# Cloud RAN: Basics, Advances and Challenges

### A Survey of C-RAN Basics, Virtualization, Resource Allocation, and Challenges

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## Abstract

Nowadays, with the increasing number of mobile internet technology, operators like AT&T and Telcom are faced with huge pressure on the increasing number of operating expenses with much less growth in their income. Such growth would require more and more base stations to support user needs which would be really expensive to deploy and manage. Cloud Radio Access Network (C-RAN) is an innovative new architecture that tries to meet such needs by centralizing the base stations and providing a cooperative solution between multiple operators. Such technology comes with minimal cost, high energy efficiency, and centralized network architecture that attracted a lot of attention in both academia and industry.

To that extent, this paper strives to review the basics of C-RAN, virtualization, resource allocation advances and the current challenges that need to be solved before such system comes to practice. We present the main architecture, structures and network components in order for the reader to understand the later advances. Then we go through network virtualization and its solutions in such systems including Network Function Virtualization (NFV) and Software Defined Networking (SDN). Resource allocation advances are also discussed with multiple objectives that are application and network specific. Furthermore, we discuss some of the currently faced challenges in C-RAN implementation which reduces its possibility of being deployed in practice. The latter discussion introduces the expected research problems in such system that need to be resolved before such system comes to practice.

## Keywords

Cloud RAN, C-RAN, architectures, structures, resource allocation, wireless virtualization, NFV, SDN, C-RAN challenges.

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# 1. Introduction

It is estimated that the requirements for high speed mobile networking including high quality video streams, social networking and machine to machine communication will increase by hundreds times by 2020 [Huang14]. This can be due to the increase of mobile users besides the high expectation to get higher quality of services. In addition, such growth will come in parallel with the promising 5G cellular networks to handle all network traffic and provide high quality services. In order to reflect such growth, operators such as AT&T and Telcoms will need to modify their infrastructure to handle such increase in the number of users and services expected [Lin14]. This can cost operators a lot in terms of capital and operating expenses which is expected to grow exponentially in such cases. On the other hand, the revenue of such operators is decreasing as they are mostly experiencing low growth in their incomes.

The part of the cellular networks that needs to be modified to handle such growth is called Radio Access Networks (RAN). RAN includes base stations and users' connections wirelessly to the system besides handling user signaling and managements. This is considerably taking the highest costs in such systems as base stations deployment and management get really complex and cost a lot. Furthermore, to solve users increase and requirement, more than one base station will need to be deployed in the same area so that a base station does not get overloaded. However, having more that one base station will introduce the problem of base stations coordination so that they do not affect each other. The system will become more and more complex in terms of geographical deployment and coordination. Moreover, the cost of such system will be much more such that no operator will be able to handle such cost and hence a better cost effective solution needed to be proposed.

To that extent, Cloud Radio Area Networks (C-RAN) was first introduced by China Mobile in 2009 to accommodate such growth in mobile networking [CRAN14]. It is a novel mobile architecture that has the potential to handle as many base stations as the network needs using the concept of virtualization. In C-RAN, the baseband and channel processing is virtualized and shared among operators in a centralized baseband pool. Such centralization and sharing allows for more dynamic traffic handling and better utilization of resources including base stations deployments. Such architecture would have the potential to decrease the expenses cost as base stations are virtualized instead of physically deployed in different areas. In addition, it reduces the energy and power consumption compared to traditional networks due to the fact that base stations will be located on the same physical device.

Therefore, C-RAN architecture was highly appreciated and targeted by mobile operators including China Mobile, IBM, Huawei, Nokia Siemens Networks, Intel and many more. Moreover, C-RAN can be seen as the typical architecture that will be adopted by the fifth generation mobile networks which is expected by 2020 [Checko15]. Hence a lot of research has been presented in the literature that tries to document C-RAN architecture in terms of components, structure, advantages, virtualization technologies, resource allocation, scheduling, and platform implementation. Furthermore, much more research is supposed to come in such field to solve its current challenges and have deployed platform that can be used by industrial companies.

In this paper, we survey different aspects of C-RAN innovation and present some of its current challenges that are faced by operators. In specific, we review C-RAN components, structures and advantages of such centralized architectures. Going forward, we discuss the most critical aspect in C-RAN innovation which is network virtualization and how base stations can be virtually implemented. Then, we discuss another important aspect of C-RAN which is resource allocation and how can share resources be distributed among others. Finally, we highlight some challenges that are faced currently in C-RAN which introduce the need for further research in such area.

