Camps-Mur, D., Yan, S., & al., E. (2020). 5G-CLARITY: Integrating 5GNR, WiFi and LiFi in Private 5G Networks with Slicing Support. In *European Conference on Networks and Communications*

Peer reviewed version

5G-CLARITY: Integrating 5GNR, WiFi and LiFi in Private Networks with Slicing Support

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***Abstract*—This paper introduces 5G-CLARITY, a 5G-PPP project exploring beyond 5G private networks integrating heterogeneous wireless access including 5GNR, WiFi, and LiFi. The project targets enhancements to current 5GNR performance including multi-connectivity and indoor positioning accuracy. It also develops novel management enablers that allow to operate the private network with a high level intent interface, while being able to natively embed Machine Learning (ML) functions.**

***Index Terms*—5G, ML, WiFi, LiFi, private networks, SDN, NFV**

I. Introduction

5G-CLARITY project belongs to the third phase of the European 5G-PPP initiative [1], which is investigating how the concept of private 5G networks should evolve beyond 3GPP Release 16 [2]. This project brings innovations in two main pillars: First, novel user and control plane components will be developed to deliver a private 5G network that integrates 5G New Radio (5GNR), WiFi and Light Fidelity (LiFi) to enhance 5GNR capabilities in terms of peak data rates, area capacity, low delay and precise localization. Second, management enablers that allow to slice the heterogeneous access network, integrate private and public networks, operate the network using a high level intent language, and incorporate ML models to support the operation of network functions.

The 5G-CLARITY innovations will be applied to a robot-human interaction use case in a museum in Bristol, UK, and to two industry 4.0 use cases in an automotive factory in Barcelona, Spain.

II. 5G-CLARITY Architecture and Innovations

5G-CLARITY includes a novel SDN/NFV based architecture for private networks (see Figure 1). It enables advanced traffic switching, splitting and steering through the 5GNR/WiFi/LiFi access nodes to increase capacity, enhance reliability or reduce delay. 5G-CLARITY management plane allows private networks operators to deploy E2E networks slices and interconnect them with public 5G network slices. It supports ML functions in the management/control plane and enables cm-level localization in indoor environments.

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5G-CLARITY adopts the design principles of the open radio access network (O-RAN) architecture [3], leveraging its open standards features. Its four main buiding blocks are: (a) the physical infrastructure, that consists of COTS servers divided in *RAN/edge compute* servers, white box enterprise Ethernet switches with SDN support, and a heterogeneous wireless access network; (b) an Infrastructure Management Framework (IMF) that includes NFV MANO functionality and an SDN controller; (c) a Service Management and Orchestration (SMO) framework that manages isolated E2E slices; and (d) a set of dedicated control and user plane VNFs supporting the wireless access networks. The O-RAN reference architecture is also leveraged for the definition of interfaces between the SMO framework and the control/user plane RAN functions for typical Fault, Configuration, Accounting, Performance, Security (FCAPS) functionality and ML training/inference processes.

A. Control and User Plane

The intelligent integration of 3GPP and non-3GPP (e.g., WiFi and LiFi) access networks provides effective solutions to relieve data congestion, and addresses capacity and coverage issues by enabling offloading, utilizing unlicensed spectrum and deploying dense, smaller cell networks. Access to non-3GPP technologies is provided by the Non-3GPP Inter Working Function (N3IWF) and the Trusted Non-3GPP Gateway Function (TNGF) of the 5GC.

5G-CLARITY proposes the integration of WiFi/LiFi networks as a single SDN controlled Layer 2 network that supports seamless mobility between the two technologies, based on the SDN architecture introduced in [4].

The near Real-Time RAN Intelligent Controller (RT RIC) function processes policy instructions from the non-RT RIC. It is also in charge of the near real-time control; and optimization of the Centralized Unit (CU) control/user plane, and Distributed Unit (DU) functions via data collection and actions over the O-RAN E2 interface. It also hosts one or more *xApps*, that are applications designed to run on the near RT RIC.

