The Importance of Network Slicing and Optimization in Virtualized Cloud Radio Access Network

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***Abstract*— The rise of 5G mobile network and the increasing of the number of connected devices with the deployment of new technologies, make the operator thinking of using new network architecture to meet the requirement of such situation. Cloud Radio Access Network (C-RAN) is a network that become the infrastructure of next generation, with the new evolving technologies, such as Network Function Virtualization (NFV) and Software Defined Networking (SDN). Network slicing enables the orchestration of Radio Access Network (RAN) resources, by isolating the physical network to virtual slices each of them reserved for determined application or services. Besides, implementing optimization method on C-RAN infrastructure led to a large number of profit chances. This paper will explain in depth the importance of such technologies and methods in Virtualized C-RAN.**

Keywords*— *Cloud Radio Access Network, 5G, Virtualization, Network Slicing, Optimization.

I. INRODUCTION

The deployment of new technologies and the fast growth in the size of connected devices (tablets, smartphones, IoT devices, etc.) caused the increase in demands of mobile data traffic and the network costs, including Capital Expenditure (CAPEX) and Operational Expenditure (OPEX). Also, the current network architectures cannot deal with these demands any longer. Therefore, to fit these demands for support 5G services with low latencies and high data rates; a new network architecture need to be investigated by network operators [1].

A Cloud Radio Access Network (C-RAN) has lately raised as an effective solution for constructing high performance and low-cost Radio Access Network (RAN) in 5G (Fifth Generation). C-RAN depends on the concept of pooling the base station in central servers, that submit surpassing performance gains and reduces execution cost. Lately, a technology of virtualization also has many benefits, such as reducing costs, minimizing the investment capital, reducing power consumption, increasing flexibility and reliability in utilizing the server/network resource [2].

In order to improve quality of experience "network slicing" come into the vision and is considered as a promising solution to C-RAN to provide tailored services. Network slice is considered as a logical network on a physical infrastructure that is shared by a set of isolated virtual resources. Network slicing can modify slices for complex and diverse 5G scenarios and it has the ability to allocate and reallocate resources depending on the changed demands [3].

Finally, C-RAN has to be planned in a way that it can meet the 5G networks requirements. Therefore, using optimization for supporting a huge number of user devices, reducing cost and delay, increasing throughput and reliability, and allocating of radio and computing resources are the challenges in C-RAN [4].

II. CLOUD RADIO ACCESS NETWORK

A. Cloud Radio for mobile Networks

In traditional cellular networks, a base station serving the cells that is in the same coverage area and users communicate with the base station. The main base station functions consist of radio and baseband processing functionalities. Power amplification, frequency filtering and digital processing are the responsibility of the radio function, while the functions of baseband processing are responsible of coding process, modulation process , Fast Fourier Transform (FFT), etc.. In 1G (First Generation) and 2G (Second Generation) mobile networks architecture, baseband processing and radio functionality is united inner a base station. Generally, the antenna is located in a few meters from the radio station and connected with it by coaxial cables that suffers from high losses. the interface defined between base stations is X2, and the interface that connects a base station with mobile core network is S1 as shown in Fig. 1. In 3G (Third Generation) and 4G (Fourth Generation) the base station is isolated into a signal processing unit and a radio unit , as shown in Fig. 2. The radio unit is called a Remote Radio head (RRH) or Remote Radio Unit (RRU). On the other hand, processing part is called a Data Unit (DU) or Base Band Unit (BBU). In C-RAN, a BBU/DU Pool/Hotel is the entity that the BBUs are centralized and it is virtualized and shared between cell sites as shown in Fig. 3 [5].

