Redesigning the network edge for a new era

Cloud central office; CO infrastructure; PON access; Mobile access; Edge; MEC; 5G small cell

White paper

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Introduction

Society, as we are experiencing it today, is the result of the major impacts produced by a new worldwide COVID-19 pandemic. The health crisis led to big changes in the way we relate to each other at both personal and professional levels, where the once common close proximity between people was replaced by social distancing and remote interactions. This new way of life also promoted a huge move of work locations since a significant number of people switched their workplace in a couple of days and started to work from home. As a result, there was a big shift in the point of access distribution in the telecom operators' network, together with a steep increase in the overall data traffic. It is expected that these types of changes may happen more often. Hence, the operators need to have an agile network infrastructure that can quickly be adjusted to cope with these needs and the ever-increasing demand for new services while assuring the reliability and resilience required so that businesses can perform and prosper in this "new normal", much more dependent on digital.

With the emergence of more digital services, there was also the need for higher broadband demands, both in latency and throughput. These requirements led to the study of a new geographical distribution of the services, moving them closer to the user and thus paving the way for the re-architecture of the central office (smaller data-centers that are closer to the user and the termination of the access network). As an important player in this ecosystem, Altice Labs has been targeting these moves and since last year has been working on the definition of its approach to what it foresees as the new cloud central office (CCO). The work introduced in the 2018 edition of InnovAction [1] has evolved, resulting in a more complete architectural view, presented in this article.

These changes are also on the radar of the telecommunications community and Broadband Forum (BBF), a leading standards development organization (SDO) for the fixed broadband. In the last couple of years, BBF started working to address the new CCO and is currently specifying an architecture that gives support to the more agile and automated network infrastructure and services. In this central office, a new degree of flexibility will allow the mapping of services to the corresponding resources using as a basis a set of YANG-based common management models that will enable better and faster deployment of automated processes to manage these next-generation networks.

A set of new concepts and technologies have emerged in recent years that helped the push for digitalization of the networks and enabled service providers to a faster transition to that next generation digital service provider paradigm where network agility and automation are essential, namely: network virtualization, software-defined networks (SDN), and network functions disaggregation.

This article will explore the work Altice Labs is doing towards the automation of the service provider network, with a special focus on the CCO, where a significant part of the network infrastructure resides. It starts by providing an overview of the new CCO architecture as foreseen by Altice Labs. Next, the main processes that allow an automation of the CCO are explained, followed by some use-cases that illustrate the previously described processes. Finally, a summary of the main findings is presented in the conclusions section.

Cloud central office architecture

As mentioned before, the central office is experiencing a significant change in its architecture. More than speaking about evolution, we should more appropriately be speaking about a true revolution because most of the fundamentals of the new CCO sever the ties to the old legacy approach and create a completely renovated environment where the old monolithic and rigid functions are replaced by a dynamic, integrated and automated virtualized functions ecosystem.

Altice Labs' vision for the new CCO, presented in this section, is based on the work being conducted by the BBF regarding the CCO architecture.

BBF reference architecture

The BBF, as previously referred, is the reference SDO for the fixed access domain. In 2018 it published the TR-384 - Cloud Central Office Reference Architectural Framework [2] with the purpose of defining the architecture for the next generation central offices, leveraging the agility of SDN, network function virtualization (NFV), and cloud technologies. This architecture has already been described in the abovementioned 2018 InnovAction article [1].

Since the publication of TR-384, the CCO architecture is being revised in WT-411 - Definition of interfaces between CloudCO Functional Modules, yet to be published. **Figure 1** summarizes the CCO architecture.

There is a clear separation of the access segment, the edge segment, and the NFV infrastructure (NFVI). Each segment has an SDN manager & controller (SDN M&C) not only responsible for delivering traditional fault, configuration, accounting, performance, and security (FCAPS) functionality (the edge management plane functions block in **Figure 1**) but also for providing disaggregated control plane functionalities (the edge control plane functions block in **Figure 1**).

The CCO domain orchestrator (CCODO) role is to orchestrate all the network segments and provide a high-level view of the CCO network. The latest is provided through a northbound (NB) API that abstracts the CCO network without the need to expose the internal CCO architecture components, allowing the use of a network-as-a-service (NaaS) paradigm. To complement this work, a set of TM Forum API have been identified by the BBF to be used on the operations systems-management-CCO domain orchestrator (OS-Ma-ccodo) reference point, including the service inventory, service catalog, and service fulfillment API. The NB API exposed by the CCODO makes use of a dynamic data model that is provided to different actors: the service consumer, the service developer, and the service provider.

The end-to-end service orchestrator (E2ESO) provides the E2E view of the operator network and coordinates multiple CCODO as well as the wide-area SDN controller and orchestrator that connects the different CCO domains.

The access segment has no user plane Virtual Network Function (VNF) because it concerns the access nodes (e.g., optical line terminations - OLT, distribution point units - DPU), which connect the end customer to the operator network. In the access segment there is also the broadband access abstraction (BAA) layer, which provides a standardized NB API for all access nodes, including legacy nodes.

