Integrated IT and Network Orchestration Using OpenStack, OpenDaylight and Active Stateful PCE for Intra and Inter Data Center Connectivity

A. Mayoral(1), R. Vilalta(1), R. Muñoz(1), R. Casellas(1), R. Martínez(1) , J. Vílchez(1)

(1) Centre Tecnològic de Telecomunicacions de Catalunya (CTTC), Av. Carl Friedrich Gauss 7, Castelldefels, 08860, Spain, arturo.mayoral@cttc.es

Abstract We present an integrated IT and network orchestration using OpenStack for the deployment of virtual machines within DCs and OpenDaylight SDN controller for end-to-end connectivity provisioning across Ethernet networks (Intra-DC) and a GMPLS-enabled WSON with an active stateful PCE (Inter-DC).

Introduction

Cloud computing services are becoming an essential part of any enterprise IT infrastructure. Thus, it is one of the faster emerging businesses for Internet Server Providers (ISP). Data Centers (DC) interconnection is one of the major problems that service providers have to face. DCs have been spread geographically to reduce services' latency to the end user, and that has led into an exponential growth on the inter-datacenter traffic[1]. There is the need to adapt the actual rigid and fixed transport networks, enabling them with the flexibility provided with the Software Defined Networking (SDN) architecture.

SDN has emerged as the most promising candidate to improve network programmability and dynamic adjustment of the network resources. SDN proposes a centralized architecture where the control entity (SDN controller) is responsible for providing an abstraction of network resources through programmable APIs. One of the main benefits of this architecture resides on the ability to perform control and management tasks of different network forwarding technologies such as packet/flow switches, circuit switching and optical wavelength switched transport technologies, by the same network controller[2] altogether with upper-layer applications.

OpenFlow protocol[3] allows to program forwarding rules into OpenFlow virtualized switches inside DCs, through the definition of flows which can filter traffic of different traditional networking protocols. Inter-DCs aggregated traffic can be transported by a Generalized Multiprotocol Label (GMPLS)-controlled optical transport network (e.g., WSON or Flexi-grid DWDM transport network). A centralized entity, defined as SDN controller, integrates control functionalities of both network domains.

An Active Stateful Path Computation Element (AS-PCE[4]) is a PCE which maintains not only the traffic engineering information (link and node states), but also the state of the active connections in the network. The AS-PCE can receive the right of managing the active paths controlled by the nodes, allowing the PCE to modify or tear-down the connections established in the data plane. Here we propose to introduce an external AS-PCE as an SDN-enabler for a GMPLS-controlled optical transport network.

We propose an integrated orchestration of IT and network resources to provide intra/inter-DC network connectivity for deployed virtual machines (VMs) using OpenStack Cloud Computing system. The Intra/Inter-DC network connectivity is controlled by OpenDaylight (ODL) SDN Controller, with proposed extensions to request LSP provisioning to an external AS-PCE. Finally, we provide an experimental validation on the Cloud Computing Platform of the ADRENALINE testbed.

Architectural overview.

Fig.1 (left) shows the considered system architecture. On top, the SDN Data Center and Network Controller (Orchestrator) is responsible for handling Virtual Machine (VM) and network connectivity requests, which are processed through the Virtual IT resource controller (VIRC) and the SDN controller.

The orchestration process consists of two different steps: the VM creation and network connectivity provisioning (Fig.1, right). The orchestrator requests the creation of virtual instances (VMs) to the VIR, which, is responsible for the creation of the instances. The VIR is also responsible to attach the VMs to the virtual switch inside the host node. When the VMs creation is finished, the VIRC replies the VM's networking details to the orchestrator (MAC address, IP address and physical computing node location).

The SDN controller is a framework to implement end-to-end network control services in a centralized network entity. The SDN

