Virtualized Heterogeneous 5G Cloud-RAN deployment over Redundant Wireless Links

Nikos Makris†⋆, Christos Zarafetas†, Kostas Choumas†, Paris Flegkas†⋆, Thanasis Korakis†⋆
†Department of Electrical and Computer Engineering, University of Thessaly, Greece
⋆Centre for Research and Technology Hellas, CERTH, Greece
Email: {nimakris, hrzarafe, kohoumas, pflegkas, korakis}@uth.gr

***Abstract*—5G networks bring increased flexibility for the operator at different levels. On one side, RAN disaggregation based on the Cloud-RAN concept allows the instantiation of base stations in an area based on demand, whereas on the other side NFV-MANO orchestration brings effortless delivery of services deployed over distributed infrastructure. In this paper, we demonstrate a disaggregated heterogeneous Cloud-RAN, consisting of cellular and WiFi infrastructure, deployed through the Open Source MANO orchestrator in the distributed infrastructure of a testbed. Through a pair of mmWave and WiFi redundant links, we backhaul the RAN and in case of a broken link, seamlessly switch technologies without affecting the traffic delivered to the end-user.**

I. Introduction

Network Functions Virtualization (NFV) allows the redefinition of the services used by network providers and administrators as it has the potential to offer enhanced agility and flexibility and improved sustainability through service replication, migration and quick deployment. The NFV-MANO architecture provides abstractions for the underlying hardware, and concentrates only on the orchestration, provisioning and cross-interaction of the deployed functions, taking care of all the configurations for setting up end-to-end paths between the functions. However, the advent of fully softwarized architectures for the RAN provides space for the re-consideration of services deployed in the network, moving beyond just application servers towards full stack networking systems.

In this work, we consider a 5G radio network, disaggregated at two different components, based on the interfaces standardized by 3GPP [1]. The disaggregation takes place at the higher Layer-2 of the OSI stack, realizing the 3GPP suggested Option-2 split [2], between the Packet Data Convergence Protocol (PDCP) and Radio Link Control (RLC) layers of the mobile stack. Two different elements that can be deployed as services are defined through this split process: the Central Unit (CU) integrating the PDCP and above layers, and the Distributed Unit (DU) that handles the lower transmission and reception functions, up to the RLC layer. Leveraging our prior work in integrating WiFi cells as WiFi DUs in such setups [3], we develop the appropriate functionality for wrapping the network elements as services and deploy them through the Open Source MANO (OSM) orchestrator. We use an extended version of OSM, that allows us to configure different types of wireless connectivity between VNFs, as shown in [4]. For the wireless network, we use an extended version of OpenAirInterface (OAI) [5], which provides an implementation of the cellular base station stack.

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II. Experiment Setup

We setup the experiment in the NITOS testbed, a heterogeneous remotely accessible testbed, located in University of Thessaly, Greece. Below, we detail our experimental settings, whereas Figure 1 illustrates the experiment setup.

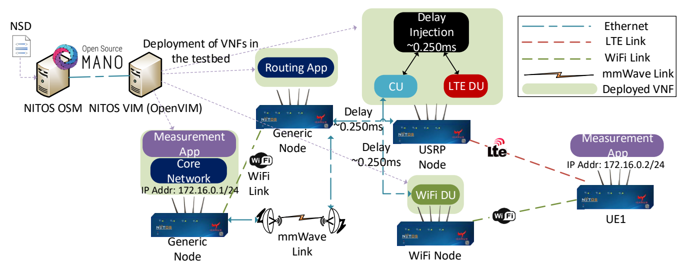
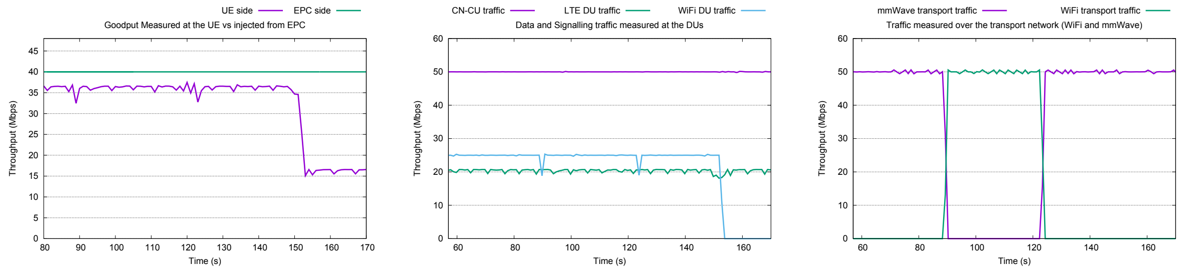


Fig. 1: Experimental topology: CU, heterogeneous DUs, Core Network and Routing services are deployed over the NITOS nodes, considered as the compute infrastructure.