The edge segment is the place of the broadband network gateway (BNG). TR-459 [3] defines an architecture and requirements of a disaggregated BNG (DBNG) leveraging control and user plane separation (CUPS) and virtualization principles. A DBNG can have a single control plane instance controlling multiple user plane instances. The control plane and user plane instances can be either virtual or physical and can be scaled independently.

Currently, one of the main goals of the SDN/NFV work area of the BBF is to define all the interfaces between the CCO components. Many of these interfaces rely on NETCONF/RESTCONF [4][5] and YANG for modeling, so in the last few years, a great amount of work has been done by the BBF in publishing standardized YANG data models [6].

Another goal of the SDN/NFV work area is to identify and disaggregate the functionalities of the access nodes so that they can be implemented outside of the access node and increase flexibility. The BAA layer is a good candidate to absorb these functionalities.

An example of such a disaggregated function is the virtual ONT management control interface (vOMCI). . A reference implementation of the vOMCI specification is currently in progress in the open broadband - broadband access abstraction (OB-BAA) open-source project. The OB-BAA project is the Broadband Forum's reference implementation of the BAA layer, and Altice Labs is actively contributing to it.

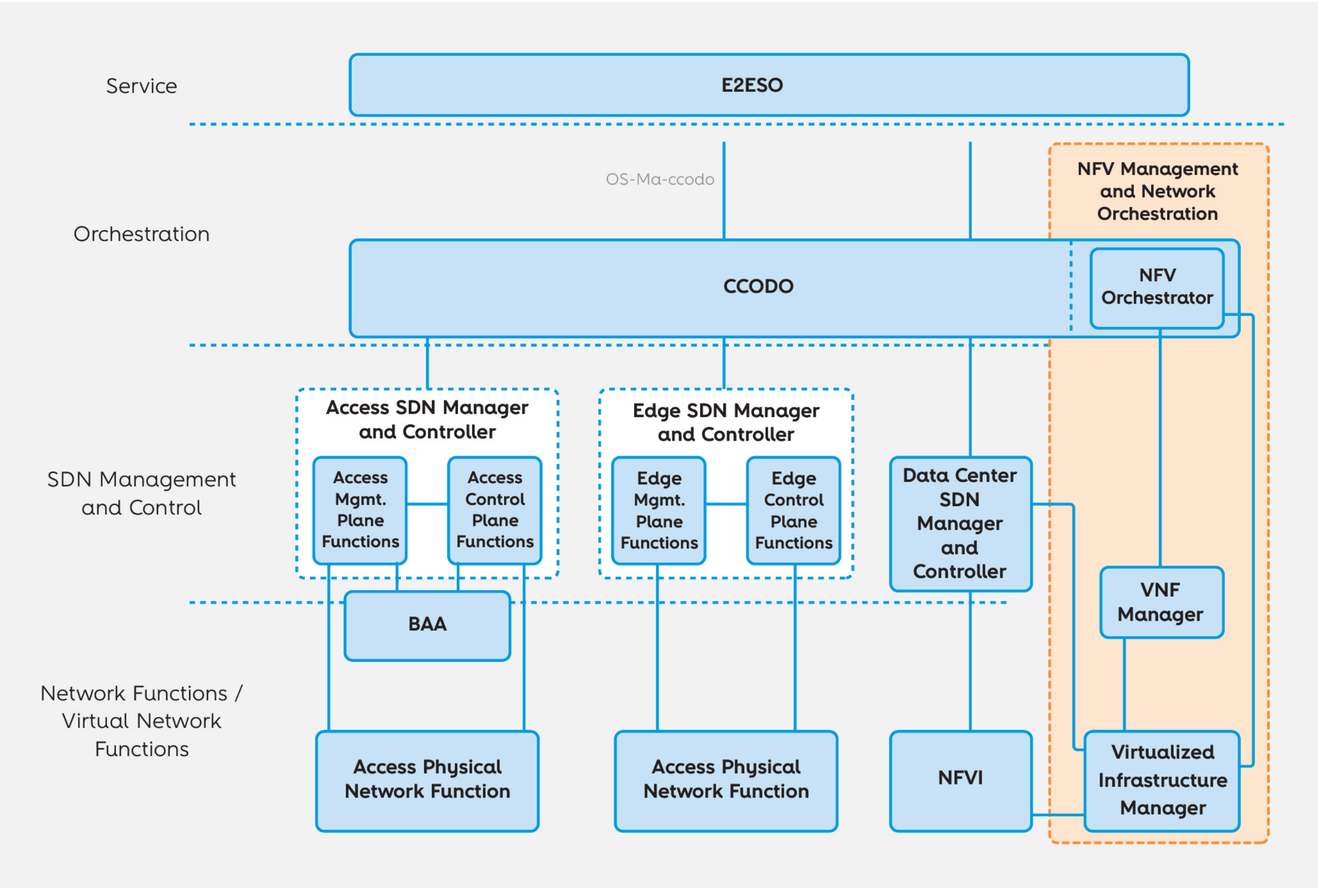

Figure 1 – BBF reference CCO architecture

Altice Labs' reference architecture

Altice Labs has been closely monitoring the work of the BBF and defined its own and aligned view of the, and, more generally, to the edge of the operator's network, setting up the scenario for the evolution of its own portfolio. In this view, various access networks converge and benefit from co-location and from the softwarization of their functions to enable truly convergent approaches [7]. Edge network functions, like the BNG for fixed networks or the user plane function (UPF) for 5G, also relate and coexist, share services, and reorganize into convergence supporting functions, like the access gateway function (AGF) or the fixed-mobile interworking function (FMIF). Edge computing is also supported to enable other functions, eventually from other providers or clients themselves, to be supported on the networks' edge.

