Blueprint-based reproducible research with the SLICES Research Infrastructure

Damien Saucez
Inria
Sophia Antipolis, France
damien.saucez@inria.fr

Sebastian Gallenmüller
Technical University of Munich
Munich, Germany
gallenmu@net.in.tum.de

Raymond Knopp
Eurecom
Sophia Antipolis, France
raymond.knopp@eurecom.fr

Nikos Makris
University of Thessaly
Volos, Greece
nimakris@uth.gr

Serge Fdida
Sorbonne University
Paris, France
serge.fdida@sorbonne-universite.fr

***Abstract*—5G has evolved into a cloud-native disaggregated infrastructure, enabling the concept of modularization in its design and supporting a service-based architecture. As such the concept is not new, except that it has not been applied in the telecommunication world, which has resulted in vendor lock-in, limited innovation, and high costs. With modular design at all levels, 5G allowed the telco world to meet the IT world and outstanding innovations followed with the so-called post-5G propositions. The EU SLICES Research Infrastructure (RI) is developing an open, reproducible, distributed post-5G architecture built on top of blueprints aimed to be replicated by researchers, companies, and operators and to evolve in a collaborative manner. In this demo, we will explore the blueprints that allow building a cloud-native 5G core and a split 7.2 radio network, based on open-source software while being fully reproducible. The objective of the demo is not only to show a deployment but to motivate the research community to participate in the collaborative SLICES-RI project and to adopt a reproducible methodology supporting the full research life cycle.**

***Index Terms*—5G, blueprint, reproducibility, RAN, SLICES**

I. Objectives and motivation

Modular design is a fundamental principle of software engineering, but it became a reality in the telco world [1] when ETSI defined the 5G specifications. In fact, the 5G architecture introduced the separation between *User Plane* and *Control Plane*, stateless *Network Functions*, and the definition of procedures as services. It rapidly followed with outstanding open innovation, each project proposing a solution for a particular function or service of 5G, some for implementing a cloud-native control plane, and others focusing on radio optimization and spectrum efficiency.

As a consequence, researchers have a wonderful object to experiment with new ideas at all levels. Unfortunately, as every single detail counts, deploying a full-fledged 5G remains a matter of specialists who have to choose the right combination of software, hardware, and locations of the infrastructure. This may divert researchers from their core research as they may have to invest a substantial amount of time and money just to set up their experimental platform.

This is precisely the vision and mission of SLICES-RI to serve the community [2]. The EU-funded SLICES Research Infrastructure aims to provide post-5G experimentation support. One important role of SLICES-RI is to provide long-term access to large-scale distributed cutting-edge hardware and state-of-the-art deployments. However, an equally important offer from SLICES-RI is to provide blueprints and their associated support to allow researchers to replicate and extend the work done by the community. To reach this objective, the blueprints provide a set of replicable software, hardware, and methodology to make sound experimental research with cutting-edge 5G environments. As such, researchers worldwide can focus on their core research (e.g., testing a new frequency allocation scheme) and leverage the rest of the infrastructure offered by the community.

In this demo, we show how to automatically build a post-5G experimental playground, particularly the high-speed networking aspects. In the demonstration, a 5G core is deployed in a Kubernetes cluster to which a 7.2 split RAN is connected with hardware in-the-loop. Performance evaluation is realized on this network. The entire experiment (i.e., deployment of the core, the RAN, connection of the RAN to the core, performance evaluation, and result publication) is orchestrated with the pos framework [3].

The objective of the demonstration is two-fold. On the one hand, we promote reproducible experimental research by sharing a set of good practices with the combination of blueprints, open-source software, and shared research infrastructure. On the other hand, we present to the community the SLICES Research Infrastructure, empowering their experimental research by leveraging results and hardware by focusing only on their main field of research, also contributing to the overall effort.