### 1.1. Related Works

C-RAN is a considerably hot research area in computing over the past six to seven years. Hence, a lot of research has been conducted in this area and lots of survey papers have been presented in literature. Some of the most relative, recent and highly important ones are presented in [Checko15], [Huang14], and [WU15]. In [Checko15], the authors surveyed possible architectures, advantages, challenges and some implementation techniques in C-RAN. In [Huang14], the authors presented the recent progress in C-RAN up to 2014 including their deployment, concepts, features, and some challenges that are mostly solved by now. In [WU15], the authors defined C-RAN architectures, functions, challenges, infrastructures user scheduling algorithms and performance evaluation of some employed C-RAN systems.

This paper can be seen as an extension of other survey papers in terms of architecture and virtualization. In addition, we review some resource allocation mechanisms which are newly proposed and not discussed in other survey papers. More importantly, we highlight some of the challenges that were not set forth in the other survey papers and are currently considered as critical challenges in deploying C-RAN architectures by operators.

### 1.2. Paper Organization

The rest of the paper is structured as follows: Section 2 will handle C-RAN basics in terms of architectural components, structures and centralization advantages. Section 3 will discuss virtualization technologies by introducing them and going through Network Function Virtualization (NFV) and Software Defined Networking (SDN) techniques to achieve such virtualization. Section 4 will present the resource allocation problem and some of its current solutions. Section 5 will highlight current C-RAN challenges and Section 6 will conclude the main ideas in the paper.

## 2. C-RAN Basics

In this section, we review the basics of C-RAN technologies including their architectures components, their structures and their advantages. It should be noted that the discussed components and structures are the most commonly used ones nowadays; however, there exists some outdated architectures which are out of the scope of this paper.

### 2.1. C-RAN Architecture Components

A C-RAN architecture consists of three main components: Base-Band Unit (BBU) pool, Remote Radio Unit (RRU) networks, and transport network or what is normally called Fronthaul. Figure 1 shows the overview of C-RAN architecture while the following summarizes the main functions of each component [Huang14]:

- **BBU pool:** a BBU pool is located at a centralized site like a cloud or a data centers. It comprises of multiple BBU nodes that have high computational and storage capabilities.

Those BBUs are responsible for processing resources and dynamically allocating them to RRUs based on the current network needs.

- **RRU network:** a RRU network is a wireless network that connects wireless devices just like access points or towers in traditional cellular networks.
- **Fronthaul or transport network:** Fronthaul is the connection layer between a BBU and a set of RRUs that provides high bandwidth links to handle the requirements of multiple RRUs. Fronthauls can be realized using different technologies that include optical fiber communication, cellular communication or millimeter wave communication. Optical fiber communication is considered to be ideal in C-RAN as it provides the highest bandwidth requirement. However, it comes with high costs and not flexible implementation. On the other hand, cellular communication or millimeter wave communication is cheaper and easy to deploy. However, it comes with the cost of less bandwidth and more latency than optical fiber.

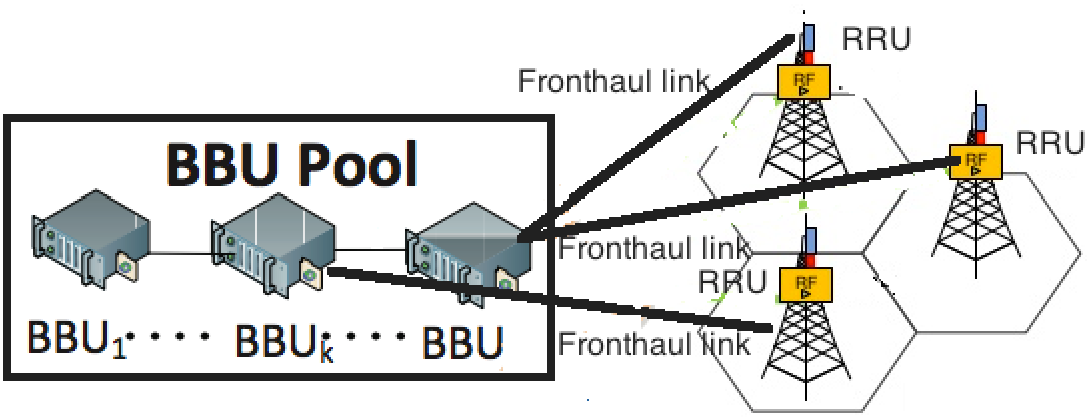


**Figure 1: C-RAN architecture components**

## 2.2. C-RAN System Structures

According to BBU and RRU functionalities, a C-RAN system structure can be divided into fully centralized, partially centralized and hybrid. The basic division here depends on where physical layer, Media Access Control (MAC) layer and network layer functions are handled. Physical layer functions include baseband processing, i.e. radio functions, while MAC is access control mechanisms and network layer is routing mechanism. In the following, we discuss each of these structures in brief:

- **Fully centralized:** a fully centralized structure would move all physical, MAC and network layers' functionalities to the BBU. BBUs handle all the functions of managing and processing resources and hence such structure can benefit from easy operation and maintenance significantly. However, communication overhead between the BBU and RRUs causes a significant burden to such structures as the performance will be limited to Fronthaul capabilities.
- **Partially centralized:** in partially centralized structures, the physical layer functions are done at RRUs while MAC and network layers' functions are performed at the BBUs.

This can greatly reduce the overhead of RRUs-BBUs communication as the physical layer take a major computation burden of C-RANs. However, these structures come with complex physical and MAC communication and not supporting physical layer resource sharing between different RRUs.

- **Hybrid centralized:** In a hybrid centralized structure, part of the physical layer functions are done in RRUs while others are done in BBU. RRU takes the responsibility of users or cell specific functions that are mainly concerned with signal processing. Such structure can be the most flexible one in resource sharing besides having the potentials of reducing energy consumptions and communication overhead in BBUs.

## 2.3. Advantages of centralized BBU in C-RAN

A centralized BBU comes with many advantages that include: the possibility of implementing advanced technologies, resource virtualization, and service deployment at the edge facilitation. A centralized BBU pool means that BBUs are located at the network center while RRU are distributed. This enables C-RAN to have several advantages over traditional cellular networks in which BBUs are distributed.

The first advantage is the possibility of implementing various advanced technologies that require high processing and cannot be implemented in traditional networks. As BBUs can be located in powerful data centers and have efficient information exchange, they can do extensive computation that cannot be done in current networks. As a result, joint processing and cooperative radio sharing technologies will become possible with C-RAN architecture.

In addition, with multiple BBUs that share a common pool, resource sharing can become feasible and hence allocation can be more flexible and on demand unlike traditional networks. This can improve resource utilization, result in less power consumption and have more user satisfaction due to the larger pool of resources.

Moreover, with such large and distributed networks, services can be deployed on the network edge instead of the core. As C-RAN servers are powerful and have large computations, the realization of edge service deployment becomes much easier. In this way, services will move closer to the user and hence faster responses and better user satisfaction. Besides, this can narrow the load in the backhaul networks and hence they become more flexible and scalable than their current state.

Therefore, the realization of centralized BBUs in C-RAN can come with many advantages including joint processing and resource sharing capabilities in addition to services implementation at the edge. This can enhance user satisfaction, improve resource utilization and reduce backbone server pressure.

## 2.4. Summary

In this section, we presented the basics of C-RAN technology including its different architecture components, its possible structures and its advantages. C- RAN components are centralized BBUs, distributed RRUs and their inter-connection networks which are called Fronthauls. C-

RAN structures can be divided into a full, partial or hybrid structures and full centralized is the most promising one till now. Its centralized BBUs with their high computation capabilities gave C-RAN some unique advantages including resource and radio sharing and the ability to have edge implemented services.

# 3. Virtualization in C-RAN

In this section, we present some work done in network virtualization of C-RAN architectures. We start by discussing the virtualization concept and the kind of virtualization technologies exists. Then we discuss some solution of those virtualization technologies. Furthermore, we go through some NFV standards and ongoing work in SDN and their existing system.

## 3.1. Virtualization Concept

Virtualization technology facilitates the logical isolation of resources while the physical resources are shared in a dynamic and scalable way. Those resources include network, computing or storage resources. From those resources, network virtualization is critical in C-RAN and its deployment architectures. Network virtualization consists of multiple nodes and links that are deployed on the same physical machine. Thus, such technology enables flexible control mechanism, efficient resources, low cost and diverse applications [Hoffmann11].