Figure 2 shows a very high-level view of the reference architecture defined by Altice Labs. Aligned with the BBF approach, it features several technical domains or segments: access segment, corresponding to the termination of the various access networks, edge segment for network edge functions, multi-access edge computing (MEC) segment for edge cloud, and data a center infrastructural segment comprising NFVI, management and network orchestration (MANO), and data center SDN Manager & Controller (M&C). For each of these segments, there is an M&C plane specific to the segment to expose to the CCODO the interfaces that will allow it to manage and coordinate all the processes across the CCO. Above the CCODO, an E2ESO will coordinate the activities necessary to provide and maintain services across the various networks and platforms.

The major principles that drive this architecture are evident in **Figure 2** representation. Horizontally, there is a clear and fundamental separation between the user plane and the control plane to guarantee the CUPS advantages [8]. Vertically, there are apparent silos in the approach. These correspond to internal technical domains under common orchestration and whose control mechanisms can be shared across domains, enforcing the SDN principle of centralized control.

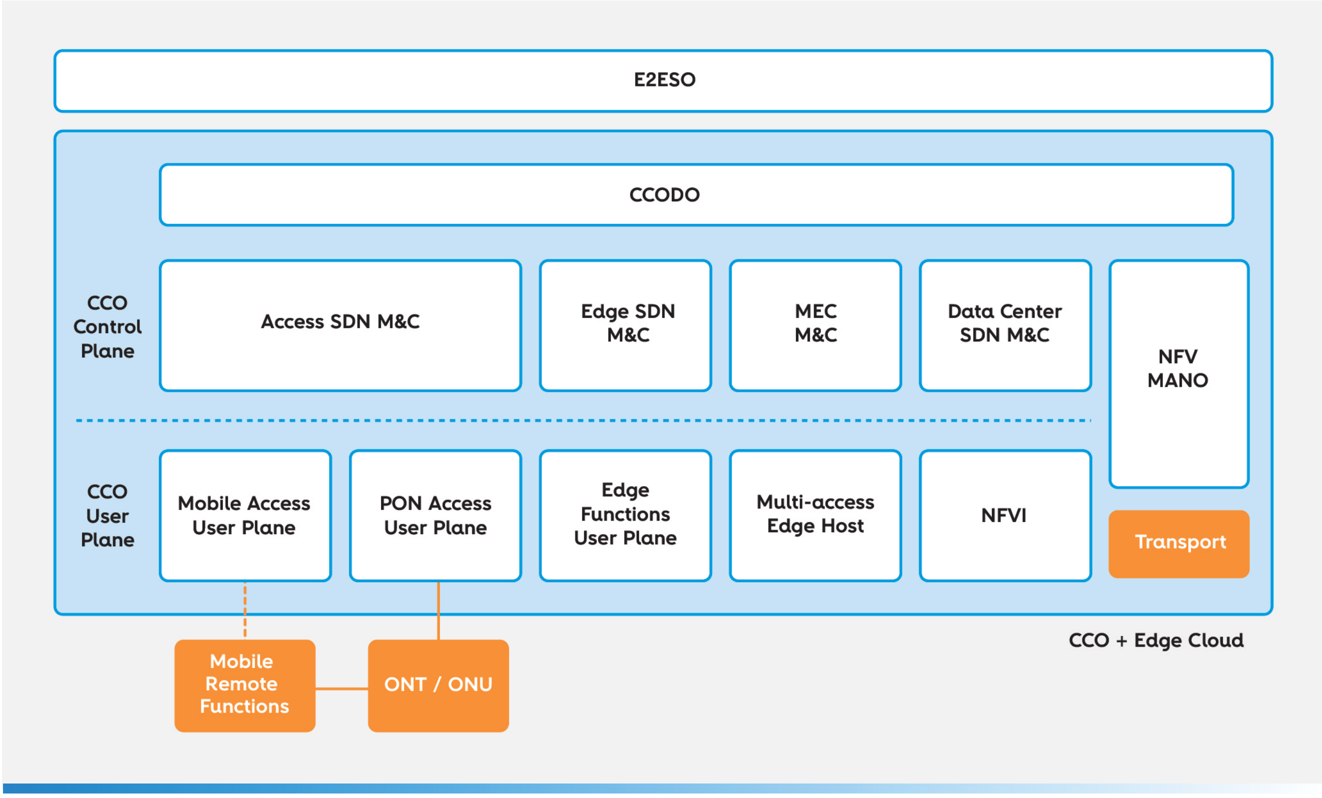

Figure 2 – Altice Labs' network edge reference architecture - high-level view

PON access

Altice Labs' architecture for the passive optical network (PON) access network is depicted in **Figure 3**.

