An Overview of a Distributed post-5G Network Architecture within the EU SLICES-RI Research Infrastructure

Abstract

We provide an overview of a blueprint for a disaggregated real-time post-5G network architecture that can be deployed on commodity networking and computing equipment. This activity is part of the European SLICES-RI research infrastructure and constitutes a distributed experimental post-5G playground for academic research purposes to be deployed across several EU countries. The blueprint is meant to be reproducible and to evolve in a collaborative manner. It makes use of open-source solutions such as SD-Fabric, Aether, OpenAirInterface, Nephio and others. The tutorial focuses on key networking components such as software-defined edge fabric, P4-based switching implementing the 5G user-plane function (UPF), cloud-native 5G radio-access (RAN) and core network functions (5GC), O-RAN near real-time RAN intelligent controllers (nRT-RIC), O-RAN Open-fronthaul interfaces and multi-cluster orchestration solutions. The tutorial will demonstrate live deployment and operation of a radio-edge site in Sophia Antipolis, France making use of some of the above technologies.

Objectives and Motivation

SLICES-RI is a new multi-country European research infrastructure (RI) aiming to provide a distributed experimentation platform for researchers in high-performance networking and computing. In particular, the use-case of a cloud-native post-5G experimental playground is of utmost importance to highlight during the preparatory phase of the RI because of its underlying technical challenges requiring highly-interdisciplinary skills. A high-level view of the post-5G playground is shown in Figure 1 where we highlight the interconnection of several radio edge-cloud at various locations in Europe with a central cloud and show the various 5G network interfaces between them. The proposed tutorial focuses on the design of this post-5G OpenRAN and Core experimental playground within SLICES-RI, and in particular the high-speed switching and networking aspects. On the latter, we will cover

a) the design of radio edge-cloud fabric for real-time radio-processing server applications
b) multi-slice user-plane protocols using P4-based technology and
c) PTP-based time-sensitive O-RAN fronthaul interconnections with commercially available radio-units.

In addition, we will provide an overview of the various open-source software packages (OAI, SD-Fabric, Aether) used to build the radio edge-cloud. We then shift to the design of central clouds for controlling, monitoring and operating multiple edge sites which will be described with a focus on recent orchestration platforms such as Nephio and those that are part of ONF Aether. Finally we show how to integrate O-RAN compliant near real-time RAN intelligent controllers nRT-RIC in both the edge-cloud sites, for instance to support low-latency local breakout applications, as well as in the central clouds.

We strongly believe this tutorial is timely since it deals with cutting-edge hardware and software networking components targeting disaggregated 5G. It will be extremely useful for labs aiming to replicate this OpenRAN framework based on the open blueprint described in the tutorial. The target audience is high-performance experimental networking enthusiasts both from academic and industrial research organizations. The duration of the tutorial is 3 hours.

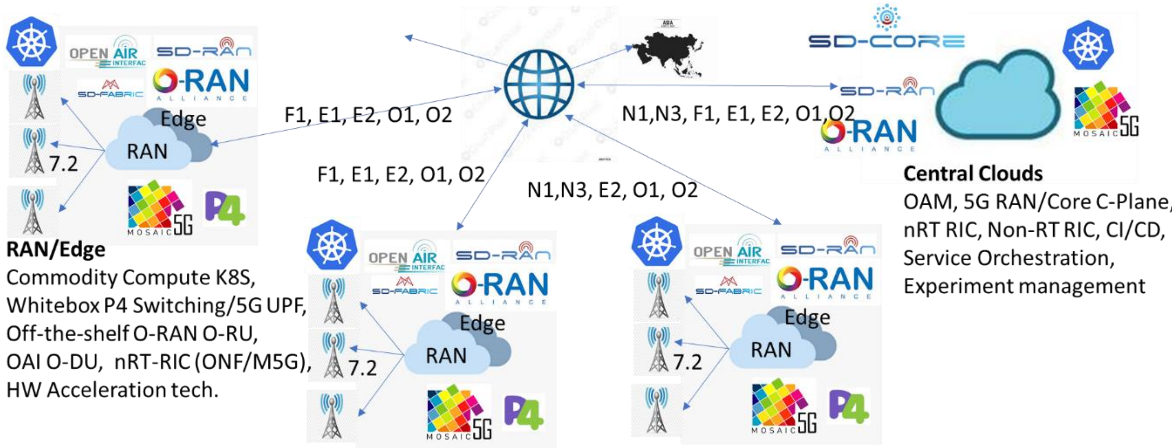

Figure 1: High-Level Overview of the SLICES-RI 5G PoC Architecture

Speaker Biographies

Professor Raymond KNOPP received his PhD degree in Communication Systems from the Swiss Federal Institute of Technology (EPFL), Lausanne in 1997. His current research and teaching interests are in the area of digital communications, software radio architectures, and implementation aspects of signal processing systems and real-time networking protocols. He is currently head of the Communication Systems Department at EURECOM, Sophia Antipolis, France. He is a leading figure in the OpenAirInterface (OAI) Community and has been instrumental in making open software for Radio Access Networks a reality through contributions over two decades. He is one of the very first and one of the most significant contributors to the OAI codebase. He was elected as the President of the OpenAirInterface Software Alliance (OSA), a non-profit organization federating the OAI and Mosaic5G codebases in December 2018.

