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Abstract

Fifth generation of mobile networks (5G) is designed to introduce a multitude of new services which require higher processing resources and lower latency. Cloud Radio Access Network (Cloud RAN) is one of the most promising solutions for next generation networks. The basic idea of C-RAN is to migrate Baseband Units (BBU) to the cloud for a centralized processing and management. In our work, we propose to extend C-RAN architecture with an edge cloud: the Cloud RRH in order to enhance the quality of service (QoS). In this paper we propose a service orchestrator in the Cloud RAN based edge cloud in order to enhance resources utilization while keeping a good QoS.

1 Introduction

In recent years and thanks to the development of mobile devices, the services offered to users have been multiplied in number and diversity. These services are increasingly greedy in terms of resources. This evolution in the usage model has led to an exponential increase in traffic. It is estimated to grow 13-fold from 2012 until 2017 according to Cisco [1]. Therefore, to cope with this increase, mobile network operators have to increase the capacity of their access networks. Several solutions was proposed such as access network densification, however, this solution is very expensive because it requires the implementation of new access points. Moreover, reducing the cell size was proposed as a solution since limited spectral resources can be reused among the small cells more frequently, thus enhancing the total system capacity. However, it increases the problem of inter cell interference.

A major orientation adopted by 5G is based on the use of the cloud. Among the proposed approaches, there is the virtualization of the access network that gave birth to the Cloud RAN. The concept of C-RAN was first introduced in [3] and described in details in [4]. In Cloud RAN architecture, baseband units (BBUs) are centralized and virtualized in BBU pools. Therefore, traditional complicated base stations can be simplified to cost-effective and power-efficient radio units RRHs (Radio Remote Heads). This helps to reduce the network costs in terms of CAPEX and OPEX.

This new access network architecture brings several advantages. Indeed, C-RAN permits to benefit from all the advantages of cloud computing paradigm. It also benefits from centralized management and processing thanks to the provision of BBUs as pools in the cloud. Moreover, Cloud RAN permits better spectral and energy efficiency.

In other hand, running applications specifically developed for mobile devices, for entertainment, health care, business, social networking, traveling, news… becomes an everyday habit. However, there is a gap between mobile handset's capabilities and those required to run such sophisticated applications. Mobile Cloud Computing (MCC) and cloud edge are becoming a key flexible and cost effective tools to allow mobile terminals to have access to much larger computational and storage resources than those available in typical user equipment.

In our work, we propose a novel Cloud RAN heterogeneous architecture where we introduce the Cloud RRH as an edge cloud. The basic idea consists on providing additional computational and storage resources to High RRHs to bring resources closer to end user. Containers is the technology used to support this offloading [3] because it is able to provide a higher level of abstraction in terms of virtualization and isolation compared to other virtualization techniques. Using this infrastructure, mobile users will be able to execute their applications locally on mobile handset or to offload them in Cloud-RRH or in BBU pools. Therefore, in order to fully profit from this architecture we need to efficiently orchestrate services execution among available resources. That's why we propose a service orchestrator in order to efficiently decide where to execute applications.

The remainder of this paper is organized as follows. In the next section, we present our system model and the basic idea of the proposed solution. Finally, section III concludes this paper.

2 Proposed service orchestrator

2.1 System model

The scenario is represented in figure 1. We consider a HetNet Cloud RAN infrastructure composed of H-RRHs (High RRHs) which acts as macro cells and L-RRHs (Low RRHs) which acts as small cells. In our system, we propose to introduce additional cloud capacities in the edge network named Cloud RRH. Unlike a traditional C-RAN architecture where all RAN functionalities are centralized in the cloud, we propose to flexibly split of these functionalities between Cloud RRH and central cloud. We suppose also that additional computation and storage resources are available in the edge for computation offloading. These additional resources are represented by cloud containers

Moreover, as part of the cloud management, we propose to add a new functional entity that we call Cloudlet Manager (CM). The main functionalities of the CM are containers placement, deployment, monitoring and resource and applications scheduling.

Mobile users can access their services directly in the Cloud RRH. In this case, the CM could instantiate containers in the edge and offload the service logic computation in these containers. Containers are not always active, rather they are activated or deactivated accordingly. Different interactions schema are represented in figure 2.