As mentioned previously, this architecture is aligned with BBF's CCO architecture. It includes the evolution of Altice Labs' AGORA management solution [9] into an access SDN manager and controller with the possibility of running control plane functions separated from the devices.

One important aspect for operators is the availability of a smooth migration path given the large number of OLT already deployed in their current networks. In Altice Labs' architecture, some management and control plane functions can still remain within the devices, while new added value disaggregated functions can be progressively deployed in the NFVI and therefore increasing the network agility. One example of such functions is virtual optical network unit (ONU) management control interface (vOMCI), which allows deploying new types of optical network terminal (ONT) without having to upgrade the entire OLT software. The OB-BAA component has an important role in providing such disaggregated functions as well as providing an adaptation function to third party and legacy access nodes.

Other important aspects for operators are network programmability and automation, which are enabled by using open interfaces based on the NETCONF or RESTCONF protocol and standardized YANG data models.

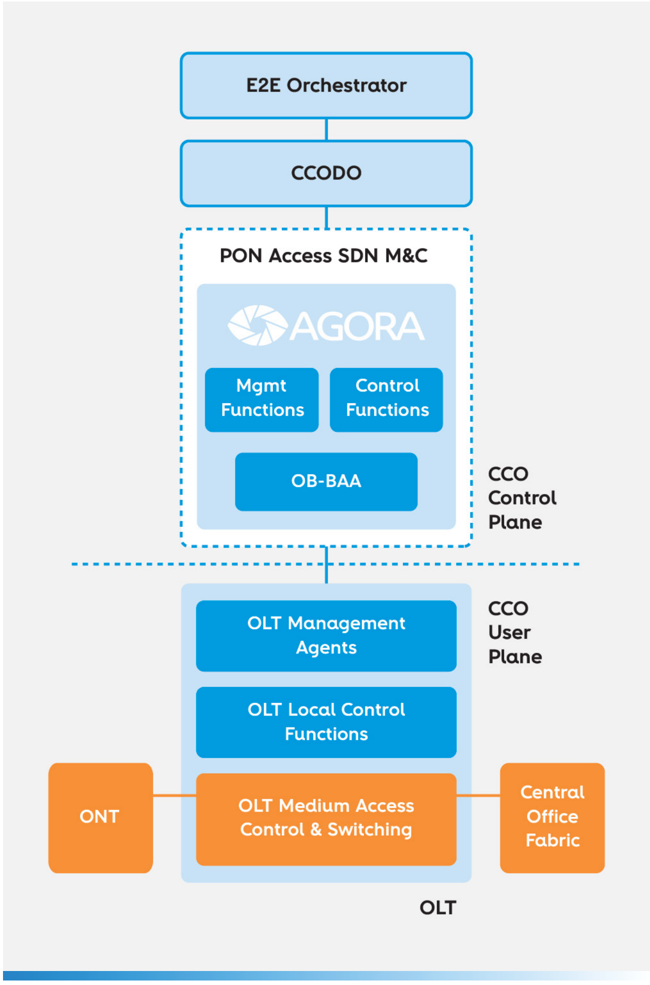

Figure 3 – Altice Labs' architecture for the PON access network

Mobile access

Figure 4 illustrates the structure of mobile access within the CCO architecture. It represents the various hauling options (front-haul, mid-haul, and back-haul). In Altice Labs' reference architecture, these options are covered by a PON. Among the various function splitting possibilities considered for the access, the option chosen for implementation by Altice Labs is named "front-haul x", using PON for transport between distributed unit - low (DU-L) and distributed unit - high (DU-H), represented by the third option in **Figure 4**.

Function placement in the CCO will depend on the splitting option, but, in general, the management of these functions is the responsibility of the mobile access manager (MA-M).

The radio unit (RU) and distributed unit (DU) are, basically, real-time user plane functions, but the centralized unit (CU), less constrained by time, has a separated control plane implementation (CU-C).

