Enabling Data Analytics and Machine Learning for 5G Services over SDN-Controlled Disaggregated Multi-Layer Transport Networks with Model-Driven Development

Ramon Casellas, Ricardo Martínez, Ricard Vilalta, Raül Muñoz (**CTTC/CERCA**)
e-mail: ramon.casellas@cttc.es

EXTENDED ABSTRACT

SDN solutions for transport networks are often associated to single-vendor optical domains, managed as single entities, commonly referred to as fully aggregated. Controllers do export and expose interfaces for the limited control of abstracted resources and operations via north-bound interface (NBI) but such APIs are often vendor specific and internal control aspects related to provisioning, monitoring and resource management remain proprietary and not disclosed. Disaggregation of optical networks refers to a deployment model of optical systems, by composing and assembling open, available components, devices and sub-systems. This disaggregation is driven by multiple factor (the mismatch between the needs of operators and the ability to deliver adapted solutions by vendors or the increase in hardware commoditization) and disaggregated networks are an excellent use case for open and standard interfaces, showing the benefits of a unified, model-driven development.

In addition to this, recent advances related to the concepts of Artificial Intelligence (AI) and Machine Learning (ML) and with applications across multiple technology domains, have gathered significant attention due, in particular, to the overall performance improvement of such automated systems when compared to methods relying on human operation. Using AI/ML for managing, operating and optimizing transport networks is increasingly seen as a potential opportunity targeting, notably, large and complex environments. Such AI-assisted automated network operation is expected to facilitate innovation in multiple aspects a promising milestone in the evolution towards autonomous networks, where networks self-adjust parameters such as transceiver configuration. Current network control, management and orchestration systems need to enable the application of AI/ML techniques.

We present the control, orchestration and management (COM) architecture designed to allow the automatic deployment of 5G services (such as ETSI NFV network services) across metropolitan networks, conceived to interface 5G access networks with disaggregated elastic core optical networks at multi Tb/s. This network segment, referred to as Metro-haul, is composed of infrastructure nodes that encompass networking, storage and processing resources, which are in turn interconnected by open and disaggregated optical networks. In particular, we detail subsystems like the Monitoring and Data Analytics or the in-operation planning backend that extend current SDN based network control to account for new use cases.

The underlying infrastructure (spanning multiple geographic locations) relies on macroscopic nodes, combining networking, processing and storage resources. Such modular devices are composed of different components operating at different layers and technologies, including local pool of servers to instantiate virtual network functions (VNFs) with configurable amount of processing, memory and storage. Concrete specializations of the generic architecture are at the Access Metro Edge nodes (AMEN nodes) to interface with heterogeneous access technologies and at the Metro Core Edge nodes (MCEN nodes). Main parts include, notably: 1) The *Optical disaggregated transport network,* which provides high bandwidth, low latency connections between remote locations and constitutes the infrastructure core part; 2) *Packet switched networks*. Each location includes a Layer 2/Layer 3 packet switched network that aggregates traffic coming from access and aggregation networks and which provides connectivity to functions and applications running locally. 3) *Computing and Storage Infrastructure*. A variable number of computing, storage, and virtualization servers, available at every location, part of the NFVI.

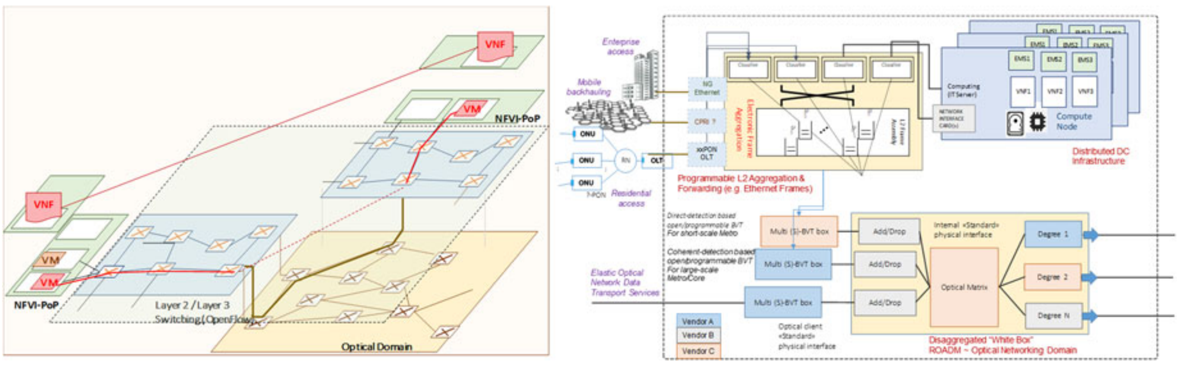

Fig. 1. Metro-Haul Infrastructure, showing the main components: the disaggregated transport network interconnecting Metro-Haul locations (AMEN/MCEN nodes), the packet switched networks and the NFVI PoP encompassing computing, storage resources.