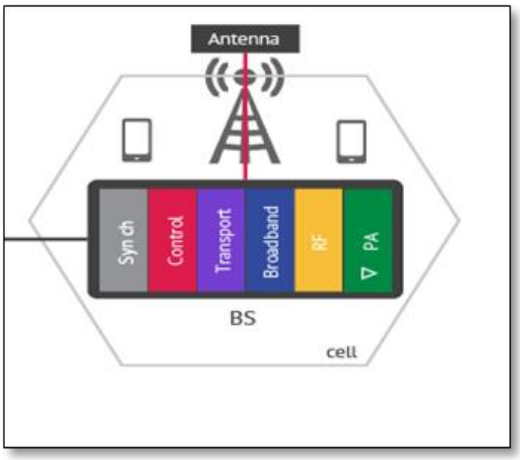

Fig. 1. Traditional Macro station

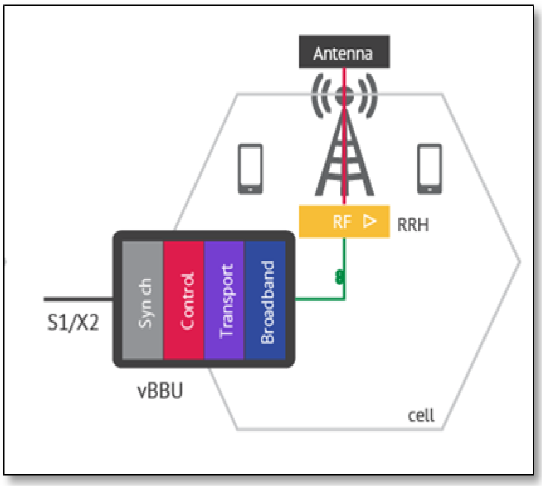

Fig. 2. Base Station with Remote Radio Head

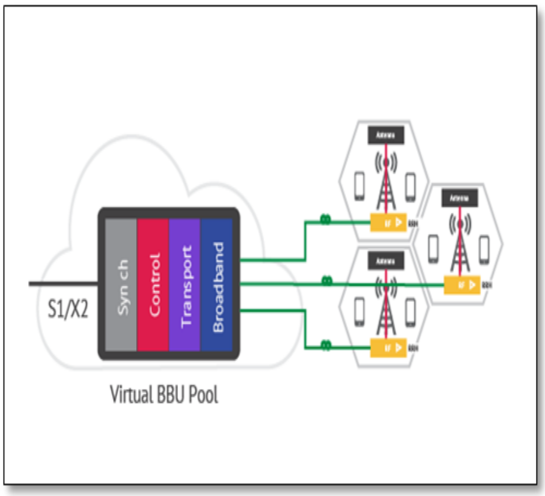

Fig. 3. Cloud Radio Access Network with Remote Radio Head

Nowadays, a serious situation is faced by mobile operators especially with the 5G. Increasing the number of mobile devices, lead to increasing mobile data traffic and CAPEX and OPEX. So, in order to offer best services for users and confirm a well profit, the operators need to transform from previous network (shown in Fig. 4) and have to get new solutions. Today, the cloud computing become a promising choice for both mobile operators and Information Technology service providers. Facilities of cloud computing are used by mobile operators to getting low-cost operation and to forming a pool of resources shared in a large geographical area. A new paradigm based on cloud computing with power efficient infrastructure, collaborative radio and centralized processing proposed by a few operators (China Mobile Research Institute) called Cloud Radio Access Network (C-RAN) (shown in Fig. 5) and it consider as the infrastructure architecture to 5G [6].

Because of 5G higher bandwidth; it connects billions of devices with low latency and very high speed. Also, according to uploading and downloading speeds 5G will pass up to 100 times than the current 4G standards. For example, if a file takes two hours to download in 4G it would take just six minutes to download in 5G. Table I explains a comparison between mobile generations [7].