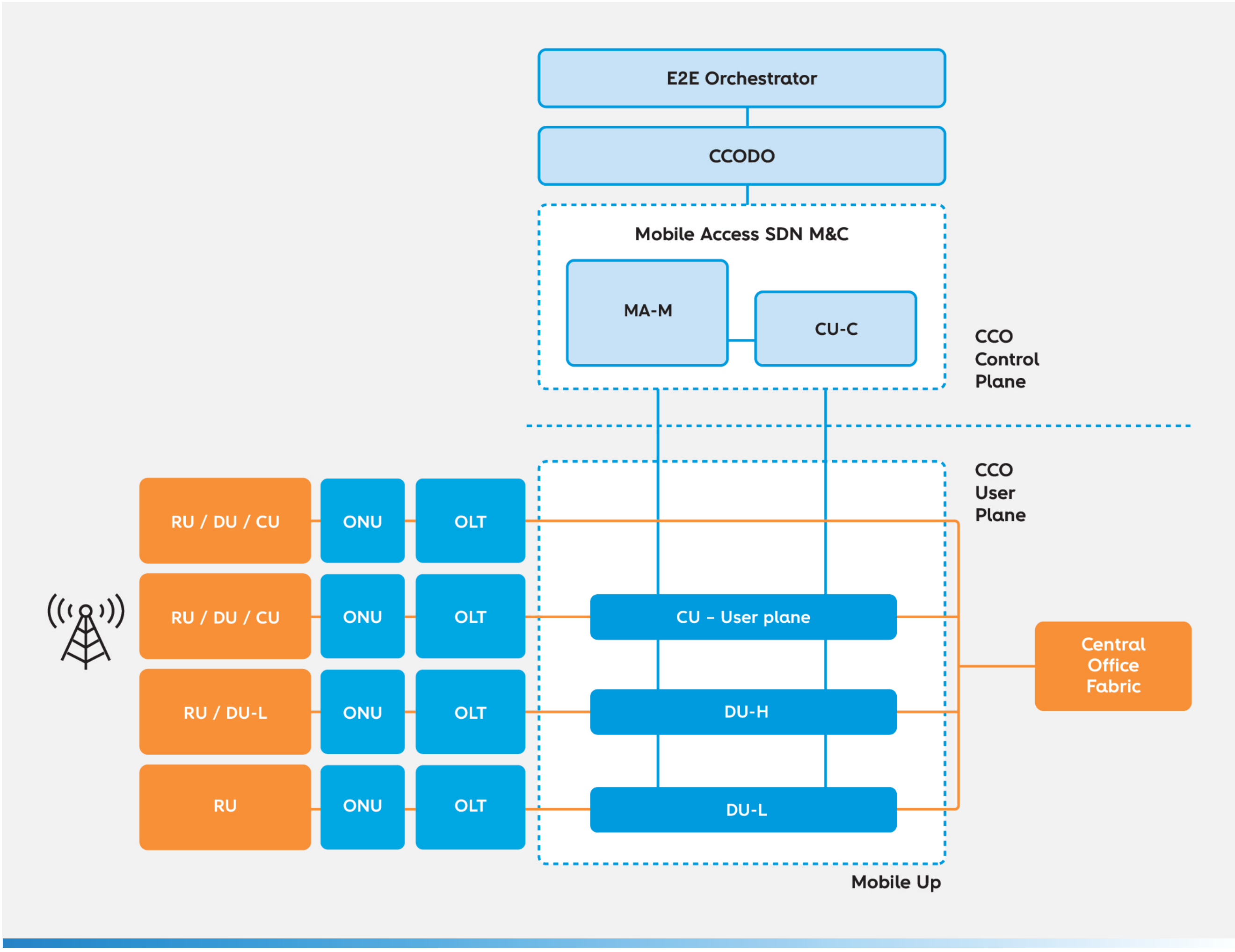

Figure 4 – Mobile access segment

Edge

Another CCO segment of major interest for Altice Labs is the edge, depicted in **Figure 5**. In this segment of the architecture, we can find the various service gateways that can be employed in the context of the fixed and converged network, namely the BNG, AGF, and FMIF. According to Altice Labs' vision, in a full wireless and wireline convergence, we should also consider in this segment the 5G user plane function (UPF). The edge provides the interconnection of the access network with the transport and services networks, and also the control of the data sessions that cross its user plane ("edge" is a somewhat overloaded term. In this article, it refers to the network edge, as defined above).

Following the chief principles that guide the CCO, the functions that are part of the edge must be fully virtualized and implement a control and user plane separation where the different user planes are managed by their respective control plane.

The functions in this segment are to be part of a larger integrated solution, first in the CCO domain and afterward in the E2E service delivery. So, the CCODO must be integrated with the control plane of the edge segment to manage the lifecycle of the different functions in an integrated way, thus providing the needed automation of these cloud network functions.

To allow the automated management by the CCODO, the control plane that manages these functions exposes a set of API that enable the creation, configuration, monitoring, scaling, update, and removal of each function.

