. CANDI clarifies issues to be solved for the future vision of packet optical transport networks
2. CANDI will take step by step approaches for achieving each use-case (Figure 1)
3. The main objectives of the first PoC are as follows:
    - To establish and test the basic architecture and workflow as a first step
    - To include both packet networks and optical networks, but not fully integrated

This white paper summarizes the first PoC realized by the CANDI work group and the lessons learned after the trial. CANDI will continue to contribute to conducting enhanced PoCs twice a year to test and confirm of agreed upon use-cases and find the issues for developing the technology required to confirm the feasibility of operator's use-cases.

1.2. Summary of operator's use-cases

During its first phase, CANDI collected use-cases from operators. These use-cases are shown in Fig. 1. Initially, 10 use-cases were proposed from 5 carriers. 5 of the use-cases (use-cases 1, 3, 7, 9 and 10) were merged to "Provisioning of services in open optical and packet networks" because these use-cases are all related to the provisioning of network termination in both optical and packet networks. The current set of use-cases is detailed on the right part of Figure 1.

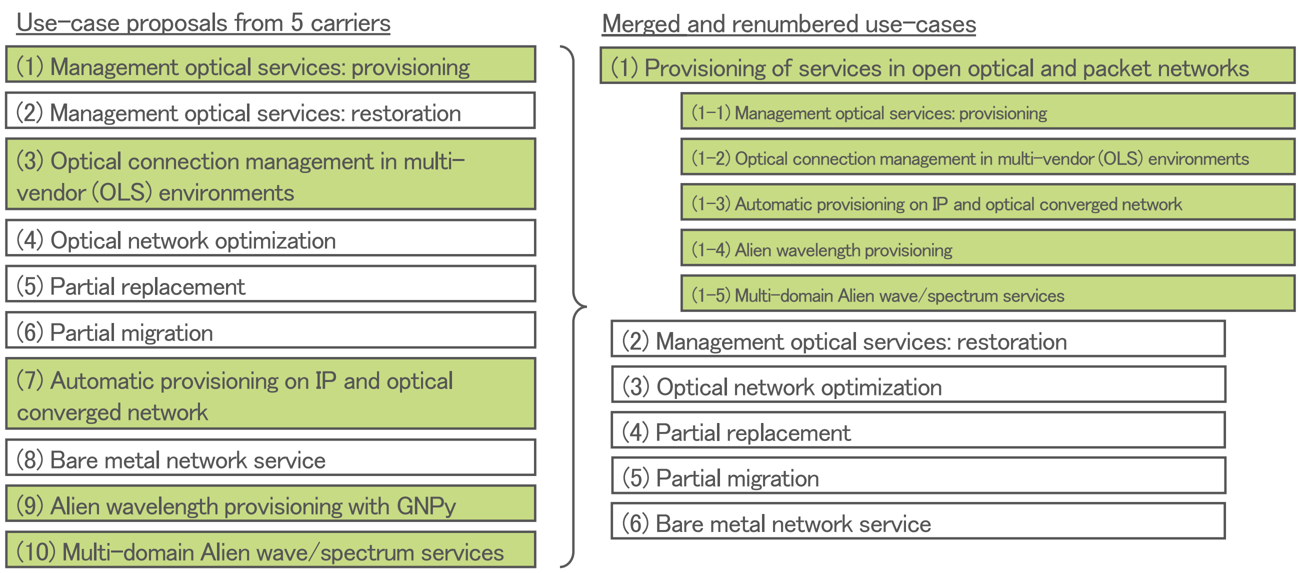

Figure 1. Use-case proposals

2. First experimental demonstration

2.1. Scope of demonstration scenario

Figure 2 shows the candidates of PoC trial scenario. CANDI's trial scenarios are assumed to be separated into Provisioning scenarios and Event-driven scenarios.

Provisioning scenarios are based on some operators' use-cases regarding service provisioning. We aim to not only perform IP termination point provisioning but also do optical circuit provisioning. First of all, in provisioning scenarios, we start with step-by-step configuration testing because we will define both the basic network design and operations for end-to-end service provisioning by this test. After that, we are planning service provisioning testing including path computation function. On the other hand, event-driven scenarios are based on use-cases except for provisioning use-cases. Currently, we consider the restoration scenario and network element update/migration scenario. Red dot boxes indicate the first trial target scenario.

