Virtualized C–RAN Orchestration with Docker, Kubernetes and OpenAirInterface

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Virtualized C-RAN Orchestration with Docker, Kubernetes and OpenAirInterface

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Abstract— **Virtualization is a key feature in Cloud Radio Access Network (C-RAN). It can help to save costs since it allows the use of virtualized base stations instead of physically deployment in different areas. However, the creation and management of virtual base stations pools is not trivial and introduces new challenges to C-RAN deployment. This paper reports a method to orchestrate and manage a container-based C-RAN. We used several instances of the OpenAirInterface software running on Docker containers, and orchestrated them using Kubernetes. We demonstrate that using Kubernetes it is possible to dynamically scale remote radio heads (RRHs) and baseband units (BBUs) according to requirements of the network and parameters such as the server resources usage.**

Keywords— **C-RAN, 5G, OpenAirInterface, Container, Orchestration, Docker, Kubernetes.**

I. INTRODUCTION

Cloud Radio Access Network (C-RAN) [1] are a new design for the cellular architecture. It is an evolution of the distributed base stations concept in which baseband and network processing are moved to a centralized processing center, creating a virtual base station pool [1]. Therefore, the original base station (BS) is split into centralized baseband units (BBU) with all baseband processing functions and remote radio head (RRH) at the network edge, which contains radio functions, and the communication between these two units is made through the fronthaul (FH) link.

In the virtual base station pool, an attractive feature is the possibility of sharing the processing resources among different base stations, which may help to decrease costs. However, by virtualizing the BS we introduce the need to properly manage this new infrastructure. Therefore, we present in this paper a method to orchestrate a C-RAN infrastructure by applying containerization on OpenAirInterface (OAI) [2] and using Kubernetes [3], an existing container orchestration platform.

II. OAI, VIRTUALIZATION AND ORCHESTRATION

The OAI is an open-source project created by EURECOM that aims to implement the 4th and 5th generation of mobile cellular systems. It is fully compliant with the 3GPP LTE standards. Thus, this platform can be used for 4G/5G research

and development of new and advanced features, as it provides a complete software implementation of all elements of the 4G system architecture: user equipment (UE), eNodeB (eNB), and the Core Network (EPC).

OAI is divided into two projects: *openair-cn* and *openairinterface5G*. The first implements the Core Network and the second implements the Radio Access Network (RAN) functionality. OAI supports connectivity to actual UEs (smartphones), using a commercial software-defined radios (e. g. USRP). Alternatively, the OpenAirInterface System Emulation (OAISIM) module can be used to emulate a UE. OAISIM is useful for scenarios when one needs to change the UE software to test new features [4].

Operating system-level virtualization, also known as containerization, refers to a feature that enables the creation of multiple isolated user-spaces on top of a single operating system (OS) kernel. A simplified way to create, deploy and manage containers is by using Docker [5], the most popular containerization platform. This technology can be used for telecommunications infrastructure, to increase density, scaling, speed of deployment, portability and decrease cost [6]. However, containers also introduce new challenges and more complexity by creating an entirely new infrastructure.

In this context, orchestration platforms were designed to manage virtualized deployments in large-scale clusters, alleviating the difficulty of maintaining a large number of standalone containers. Orchestrators must address several important challenges including scalability, fault tolerance, availability, efficient resource utilization, among others [7]. In this work, we adopted Kubernetes [3], which is the world's most popular open-source orchestration system for Docker containers.

A Kubernetes cluster consists of at least one master and multiple computer nodes. The master is responsible for exposing the application program interface (API), scheduling the deployments and managing the overall cluster. The smallest unit in Kubernetes is a Pod, which consists of one or more containers that share the same context and resources. Also, each node runs a container runtime, such as Docker, along with kubelet, a Kubernetes agent for maintaining the local pods according to the information provided by Kubernetes API.