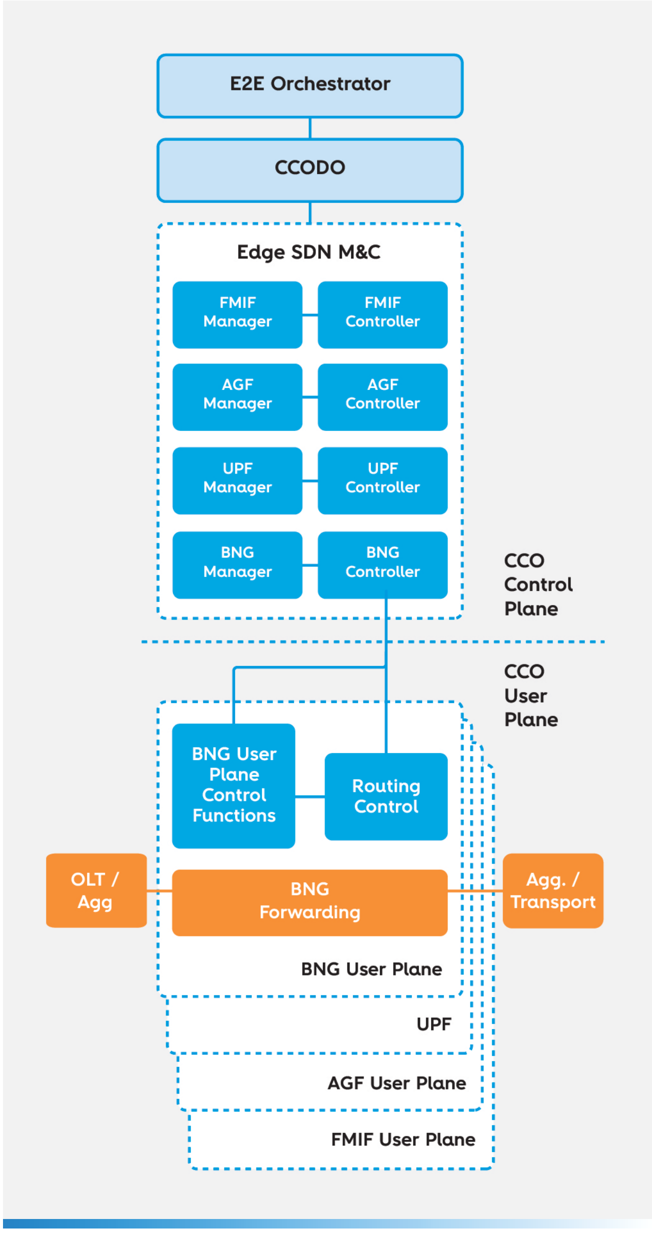

Figure 5 - Edge segment

MEC

MEC, defined by ETSI MEC ISG [10], is a layered, hierarchical architecture that represents the extension of the central/public clouds to the network edge, closer to end-users. It provides a heterogeneous application ecosystem, created to be explored via partnerships and an ever-growing applications market.

MEC provides a set of API to support the development of edge applications and is integrated with CCODO (e.g., for traffic steering, prioritization, and function lifecycle management). Besides this integration, MEC will have its own orchestration, managing the delivery of services/applications to the network edge.

Altice Labs' reference architecture uses the MEC architecture [11] as its reference. **Figure 6** illustrates at a very high level how this alignment is guaranteed.

In a virtualized user plane, mobile edge platforms (MEP) run on mobile edge hosts, most likely collocated with the CCO, at the access, or even in customer premises. A mobile edge platform manager & controller (MEP/MEPM) will take care of managing these applications. The eventual MEC orchestration, bearing the orchestration aspects specific to the edge cloud, is not represented in **Figure 6**.

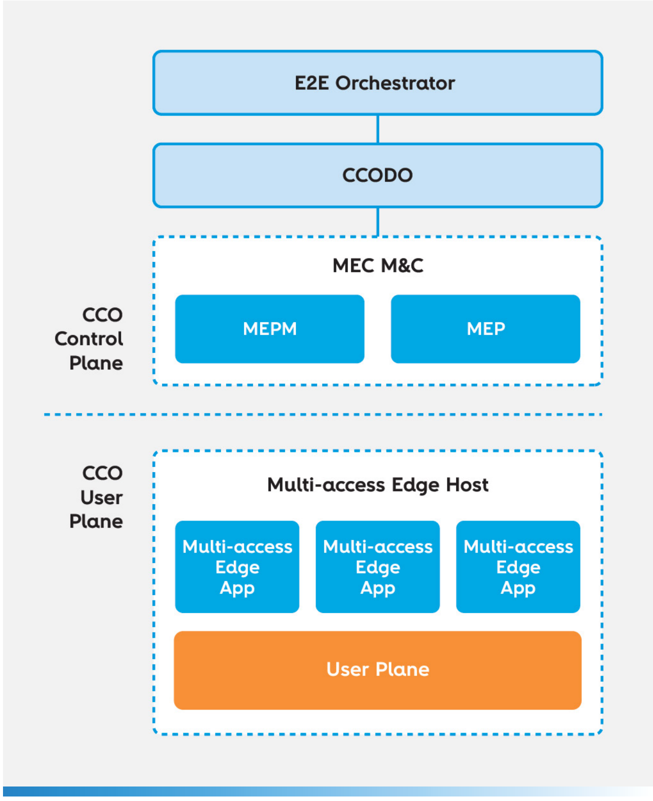

Figure 6 – MEC segment

CO infrastructure

To virtualize network functions, the CCO has to offer all the necessary mechanisms to run those functions on a set of switches, servers and some specific hardware that make the NFVI.

In this view, those mechanisms have two major components: NFV MANO, which controls the lifecycle of all VNF, according to the standard defined by ETSI NFV ISG [12], and the data center SDN M&C (DCSDN M&C), that takes care of all network aggregation and routing control that occurs at the CCO and is not directly related to the lifecycle of network functions and network services. These two components are orchestrated by the CCODO via their standard interfaces. The CCODO orchestrates the NFV MANO sub-system via interfaces standardized by ETSI [13] and the DCSDN M&C component via interfaces under standardization by the BBF SDN/NFV WorkGroup [14]. **Figure 7** illustrates this part of the architecture.