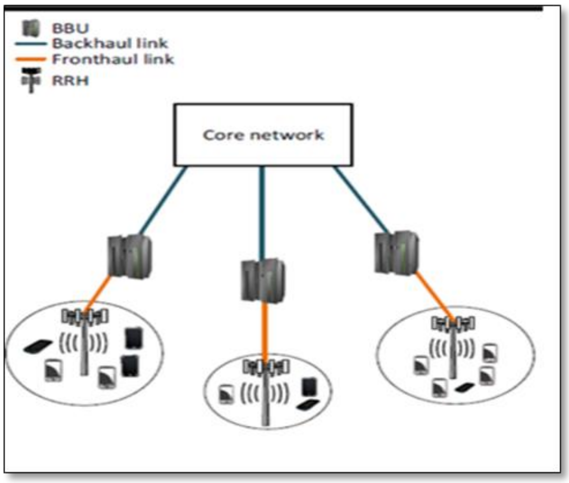

Fig. 4. Radio Access Network

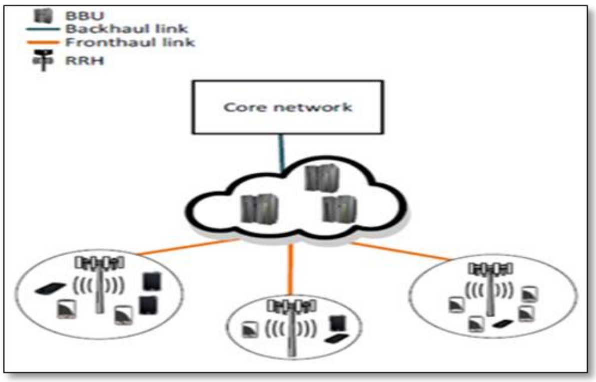

Fig. 5. Cloud Radio Access Network

TABLE I. COMPARISON BETWEEN MOBILE GENERATIONS

Criteria	**Mobile Generations**			
	2G	***3G***	***4G***	***5G***
Introducing year	1993	2001	2009	2018
Technology	GSM	WCDMA	LTE, WiMAX	MIMO, mmWaves
Access System	TDMA, CDMA	CDMA	CDMA	OFDM, BDMA

Criteria	**Mobile Generations**			
	2G	***3G***	***4G***	***5G***
Switching Type	Circuit, packet	Circuit, packet	packet	packet
Network	PSTN	PSTN	packet Network	packet Network
Internet service	Narrowband	Broadb-and	Ultrabro -adband	Wireless World Wide Web
Bandwidth	25 MHz	25 MHz	150 MHz	30-300 MHz
Speed	64 Kbps	8 Mbps	300 Mbps	10-30 Gbps
Latency	300-1000 ms	100-500 ms	20-30 ms	1-10 ms
Mobility	60 km	100 km	200 km	500 km

B. Cloud radio access network architecture

Generally, The C - RAN architecture consists of three basic components: the remote radio units (RRUs) , the fronthaul network and the centralized BBU pool. In the downlink, the RRUs responsible for transmitting the Radio Frequency signals to user equipment, whereas in the uplink, it responsible for forwarding the baseband signals from user equipment to the centralized BBU pool. Optimizing the network resource allocation for RRUs and processing baseband signals are the function of BBU pool which run as virtual base stations. In addition, the unprocessed Radio Frequency signal is transport from antenna to virtual BBUs by the fronthaul network. Also, backhaul connecting a BBU pool with the mobile core network [8].

Technology of virtualization is used in this architecture, where the BBU's functions installed as software on the physical servers called the virtual BS as shown in Fig. 6.[2].

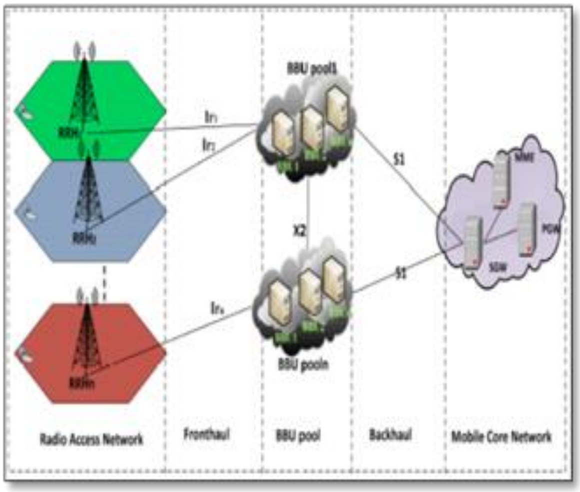

Fig. 6. Virtualized Cloud Radio Access Network architecture

C. Cloud radio access network benefits

In C-RAN, C letter has several features such as Centralization, Cloud computing, Cooperative radio, and Clean system [2]. C-RAN has many benefits: First, reducing inter-channel interferences by processing and joint scheduling and increasing in capacity and this attributed to existence of centralized BBU pool in which the resources can be shared cooperatively and dynamically between multiple cells of different operators. Second, improving System throughput; in areas that express high throughput needs C-RAN allows dense RRH deployment modules. Third, Reducing OPEX and CAPEX; this attributed to centralization of BBU and isolation from RRHs thus lead to great reduction in maintenance and deployment costs. Forth, Coexistence of multiple standards; multiple standards can be useful used for each of user demands and supported by Centralized BBU. Finally, Green Radio; in C-RAN number of cell sites is reducing thus improves energy efficiency also led to reducing in power consumption of site and equipment. Also, in the period of low traffic C-RAN has the ability of turn off the BBUs that under level of utilization and migrated their traffic to effective BBUs [9].