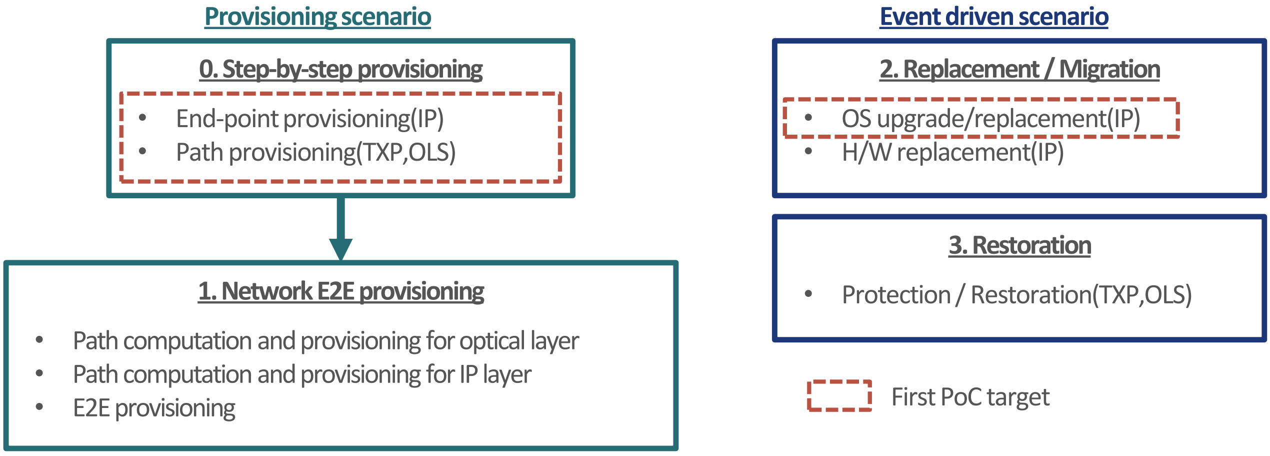

Figure 2. CANDI's trial scenarios

2.2. Schedule

Table 1. Schedule for PoC testing

Items	Due date
Start Develop/prepare environment	July 1, 2019
Complete PoC environment	September 30, 2019
Start PoC	October 1, 2019
Complete all PoC testing	November 13, 2019

2.3. Location

We conducted the PoC testing at Telefonica's laboratory in Madrid, Spain.

Telefónica Investigación y Desarrollo

Calle de Zurbarán, 12, 28010 Madrid, Spain

3. Provisioning testing

3.1. Test scope

3.1.1. Overview of related use-cases

The fundamental use-case for this testing scenario is UC1, which consists of several use-cases in both optical and packet networks. UC1-1, UC1-2, UC1-4, and UC1-5 are relating to optical networks, and these are based on the Alien wavelength provisioning service, which includes interoperability of both multi-vendor transponders and Open Line Systems (OLSs). UC1-3 is a use-case including packet networks, and that conducts to define the workflow of the end-to-end provisioning across both packet and optical networks. Also, UC1-3 aims at provisioning not only the packet network termination but also the optical network termination, so UC1-3 is addressing the provisioning of any network interface. See the right side of Figure 1.

3.1.2. Motivation

This test case has two aspects, efficient and user-friendly management and multi-vendor open systems. In terms of management, the Telecommunication Operators (TELCOs) separates the transport network service management between the optical layer and the IP layer due to the difference between IP and optical technologies, and a transport provisioning is performed based on two steps generally. Firstly, an optical path is created, and then an IP network is built on it based on demands, which include capacity, latency, and so on. This separation might cause inefficient end-to-end provisioning and a complicated operation flow. So, as the first step, we'd like to conduct a converged IP and optical workflow to make the current operation flow more efficient and comfortable.

On the other hand, we also consider open multi-vendor systems. Currently, TELCOs often rely on systems and solutions developed by a single vendor. However, closed solutions lead to delays in introducing new functionality and innovations, limitations of the functional variations and cost increase. In packet transport, hardware and software are currently coupled, so many functions of a vendor's IP device are in black-box and its capacity, features and operation are tightly coupled, that is, they are locked-in by each device's capability. Also, in optical transport network systems, both transmission and line, are usually provided by a single vendor. However, the life time of transponders (related to the traffic increase) is different from that of the optical line-systems (related to the investigation) [1]. Disaggregation of network components and open integration of them are promising paths for addressing those issues. Disaggregation breaks conventional network systems into some interoperable components, which expands choices of device or functional components [2]. Furthermore, integration of the components has a huge potential to lead to more efficient, easily manageable and significantly adaptive transport networks. In this test case, we'd like to confirm the achievement of interoperability in disaggregated network and standard's models for system integration.