A key RAN optimization function is the combined use of multi-wireless access technologies in such a way that they can be selected, aggregated and steered intelligently to optimize the overall network performance while addressing the diverse per-User Equipment (UE) requirements. The Access Traffic Steering, Switching and Splitting (AT3S) framework [5] is the chosen technique to enable the intelligent integration of 3GPP

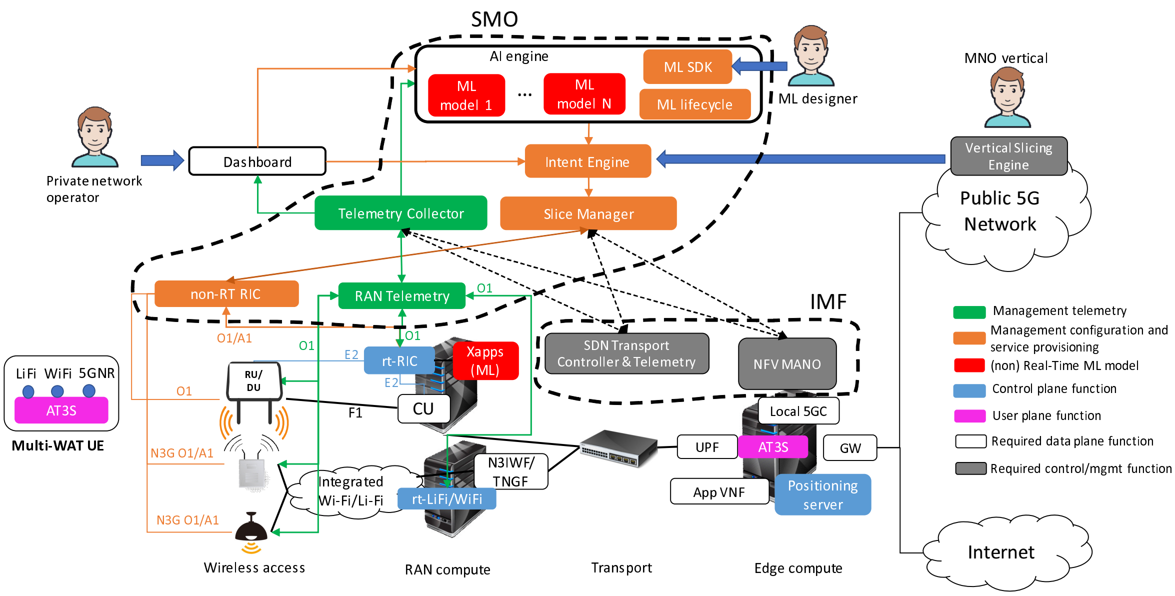

Fig. 1. 5G-CLARITY high level architecture

and non-3GPP access networks. 5G-CLARITY enhances the AT3S framework by running an instance of the AT3S control plane functionality as an xApp that can be implemented using ML models.

5G-CLARITY will also develop localization mechanisms leveraging the proposed 5GNR, WiFi, LiFi private multi-access network. The main challenge is to present the localization data given by the mentioned technologies on a unified interface. To create this interface, an abstraction layer running at the positioning server will be developed. This server will merge the location data for a given UE from the available technologies in order to obtain an improved position estimate.

B. Management Plane

The key pillars of 5G-CLARITY management plane are (a) the provision of services through E2E slices, (b) the adoption of an Intent Engine and an AI Engine to automate the configuration and management of these services; and (c) the support of public services by the integration of private and public networks.

A private E2E network slice is composed of a wireless, a transport and a compute service. A wireless service is in turn composed by a subset of physical devices radiating a given Public Land Mobile Network Identity (PLMNID) in the case of 5GNR, and a Service Set Identifier (SSID) in the case of WiFi or LiFi. This service also delivers the incoming traffic to a specific transport Virtual Local Area Network (VLAN), which would then bridge to the VNFs that constitute the compute service. These network domains also include a resource quota, defined as a share of the resources that are reserved for each service.

The Intent Engine function is introduced to enable an easy interaction with the private network taking a high level *intent language*, translating it into a technical configuration, analysing its feasibility, realizing the intent and then continuously monitoring if the intent is still valid or violated.

5G-CLARITY also adopts the AI engine function with the goal of hosting ML modules. These modules will process the data received from the Telemetry Interface for their specific use cases, e.g. to make predictions or detect anomalies. Self-training models will also use parts of the same data to retrain themselves. After a model concludes its processing, it can then send its output to the Intent Engine, which can act upon the provided model output.

Technical and business reasons could lead an industry vertical to deploy a private network with the support of a public network. To enable such interaction 5G-CLARITY envisions a public-private orchestrator that orchestrates both networks domains individually, by delegating resource orchestrations to each one. Minimum functionalities will be implemented to achieve E2E orchestration. To this end, capability exposure and non-repudiation mechanisms must be defined.

III. Acknowledgements

This work is supported by the European Commission's Horizon 2020 research and innovation program under grant agreement #871428, 5G-CLARITY project.

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