Resource Management in a Hierarchically Controlled Multi-domain Wireless/Optical Integrated Fronthaul and Backhaul Network

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***Abstract*—This demo presents an end-to-end hierarchical control of a multi-domain multi-technology integrated fronthaul and backhaul network where a parent controller coordinates the operation of a wireless and optical child controllers managing real wireless and optical data plane resources. The services offered by this hierarchical control infrastructure are accessed through the offered REST-based northbound API by the resource management application (RMA), which is able to determine the appropriate network resource allocation based on the requested traffic profiles and the position of the different mobile entities deployed in the network. Interestingly, the same REST-based API is used between the parent and child controllers inside the control infrastructure, allowing recursive and scalable deployments. The RMA manages fronthaul and backhaul traffic generated by a flexible mobile network deployment featuring user equipments, a remote radio head, a baseband unit, an eNodeB, and an EPC.**

I. Introduction

5G networks will feature a variety of Radio Access Network (RAN) functional splits with diverse requirements. In general, current deployments use different transport networks and interfaces for fronthaul (e.g., CPRI) and backhaul traffic. However, the trend towards packet-based fronthaul fosters a unified transport network to fulfill the requirements of all RAN splits (including regular backhaul traffic). Furthermore, the envisaged deployment scenarios for 5G networks usually entails a variety of transport technologies that, ideally, should be managed homogeneously. 5G-Crosshaul project [1] designs such an integrated fronthaul and backhaul network under the control of what is referred to as the 5G-Crosshaul Control Infrastructure (XCI) [1].

This demonstration presents a hierarchical XCI enabling End-to-End (E2E) orchestration of resources across multi-domain multi-technology transport networks. On top of this XCI, network management applications, such as the Resource Management Application (RMA), are in charge of efficiently using the underlying network resources. Examples of the application of the concept of hierarchical control of SDN networks can be found in data centers [2]. In the context of transport networks, an example by the same authors of this demonstration can be found in [3]. Additionally, we are presenting a real use case, namely a flexible mobile network infrastructure featuring different functional splits. A Remote Radio Head (RRH), a Baseband Unit (BBU), and an eNodeB (eNB) generate the fronthaul and backhaul traffic flows that are managed by the hierarchical XCI to eventually reach the Evolved Packet Core (EPC).

II. System Architecture

Figure 1 presents the demo system architecture including all the elements defined in the 5G-Crosshaul transport network solution [1]. Our main goal is to demonstrate how hierarchical SDN principles are used to manage heterogeneous transport networks to fulfill the 5G requirements stated previously. Data Plane and Control Plane elements come from two testbeds located at the CTTC premises (Barcelona), while the Application plane element is located at NEC premises (Heidelberg).

A. Data Plane

The data plane combines several domains using different transport technologies. The *mmWave/Wi-Fi transport network* represents the wireless edge packet-switched domain of the network. Wireless transport nodes feature several wireless Gigabit interfaces based on mmWave (IEEE 802.11ad) and Wi-Fi (IEEE 802.11ac) technologies. The wireless edge infrastructure, due to its distributed computing capabilities, also deploys all the softwarized mobile access entities (RRH, BBU, eNB) and the user equipments (UEs) of the OpenEPC platform [4], where each entity runs in a different virtual machine (VM). The *Multi-layer optical transport network* represents the core transport domain featuring two layers, namely 1) a packet service on top of 2) a wavelength-switched domain (i.e., WDM), which features an all-optical mesh network with two colorless Reconfigurable Optical Add/Drop Multiplexer (ROADM) nodes and two Optical Cross-Connect (OXC) nodes interconnected with five bidirectional optical links using a total of 610Km of optical fiber. The softwarized EPC entity [4] runs in different VMs placed in a datacenter infrastructure connected to this domain.

B. Control Plane

We follow the hierarchical XCI approach designed in 5G-Crosshaul [1], where each domain is controlled through its own technology-aware controller. On top of this hierarchy, we find the *E2E SDN Transport Orchestrator* based on the IETF Application-Based Network Operations (ABNO) architecture (acting as parent ABNO, or pABNO). The pABNO supports hierarchical deployments with arbitrary depth leveraging thanks to its unified Southbound/Northbound Interface