3.1.3. Issues to be solved

Issues are categorized as "Disaggregation technology" and "Integration technology." In terms of disaggregation technology, main issues are addressing interoperability.

(IP layer)

1. Data plane interoperability among different Network OSs(NOSs)
2. Possibility of the mounting of different NOS on the same white-box hardware

(Optical layer)

1. Interoperability between OLS and several vendors' transponders
2. Interoperability between multi-vendors' OLSs

In terms of integration technology, we focus on standard model, and provisioning workflow.

1. Implementation status of open interface(OpenConfig and TAPI in 1st PoC case) in IP and optical components
2. Definition of end-to-end management workflow

In CANDI's first demonstration, we conducted end-to-end provisioning testing in IP and optical network, which include multi-vendor network components and hierarchical management systems, in order to confirm the status of achievements of above. However, please note that interoperability among multi-vendors' OLSs is out of scope in the first PoC. This will be confirmed in the second PoC or later testing.

3.2. Contributors

Telefonica: Provide PoC environment, optical devices, servers and controller / Provide test scenario on optical side / Define issues on optical side / Complete test on optical side

NTT: Provide test scenario on IP side / Define issues on IP side / Complete test on IP side / Provide packet controller

Telia Company/Orange/Geant: Comment to PoC

ONF ODTN [3]: Technical support on ONOS optical controller

ADVA: Technical support on OLS

ZTE: Technical support on transponder

3.3. Test specification and results

3.3.1. Service Deployment architecture, standards and workflow

In this test, we focus on a layer 2 VPN (L2VPN) provisioning scenario. The control architecture (Figure 3) considers that the open packet networks and optical networks are provisioned through a packet SDN controller and optical SDN controller (OSDNc) respectively, with a hierarchical controller ensuring coordination. OSDNc is in charge of configuring both the OLS and the Open Terminals, which is an X-ponder with open interfaces. OLS elements could be configured either directly from the OSDNc or via an OLS controller. In this testing, the management by OLS controller has been chosen because it simplifies the control of the Line System and removes the complexity from the OSDNc.

The configuration of both packet and optical network elements for the L2VPN provisioning is done with open interfaces' models. Both packet elements and open terminals are configured by using OpenConfig, which enables the device management including discovery, inventory retrieval, and configuration management. OLS is configured by OLS controller with the vendor's interface, but the North bound Interface (NBI) for the OLS controller is deployed with an open interface, ONF TAPI. The NBI for OSDNc is also using TAPI. TAPI provides three main end-to-end functions for optical management: (1) topology information, (2) service provisioning and (3) path computation. The NBI for the hierarchical controller to receive a service request is based on Restconf with the IETF L2VPN Service Delivery model [4]. Such a model describes the needs of a network VPN service in a vendor-neutral manner.

Figure 4 shows the schematic of the provisioning workflow used in this testing. This workflow starts from the network service call to the hierarchical controller, which contacts OSDNc if existing bandwidth is not enough and later contacts the packet controller for the VPN service setup in the white-boxes. In addition, the controllers are periodically retrieving the context, that is, the current status of topology and ports.