A. Radio Access Network (RAN)

For the wireless part of the network, we employ the OpenAirInterface platform appropriately extended in order to integrate WiFi technologies in the RAN. The functionality relies on the disaggregation of the traditional base station architecture to two different parts, the CU and the DU, and the introduction of signalling between these two entities. In [3] we present the signalling format, and the manner in which new DUs can be supported by OpenAirInterface. Through a thin software layer running on top of traditional WiFi Access Points, we are able to control the traffic that goes through the wireless network from the CU point of view (PDCP layer and onwards). Different policies can be applied, controlling how the traffic is split to the available DUs. For this paper, we use two DUs, an LTE and a WiFi, managed through the same CU, and we split the traffic with a 50% ratio to each DU. As the split for OpenAirInterface regards only the data plane operation of the platform CU and LTE DU are collocated on the same service. However, as the data plane communication takes place over an IP interface, we emulate this behaviour by injecting delay on the interface equal to the mean measured delay between the CU and the WiFI DU (approx. 0.250ms). The configuration of the LTE network is a 5MHz LTE cell operating at FDD band 7, and as a UE we use an off-the-shelf dongle with our own SIM cards. For the WiFi network we use



(a) Application Goodput (Traffic injected at EPC vs reaching the UE

(b) Traffic (payload and signalling overhead) measured at the DUs

(c) Traffic measured at the transport network (mmWave and WiFi)

Fig. 2: Experimental results after deploying the VNFs on the NITOS node

a 40MHz IEEE802.11n configuration, operating in an entirely free from external interference environment.

B. *Transport Network*

For the transport network, we employ two different links: 1) a mmWave point-to-point link, operating at the 60GHz V-band, and 2) an IEEE 802.11n WiFi link. The links are redundant and are used in order to backhaul the operation of the disaggregated wireless RAN. Primarily, the mmWave link is used, but in case of a failure traffic is switched over the WiFi link. For this failover operation, we rely on the use of an OpenDayLight OpenFlow controller, that establishes the flows on the involved network nodes in order to redirect the traffic over the selected technology. The joint mmWave and WiFi network is seen as only one *provider* network at the orchestrator level, allowing the deployed VNFs to attach on it and make use of it. For our experiment setup, we use the LTE Evolved Packet Core (EPC) and a routing VNF that establishes static routing rules between the CU and the EPC as the two entities between which the failover link is configured.

C. *RAN as VNFs*

For the operation of the wireless RAN we rely on the OpenAirInterface, the WiFi DU and the core network. For the first two software elements, the proper RF devices need to be present on the nodes. OpenAirInterface requires an appropriate RF front-end, which for our case is a USRP B210 device, that is attached on the OAI VNF. To do so, and to accomplish the transfer speeds between the VNF and the USRP device, we pass-through the entire USB controller of the compute node. Similarly for the case of the WiFi DU, we pass-through the WiFi device on the compute node's PCI port to the VNF.

When deploying the VNFs, further configuration is needed for the running services. This is accomplished through Cloud-Init, and by a lightweight service [6] exposing some of the network parameters needed for the proper setup of the network. These include the address configuration for OAI communication with the Core Network, the radio parameters (number of antennas, PLMNID, etc.).

III. Experimental Results

Fig. 2 shows our experimental results. We inject 40Mbps of traffic through the *iperf* application at the core network (EPC) and measure the traffic delivered at the UE side. The UE is connected concurrently to the LTE and WiFi DU. Fig. 2a shows the measurements at the two communication sides: we see that traffic reaching the UE is less than what is injected at the EPC side, as it depends on the radio characteristics. LTE SISO mode with 5MHz bandwidth may achieve up to 16Mbps in our setup, and as the traffic is split over the two DUs (20Mbps/DU), only about 36Mbps is reaching the UE.

Fig. 2b shows how the traffic is split between the two DUs, based on what is measured at the output of the Core Network. The WiFi DU network traffic is higher than the LTE DU, reflecting the aforementioned settings. At the 150sec point of the experiment, we stop the WiFi DU and see that the UE gets only 16Mbps of traffic (Fig. 2a). Fig. 2c shows the traffic that is measured on the transport network (mmWave and WiFi). We see that although changes at the transport network technology happen twice, the connection between the core network and the RAN is preserved and the UE continues to receive traffic.

IV. Conclusion

In this paper, we demonstrated the deployment of a disaggregated network, consisting of multiple DUs at the RAN. The functionality is wrapped as VNFs and is orchestrated through Open Source MANO in the NITOS testbed. We use a failover wireless link, consisting of mmWave and WiFi technologies in order to backhaul the cell, controlled through a controller that is able to re-route the traffic over different technologies in case of a link outage. All the functionality is deployable in a single-click fashion through OSM.

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