D. Virtualization Concept in C-RAN

Virtualization can be defined as a technology that has an ability to create a logical, isolated entity from a physical entity. Furthermore, technology of virtualization is used for years for desktop, network, storage, and data virtualization. Virtualization of network is a significant technology to architecture of C-RAN. It comprises a number of virtual links and virtual nodes. Virtual networks are used in the heterogeneous network that will provide low cost, flexible control, diversified applications and efficient resource usage [2].

Technology of network virtualization separates applications, data storage, management control and operating systems. The Virtual Base Stations (VBSs) called on the functions of a base station that are considered as software instances. A common resource such as systems and hardware are shared by multiple VBSs as shown in Fig. 7, thus lead to flexible and efficient utilization [5].

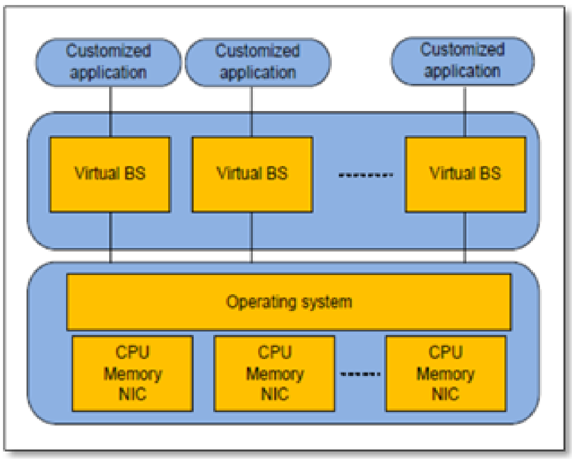

Fig. 7. Virtualization Concept in Cloud Radio Access Network

However, there are many motivations concern using virtualization in C-RAN; reducing the finance capital, providing different authentication mechanism for different services, minimizing cost, reducing consumption of time for testbed setting, and providing reliability and flexibility in terms of being able to add or remove virtual operators [2].

For managing future networks and implement virtualization technology, two promising technologies come into seen: Software Defined Networking (SDN) as shown in Fig. 8, and Network Function Virtualization (NFV) as shown in Fig. 9. The most important key objectives in controlling and managing network; is decreasing operational costs and increasing network resource utilization. **SDN** and **NFV** have massive benefits, including easier management needs, best resource utilization and reducing operational costs. **SDN** has arisen with the growth of cloud services and applications across cloud providers and enterprise. For more flexibility **NFV** allows migrating network functions from hardware to virtual machines. [10].