In the context of C-RAN, network virtualization is done at the BBU pool level. Each BBU is a virtual node while the communication between them is the virtual links. The pool operates on the one physical machine sharing CPU, memory and network resources between multiple BBUs. Figure 2 illustrates the resource sharing in a BBU pool where the pool is deployed in a physical machine while BBUs are on virtual machines. RRUs basically connect the BBU pool which distributes them over the BBUs in its virtual machine. Such technology comes with many advantages including reducing the cost, minimizing time required for BBU communication, and most importantly scalability. Adding or removing of BBUs becomes easier as those BBUs are virtual machines which are much easier to turn off and up than physical machines. As C-RAN is mostly concerned with network virtualization, the following section will be discussing approaches to reach that.

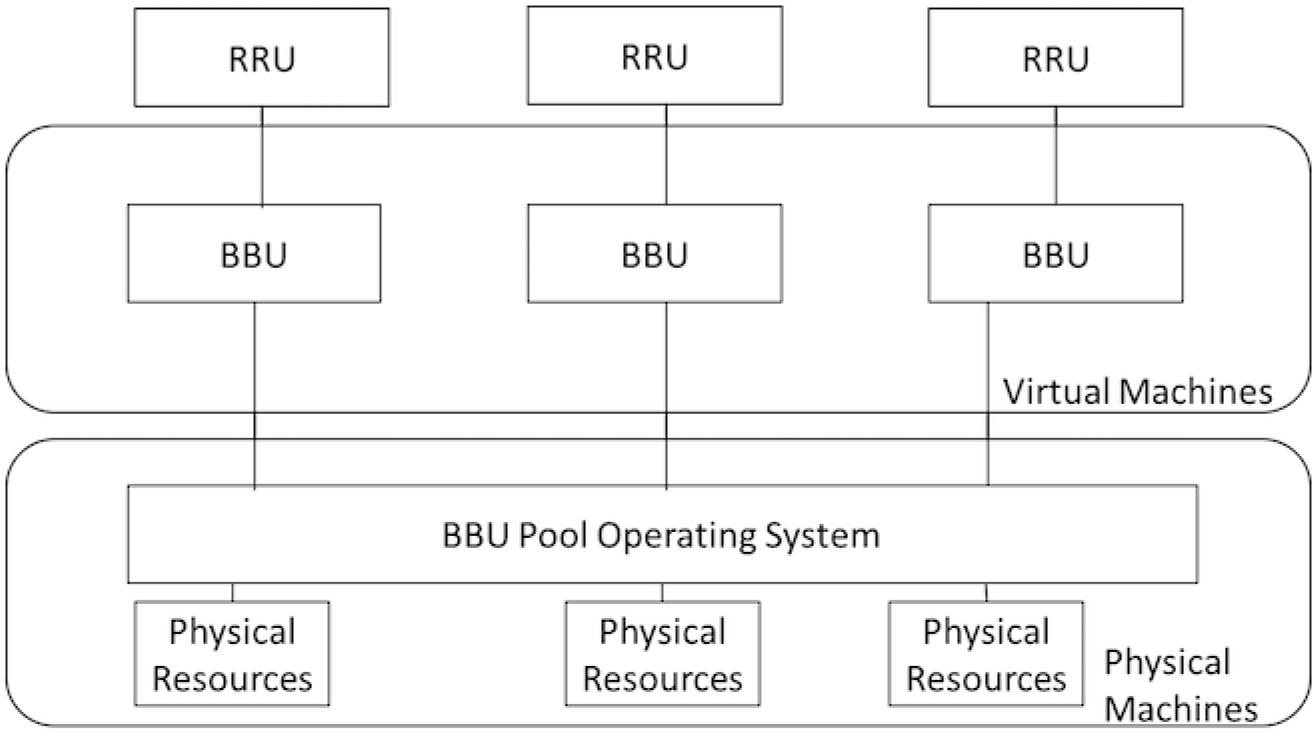


**Figure 2: Virtualization the BBU pool in C-RAN**

## 3.2. Existing Solution for Virtualization

In order to achieve wireless virtualization discussed in the previous subsection, wireless network architecture and hardware virtualizations should be considered. C-RAN is actually a wireless network virtualization that shares resources among BBUs and balances the load over a low cost implementation. In order to realize that in existing wireless architectures such as WiFi and Long Term Evolution (LTE), new solutions had to be suggested. In [Xia11], the author proposed a virtual WiFi in which the full wireless functionalities are implemented on virtual machines. Each virtual machine can establish its own virtual connections that are linked through one physical interface. This was one of the earliest works in network virtualization which propose a framework to be followed in order to implement such system. In [Zhao11], the authors discussed the same approach in LTE networks and how virtualization can be achieved by the simulating such environments.