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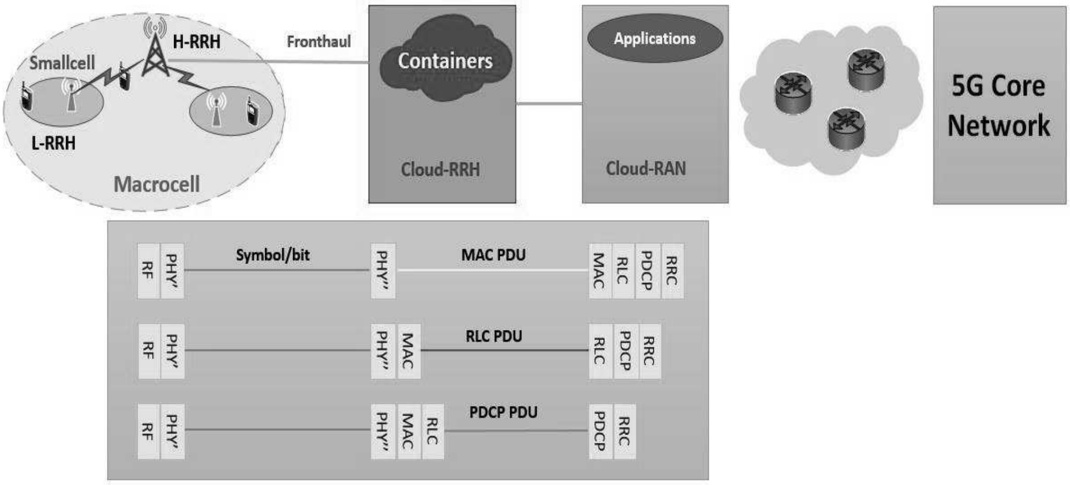

Figure 1: C-RAN Architecture proposed model

Mobile services are increasingly sought after by users in all areas: sports, health, leisure, transportation, studies.... In our architecture, these services can be executed on the mobile terminal, in the Cloud-RRH or in the Central Cloud (BBU pools). However, the main problem is how to make the decision about the place of execution of a given service while assuring an amount of condition such as QoS improvement, cost reduce and resources utilization optimization. Therefore, we developed a service orchestrator in a 5G cloud RAN environment.

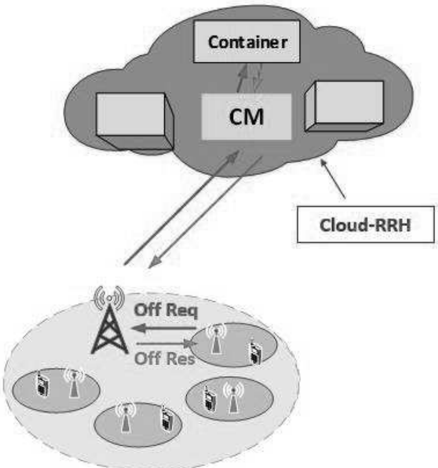

Figure 2: Cloudlet Manager interactions

2.2 Service orchestrator

As we have explained, a given service can be executed in three parts of our Cloud RAN architecture which are the mobile, the cloud edge and the central cloud. Actually, the assignment of a service to a processing unit depends both on the resources required by the service to launch and the free capacities of the processing units. And here comes the role of the decision algorithm in our orchestrator.

Different, decision algorithms exist in the literature [5][6][7]. In our work, we propose to use fuzzy logic as a decision algorithm. As represented in figure 3, fuzzy logic controller (FLC) is essentially composed of three steps. The fuzzification is the first step of the fuzzy logic process. This step takes as input the numerical values of the variables on which the fuzzy controller will base its decision $x_i \ (i = 1,2,...,n)$ and gives as an output m fuzzy variables, denoted by $F_{ij} \ \ (j = 1,2,...,m)$. Therefore, a continuous space is mapped into a discrete space. The matching between the numerical and fuzzy variables is made using a membership function $\delta_{ij}(x_i)$ which defines the membership degree of the numerical input x_i with the fuzzy output F_{ij}. In our work, we use the Gaussian membership function as follows:

$$\delta_{ij}(x_i) = \exp\left[\frac{-(x_i - F_{ij})^2}{2\sigma^2}\right] \qquad (1)$$

Where σ is the membership functions width, $i \in \{1,2,...,n\}$ and $j \in \{1,2,...,m\}$.

The second step is inference. This step takes as input the fuzzy variables and the $s \in S$ rules defined for the fuzzy controller and calculates validation degree of each of these rules. All rules have the following form:

$$if \ x \ is \ r \ then \ a = c_s \qquad (2)$$

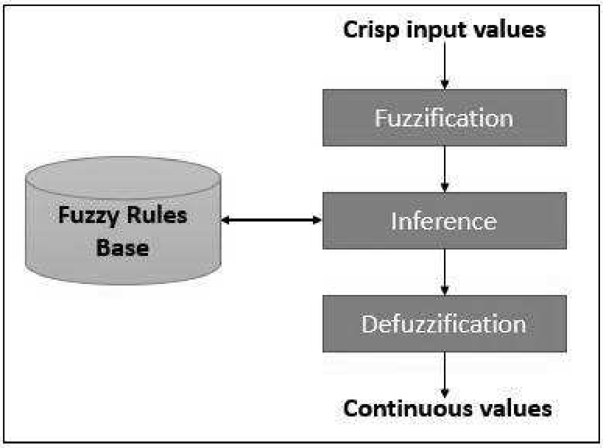

Figure 3: Fuzzy Logic Control Process

In deffuzification step, the output action a is given by the gravity center of conclusions c_s in each rule weighted by the membership function using the following expression:

$$a = \sum_{s \in S} \prod_{i=1}^{n} \delta_{ij}(x_i).c_s \qquad (3)$$

To use fuzzy logic, we need to define the inputs of the decision algorithm, the sets of values, then the membership functions of the inputs to the sets of values and finally the rules on which the algorithm will be based to make its decision on where the service should optimally be executed.