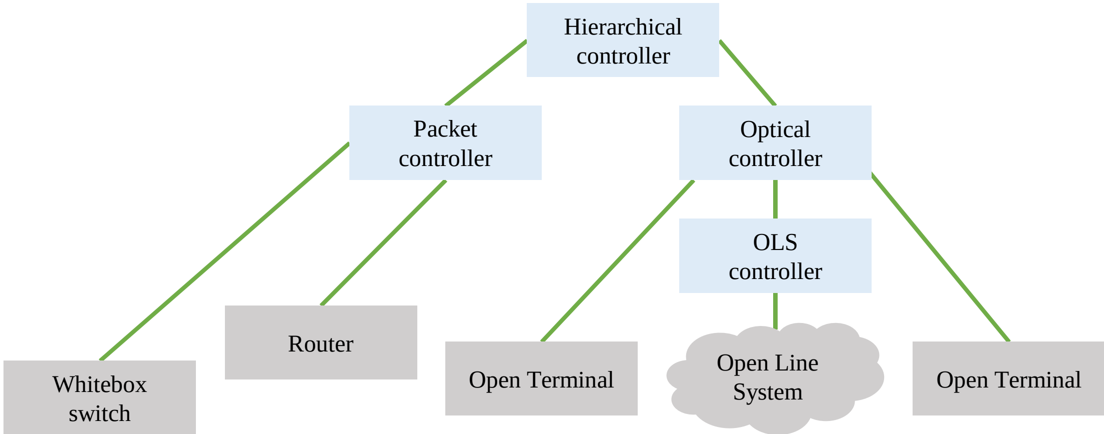

Figure 3. Architecture

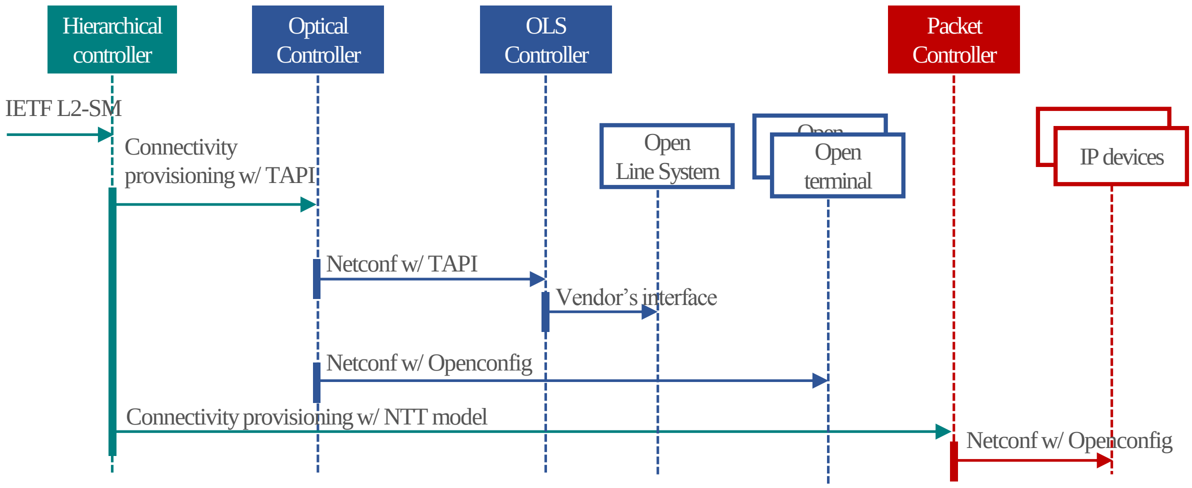

Figure 4. End-to-end provisioning workflow

3.3.2. Network configuration

The experimental testbed implements a partially disaggregated optical layer and a white-box based IP packet layer as shown in Figure 5. This optical layer is composed of two different paths. The first path used two commercial transponders from ZTE with open interface and client ports of 100Gbps connected to an open line system (OLS) from ADVA. The OLS is composed by 3 nodes in a ring topology (bottom Figure 5). The optical media channel used a 50GHz grid. The second path used 2 Cassini white-boxes (used as transponders) from Edgecore with software from IPInFusion with a 40Gbps client port connected to the IP white-boxes. The 40Gbps ports of Cassini are added into a 200G lambda. Cassini's line ports are connected directly as shown in Figure 5. The optical layer is managed by ODTN ONOS Optical controller.

The IP segments are composed as two sites. The first site is shown in left of Figure 5, and is built up with four IP white-box switches from Edgecore hardware with software from IPInfusion, Cumulus, and open-source Beluganos [5]. Leaf2 is used as border Leaf in site 1. Leaf2 is connected both to Cassini's IP port and ZTE transponder's client port. The second site is constructed from one Edgecore IP switch with IPInfusion software which is connected to both Cassini and ZTE transponder to connect with site1. Both two IP segments are managed by Multi-Service Fabric (MSF) packet controller [6] that is contributed by NTT. MSF manages both IP underlay and overlay configurations Underlay settings are completed before L2VPN provisioning testing by using single area OSPF is done. In the test, L2VPN will be established between Leaf1 with Cumulus and Leaf3 with Cumulus, by using EVPN-VXLAN. Network settings will be configured via Netconf/OpenConfig. Lastly, the parent controller from the Metro-Haul project [7] is used as hierarchical controller to connect via RESTCONF TAPI to ONOS and REST to MSF.

