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Design and Implementation of Cloud Radio Access Network (C-RAN) using OMNET++ Platform

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ABSTRACT

For fast data rates, commercial 5G wireless communication systems are in use. However, for 5G, the challenge lies in the expansive use of smart devices and the need for ultra-reliable and low-latency communication in Internet of Everything (IoE) services. The data rates achieved in 5G are too low for this exponential increase in traffic and, as such, there is the need for 6G network technologies that can enable this. Cloud Radio Access Network (Cloud-RAN) is one such network that has been proposed for B5G services. In this work, it is proposed to develop and test a C-RAN on the OMNET++ simulator. In this network setup, the BBUs are separated from the RRHs, and the baseband processing tasks are completed in the cloud for cost-effectiveness. Simulations were done on Simu5G for the RRH and user part, and iCanCloud for cloud-based BBUs. Results demonstrate that considerable improvements of up to 30% in energy consumption, 45% in the efficiency of use of resources, and low latency of less than 10ms, as well as stable throughput performance for different user loads, were achieved. Results validate that the implementation of C-RAN can improve efficiency and scalability. The conclusion drawn from this study is that the proposed C-RAN architecture is a viable and impactful solution to meet the growing demands of future wireless networks.

Keywords: Cloud radio access network, OMNET++, Simu5G, iCanCloud, Energy efficient, Resource utilization.

1. INTRODUCTION

Over the past few years, there has been significant growth in the amount of mobile data traffic worldwide. According to assessments discussed in the WWRF Outlook 33 report and recent International Telecommunication Union (ITU) **(Alexiou, 2024)** studies, global mobile data traffic continues to increase rapidly as smart devices, high-definition streaming, and Internet-of-Everything (IoE) applications become more prevalent. This exponential rise in data demand places increasing pressure on current network infrastructures and motivates the transition toward more flexible and cloud-enabled architectures.

While 5G networks have brought remarkable improvements in data speed, reliability, and connectivity, their current architecture faces notable challenges in scalability and energy

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efficiency. Although 5G supports and paves the way for better connectivity, its inflexible network architecture is unable to cope well with the exponential growth of data traffic. Thus, the technical and research community has focused on the Cloud Radio Access Network (C-RAN), which is essentially the technical backbone for 6G.
In addition, the 6G network promises to be more than just an advancement of the existing 5G network in terms of their spectrum bands and data rates. In this aspect, the 3rd Generation Partnership Project (3GPP) **(Jiang and Liu, 2017)** has grouped use scenarios into three families, as depicted in **Fig. 1**. However, the use of such innovative technologies is contributing substantially to rising network expenditure in terms of CAPEX (Capital Expenditure) and OPEX (Operational Expenses), in addition to baseband processing and inter-cell interference problems associated with large cell density. However, the present network structure will be unable to support the rising demands for ultra-high-speed data transmission and very low latency for the emerging 6G services **(You et al., 2021)**

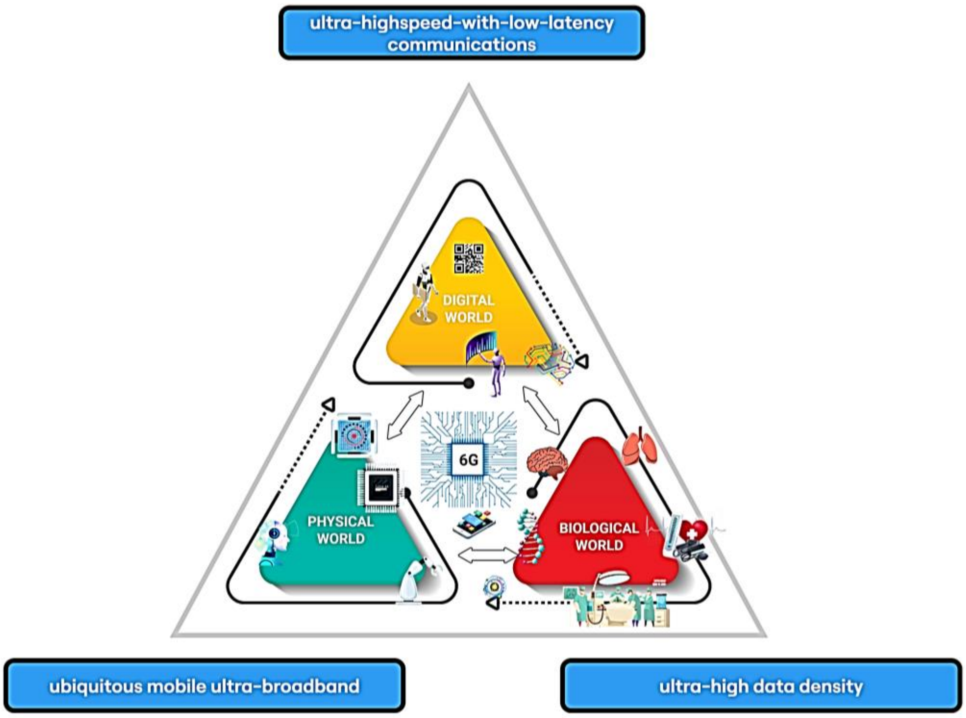

Figure 1. Services and usage scenario for 6G **(Ismail and Kadhim,2024)**.