Targeted Metro-Haul Services and Control, Orchestration and Management (COM) System

Our main targets are: 1) *Network connectivity services* provisioning between MAC endpoints, IP addresses or optical layer ports; 2) *Virtual Services*. Metro-Haul include cloud resources to support the instantiation of VMs and VNFs, being able to configure VMs and attach virtual NICs to soft switches, 3) *ETSI / Network Function Virtualization (NFV) Network Services and slicing* and 4) *Monitoring Services*. Cognitive network architectures have been proven to self-adapt the network in a cost-effective manner (autonomic networking). Specifically, by applying data analytics to monitored data, control loops can be enabled, where analysis outcomes can be used to recommend network reconfiguration actions to the SDN controller. The use cases are related to i) **Open Line Systems (OLS) monitoring**. Considering the disaggregation of a network into functional blocks (such as transponder, ROADMs and/or degrees in a switching fabric). Such disaggregation benefits from monitoring e.g. for alien wavelengths, and to optimize the power levels. Similarly, for coherent transmission, additional parameters (dispersion, differential group delay, BER) can be monitored and estimated, enabling closed loop control and optimization of bandwidth-variable transponders; ii) **Transport Network Re-optimization.** The collection of statistics and historical data regarding service requests allows to predict demands (e.g. using ML) and to re-optimize periodically ensuring an efficient network-resource optimization, towards an autonomic infrastructure that proactively self-configures and self-tunes may. Traffic matrices may be estimated periodically with dedicated probes, and algorithms may re-arrange connections and iii) **VNF placement across transport networks**. 5G services requiring the deployment of virtualized network functions (VNFs) may be constrained in terms of latency, jitter or bandwidth, especially if deployed in a metropolitan or WAN network. For example, some of the VNFs may be located near the end users, while those requiring additional computing power only in dedicated data centers.

To dynamically deploy such services, we adopt SDN/NFV principles and frameworks, extended with additional dedicated systems. Its architecture consists of four blocks: *Network Control and Orchestration* relies on an over-arching control adopting hierarchical control architectures with a parent SDN controller abstracting the underlying complexity; *Compute and Storage Integration via SDN/NFV:* Joint IT/Cloud and Network Orchestration is used to refer to the coordination of resources to deploy services and applications that require storage, computing and networking resources.; *ETSI MANO / Slicing Integration: t*he ETSI NFV framework can be used as a starting point for generic slicing architecture, in which network slice instances are NFV Network Services (NS), encompassing NS endpoints and one or more VNFs interconnected by logical links, forming VNF forwarding graphs (VNFFGs) and *Monitoring and Data Analytics* Autonomic networking entails the capability to do measurements on the data plane and generating data records that are collected and analyzed to discover patterns (knowledge) from data.

The core of this work is the SDN control of the optical transport network. The approach is based on having a SDN controller controlling one or mode devices, which are characterized by their data model. In general, a device *Data Model* determines the structure, syntax and semantics of the data that is externally visible. YANG is the selected data modelling language and we are considering mainly two sets of data models for abstracting optical hardware devices. OpenConfig for terminal optical devices within a DWDM system and the OpenROADM multi-source agreement which focuses on functional disaggregation and covers pluggable optics, transponders and ROADMs. A *protocol* offers primitives to view and manipulate the data, providing a suitable encoding as defined by the data-model. For YANG, the NETCONF protocol, enables remote access to a device.

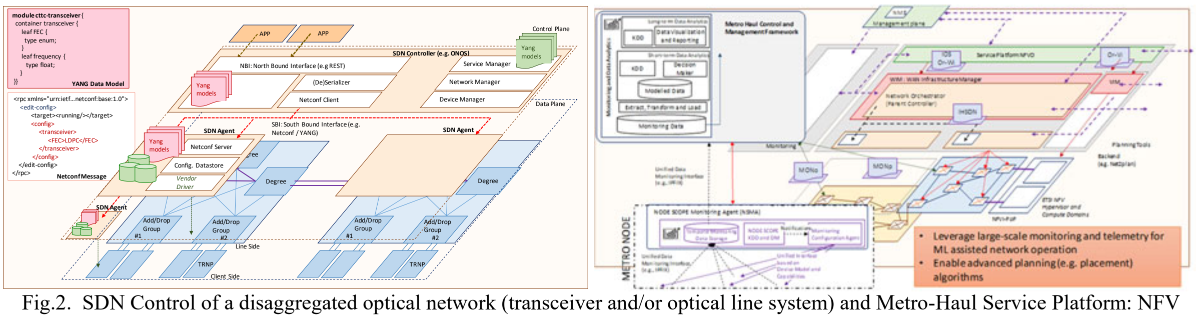

Fig.2. SDN Control of a disaggregated optical network (transceiver and/or optical line system) and Metro-Haul Service Platform: NFV MANO system, a hierarchical packet over optical SDN control extended by dedicated Monitoring and Data Analytics Subsystem (MDA) and a Network Planner (NP) backend

Acknowledgements: The work presented in this paper has been partially funded by Spanish MINECO DESTELLO (TEC2015-69256-R) project, and project H2020-ICT2016-2 METRO-HAUL (Proposal number: 761727).