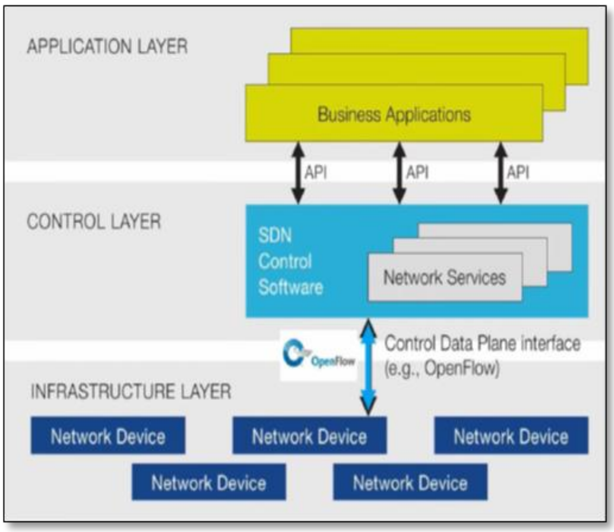

Fig. 8. Software Defined Networking

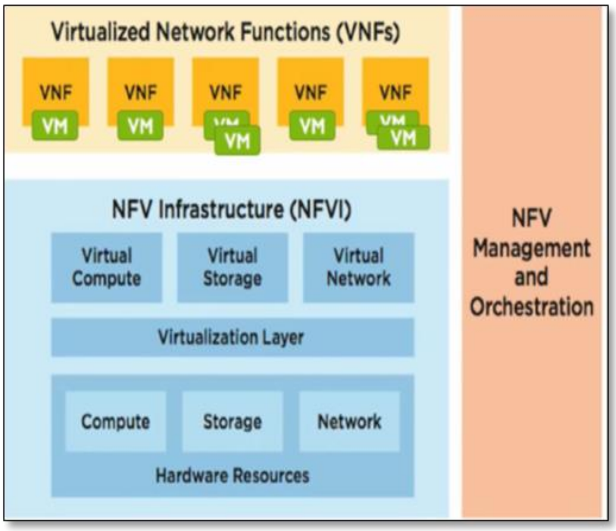

Fig. 9. Network Function Virtualization

III. NETWORK SLICING

The process of producing multiple virtual networks from partitioning one physical network is called Network Slicing. Each of virtual network or slice optimized and architected for a precise service or application. Each network slice has its own topology, virtual resources, provisioning rules and traffic flow. Resources can be shared between network Slices even they are logically isolated. In the future mobile network, there are different network slices that required for the needs of different users. Fig .10 shows the concept of network slicing [3].

Each network slice assigned with a different number of resources and can be confined to deal with specific class of traffic with different security needs; also, network slicing is dominated by software components, which enable on demand and real-time reconfiguration. Moreover, underutilized resources can be leased as network slices, thus generating new gain chances for providers of infrastructure and maximizing utilization of resource [11].

As number of use cases and the scale of deployments increases, the risk of resource starvation increases and radio resources become scarcer. Furthermore, services that supported by 5G system must include high bit rates and ultra-low latency. Network slicing enables the orchestration of RAN resources, functions and Quality of Service (QoS) policies in a way that can guarantee fulfillment of service level agreement (SLA), while maintaining access to available resources for different service categories [12].

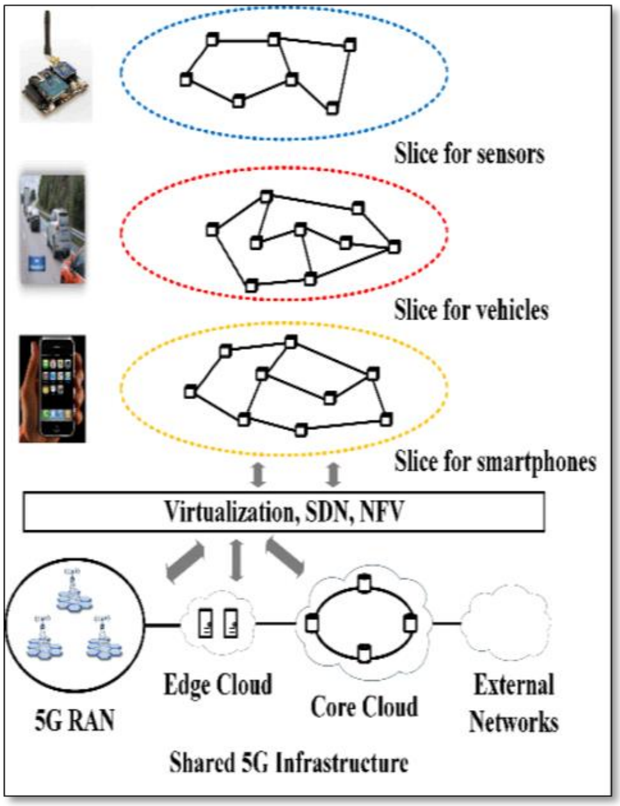

Fig. 10. Conceptual illustration of network slicing

IV. OPTIMIZATION AND IMPROVEMENTS IN C-RAN

As a candidate technology for 5G mobile networks, C-RAN have serious challenges. For improving and optimizing C-RAN for utilizing it as a communication system; a great effort of research is needed. The fronthaul network that links RRHs with BBU cloud have to have high capacity and low latency, and resource scheduling and allocation mechanisms are needed for optimize network. Also, the process of service delivering to the users in reliable manner and in exact time that called mobility management can be serious challenge. Moreover, C-RAN need to find a solution for supporting the huge number of Internet of Things (IoT) devices, IoT is a part of future 5G networks. Besides, there is a security threats to which the C-RAN is exposed by both wireless communication and the cloud computing systems. As a summary, a whole new concept in the mobile system has brought by C-RAN [4].