In this approach, one aspect remains unclear: The ETSI NFV Industry Standards Group went to considerable lengths to fully standardize an architecture for the virtualization of Network Functions, where it is implicit that these functions process user data packets (user plane), and hence needs a particular set of capabilities for

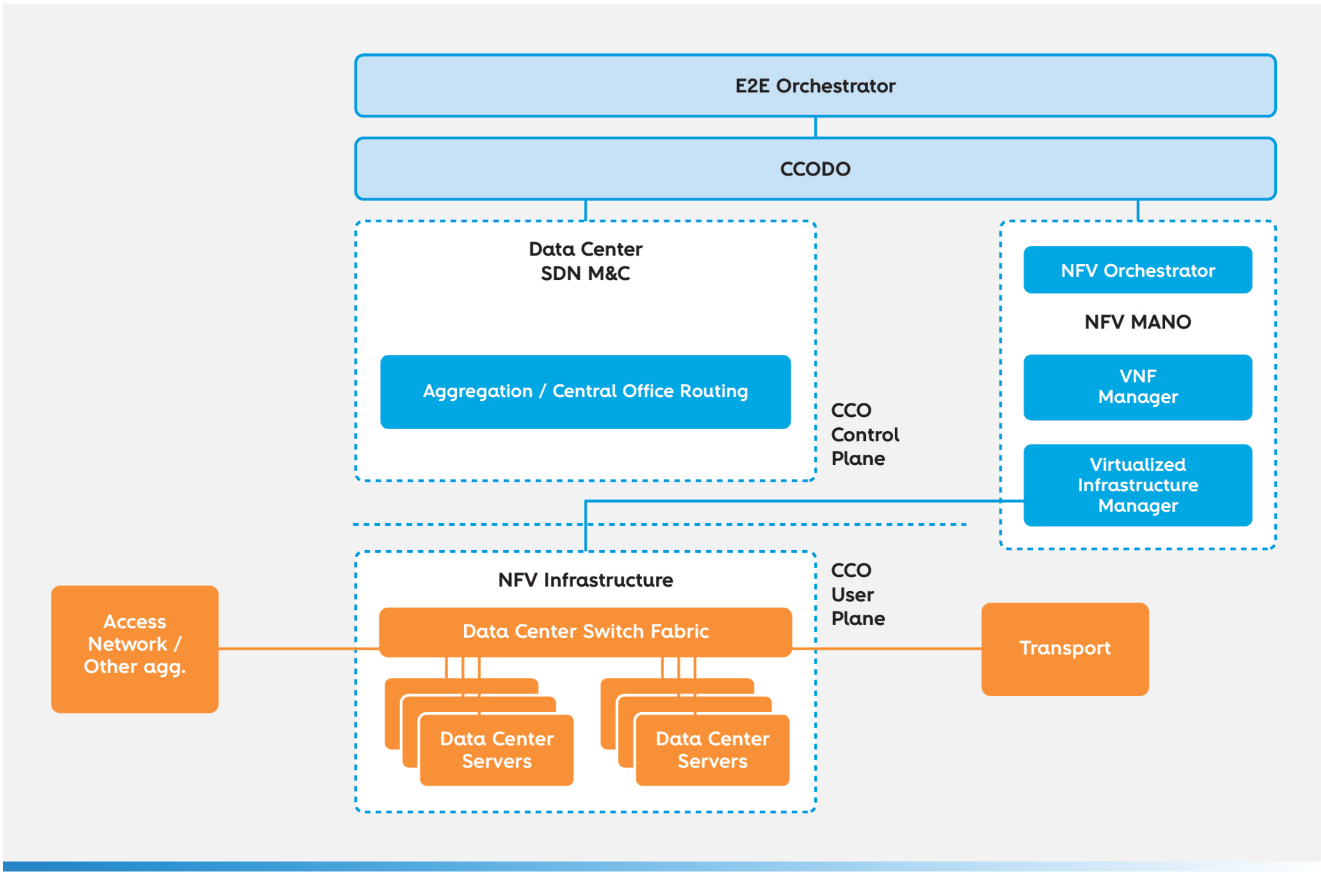

Figure 7 – Infrastructure segment

combining/chaining them into network services. This leads to a complex architecture that includes a set of constraints that limits its flexibility. Here we take an approach where it is assumed that UP and CP are separated a priori, and thus it is fair to question whether a "pure" standard NFV environment is the most adequate for the CO infrastructure. Actually, the lifecycle of the functions described for the SDN M&C areas in the sections above can (and probably will) be managed using simpler, more IT-centered solutions, that do not need to deal with the complexities and restrictions of the UP virtualization. These mechanisms will take their place in the DCSDN M&C (see **Figure 7**) and will be subject to CCODO orchestration, using the interfaces that they make available.

Orchestration

The orchestration is separated into two different layers, the E2E layer and domain-specific layers, so that the inherent complexity of each domain or sub-domain can be abstracted. This contributes to the overall capacity of the E2E orchestrator to coordinate the different domains, CCO or other, in a simpler way. **Figure 8** depicts this layering.

The CCODO NB API will be composed of a set of TM Forum API that will allow access to the services and resources provided by the CCO domain. The services will be modeled as technical services [15] and the resources as physical, logical, or as resource functions in the case of virtual resources.

Through this set of API, a service design application will be able to model the set of services it needs for a specific CCO domain and onboard them. The modeled services can then be managed by a service provider, and, after instantiated, consumed and configured to the customers' needs. This is one of the key aspects because the entities available in the CCO domain are tailored to each of the needs of every role, allowing it to be adapted to the network evolution or the network/service provider requirements.

