Towards an Open Networking Architecture

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***Abstract*—Open Networking is a very relevant concept for the networking industry: including Over-The-Top providers as well as Telco operators. There are two main concepts to enable an open environment: Software-Defined Networking (SDN) and White-boxes. SDN solution allows operators to deploy different network elements with a common view of the hardware components. Regarding SDN, there are initiatives to define a standard interface to the devices, like OpenConfig and OpenROADM. Similarly, there is an important effort for network abstraction at the Open Networking Foundation for the optical layer and IETF for the IP layer.**

On the other hand, white-boxes decouples the bare-metal from the installed software in a network element; this is the so-called: Network Operating System (NOS). There are two main initiatives to work in white-boxes for telco networks: Open Compute Project (OCP) and Telecom Infra Project (TIP). TIP and OCP have worked on white boxes for IP and optical networks.

This article presents how networks can evolve to an open networking architecture following an evolutionary approach levering on SDN and white-box technologies.

Keywords—Software Defined Networking; Telemetry; Disaggregation; Open Networking

I. INTRODUCTION

Network operators provide transport services to their customers thanks to the systems and solutions developed by the vendors. Closed solutions delay the introduction of new functionalities in the BSS/OSS layer as well as limits the innovation to program the network. Software Defined Networking (SDN) enables the configuration of network elements from a central controller. Operators have worked on the automatic provisioning of services in multi-layer [1] and multi-domain networks [2] with standard interfaces. The first step in this SDN evolution is to abstract a transport network as a domain and to program end-to-end services in the entire network. NETCONF/YANG [3] is a valid solution to program network elements and RESTconf [4] is the adopted technology to provide the connectivity between the SDN controllers. However, network disaggregation is a relevant concept for all the industry including network operators [5].

The network disaggregation paradigm started in 2009 with the Open Compute Project (OCP) [6] leaded by Facebook. This project was released with the goal of creating of open hardware specification (servers and racks) for datacenter and fulfill the technological requirements of the application. Later, in 2016 the Telecom Infra Project (TIP) [7] was released as a collaborative effort with the aim of provide open hardware for telecommunications. Those open initiatives had changed the networking paradigm and has led to the reduction of CapEx investments in infrastructure as well as some OpEx reductions based on the optimization of the power consumption or the selection of "base" components. In the majority of the cases, the open-hardware inclusion in the telecommunications infrastructure is focused on the disaggregation of some of the functionalities, including switching (rack interconnection) and transmission infrastructure (WAN interconnection).

Taking the optical domain as an example, there are three main alternatives when considering disaggregation. Fig 1 illustrates these three alternatives. Each architecture differs in the level of disaggregation. An aggregated architecture consists of a network where all the elements of the line system belong to the same vendor and operate as an end-to-end entity (Fig 1-a). Fig 1-b shows a partially disaggregated scenario, which have two elements: Open Terminals (OT) and Open Line System (OLS). The OTs are the transponders with a standard interface and the OLS is composed by the WSSs, wavelength multiplexers, optical amplifiers, etc. Fig 1-c depicts a fully disaggregated scenario decouples. This alternative separates all the elements in a line system and allows them to operate as a stand-alone entities. Similar disaggregation scenarios can be replicated for other network technologies such as the RAN, IP routers or the Access devices.

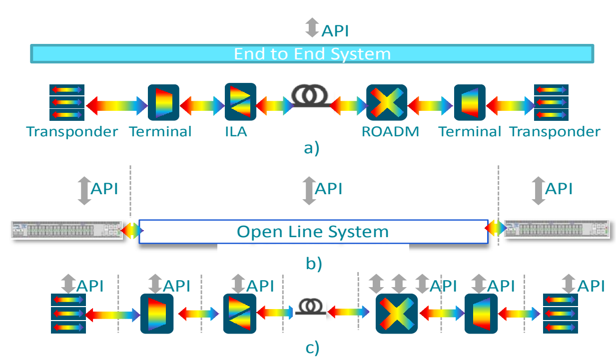

Fig 1 Disaggregated Network Architectures: a) Aggregated, b) Partially Disaggregated and c) Fully Disaggregated [3]