III. SYSTEM DESCRIPTION AND RESULTS

Figure 1 shows the developed system architecture, where RRH and BBU modules of OAI were deployed on Docker containers. Dockerfiles were used to create Docker images for BBU and RRU, with requirements based on OAI documentation [8]. For the EPC, all modules were compiled on a virtual machine since it will not be orchestrated.
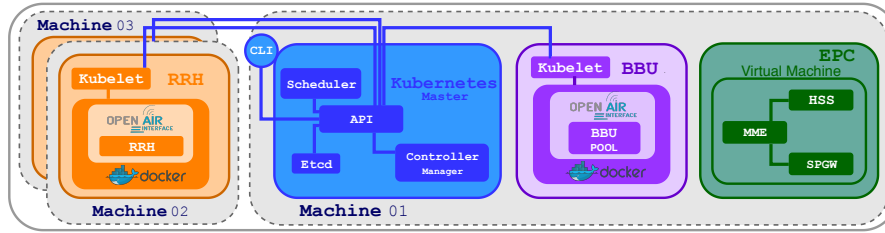
Fig. 1

ORCHESTRATION SYSTEM ARCHITECTURE WITH THE MAIN COMPONENTS OF EACH MODULE INCLUDING THE ORGANIZATION BY MACHINE USED IN THE TESTBED.

BBU and RRH units for Kubernetes were made based on created Docker images. In order to deploy theses units, StatefulSets were used. It's a Kubernetes controller used to scale a set of pods and to guarantee ordering and uniqueness of them. To establish host and pod communication, Calico [9], a Container Network Interface (CNI), was used to provide a layer 3 networking capability and associate a virtual router with each node.

In order to connect RRH with BBU, OAI requires some parameters: BBU, RRH, and EPC IP addresses and also SIM card information when OAISIM is used. So, to be able to dynamically scale the BBU and RRH, all needed information have to be stored on the ETCD, which is a distributed key-value store. When BBU or RRH run, it accesses the ETCD using the container name as a key taking all the values associated and storing its IP address. RRH run first and stores its IP address on ETCD, after, BBU can run and take this information.

The system represented in Figure 1 was created on a local cluster with three machines with 7th generation Intel(R) Core(TM) i5 processor and 8GB of RAM. One machine acts as Kubernetes master and holds all the BBU needed pods and a virtual machine for EPC, as depicted in Figure 1. The other two are worker nodes and will hold one RRH container each.
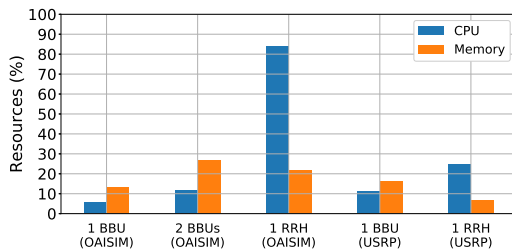

Fig. 2

HOST'S CPU AND MEMORY USAGE COMPARISON OF BBU AND RRH WITH OAISIM AND A REAL UE (USRP).

Figure 2 shows the percentage of the host's resources used to run the BBU and RRH. CPU and memory information can be used to create a load balancing policy, which could allow dynamic changes to support network requirements. Also, the resources used by BBUs grow proportionally, as can be seen by comparing the first two blocks. It also shows the OAISIM

requirement: more than 60% of CPU usage when compared with the use of a real UE, since all UE baseband processing is executed within RRH unit in the machine CPU.
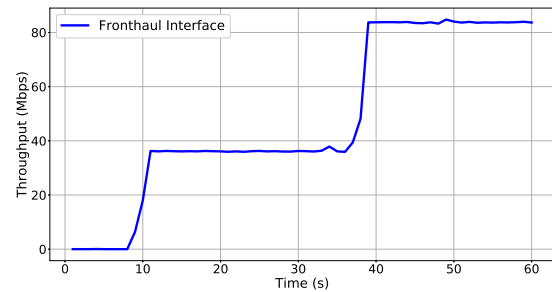

Fig. 3

FRONTHAUL THROUGHPUT CHANGING WHEN A NEW INSTANCE OF BBU AND RRH STARTS ITS OPERATION.

Figure 3 shows the fronthaul throughput changing according to the number of BBU-RRU pairs that are running. When the first BBU starts its operation, the throughput increases, and then it stays constant. When the second BBU is scaled up, the impact can be observed in the data rate, which doubles its value. Thus, this is a flexible and scalable system as we can increase the number of BBU-RRU pairs in an easy way based on some metric or specifying a number.

IV. CONCLUSIONS

This paper presented an orchestration of C-RAN using OAI with the most popular virtualization technologies. This is a flexible system that can be used for research and development in any cloud or local computing infrastructure, being possible to deploy LTE RAN stack elements in order to allocate resources according to the aimed network scenario.

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