V. RECENT RESEARCH IN C-RAN BASED ON NETWORK SLICING AND/OR OPTIMIZATION

The authors in [13] proposed a prototype of Flex RAN SDN controller and Open Air Interface (OAI) platform for network slicing in a C-RAN with the objective of sharing spectrum between different slices in an efficient way with considering their requirements. The result showed that the proposed prototype has the ability for providing isolation between multiple slices in a dynamic manner.

While the authors in [14] used a CRAN as use-case and analyzed the performance of virtualized network functions (VNFs), in terms of latency. Performance results focused on significant latency gains and enables reducing CAPEX and OPEX.

The authors in [15] presented a prototype of (C-RAN) based on the platform of Open-Air Interface (OAI) and Docker container technology, with the aim of distributing the spectrum resources among multiple slices in an efficient manner. Also, designed a northbound SDN application. And by using IoT devices orchestrated by the Behavior Crowd Centric Composition (BeC3) framework and real smartphones, for validating the prototype ability in configuring in real time each slice. And as a result, the prototype enabling efficient splits of spectrum resources between slices.

The author in [2] focused on load balancing, saving energy and analyzing and modeling of power consumption in C RAN by proposing an Orchestra Server (OS) in the BBU pool that hosts an intelligent algorithm. The main purpose of this algorithm is to optimize the configuration of the BBUs to the right RRHs. The results showed that the proposed PSO algorithm was estimated the best locations of BBU pools as well as solving the pooling problem of network.

In [16] the author studied the virtual network function placement (VNF-P) problem in the perspective of NFV, with the aim of minimizing the delay with the bandwidth storage, compute, and I/O consumed resources. Also proposed an integer encoding grey wolf optimizer (IEGWO). Results obtained from Simulation explained that IEGWO works better than the set of optimization algorithms, according to the exploration and exploitation.

The authors in [17] formulated a mathematical method that optimizes the number, deployment location and routing path of CUs; with the objective of minimizing the vRAN data routing costs and operational expenditures. The results showed that more functions at the CUs even for high DU traffic loads and routing costs in vRAN more can support higher level of centralization.

The work proposed by the authors in [18] present Cross Layer Controller and SDN-SDR in order to optimize the execution of RAN for 5G and providing the needed flexibility to the polices of the network slicing. The proposed solution provides the ability to optimize the slicing policies in real-time and approaches between the radio and network.

In [19] the authors presented a standard architecture for cloudified RAN called Open radio access network (O-RAN) with the aim of splitting and deployment of different layers of RAN as virtual functions while allowing these functions to communicate with each other cooperatively for provisioning of service. This model considers as a solution to increasing chance of selecting proper resources and reduces the service requests delay.

Finally, the authors in [20] addressed a basic optimization method in next generation fronthaul interface. The optimization method deals with the process of data flows and allocation of the transmission resources according to the bases of quality of service (QoS) requirements. And by applying the mixed integer programming (MIP) approach for formulating the latency-aware flow allocation (LFA) optimization problem. The numerical experiments results show the effectiveness of the meta-heuristic method, when compared to the MIP approach.

VI. CONCLUTION

As a result of fast evolution in the number of connected devices (tablets, smartphones, IoT devises, etc.), and the deployment of new technologies; demands of data traffic and network costs (CAPEX and OPEX) increased. Therefore, new network architecture needs to be investigated to meet the requirement of new generation of mobile networks (denoted by 5G) thus a Cloud Radio Access Network is developed for that purpose. Also, the increasing in number of connected devices need to be managed to introduce the service on demand. Network slicing provides a set of isolating slices each of it meet the requirements of a specific application, and for applying such process we need the help of virtualization to deploy a scalable slice. Moreover, using of optimization methods for improvement and enhancement the work of mobile networks. This paper explained with a great deal the importance of such methods and technologies in C-RAN that considered a promising infrastructure for 5G mobile networks.

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