In order to virtualize the hardware, Intel has proposed their own solutions to manage resources in such system and to simplify the processing in a more efficient way. Zhu et al. [Zhu11] discussed a realization of moving from traditional radio resources to cloud provided resources for Ethernet RRUs and wireless BBUs. Another work discussed the implementation of multiple virtual infrastructure on one physical infrastructure. In addition, some others discussed power management and handover scenarios in such a virtualized system [Checko15].

To summarize, some attempted to demonstrate wireless virtualization as presented and reviewed in this section. Those approaches are based on old virtualization technologies that are used in IT clouds. However, those attempts are mostly infrastructure and hardware specific and hence more sophisticated ways need to be proposed to solve those problems. Such solutions including NFV and SDN will be addressed in the following subsections.

## 3.3. NFV and its Standards for C-RAN

NFV aims to address virtualization problem by leveraging standard virtualization technologies to present various network equipment devices. Those devices include expensive routers and switches that are replaced with a software implemented on high volume servers, switches and storage units located in the clouds. In such way, the cost is deducted, the power and locations of those equipment are saved, and the adaptation of those devices will be facilitated. In addition, operators can have flexible services based on geographical location and customer privileges. Moreover, resources can be shared in an easier way with other operators located at the same server.

To that extent, European Telecommunications Standards Institute (ETSI) created a working group of known and world leading operators like AT&T and Telcom in order to standardize NFV for wireless virtualization. Their main work focuses on standardizing the core network and allows networking function to be implemented as NFV. In addition, BBU virtualization, which is at the heart of C-RAN, also needs to be standardized where BBU functions can be implemented on high performance servers [ETSI13].

NFV for C-RAN is not standardized yet but it shows critical benefits due to the flexibility in using software as hardware components supported by different vendors. Hence, such technology is likely to affect C-RAN realization in practical implementation in the near future.

## 3.4. SDN and its existing systems for C-RAN

SDN is another technology that can be utilized to implement wireless virtualization in C-RAN. Such technology, which is largely evolving in networking, separates the control plan from the data and centralizes the control. Network switches are considered as forwarding devices that are monitored by a centralized entity. To map to C-RAN, switches are basically the BBUs in one pool while the controller is the pool coordinators that control those BBUs. In the following, we briefly discuss some existing systems that utilized SDN concept in C-RAN virtualization:

- **SoftRAN:** Software Defined centralized control plane for Radio Access Network (SoftRAN) is a system proposed by [Gudipati13] to achieve wireless virtualization. It divides the model into two tiers where the unsophisticated part of the control stays locally while the other goes to a centralized controller. In the central controller, the distributed physical BBUs are considered as one big and powerful virtual switch that perform the operation required by every BBU. In such way, the load can be balanced, the interference is managed, and the system can achieve maximum utilization and throughput in a C-RAN system.

- **MobileFlow:** another system that introduce Software Defined Mobile Network (SDMN) architecture where the network virtualization is employed [Pentikousis13]. Such system uses OpenFlow network to control the routing and interference management introduced in the mobile network. The concept was experimentally validated and showed that it can flexibly configure the network architecture built around user demands.
- **CROWD:** Connectivity management for eneRgy Optimized Wireless Dense networks (CROWD) is a project that uses SDN as an effective solution for the MAC layer reconfiguration and connectivity management is wireless virtual networks. CROWD provides four key objectives: more capacity when needed, optimizing MAC layer operation, energy consumption and assuring good quality of services to users [CROWD14].

With those systems being employed for C-RAN, operators would benefit from SDN in realizing C-RAN in practice. SDN can provide a suitable solution for resource management and network virtualization in addition to automatic recovery in case of failure.

## 3.5. Summary

In this section, we discussed network virtualization and its benefits in C-RAN. Virtualization can be done at the network level in C-RAN where BBUs are virtualized and implemented on one physical BBU pool. Traditional virtualization technologies can be used to virtualize the network however they are infrastructure and hardware specific approaches. A more sophisticated solution can be using SDN or NFV standards where BBUs are considered as software functions to be implemented in a centralized, dedicated servers.