In order to face such challenges and minimize CAPEX and OPEX costs, telecom operators should look for new approaches in the next generation of wireless networks. In this regard, C-RAN has emerged as an attractive solution that can satisfy different service demands and provide end-users with high-quality connectivity **(Ismail and Kadhim, 2024)**. In C-RAN, for example, the BS is separated into two different units known as the Baseband Unit (BBU) and Remote Radio Head (RRH). Later, cloud computing and virtualization methods are utilized to combine and virtualize different BBUs from different locations **(Jiang and Liu, 2017)**. This virtualized and polled approach makes it possible for the system to dynamically adjust to varying levels of network traffic, and this prevents any network interference. In this scenario, the fronthaul link links the RRHs to the centralized BBU pool, and this enables joint processing of the RRHs in order to reduce interference. However, the fronthaul capacity also imposes a limit on how many users each RRH can serve at a given moment **(Farhat et al., 2024)**.

Thus, this work proposes the design and implementation of the Cloud Radio Access Network (C-RAN) based on the simulation platform of OMNeT++. In this proposed system, Simu5G and iCanCloud are used for representing the RRH and user side, as well as cloud-based BBU systems, respectively. And this work shows in detail the processes for designing and evaluating the performance of C-RAN to act as an effective guide for such implementations.

2. ARCHITECTURE OF CLOUD RADIO ACCESS NETWORK

By decoupling the processing unit and the antennas unit and integrating the processing capabilities into the core data centers or BBU pools, the core concept of C-RAN emerges. Shared among multiple base stations are the BBU processing resource pools that can fully utilize the available network resources. In **Fig. 2**, the C-RAN architectural framework is highlighted, which is state-of-the-art in radio network implementation and increases network efficiency, flexibility, and scalability. In C-RAN, functionality for faster data rates, lower latency, and better resource utilization and allocation support the needs of 5G and upcoming 6G wireless communication systems.

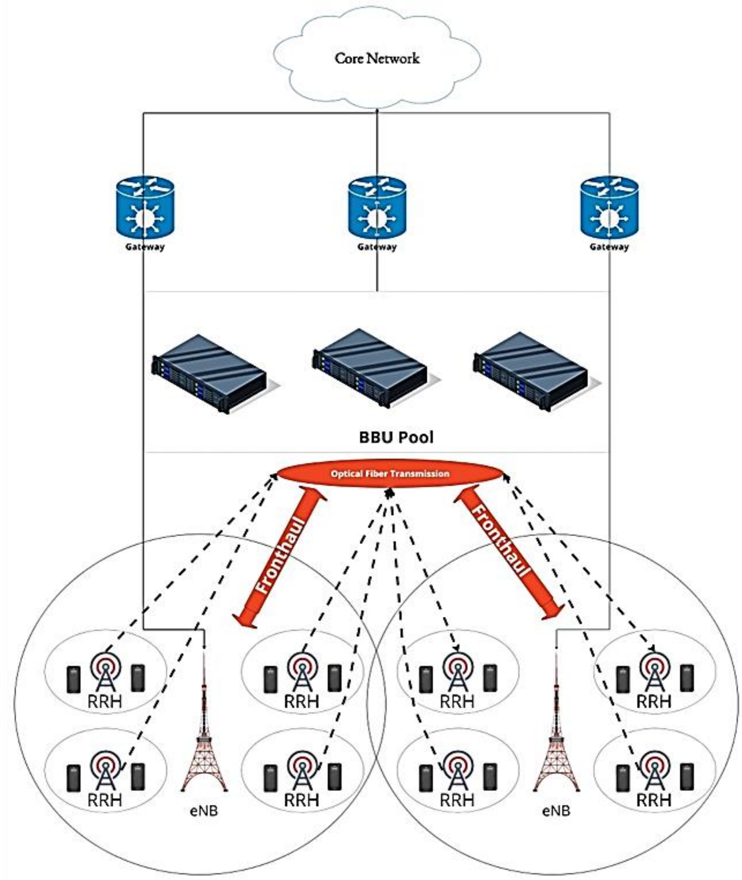

Figure 2. Architecture of Cloud Radio Access Network **(Ismail and Kadhim,2024)**.