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II. STANDARDS-BASED SDN ARCHITECTURE

SDN concept has radically evolved in order to be adopted by the service providers (CSP). The initial SDN architecture was released in 2011 and promotes the idea of a decoupled control/forwarding plane. It includes a centralized controller to manage the entire network intelligence. In the last years, this concept has been left behind and just promoted for small networks or greenfield deployments. In carrier-grade scenarios were the service reliability and network availability are crucial for business continuity, the SDN controller (SDNc) concept has evolved and re-defined.. Thus, for the service provider scenarios, the physical devices still preserve some of their intelligence (the control/forwarding decouple is fuzzy) and some decisions are complemented with the controller's usage. The controller still supports the application's integration and intelligent routines to control the devices in some of the packet forwarding tasks. As a centralized element, the SDNc is the key to maximize the usage of the network (i.e. devices and links occupancy) and support lot off the operational tasks such as: monitor, manage and troubleshoot services.

Authors in [8] presented an SDN architecture to enable the SDN adoption and deployment in the service providers. This architecture was named iFUSION and it includes a reference model to hierarchically decouple the service and network domains. The iFUSION architecture (Fig 2) defines the roles and functionalities of each of the components in the SDN environment and is designed to support abstraction and modularity.

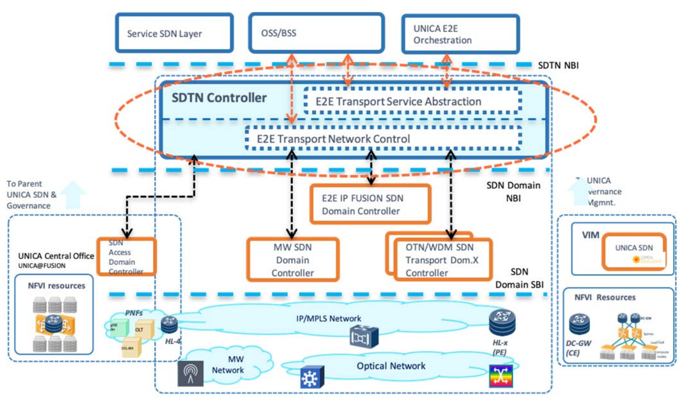

Fig 2 iFUSION Architecture

The iFUSION architecture is mainly based on the concept of hierarchical orchestration. In that way, each technology (IP, MW or TX) is managed by its own SDNc:

- IP and MW domains have a high level of vendor interoperability, for this reason only one domain controller is required per technology type.
- The optical domain requires an SDNc per vendor to deal with physical impairments' calculation and OTSi signal equalization.

Based on this, every domain SDNc abstracts the complexity of deploying or discovering a service within its own domain, delegating multi-layer and multi-domain logics to a higher-layer orchestrator, called Software Defined Transport Network controller (SDTNc). The SDTNc acts as the single entry-point for operational/business systems to request network resources and data. The SDTN has two logical layers: the E2E transport network control, capable of gathering data from the different layers and provide a coherent aggregated view; and the E2E transport service abstraction, in charge of implementing the logic for service mapping, service binding and multi-layer optimization. Each management layer intends to reduce the complexity to enhance network operation and service delivery by reducing integration costs between management layers.

In the bottom part of this architecture is the Fusion Network which is a new generation IP/MPLS + DWDM transport network. Thus, the integration of disaggregated optical networks is key to operate the network as whole system. To do so, there are two key aspects from the SDN perspective. First, the support of OpenConfig[13]/OpenROADM[14] in the transponders or Open Terminals (OT). Secondly, an SDN controller that can configure such OTs using the selected interface. The entity to configure such OTs should be the Optical SDNc, but there is not a great support in the market for OpenConfig as a South Bound Interface (SBI). Therefore, we could provide the end-to-end view of the optical layer from the SDTNc, as it has the capability to provision multi-technology services. Both options are open and the industry will decide which is more attractive.

