Developing a Flexible Spectrum Management for 5G Heterogeneous Radio Access Networks

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***Abstract*— The COHERENT project aims to design, develop and showcase a novel control framework for 5G heterogeneous mobile networks (HMN), which leverages the proper abstraction of physical and MAC layer in the network and a novel programmable control framework, to offer operators a powerful means to dynamically and efficiently control spectrum and radio network resources in their increasing complex HMN. In this extended abstract, we investigate design aspects of COHERENT architecture.**

Keywords—COHERENT project; 5G; architecture design; heterogeneous mobile networks; software defined networking

I. Introduction

The COHERENT project [1] aims to design, develop and showcase a novel control framework for 5G heterogeneous mobile networks (HMN), which leverages the proper abstraction of physical and MAC layer in the network and a novel programmable control framework, to offer operators a powerful means to dynamically and efficiently control spectrum and radio network resources in their increasing complex HMN.

COHERENT proposes the proper abstraction of physical and MAC layer states, behaviours and functions to enable a centralized network view of the underlying radio networks with significantly reduced signalling overhead. The centralized network view with sufficient but abstracted information on spectrum, radio links, interference, network topology, load information, and physical layer reality is essential to enable optimal resource allocation in the network.

The innovative impact of the COHERENT project is the development of an additional programmable control framework, on the top of current control planes of operators' mobile networks, being aware of underlying network topology, radio environment, traffic conditions and energy consumption, and being able to efficiently coordinate wireless network resources cross the border of cells. The tools that will be developed within the project are intended to be deployable by the carriers in an incremental fashion and actually lay down the foundations for 5G and beyond mobile networks.

In this extended abstract, we investigate design aspects of COHERENT architecture. The proposed design leverages a centralized control layer where the global view of the network is gathered and exposed to the applications developers through a set of high-level programming APIs implementing the proposed abstractions.

II. SDN Perspective of COHERENT Design

A. COHERENT SDN Architecture Design Aspects

The COHERENT SDN architecture is inspired by the insights on the abstraction of low-layer states, behaviors and functions, with the aim to fundamentally improve the control and coordination among heterogeneous radio access networks, and to enable an open control framework which evolves with new radio access techniques. The COHERENT SDN architecture spans multiple planes as depicted in Figure 1, including data plane, control plane and application plane. Additionally, two abstraction layers are proposed for COHERENT SDN architecture, namely the ***infrastructure resource abstraction layer*** and ***network service abstraction layer***. The infrastructure resource abstraction layer abstracts the underlying physical and MAC layer to the control plane, while the network service abstraction layer provides service abstractions for the applications and services.

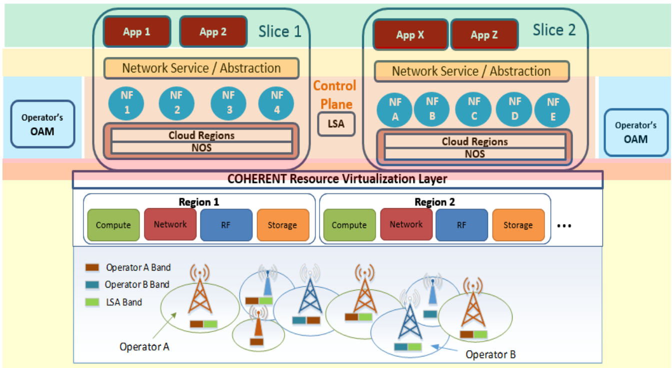

Fig. 1. COHERENT conceptual high-level SDN architecture

B. Control Plane

The control plane in COHERENT SDN architecture configures the data plane according to the environment (e.g. channel condition) or an operator's policy (e.g. middleboxes, application types). The COHERENT controller consists of a Network Operating System (NOS) running a collection of application modules, such as radio resource management for RAN sharing and spectrum sharing, mobility management, and traffic steering. The handling of data plane often requires multiple application modules. Therefore, the NOS should coordinate the application modules and unify a single set of forwarding decisions in each network devices. Owing to the distributed nature of control plane, the control plane can span over multiple cloud regions. The concept of the cloud region could be in different aspects (e.g., geographical region, radio access networks, core networks, multi-operators, multi-RAT).

C. *Infrastructure Resource Abstraction Layer*

A key element in the preliminary COHERENT SDN architecture is the introduction of an infrastructure resource abstraction layer between ***data and control planes***. The separation of data and control planes allows the applications to programmatically control the heterogeneous mobile networks with lower complexity. The infrastructure resource could be the resources of a mobile network, comprising access nodes, cloud nodes (processing or storage resources), networking nodes and associated links. 5G devices (e.g., mobile handheld devices, IoTs) are also considered in COHERENT as the infrastructure resource since they may act as a relay / hub or a computing / storage resource (e.g., Device-to-Device communications and/or UE-Relay operation).