# 4. Resource Allocation in C-RAN

In this section, we discuss different Resource Allocation (RA) mechanisms that are designed for different C-RAN objectives. We start by introducing the RA problem and its challenges in C-RAN. Then we discuss some RA mechanisms for cost reduction, power and energy consumption, and multiple other objectives.

## 4.1. RA problem in C-RAN

As resources are expected to be shared and virtualized in C-RAN, the problem of allocating them to users becomes more complex and challenging. Hence, traditional RA mechanisms that are still used in today's network will not be adapted by C-RAN. RA becomes an optimization problem with different objectives that differ based on the application. Objectives can include delay, power consumption, complexity, cost and hybrid between two or more of those objectives. The rest of the section will handle some mechanisms that are designed for those objectives. However, it should be pointed out that more work exist in the literature to solve such problem but we will discuss only few of them in brief.

## 4.2. RA with operator cost objectives

Cost effective RA can be seen as one of the highest objectives from operators' point of view. In other words, maximizing revenue of RA algorithm can be essential for operators. In [jia15], the authors discussed an algorithm that splits resources into shared and fixed categories. A shared resource between BBUs can be allocated to users with low cost when the system is loaded. Otherwise, if the BBUs are not loaded, their fixed resources can be used when the cost is higher for those. In this way, the revenue can be maximized to the operators while meeting users' requirement even in reasonably high load scenarios. A central control server will be handle the RA based on user priority, their willingness to charge and the current use of resources.

## 4.3. RA with power minimization objectives

Minimizing power constitutes one of the critical objectives when distributing resources among users. Such a problem should include a dual minimization problem of the best RRUs selection and minimum power used in multiple channels to achieve communication. In [Shi14], the authors formulated the problem as a power consumption minimization problem subject to the highest quality of service to users and RRU power budget. They utilized greedy selection algorithm to solve such minimization problem, in which one RRU is selected to be switching off at each time stamp. This selected RRU should maximize the power reduction of the network each time. Their simulation results showed a good power reduction with low complexity algorithm and near optimal solution to the minimization problem. However, their method ignored the capacity limitation of the Fronthual as they assumed unlimited capacity which is not realistic in practice.

## 4.4. RA with energy consumption objectives

Energy consumption is another RA objective that id concerned with the energy level of BBUs and RRUs. The difference between power and energy consumption here is that power was devoted to RRUs sending powers while energy is considered with RRU and BBU sleeping time. Such minimization is important for battery operated devices and to let devices reduce their energy consumption when not being used. In [Khan15a], the authors proposed an energy consumption model for dynamic RA mechanisms in C-RAN. The proposed algorithm adds a server, named "Host Manager", to the BBU pool that monitor the load on each BBU in the pool. If a certain load condition is satisfied at a BBU, then the server would apply an algorithm to rematch BBUs and RRUs and switch off some BBUs.

Another work that was recently proposed in [Pompili16] allows elastic resource utilization in which network size, RRUs density, and transmitting power can drastically change to meet users' requirements. The proposed solution involved both proactive and reactive components in their model. A proactive component estimates the change per user demand and provision its need in advance. On the other hand, the reactive component would monitor the load and trigger the rematch algorithm of BBUs and RRUs when the resource utilization goes below a certain level.

Such algorithms were able to minimize the energy at BBUs by allowing them to switch off when the network load is small. However, they come with a delay cost resulting from switching and re-assigning BBUs to RRUs.

### 4.5. RA with other objectives

Some additional objectives to consider in RA might include minimizing delays, complexity and giving the highest quality of service to users. For example, in [Li14], the author solved the RA minimization problem as a tradeoff between processing delays and tradeoff between fronthaul energy consumption. In [Abdelnasser16], the author considered reducing the complexity of RA mechanisms that minimize the power consumption at BBUs while meeting quality of service requirements. Another work is presented in [Khan15b] considers dynamic BBU-RRU mapping in C-RAN which reduces the possibility of not meeting users' capacities in cell while maximizing quality of services in the network. Furthermore, resource fairness and multiple objectives of RA can be considered as a future problem to be considered in C-RAN system.

### 4.6. Summary

The RA problem in C-RAN is one of the critical problems in C-RAN as resources are virtualized and shared among BBUs in the same network. This section discussed solving the problem with multiple individual objectives that include operators' cost, energy consumption, power reduction and multiple others. The problem of sharing virtualized resource and how to share those resources with multiple application objectives is still a challenge in such systems. Such challenge will be discussed later in section 5 where we discuss multiple C-RAN challenges.