III. WHITE BOXES ARCHITECTURE (0,75 PAGES)

Similarly as the SDN architecture has a modular architecture, White-boxes can have several flavors based on the combination of their components and the way those are deployed. To form the "box-system" the hardware and software components are required but the provider can select them in separately:

- Baremetal Hardware: Hardware system formed with a set of components such as: chipset, memory, pluggables, etc.
- Network operating system (NOS): Software installed in the bare metal to support the networking functionalities (L2, L3, etc.).
- Box system: Consists of the NOS plus a selected bare metal.

Regarding the baremetal hardware It has been available as part of the datacenter infrastructure since several years ago. Several commercial solutions have adopted an architecture combining an underlay leaf-spine fabric based on baremetal hardware with a virtual network overlay controlled by a common SDN controller for both networks (i.e. physical and virtual) [15-16]. Usually, this physical layer includes commodity L3-switches with a high port capacity/density. Those switches usually have a modular distribution to support stacking in datacenter environments. Until now, several advantages have been reported by these deployments including: Simple and flexible network control, reductions in the Total Cost of Ownership (TCO) and eliminate vendor lock-in. Nowadays, the bare metal ecosystem has been growing and there are several possible combinations to acquire the HW or SW based on the necessities.

Lately, the baremetal optical devices has evolved from the IP infrastructure. To the common datacenter fabric switches some line-side ports has been added to support optical transmission. These devices are industrially known as Disaggregated Optical Systems (DOS). Nowadays there are four DOS defined within the TIP-OOPT group: Voyager, Cassini, Phoenix and Galileo. Each option has their own features and a particular maturity level:

- Voyager architecture was an original design contributed by Facebook that is now being evolved and taken to market by Adva Optics, running software from Cumulus Networks. The design is a 1 Rack unit (RU) with 2.0Tbit/s of I/O capacity and 4x100/200 Gbps coherent optical interfaces.
- The Cassini is an open packet transponder tested in several scenarios; including some commercial ones [17]. The hardware is commercially available from EdgeCore Networks and the NOS from IP Infusion. The design is a 1.5 RU with 3.2Tbit/s of I/O capacity and it offers a great mix of interfaces including 100GigabitEthernet, L2/L3 switching interfaces and 100/200Gbps coherent optical interfaces.
- Galileo it is a 1 Rack unit (RU) form factor with 12 QSFP28 ports and 4 Plug-In Unit line card slots.
- Phoenix is an open white-box L0/L1 transponder. It is completely based on disaggregated components to support up to 400G interfaces. The design is still under design.

The three first solutions share a common design including: host board, Ethernet application-specific integrated circuit (ASIC), and optical transport module. Phoenix does not have an ASIC. The NOS runs on the host board, which consists of the CPU, memory, and storage.

In the case of the NOS, it has two main roles: to control the hardware components and to provide a management interface for the user and SDN controller. Similarly, to the hardware, multiple commercial NOS vendors are used in disaggregated networking hardware. However, there are just three open source NOS implementations:

- Open Networking Linux (ONL) is a software layer to deploy a modular NOS architecture on open networking hardware. Since it does not include components for Ethernet ASIC control, ONL itself is not a functional NOS. However, it provides an abstraction layer to port the system into different hardware.
- Software for Open Networking in the Cloud (SONiC) is an open-source NOS. It includes Ethernet ASIC control and user interfaces, so works as a full functional NOS.
- OOPT NOS focuses on a reference open source NOS that supports OOPT disaggregated hardware platforms offering the following benefits to accelerate the innovation in IP and Optical networks. Now, it is in an early stage.

IV. Conclusions

Network operators deploy their transport services using the systems and solutions developed by the vendors. Current optical designs in production are mono vendor solutions. There is a trend in the industry to migrate to disaggregated environments since they speed up innovation and allow operators to select across more technological solutions. SDN is a key technology to deal with such heterogeneous scenario, so the network operation can have an end-to-end view. On the other hand, white-boxes provide to open the network a further step ahead. They enable deploying the SW and the HW for different parties. This open ecosystem creates new opportunities and challenges to change the telecommunication industry like it happened in data center architectures.

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