Through the infrastructure resource abstraction layer, the infrastructure resources are exposed to higher layers and to the end-to-end management and orchestration entity. The abstraction may be expressed by one or more abstraction models. Examples of forwarding-plane abstraction models are Forwarding and Control Element Separation (ForCES) [2], OpenFlow [3], YANG model [4], and SNMP MIBs [5], which are designed for the fixed networks.

The COHERENT intends to deal with the insufficiency of the abstraction models for heterogeneous radio access networks. More specifically, this layer provides the abstraction of the low-layer (physical layer and MAC layer) network states and behaviours of different underlying mobile networks. For example, the abstraction of spectrum usage in physical and MAC layer could enable necessary and affordable spectrum usage information for more efficient and flexible spectrum management by operators, spectrum regulators or other players in this domain. Furthermore, proper abstraction of physical and MAC layer will significantly reduce the signalling to implement physical layer cooperative technologies and the coordination between network entities for more efficient and scalable spectrum management and interference management.

D. *Network Service Abstraction Layer*

Applications and services that use services from the control plane form the application plane in the COHERENT SDN architecture. COHERENT will provide application-centric network service abstraction in order to shield the upper applications layer and users from tedious and diverse configurations at the underlying network infrastructure among multiple networking domains. This feature implies a better understanding of global network infrastructure.

III. Network Slicing

A network slice is defined as a partition of radio access network with specific configurations which are used for particular use cases or business applications [6]. The collection of all network slices aggregated together form the total network resources of a given network operator. Potentially, different network slices can be spanned over a multitude of Radio Access Technologies (or RATs) and can be used by different operators. Therefore, a network slice can span all domains of the network: software programs running on cloud nodes, specific configurations of the transport network, a dedicated radio access configuration, as well as settings of the New Radio (NR) for 5G devices [7, 8]. Different network slices contain different network functions and configuration settings. Figure 2 illustrates an example of multiple network slices in COHERENT SDN architecture concurrently operated on the same infrastructure. For example, latency may be critical for a network slice supporting eHealth and Public Safety use cases which may require a fast setup-call of 300 ms and a maximum end-to-end latency of 150 ms. For each network slice, some network functions or storage resources can be located at the edge of the networks. The COHERENT controllers should coordinate the mapping of the infrastructure resources for network slices and the management of the shared infrastructure resources and functions among multiple network slices. One example of a shared function is the scheduler of RAN sharing, which is typically shared among multiple network slices.

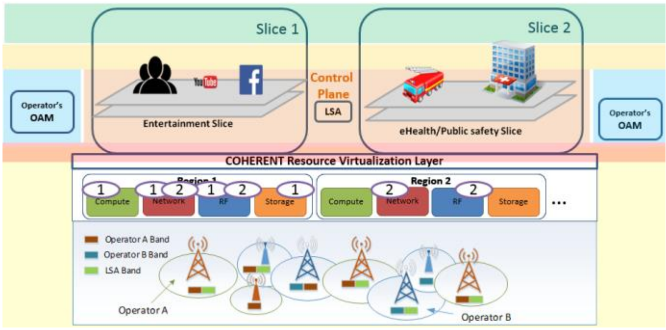

Fig. 2. COHERENT slicing and resource mapping

IV. Spectrum Sharing

Spectrum sharing is the technique that tries to increase the radio access efficiency by utilizing unused spectrum of other operators (using similar technology or different). Spectrum sharing can be used to aggregate licensed and unlicensed bands, in order to support high bandwidth applications and thus achieve data rates in the gigabit range. The management of the spectrum is achieved by a central manager who knows the state of each RAN. There is also a local controller (LC), who is attached close or at the RAN that controls/coordinates the spectrum use and provides a channel adaptation according to the requirements of each flow. Depending on these requirements, the LC can steer a flow toward the whole band or to a specific sub-band.

V. Conclusions

In this extended abstract, we investigate design aspects of COHERENT SDN architecture in a technology-agnostic manner, which will enable the development of the COHERENT scenarios and use cases in the future. Such proposal will be further elaborated and adapted during the project.

Acknowledgment

This work was conducted within the framework of the 5GPPP COHERENT project, which is partially funded by the Commission of the European Union (Grant Agreement No. 671639).

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