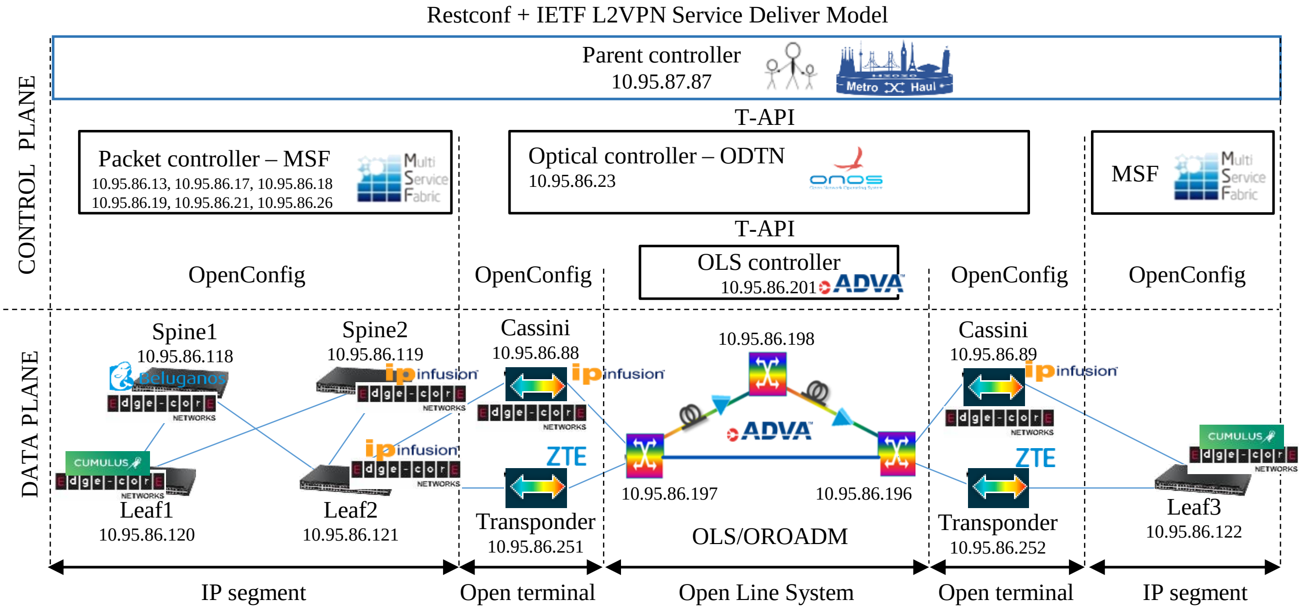

Figure 5. Experimental setup

Table 2. Management systems

Management systems			
Component	**Product**	**Quantity**	**Provider**
Parent controller	Hierarchical controller/Metro haul project	1	Telefonica
Optical controller	ONOS/ODTN	1	Telefonica
OLS controller	ADVA	1	Telefonica
Packet controller	MSF/NTT	1	NTT

Table 3. Network elements

Network elements			
Component	**Product**	**Quantity**	**Provider**
Leaf switch (H/W)	AS5812-54X/Edgecore Networks	3	NTT
Leaf switch (S/W)	OcNOS (MPLS-IPBase)/IP Infusion	1	NTT
Leaf switch (S/W)	Cumulus Linux/Cumulus networks	2	NTT
Spine switch (H/W) for Beluganos	AS5812-54X/Edgecore Networks	1	NTT
Spine switch (H/W) for Cumulus and OcNOS	AS5812-54X/Edgecore Networks	1	NTT
Spine switch (S/W)	OcNOS(DC-IPBase)/IP Infusion	1	NTT
Spine switch (S/W)	Cumulus Linux/Cumulus Networks	1	NTT
Spine switch (S/W)	Beluganos/NTT	1	NTT
Cassini (H/W)	AS7716-24SC/Edgecore Networks	2	Telefonica
Cassini (S/W)	OcNOS(OTN-IPBase)/IP Infusion	2	Telefonica
Transponder	ZXONE7000/ZTE	2	Telefonica
Line system (ROADMs)	FSP3000/ADVA Optical Networking	3	Telefonica

3.3.3. Test items and results

Table 4. Test items and results for provisioning scenario.