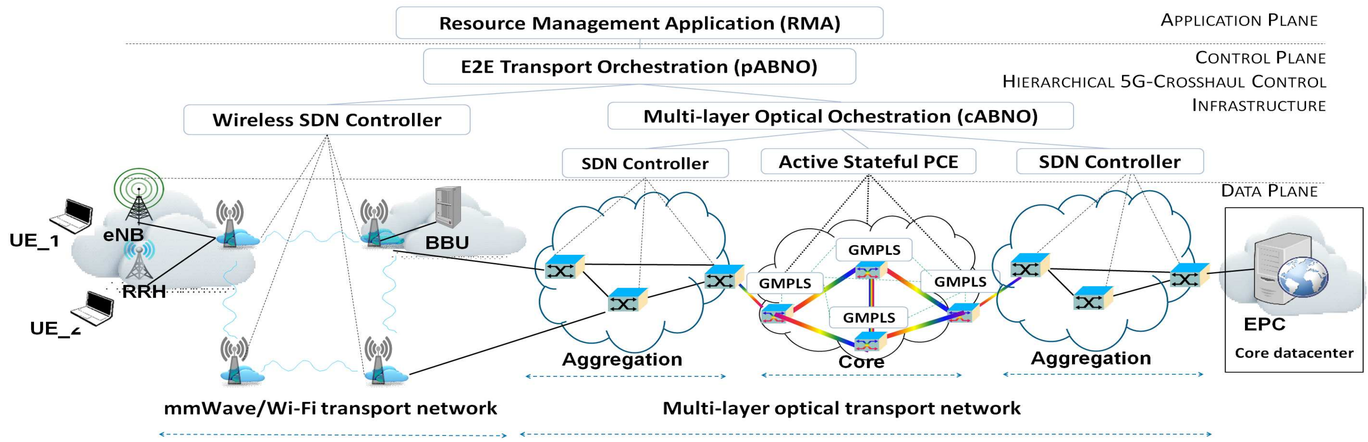

Fig. 1. System architecture under demonstration

(S/NBI) and network abstraction. It uses the Control Orchestration Protocol (COP) API [1] to bidirectionally interact with its per-technology child SDN controllers. The COP API is also used at the NBI to interact with the application plane. Below the pABNO, in the wireless domain, the wireless SDN (wSDN) controller uses OpenFlow (OF) protocol for configuration of forwarding and RESTCONF for interface management. Additionally, the multi-layer domain is controlled through a child ABNO (cABNO), which in turn controls the OF-based packet switches and a wavelength-switched GMPLS-controlled island through an Active Stateful (AS) Path Computation Element (PCE).

C. *Application plane*

The RMA manages end-to-end network resources. Through the COP API, the RMA receives an abstracted global view of the multi-domain topology from the pABNO and backhaul/fronthaul traffic profiles. Based on this information, the RMA computes paths for fronthaul/backhaul traffic across the 5G-Crosshaul network satisfying the throughput/delay requirements of the different traffic profiles.

III. Demonstration

We will demonstrate the hierarchical orchestration of E2E resources for a mobile network deployment including fronthaul (PDCP/RLC functional split) and backhaul traffic profiles across the same transport network constituted by several domains employing different transport technologies. We will show that the path setup time is in the order of seconds rather than days or hours, which is the norm in current commercial networks composed of multiple domains, contributing to the 5G target of reducing the service deployment time. The main steps of the demo are:

1) Based on the received abstracted view of the network topology, the RMA generates the set of service provisioning calls to provide the desired connectivity between mobile network layer entities satisfying throughput/delay requirements.

2) The pABNO (or parent SDN controller) processes these service provisioning calls decomposing them in different calls for each network domain, which are then sent to the underlying child controllers.

3) Child SDN controllers process the service calls from the pABNO and enforce the required rules in their underlying network elements. A chain of acknowledgment answers from the bottom (data plane) to the top level (application plane) validates the correct orchestration of the requested resources.

4) UEs attach to the EPC: UE_1 attaches through a non-splitted eNB, whereas UE_2 attaches through an RRH that generates fronthaul traffic towards a BBU. Both UEs communicate amongst them and reach the Internet through the EPC.

Additionally, each control element presents a Graphical User Interface (GUI), where useful information about the network state can be extracted. The wSDN GUI shows the configuration of the wireless interfaces, the wireless transport topology and a dynamic representation of the relative load of the wireless transport nodes and its associated links. The pABNO and cABNO GUIs show the abstracted representation of the underlying transport network according to the model defined in the COP API and the set of installed service calls. Finally, the RMA GUI also shows the abstracted view of the transport network including the placement and the associated installed flows at the deployed mobile entities.

Acknowledgments

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