The three primary elements in **Fig. 2** are:

1. Remote Radio Heads (RRHs)
   - Located at cell sites, RRHs handle signal transmission and reception from user devices.
   - Convert RF (Radio Frequency) signals to baseband signals and transmit them to the BBU pool via the fronthaul network **(Rodoshi et al.,2020)**.
   - Help reduce interference and improve network coverage by dynamically adjusting power levels.

2. BBU Pool (Baseband Unit Processing Center)
   - A centralized cloud-based processing unit where baseband processing tasks are handled **(Ejaz et al.,2020)**.
   - Virtualized BBUs (vBBUs) are deployed on cloud servers, allowing for efficient workload distribution.
   - The BBU pool can dynamically allocate computing resources based on real-time demand, reducing power consumption and optimizing network performance.
3. Fronthaul Network
   - Connects RRHs to the BBU pool using high-speed optical fiber, wireless links, or millimeter-wave technology **(Kaltenberger et al., 2020; Mai et al., 2023)**.
   - Reduces latency and improves data transmission rates.
   - Can be based on CPRI (Common Public Radio Interface) or eCPRI **(Nikaein, 2015; Kardaras and Lanzani, 2009)**, enabling high-speed data transfer between RRHs and the cloud BBUs.

3. RESEARCH ON C-RAN ARCHITECTURES

Cloud radio access network (C-RAN) is the current active research area, different aspects including network architecture, user migration, mobility and energy saving are still investigated in detail. Developments in all of these areas have expanded the possibilities for intelligent network management.

1. Architecture and Deployment of C-RAN: Among the recent advancements in C-RAN architecture, flexibility and adaptability besides supporting different traffic scenarios are the essentials. In **(Perveen et al., 2023)**, the authors utilized the fuzzy-based dynamic traffic forecasting approach for enhancing admission control in federated 5G open RANs. Along the same lines, **(Khani et al., 2023)** proposed an optimized DRL (Deep Reinforcement Learning) slice acceptance control scheme that supports optimal resource usage in cloud radio environments.
2. User Migration and Load Balancing: Load balancing and optimal BBU migration are still vital issues in virtual C-RAN systems. **(Ismail and Kadhim, 2025)** proposed the use of threshold-based dynamic BBU placement in load balancing and BBU migration in virtual C-RAN. Another work on load balancing and decision efficiency in overloaded hosts for virtual machine consolidation in data centers utilized interval-valued fuzzy logic and was proposed in **(Moura et al., 2021).**
3. Mobility management in C-RAN can be optimized remarkably well utilizing the power of **(Amiri et al., 2023)** proposed a DRL-based approach for reconfiguring the VNF to achieve optimal network functionality in varying environments such as O-RAN. Fuzzy logic in traffic prediction for parallel crawler migration has been proposed in **(Farooqui et al., 2023)**, and it holds immense potential in varying real-time traffic conditions. In addition to that, **(Jahandar et al., 2025)** proposed to explore a fuzzy-improved handover decision mechanism in edge computing for 6G communication systems.
4. Energy Efficiency and Green C-RAN: Energy consumption is one of the factors that needs attention in large-scale C-RAN systems. **(Khezami et al., 2023)** discussed in their survey the different advancements and emerging trends that made efforts towards decreased energy consumption and increased spectrum efficiency. **(He et al., 2024)** utilized DRL for context-aware service migration in the edge for optimal delay and energy consumption.

5. General Trends and Fuzzy Logic Techniques Saatchi **(Saatchi, 2024)** provide a current overview of fuzzy logic models, rule bases, and inference methods, emphasizing recent implementations in smart systems. These developments underscore the ongoing value of fuzzy logic in enabling intelligent, low-complexity decisions in future networks.

These contributions reflect the breadth and depth of current C-RAN research, indicating a strong trend toward AI-enhanced, adaptive, and energy-efficient solutions for future network architectures. Since the generic architecture of C-RAN separates the BBU from the typical BS and the multiple BSs' BBUs are pooled into a cloud in a way so the pool could be shared by many RRHs **(Hossain et al.,2019)**. From the outset, many research from industries and academia, respectively, have appeared in the literature in terms of architecture design so the users' and the operators' demand in future cellular networks could be met.