Items	Description	Result
IP1	[Verify interoperability among different NOSs in underlay setup] - Construct IP segment with several NOSs, Cumulus, OcNOS, and Beluganos. - Configure underlay with single area OSPF	☑
IP2	[Verify L2VPN connectivity among the same NOSs across to optical line] - Establish L2VPN between Leaf1 (Cumulus) and Leaf3 (Cumulus) - Establish optical paths before this test item.	☑
IP3	[Verify L2VPN connectivity among different NOSs across to optical line] - Establish L2VPN between Leaf2 (OcNOS) and Leaf3 (Cumulus) - Establish optical paths before this test item.	☐
IP4	[Verify OpenConfig implementation for packet elements] - Configure Cumulus, OcNOS, and Beluganos via Netconf/OpenConfig	☑
Opt1	[Verify Media channel provisioning in OLS with TAPI] - ONOS Optical Controller retrieves contexts and creates connectivity services (media channel) from/to SIPs (SERVICE INTERFACE POINTS). Restconf/TAPI 2.1.1 is used in ONOS-OLS Controller communication.	☑
Opt2	[Verify OpenConfig implementation in Open Terminal] - From ONOS configure the frequency (calculated by ONOS from OLS response) and power in the CASSINI box. - Retrieve configuration from the CASSINI box - From ONOS configure commercial ZTE terminal using standard OpenConfig interface.	☑
Opt3	[Verify optical connection provisioning in Optical Controller with TAPI and OpenConfig] - From Hierarchical controller retrieve context and create connectivity service from/to SIPs (client's ports of the transponders). Optical Controller selects the frequency of the media channel, provisions the media channel in the OLS and configures the transponder of the Cassini white-box with the chosen.	☑
(IP/Optical)	[Verify end-to-end provisioning through vendor-neutral VPN service model] - Establish L2VPN between Leaf1 and Leaf2 conducted by Hierarchical controller	☑

☑: Approved, ☑: Partially Approved, ☐: NG

3.3.4. Analysis

Some testing items are not achieved. The following conclusions are based on the authors' analysis, and these will be next challenges.

(IP3) OcNOS supports EVPN-VXLAN with VLAN-Aware Bundle Service Interface, but Cumulus supports EVPN-VXLAN with VLAN-Based Service Interface. EVPN-VXLAN implementations are different from each other, so we couldn't connect OcNOS and Cumulus via EVPN-VXLAN. This is valid not only NOS for the white-box but also for NOS branded switch, which also has a different implementation.

(IP4) Open-source NOS, Beluganos is already deployed. However, commercial NOS is not supported yet. Cumulus doesn't support Netconf and OpenConfig, but it supports RESTConf with Cumulus model. OcNOS supports Netconf with OcNOS model, but OpenConfig implementation isn't deployed.

(Opt2) The OcNOS for Cassini used in the tests had a partial implementation of OpenConfig. Therefore, it was possible to configure the main parameters (such as frequency), but not retrieve the configuration. Also, ONOS could not configure commercial ZTE terminal via OpenConfig. Pending test with standard OpenConfig driver in ONOS (no mature release is available in ONOS), so this was tested with commercial controllers, which are Cisco NSO and Ciena BluePlanet.

(OP3) The optical controller does choose the media channel to use but does not perform any physical impairments validation. Next PoCs will consider the use of the GNPy tool for such purposes.

4. Partial replacement/migration testing

4.1. Test scope

4.1.1. Overview of relating use-case

This test scenario is related to both UC4 and UC5. These use-cases aim to enable to replace existing network elements (NEs) to other network elements. Furthermore, by introducing the white-box switch, we enable not only the entire network element replacing but also the network OS (NOS) replacing. We also consider an effective system which manages replacement/migration function to avoid service interruptions.

4.1.2. Motivation

A carrier must sometimes carry out NE replacement and migration, but these works take a long time and during the works we must avoid service interruptions, so these works needs to be carried out when there is little use of services (e.g., at night time). On the other hand, by introducing the disaggregation model, we obtain some benefits (e.g., easy scaling), but the number of elements will be more significant so that the replacing opportunity might increase. Also, thanks to AI and machine learning, we will be facing various service requirements, and our infra network needs to follow these requirements. The number of migrations also might increase. Both UC4 and UC5 enable efficient replacement and migration and contribute to the background as above.