## 5. Challenges

In this section, we discuss some of the main challenges that exist with the evaluation of C-RAN. Those challenges include high Fronthaul capacities needed, BBU cooperation and clustering, virtualization techniques used, security and many others. The most important ones will be considered here in brief.

### 5.1. High fronthaul capacities needed

Fronthaul link between BBUs and RRUs is required to have high bandwidth capability with low delay and cost requirements. As discussed in Section 2, the fully centralized approach is the most adopted structure in C-RAN which require a huge communication overhead on fronthaul link. As a result, high bandwidth requirement is required at the fronthaul which cannot be met by wireless communication.

Optical fabric communication can give the high bandwidth required to solve such problem. However, optical fabric comes with the problem of very high cost which cannot be afforded by most cellular providers. Hence, a compromised solution between delay, bandwidth and cost need to be taken into account in such systems before they come to reality.

### 5.2. BBU Cooperation

BBUs in the same pool need to cooperate together in order to support sharing users' data, scheduling and channel feedback collection. Such cooperation is not defined and introduces a challenge in how to deal with user privacy, high bandwidth and low latency communication between such BBUs.

### 5.3. Cell Clustering

Optimal clustering of the cells and BBU pool assignability with minimal overhead and maximum gain is still a challenge. One BBU pool should achieve the maximum number of send and receive channel while minimizing the fronthaul delay and overhead. In addition, one BBU should support multiple distributed geographical location such as offices in different states in order to consolidate them in one BBU. Therefore, such clustering and BBU assignment is still a challenge to be resolved in C-RAN systems.

### 5.4. Virtualization Technique

Virtualization techniques promote distributed processing and sharing of resources between multiple BBUs, which imposes another challenge in C-RAN. Processing needs to be real time and dynamic in order to support changing cell loads. Furthermore, the requirement for clouds that BBUs will be implemented on will be different from the known IT clouds requirements. Therefore, cloud infrastructure needs to be adjusted to meet such requirements. Hence, virtualization is another critical challenge that affect the current deployment of C-RAN in practice.

### 4.5. Security

Another significant challenge in C-RAN is the security challenge in terms of user privacy and trusted parties. As resources are shared between BBUs, breaking user privacy and accessing assumingly secured data is a possibility, especially in such distributed architecture. In addition, parties are assumed to be trusted in C-RANs including BBUs and RRUs. Such assumptions might be invalid especially with the large number of users subscribed to such systems. A compromised user can take advantage of such large, virtualized system to misbehave and threat the system. Therefore, in addition to the vulnerabilities exist in traditional cellular systems. C-RAN would present another security challenge that was not considered or less challenging before.

### 5.6. Summary

In this section, we discussed different research challenges that might rise in C- RAN and needed to be solved before such system comes to reality. Those challenges include high fronthaul requirement, BBU cooperation, cell clustering, virtualization and security. Some other challenges may include isolation of faulty resources, mobility and network managements, and hybrid objectives resource allocation. Those challenges can highlight some of the future research directions in C-RAN before getting to practical implementations.

## 6 . Conclusion

This paper surveyed some of the basics, advances and current challenges of C-RAN technology that support cloud base station virtualization in future cellular networks. Such technology has a centralized architecture composed of BBUs and their centralized pool, RRUs, and fronthaul link to connect between them. They can be fully centralized, partial or hybrid while full centralization is the highly dominate one till now. Virtualizing base stations can be done by NFV or SDN new paradigms and have many advantages in terms of cost and energy consumption. Resource allocation is an objective minimization function that includes: cost, complexity, power, energy consumption or multiple other objective. However, a multi-objective resource allocation is still a challenge in C-RAN systems. Moreover, fronthaul capacities, BBU cooperation, clustering, virtualization and security are still research challenges that need to be taken care of before next generation networks come to practice.

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# List of Acronyms

BBU Base-band Unit
CPU Central processing unit
C-RAN Cloud Radio Access Networks
CROWD Connectivity management for eneRgy Optimized Wireless Dense networks
ETSI European Telecommunications Standards Institute
LTE Long Term Evolution
MAC Media Access Control
NFV Network Function Virtualization
RA Resource Allocation
RAN Radio Access Networks
RRU Remote Radio Unit
SDMN Software Defined Mobile Network
SDN Software Defined Networking
SoftRAN Software Defined centralized control plane for Radio Access Network

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