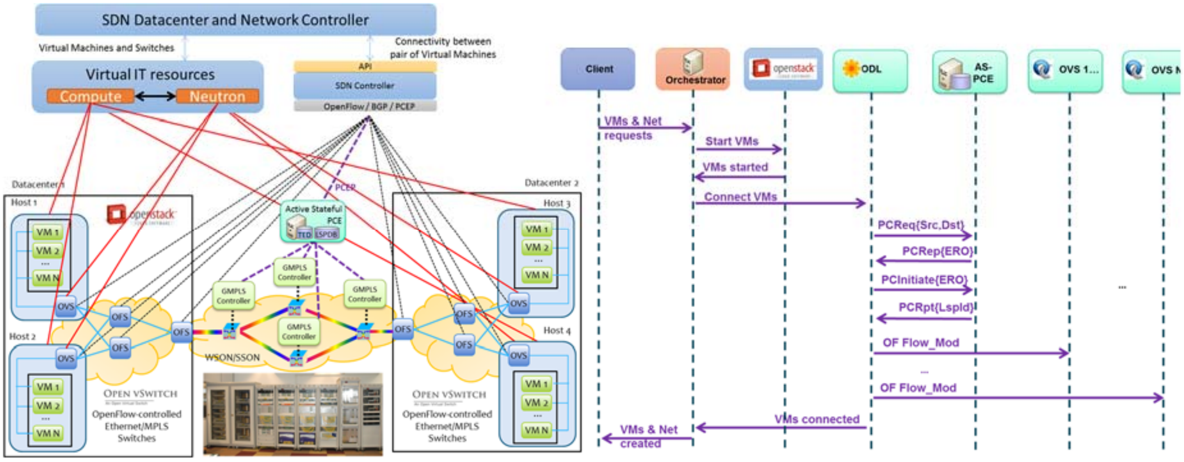


Fig. 2: Proposed architecture (left) and architecture message exchange (right)

controller offers a complete set of programmable Application Programmable Interfaces (API) to northbound applications from where to request networking information or switching configuration of the network infrastructure. The interfaces exposed are completely agnostic to the underlying network infrastructure allowing applications to request network connectivity services without being bounded to specific networking protocols. The core of the controller is a Service Abstraction Layer (SAL) which translates internal controller services and external applications' requests to the implemented networking protocols plugged in the southbound interface of the controller.

The southbound interface is composed by a set of plugins implementing different control and management protocols, to configure physical (hardware) network devices, such as OpenFlow, Netconf, Border Gateway Protocol (BGP) or PCEP among others.

The orchestrator requests to the SDN controller to perform the flow establishment between the two VMs deployed by the VIRC. After computing the route, the SDN controller is aware either of the positive reachability of the computing resources through the packet network (intra-DC) or whether an inter-DC connection is needed. In the first case, the SDN controller is ready to send the command to establish the forwarding rules to the OpenFlow-enabled switches and into the intra-DC switches. In the second case, the SDN controller needs to establish an optical lightpath between the DCs.

The AS-PCE has been demonstrated as a very robust and comprehensive solution to manage and control optical domains in a centralized manner[5]. With the presented active and stateful capabilities, the AS-PCE is a key SDN-enabler component.

AS-PCE can instantiate or tear down LSPs on the network through the stateful extensions using the LSP initiate request message (PCInitiate[6]). The PCInitiate message is the key-driver mechanism to request LSPs from outside the optical control plane. The AS-PCE acts as an interface between the SDN controller and the GMPLS control plane.

We propose to include a module into the SDN controller named PCEP-Speaker Service, which is responsible to request to an external AS-PCE the establishment of an optical LSP.

Experimental validation

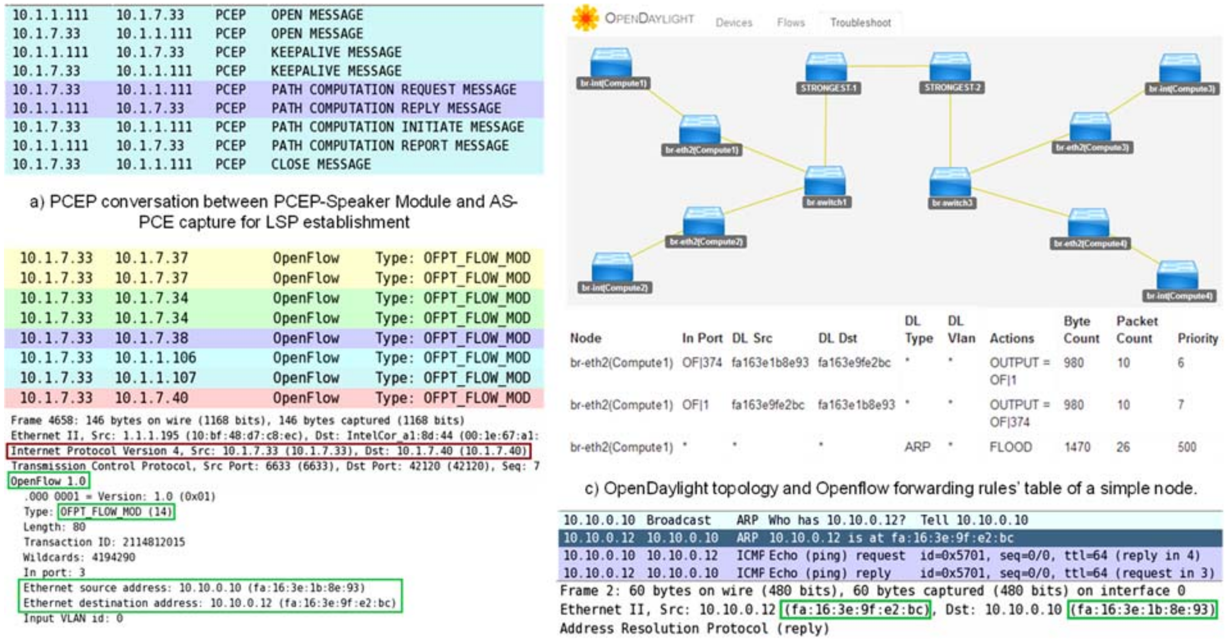
The proposed architecture has been validated in the Cloud Computing platform of the ADRENALINE Testbed. The OpenStack Havanna release has been deployed into five physical servers with 2 x Intel Xeon E5-2420 and 32GB RAM each, one dedicated to the cloud controller and the other four as compute pool (hosts) for VM instantiation.