4.1.3. Issues to be solved

Issues to be solved are targeting the interoperability between any network OS and any network hardware, and effective replacement/migration management systems. Below are the major issues with UC4 and UC5 listed.

1. Interoperability between NOS and network device
2. Short duration for replacement/migration even if it is a large carrier network
3. Procedure of replacement w/o service interruptions

Especially, we focused on 1. Interoperability and 3. Procedure of replacement in first PoC.

4.2. Contributors

NTT: Provide test scenario / Define issues / Complete test / Provide packet controller / Provide network OS for white-box switch

Telefonica: Provide optical devices and servers / Comments to PoC

4.3. Test specifications and results

4.3.1. Workflow of partial replacement

Figure 6 shows the schematic workflow for a partial replacement. This workflow starts from the replacement call to the packet controller via REST API, thereafter the packet controller manages the NOS replacement procedure. Firstly, the packet controller changes interface configuration on the target switch to avoid traffic drop via Netconf w/ OpenConfig. Secondly, the NOS information stored in packet controller is updated to target NOS. Later, the packet controller conducts the NOS uninstall procedure and transfer NOS image to the target white-box switch. So far, NOS replacement is completed. In addition, after NOS replacement, the packet controller configures the same network settings into target NOS to let target NOS handle the same network function. These are the basic automatic NOS replacement procedures defined by authors.

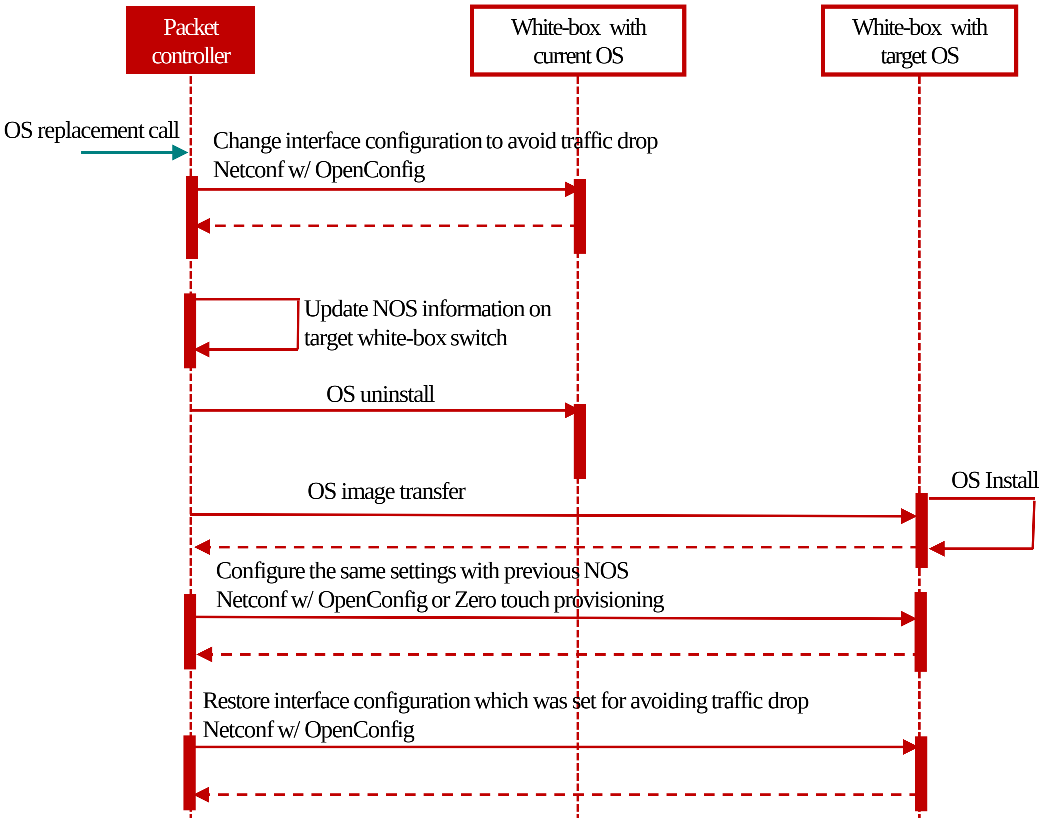

Figure 6. Workflow for automatic NOS replacement procedure

4.3.2. Network configuration

Testing environment is the same with provisioning testing, but this test case utilizes only one packet controller. In order to verify the NOS replacement without service interruptions, a L2VPN service is established before the testing. In this test, we conduct to replace OcNOS on Spine2 switch to Cumulus OS.