The NFVO standard interface functionality will be provided by the CCODO NB API, and the CCODO will be responsible for all the interactions with the NFVO. Having only one orchestrator for the CCO domain is advantageous as it avoids the need for coordination over shared resources.

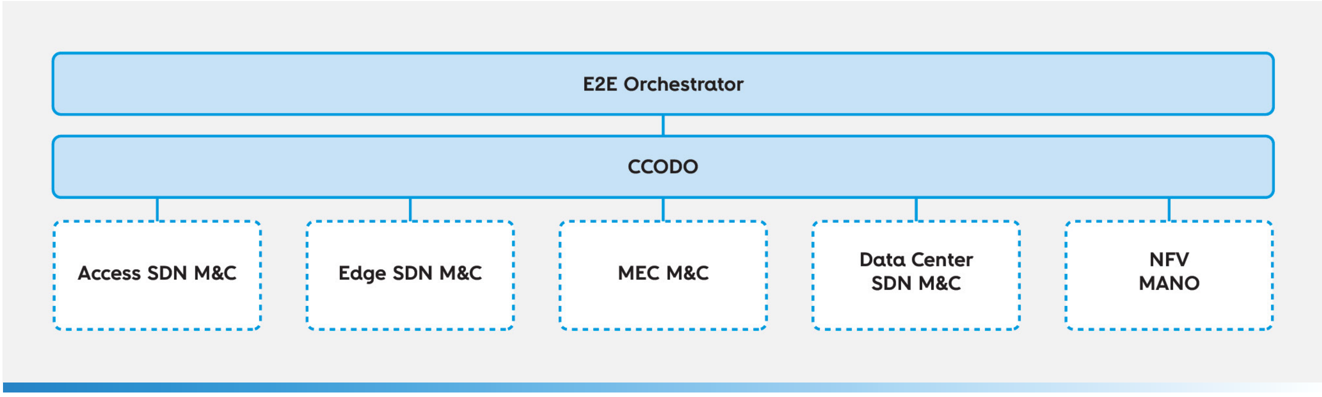

Figure 8 – Orchestration

Use cases

In the present COVID-19 scenario, along with the physical relocation of people from their workplaces, offices, or schools to their homes comes the need to provide them with a reliable and secure connection so that they can perform their activities remotely. This implies an adaptation on both mobile and fixed network access for this new traffic demand to be handled properly.

Next, we present a small set of use cases that highlight the capacity of the CCO management to adapt to this new reality.

New 5G RAN small cell

In a 5G network scenario, a need for a new cell is detected, following a high network demand. To provide that, a request is issued to the E2E orchestrator to deploy a new 5G radio access network (RAN) small cell. After the new RU is installed, the E2E orchestrator is notified. It updates its internal inventory and issues requests to the CCODO so that the 5G RAN is configured accordingly, and a new ONT is provisioned for front-haul-x. The CCODO instantiates a new DU VNF, configures it in an existing CU, and provisions the ONT.

After the 5G RAN is configured, the E2E orchestrator configures the 5G core so that this new cell becomes available. This way, the high demand can be split into more than one cell.

New OLT

A new PON is needed at a central office where all the OLT are at full capacity, so a new OLT is necessary. After the physical equipment is deployed manually by a field technician, the OLT obtains connectivity configuration through DHCP and contacts its access SDN M&C. This triggers the provisioning process in the access SDN M&C, which applies the initial configuration. Then, the E2E orchestrator is notified, and it requests the CCODO to instantiate the new OLT on the CCO. The OLT is registered in the internal inventory, and the required VNF are instantiated, if needed, and configured, both the ones internal to the virtual OLT (vOLT) and the virtual BNG (vBNG) that handles the L3 protocols.

These functions, and the network service they provided, are validated automatically by the orchestrator after a successful deployment.

New MEC application

The network operator creates a new service (e.g., e-health), which requires an application to have a permanent connection to a set of user equipment and low latency to guarantee minimum delay in the analysis of the data sent by the user equipment. After this service is designed and onboarded by the E2E orchestrator, it will be available for deployment on the MEC M&C using the CCODO interface. When a subscriber acquires the service, the E2E orchestrator provisioning interface is triggered. It contacts the CCODO to ensure that the new MEC application is deployed in the MEC host closest to the subscriber.

This allows data to be sharply monitored while offloading central servers and core communications.

Conclusions

The content in this article results from a joint work involving multiple Altice Labs' business areas in defining a common architectural view for the edge of the network. The proposed architecture is leveraged by the progress of network technologies and approaches like NFV, SDN, and function disaggregation, in the scope of 5G, fixed broadband (and convergence thereof), and the support to edge cloud. This progress will allow the designing of an ecosystem capable of supporting not only an operators' network functions and communications services but also the verticals that make use of it, and their services and applications, hence brought closer to the end-user.

The definition of a common and aligned architecture for the network edge will allow Altice Labs to steer its portfolio towards solutions that match not only many challenges presented to us today, but also those raised by new, unexpected realities brought up by an increasingly unstable world.

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