II. 5G blueprint experimental research

The SLICES 5G blueprint provides the community with a set of replicable software, hardware, and methodology to con-

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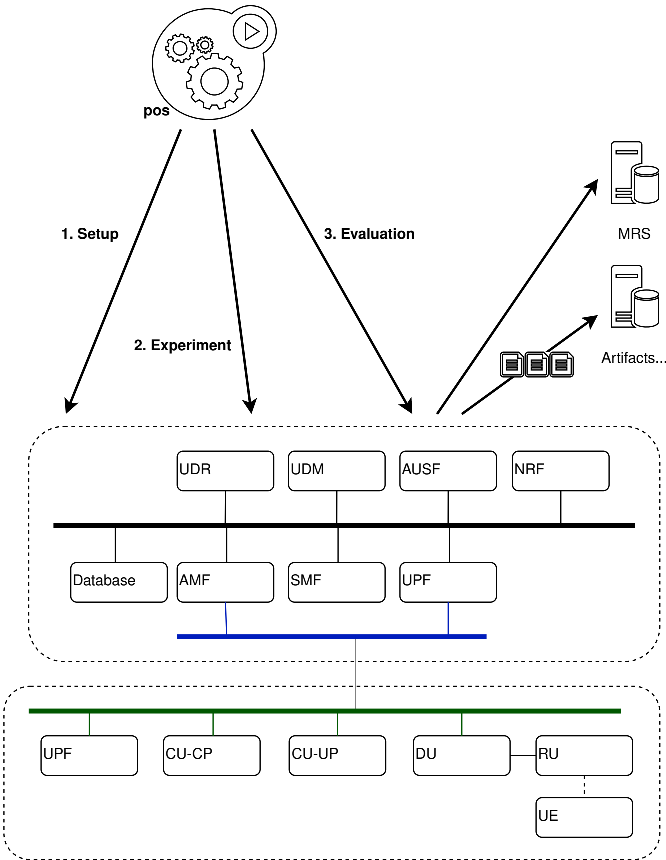

Fig. 1. De-aggregated 5G network managed by the pos framework in the SLICES Research Infrastructure.

duct experimental research with cutting-edge environments.

Our demonstration will show an advanced scenario covered by the blueprint [4], as illustrated by Fig. 1. In this scenario, an OpenAirInterface 5G core [5] is deployed in a Kubernetes cluster hosted by SLICES-RI. The core is functionally disaggregated, with each function implemented with a dedicated pod. The 5G RAN, also hosted in a SLICES-RI site, follows the 3GPP split 7.2 specifications [6] and is connected to the core via a long-distance link.

A major advantage of the RAN split is to reduce the number of features that have to be implemented at the *Radio Unit* (RU) to instead implement them in a shared *Distributed Unit* (DU). In a nutshell, the radio signal is encapsulated in eCPRI packets that can be carried over conventional Ethernet networks (instead of proprietary serial lines) and processed by the DU. However, all eCPRI nodes must be synchronized to a 3GPP-compliant clock reference; this means that the network connecting the DU and the RUs must support time synchronization and priority scheduling. In addition, to meet timing constraints, the DU must run a real-time kernel and to correctly work with high radio load, careful CPU core pinning is required. In this demonstration, the RU is implemented with commercial remote Radio Units [7] and the rest of the RAN functions are implemented in software with OpenAirInterface hosted on high-end servers with the AVX-512 instruction set and running a free real-time Linux kernel. The clock is synchronized with PTP [8].

Bandwidth and latency performance will be measured with user equipment connected to the RAN. The entire demonstration shall be seen as a scientific experiment. Reproducible experiments can be decomposed into 3 phases. First, the *setup* phase provisions and configures the experimental environment; then, the actual experiment is performed during the *experiment* phase and is finally validated, studied, and shared with the community in the *evaluation* phase [3].

In the demonstration, the lifecycle is orchestrated by the pos framework [3] that provisions the infrastructure, starts the different executions needed to build up the 5G network, run the experiment itself, and, finally, decommission the environment. Pos also collects the different artifacts used and generated by the experiment and publishes them to a repository. It then published all meta-data in the SLICES *Metadata Registry System* (MRS) so that researchers can easily gather experimental information and results in order to build their own research on top of previous validated results.

This demonstration highlights the complexity of sound experimental research today. Merely running a 5G network requires mastering high-level standards and low-level technologies and access to specific hardware. This is basically not attainable anymore by a single researcher or even a traditional team of researchers. This is where blueprint-based research helps: each piece of work is conceived as a reproducible item to be shared with the community and, when special hardware is needed, it is run on shared public infrastructures such as SLICES-RI. As a consequence, work that has been validated can be reused by other researchers to build their results upon.

Material of the SLICES-RI blueprint can be found on the official SLICES-RI website https://www.slices-ri.eu and the SLICES Academy [9].

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