a) Input specification

First of all, we should define our inputs which are the resources service requirements. We specified these resources required by the service to be the:

- CPU
- RAM
- Bandwidth
- Disk space

b) Set of values specification

Now, that we specified the inputs of our algorithm, we should define the sets of values that we will use. Since the service can be executed either on the mobile, the cloud edge or the central cloud, the sets of values will be the:

- Mobile region
- Cloud edge or cloud RRH region
- Central cloud region.

c) Membership functions

The figure 4 represents an example for the membership functions of the resources (CPU, RAM, BW, DS) to the sets of values (mobile, cloud edge, central cloud) knowing that:

- Mobile limit is taken for 5 units
- Cloud RRH limit is 10 units
- Central cloud limit is 15

d) Rules specification

Now that we defined the membership functions for our inputs, we need to define the rules on which the fuzzy controller will base its decision. The rules that we defined are:

- If ((CPU is Mobile) and (RAM is Mobile) and (BW is Mobile) and (DS is mobile)) then (Output is Mobile)
- If ((CPU is Cloud_RRH) and (RAM is Cloud_RRH) and (BW is Cloud_RRH) and (DS is Cloud_RRH)) then (Output is Cloud_RRH)
- If ((CPU is Central_Cloud) and (RAM is Central_Cloud) and (BW is Central_Cloud) and (DS is Central_Cloud)) then (Output is Central_Cloud)

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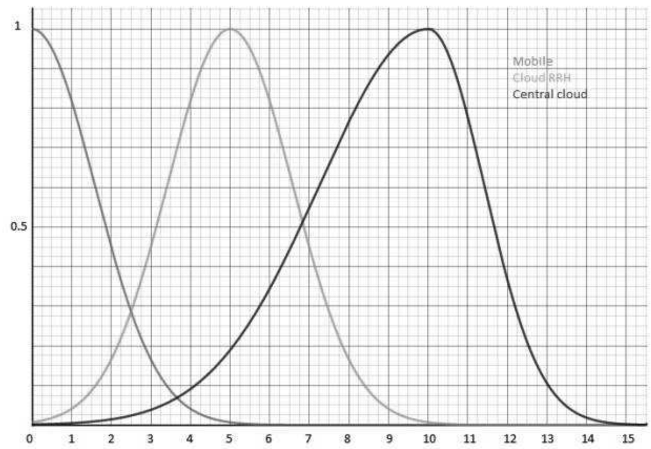

Figure 4: Membership functions

3 Simulation and results

This section provides simulation results for the proposed service orchestrator based fuzzy logic, we have compared its results with a random association of services to MT, Cloud RRH or central cloud. We considered a Cloud-RRH with N= 20 containers having heterogeneous resources. The computing capacity of containers varies from 1 to 10 CPUs. The memory is set from 128 Mbytes to 512 Mbytes and the network bandwidth is set from 100 Kbps to 200 Kbps. Services have heterogeneous requirements and the request to execute a service arrives randomly.

Figure 5 represents the variation of the response time over service's data size (ranging from 1 to 100 Kbits). Results show that the proposed service orchestrator ensures a lower response time compared to random association. Therefore, it will enhance the user quality of experience.

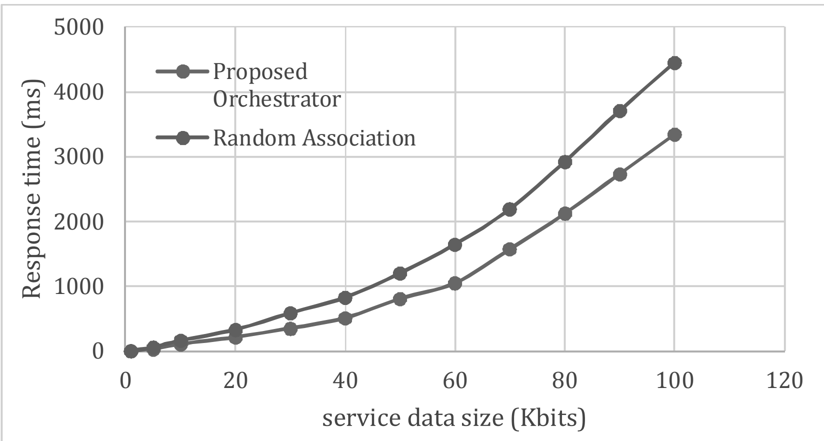

Figure 5: Services response time evaluation

4 Conclusion

This paper addresses a topical issue in the field of telecommunications and mobile networks which is the optimization of the resource usage in a Cloud RAN network which comes across the orchestration of services execution in this network. To develop our service orchestrator we have used a fuzzy logic decision algorithm. The proposed system model is expected to optimize resource utilization while keeping a good level of QoS.

As a future work, we will simulate the proposed solution in order to test its performances. Then, we will integrate the execution cost in the optimization process.

5 Acknowledgement

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