3.1 Generic C-RAN

China Mobile categorized C-RAN architectures into fully centralized and partially centralized based on the functional splitting between BBU cloud and RRHs **(Chen et al., 2013)**. Based on fronthaul restrictions and the functional division between RRHs and BBUs, **(Peng et al., 2015)** expanded the above taxonomy into fully centralized, moderately centralized, and hybrid systems. In the fully centralized case, the processing and management tasks of the conventional BS's Layer 1, Layer 2, and Layer 3 are shifted into the BBU cloud, as shown in **Fig. 3**. The BBU cloud performs all the processing and management tasks of the conventional BS.

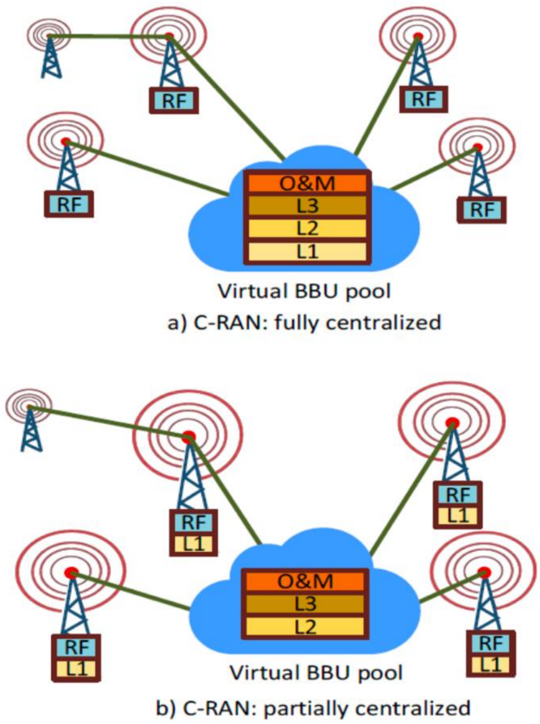

Figure 3. Cloud Radio Access Network Taxonomy.

3.2 Heterogeneous C-RAN

Some studies in **(Dahrouj et al., 2015; Meerja et al., 2015; Chen et al., 2017)** suggested architectures for heterogeneous C-RAN (H-CRAN) that incorporate both centralized processing and BS densification, driven by the significant inherent benefits of heterogeneous networks over traditional networks as shown in **Fig. 4**. By using downlink (uplink) coordinated resource allocation techniques (e.g., Beamforming, power control, association, and scheduling) at the BSs, H-CRAN promises to accomplish effective resource sharing between various entities via the cloud by jointly encoding (decoding) the messages **(Chabira et al., 2025).**

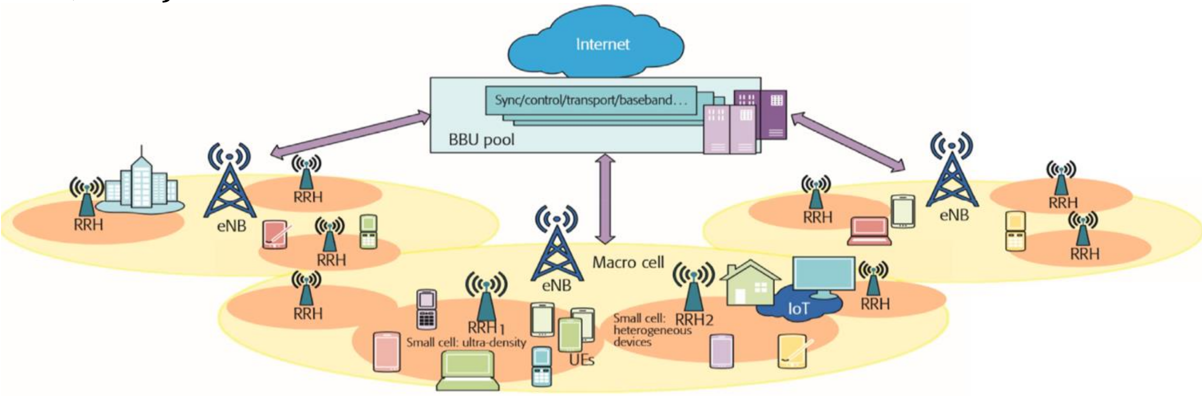

Figure 4. A typical Architecture of H-CRAN.

3.3 Millimeter wave (mmWave) CRAN

With the use of extremely dense Base Stations/Access Points and massive bandwidth available in the upper frequency bands, mmWave communication and cellular network densification are thought to be the promising enablers to satisfy the rate demands of future networks beyond 5G. Additionally, the utilization of the CRAN may make it possible to cheaply densify the network in order to improve the energy and spectral efficiency of wireless networks in the next generation. The idea of mmWave CRAN is introduced to achieve the objectives of massive bandwidth and network densification through the combination of the CRAN architecture with mmWave communication **(Stephen and Zhang,2018; Rangan et al., 2014; Kolawole et al., 2018)**.