Professor Adlen Ksentini is a professor in the Communication Systems Department of EURECOM. He is leading the Network softwarization group activities related to Network softwarization, 5G/6G, and Edge Computing. Adlen Ksentini's research interests are Network Sofwerization and Network Cloudification, focusing on topics related to network virtualization, Software Defined Networking (SDN), and Edge Computing for 5G and 6G networks. He has been involved in several H2020 EU projects on 5G, such as 5G!Pagoda, 5GTransformer, 5G!Drones and MonB5G. He is interested in the system and architectural issues but also in algorithms problems related to those topics, using Markov Chains, Optimization algorithms, and Machine Learning (ML). Adlen Ksentini has given several tutorials in IEEE international conferences, IEEE Globecom 2015, IEEEE CCNC 2017/2018/2023, IEEE ICC 2017, IEEE/IFIP IM 2017, IEEE School 2019. Adlen Ksentini is a member of the OAI board of directors, where he is in charge of OAI 5G Core Network and O-RAN management (O1, E2) for OAI RAN activities.

Dr. Damien Saucez is a researcher at Inria Sophia Antipolis since 2014 where he was previously post-doc since 2011. From October 2019 to October 2020 he was network specialist at Safran Electrical and Power in Toulouse, France, working on the design of high speed deterministic networks for aircrafts. He received his master degree in Computer Science engineering from Universitée catholique de Louvain in 2007 and his Ph.D. thesis entitled Mechanisms for Interdomain Traffic Engineering with LISP from the same university in 2011, under the supervision of Prof. Olivier Bonaventure. His current research interest is in using cellular technologies for mission critical networks. He is actively working to promote reproducibility in research by leading the ACM SIGCOMM 2017 Reproducibility Workshop and by chairing the ACM SIGCOMM Artifacts Evaluation Committee.

Dr. Nikos Makris is a Postdoctoral Researcher with the Department of Electrical and Computer Engineering, University of Thessaly, Greece and the Centre for Research and Technology Hellas (CERTH). He received his bachelor degree in 2011, a Master's degree in Computer Science and Communications in 2013, and his Ph.D. in ECE in 2020 from the same department. In the period 2020-2021 he worked as a Postdoctoral Associate in the Dept. of Electrical Engineering, Yale University, USA. Since 2011, he has been participating in several EU- and NSF-funded collaborative research projects. His research interests include experimentally driven research with several radio access technologies (WiFi, LTE, 5G-NR), conducted under real environment settings, the control- and user-plane disaggregation of base station units, Multi-access Edge Computing and NFV orchestration using open-source platforms.

Tutorial Content

1. *Overview of SLICES-RI and the post-5G playground (20min)*

We briefly set the scene of the tutorial by describing the high-level objectives of SLICES-RI and the post-5G playground. This will provide some use-cases such as low-latency/time-critical private 5G applications for industrial IoT in addition to carrier-grade networks based on OpenRAN technologies.

2. *Edge-Fabric and 5G UPF solutions (D. Saucez, 40min)*

We start with an introduction to ONOS since it is the underlying controller framework for the switching fabric. This is followed by a description of ONF SD-Fabric and how it is deployed on off-the-shelf P4 switches running the ONF Stratum network operating system. The configuration of the edge fabric will be shown live during the tutorial through a connection with the SophiaNode facility at Inria and EURECOM in Sophia Antipolis. We then describe the deployment and functions of the 5G User-Plane Function (UPF) on the P4 switches. We describe the interconnection of the UPF with the remote control plane of the 5G core network via the ONOS P4 agent and how 5G network slicing is instantiated in the edge-cloud.

3. *O-RAN FHI and OAI 5G RAN (R. Knopp, 40min)*

We start by providing an overview of the current O-RAN fronthaul (FHI) and edge-cloud architecture (O-Cloud) followed by a detailed description of O-RAN FHI for interconnecting radio-units (O-RU) with radio processing, the so-called *Distributed Units* or *monolithic gNB* (O-DU or O-gNB) running on commodity servers. In particular we describe how O-RAN FHI makes use of data-plane acceleration in Linux and its equipment constraints, in particular CPU types and O/S configurations, required PTP components. We briefly cover testing of O-RAN FHI. We then describe the real-time software environment and operation of the O-DU/O-gNB based on OAI. This is described from the perspective of users wishing to deploy the solution for experimentation.

4. *Central Cloud Site (N. Makris, 40min)*

We describe several underlying services offered by the central cloud site starting with the different possibilities for orchestration of end-to-end services and remote cluster management. We will highlight different possibilities such as Google Nephio and the Rancher-based solution provided by ONF Aether. We describe the different control plane services (e.g. 5G Core network) as well as the experiment management and CI/CD framework for researchers and developers of the 5G infrastructure and service components. Finally we will detail potential solutions for remote network management and operation of the edge sites including measurement reporting. Links will be made with operation and management procedures coming from the O-RAN ecosystem. We will demonstrate the end-to-end system with a remote central cloud and the edge site at the SophiaNode facility in Sophia Antipolis.

5. *5G Core Network Components and O-RAN nRT-RIC (A. Ksentini, 40min)*

The final component deals with specifics of the 5G core network related to network slicing and QoS management. In particular programmable controllers (e.g. SD-CORE, FlexCORE) in the central cloud for fine-grain QoS control of the end-to-end network. Then we switch to similar controllers in the radio-access network with components both in the central cloud and in the radio edge-clouds. We describe the O-RAN nRT-RIC framework and its associated service models for configuring the 5G radio-access network. The latter are used for tailoring the RAN procedures (radio-resource controller, MAC scheduler, etc.) according to the requirements of end-to-end or local services. In particular, we detail the development of so-called xAPPS used for fine-grain control of the RAN equipment . Examples will be given using the FlexRIC framework from Mosaic5G and a live demonstration of an AI-based xAPP for dynamic control of the radio-access network will be shown.

All software resources used in this tutorial are open source and will be provided to allow attendees to replicate and adapt the tutorial at their will.

Requirements

The demonstration components only require internet access to control the remote environments.