Four OpenFlow switches have been deployed using standard Custom Off The Shelf (COTS) hardware and run OpenVSwitch (OVS), which can be controlled by OpenFlow 1.0.

Each Data Center border switch has been implemented using COTS hardware, a 10 Gb/s XFP tunable transponder and OVS.

Finally, the GMPLS-controlled optical network is composed of an all-optical WSON with 2 ROADMs and 2 OXCs providing reconfigurable (in space and in frequency) end-to-end lightpaths, deploying a total of 610 km of G.652 and G.655 optical fiber, with six DWDM wavelengths per optical link.

The SDN controller has been implemented with ODL service provider distribution, which has been expanded with several components such as a PCEP-Speaker module to establish



a) PCEP conversation between PCEP-Speaker Module and AS-PCE capture for LSP establishment

b) OF_FLOW_MOD messages to push forwarding rules into the OVSs.

c) OpenDaylight topology and Openflow forwarding rules' table of a simple node.

d) Ping capture proving end-to-end connectivity between launched VMs placed in DC1 and DC3.

Fig. 2: Experimental validation results.

the PCEP session with the AS-PCE.

Fig2.a shows the PCEP conversation between ODL controller and the external AS-PCE, which acts as a SDN enabler, to establish an LSP between the border nodes in the transport network. Fig2.b shows the OFPT_FLOW_MOD messages sent from the ODL controller to the corresponding OpenFlow switches. We can observe for example a Flow rule for VM with source MAC address (fa:16:3e:1b:8e:93) to VM destination MAC address (fa:16:3e:9f:e2:bc). In Fig2.c the abstracted topology from ODL is presented, and also an example of the forwarding rules injected in one of the OVS. For example, we can observe a rule for ARP packets and a specific source MAC and destination MAC rule to filter the traffic associated to the VMs end points.

Finally, in Fig. 2.d shows the ping exchange between the two previously presented VMs through the intra/inter DC network.

Tab. 1: System setup delays

System Setup Delays	
Service	Delay (s)
OpenStack VM launching	56.672
OpenFlow rules	1.375
LSP establishment	0.873
Total time consumed	58.920

A measurement of the time spent to the IT and Network orchestration process is shown in Tab.1. We can observe that only 59 seconds have been necessary to fully deploy and interconnect two virtual machines located in different DCs.

Conclusions

An integrated IT and SDN orchestration architecture has been presented. We have proposed extensions to ODL to interact with an external AS-PCE, which acts as an SDN-enabler.

Acknowledgements

EU FP7 project STRAUSS (FP7-ICT-2013-EU-Japan 608528) and Spanish MINECO project FARO (TEC2012-38119)

References

[1] "Cisco Global Cloud Index: Forecast and Methodology 2012-2017".

[2] M. Channegowda et al., "First Demonstration of an OpenFlow based Software-Defined Optical Network Employing Packet, Fixed and Flexible DWDM Grid Technologies on an International Multi-Domain Testbed", Proc. ECOC, Th.3.D.2, Amsterdam (2012).

[3] OpenFlow [Online], http://www.openflow.org/.

[4] E. Crabbe, "draft-ietf-pce-stateful-pce-08" IETF draft 2014.

[5] R. Casellas et al., "An Integrated Stateful PCE / OpenFlow controller for the Control and Management of Flexi-Grid Optical Networks", Proc. OFC OW4G.2, Anaheim (2013

[6] E. Crabbe, "draft-ietf-pce-pce-initiated-lsp-00" IETF draft 2013.