4.3.3. Test items and results

Table 5. Test items and results for partial replacement scenario

Items	Description	Result
(1)	[Verify interoperability between white-box switch and NOS] - Install three NOSs, Cumulus, OcNOS, and Beluganos, into the same hardware (AS5812-54X from Edgecore, respectively, in manual operation.	☑
(2)	[Verify Spine switch's NOS replacement with automatically procedure] - Replace Spine switch's NOS from OcNOS to Cumulus conducting all procedure by packet controller	☑
(3)	[Verify Leaf switch's NOS replacement with slight service interruptions] - Replace Leaf switch's NOS from OcNOS to Cumulus conducting all procedure by packet controller	☑

☑: Approved, ☑: Partially Approved, ☐: NG

4.3.4. Analysis

All of the test items were partially approved. Below are considerations listed for items not reached.

(1) Installation of three NOS has been tested successfully. However, OcNOS' license is locked by the hardware MAC. So, the hardware for OcNOS replacement oriented by user is difficult yet.

(2) We've done Spine switch's NOS replacement with partial manual operations. Uninstallation of OcNOS needs access via console, so we will consider the remote procedure for the uninstallation of NOS as a next step. However, automatically configuration restoration of the target switch has tested successfully based on our workflow.

(3) Leaf switch's NOS replacement has not been done because NOS replacement needs NOSs that have the same type of implementation of the overlay protocol. According to (IP3) of provisioning testing, NOSs have different implementation on EVPN-VXLAN, so we couldn't execute test case (3). If protocol implementation is the same, we can do this test case successfully. In terms of service interruptions, it took over 30 min to complete all procedures which include uninstalling current NOS to installing target NOS, and this may affect service connectivity. As well as we expect an improvement of NOS implementation, we will consider a more reliable replacement procedure.

5. Conclusion and next steps

5.1. Conclusion

A first proof of Concept has been conducted at Telefonica's laboraory in Madrid, bringing equipment from NTT, Telefonica and the participating vendors/organizations. The use-cases chosen for the first PoC were tested successfully.

By conducting the PoC a set of challenges were found to solve the proposed operator use-cases. While OpenConfig, the chosen data model for transponders, is supported in both Open Terminals and Optical Controllers, the commercially available implementations still lack some maturity and the data model was partially implemented. Regarding IP, the commercially available Network Operating Systems still lack the desired OpenConfig support.

In addition to the maturity issues, there are a set of challenges in the available standards and mechanisms. For example, the optical transponders expose little information. Additionally, the fiber link between the line ports of the transponder is not automatically discovered, and hence they must be indicated by configuration in the optical controller.

5.2. Next steps

First PoC extracted some challenges, such as data plane interoperability, OpenConfig implementation, and so on. We will continue to consider them in order to achieve each use-case. During year 2020 the OOPT-CANDI sub-project has 2 PoCs planned. During those 2 PoCs more detailed tests will be done in the provisioning scenario. Specific new features to be tested are end-to-end provisioning in both optical and packet layers, as well as packet-optical layer. In the optical layer the full path computation process will be tested, including routing, modulation format assignment, wavelength assignment and impairment validation. We hope to be able to include multivendor OLS tests in the optical layer provisioning tests during 2020. In the IP layer, CANDI will progress in the IP network configuration use-cases with standard interfaces supporting Data Center Interconnection and main connectivity services. Also, use-cases collaborated with other SGs (e.g. DCSG) will be defined and tested in next or later PoCs.

Appx. A. References

[1] E. Ricardi et al, An operator's view on introduction of white boxes in optical networks, IEEE JLT 36 2018

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[3] Open and Disaggregated Transport Network (ODTN) in the open networking foundation (ONF) https://www.opennetworking.org/odtn/

[4] B. Wen et al, IETF RFC 8466.

[5] Beluganos: https://github.com/beluganos/

[6] Multi-Service Fabric (MSF): https://github.com/multi-service-fabric

[7] Metro Haul project www.metro-haul.eu

Appx. B. Acknowledgment

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