3.4 Distributed Antenna Systems

Unlike the existing cellular networks, the full-phase CRAN shifts all baseband processing to the cloud-based BBUs. The only radio transmission function is carried out at the RRHs. The move to a full-phase CRAN with fully virtualized BBUs in the cloud may result in significant financial and infrastructure replacement costs for the MNOs (Mobile Network Operators). The authors of **(Schwarz,2018)** proposed a transition design to address the problem.

3.5 NOMA-based CRAN

NOMA has also been suggested to be a future multiple access technology and already included in the 3GPP standard, LTE-A, to increase the spectral efficiency and energy efficiency **(Ding et al., 2017)**. The integration between the NOMA and the CRAN could be the future solution to the IoT-enabled energy and spectral-constrained wireless networks.

Considering this, **(Hao et al., 2018)** examined the NOMA-based CRANs and utilized the frequency bands of mm Wave and sub-6GHz for use in the fronthaul and access links.

3.6. Energy Harvesting-based CRAN

In an H-CRAN system, minimizing the total energy consumption of the system is one of the greatest challenges. By applying energy harvesting methods, whereby energy can be harnessed from RF energy or environmental sources such as solar and winds, this problem can be solved **(Perera et al., 2018)**. In this process, the authors in **(Chughtai et al., 2018)** investigated energy efficiency in scenarios with multiple green RRHs that can harvest energy.

3.7 Virtualized CRAN

Another novel CRAN architecture is the virtualized CRAN, and it may be made possible as an implication of software networking and virtualization concepts. In this case, the authors of **(Kalil et al., 2017)** identified the requirement and potential gain of integrating CRAN and network virtualization. In addition, network virtualization approaches for the integration of CRAN have been proposed in **(Kalil et al., 2017)**; this aims at minimizing latency and maximizing system throughput.

4. OMNET ++ FRAMEWORK ARCHITECTURE

OMNeT++ was selected as the primary simulation platform because it provides a modular, component-based architecture that enables seamless integration of wireless and cloud-computing environments. Unlike NS-3, which primarily focuses on network-layer packet transmission, or MATLAB SimEvents, which emphasizes discrete-event process modeling, OMNeT++ allows hybrid system simulation across multiple network domains. It supports Simu5G for detailed 5G and 6G radio-access modeling and iCanCloud for virtualized cloud resource management, thereby enabling end-to-end evaluation of C-RAN scenarios within a unified environment. This flexibility makes OMNeT++ particularly suitable for studying interactions between radio resource allocation, baseband processing, and energy-aware cloud orchestration—key factors in 6G C-RAN design.
Almost every type of network, including wired, wireless, on-chip, sensor, photonic, and other networks, can be modeled using the popular discrete-event modeling framework OMNeT++. Modules, which might be basic or complex, are its primary building blocks. Connecting their gates, which serve as interfaces, allows modules to communicate with one another. At the pinnacle of the hierarchy is a network, which is a unique compound module without gateways to the outside world. Connections must adhere to the module hierarchy; for example, in **Fig. 5**, simple module 3 must go via the compound module gate rather than immediately connecting to module 2. Event handlers, which are triggered by the simulation kernel upon message receipt, are used by simple modules to define model behavior **(Nardini et al., 2020)**.

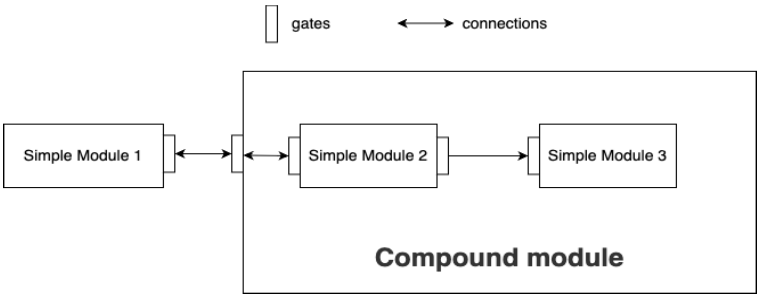

Figure 5. OMNeT++ module connection.

An example model library for the OMNeT++ tool is called INET. It provides models to depict a wide range of elements in a communication network, including connections, network nodes, communication protocols, etc. It provides models to depict the wired and wireless link layer protocols (Ethernet, PPP, IEEE 802.11, etc.), the Internet protocol suite (TCP, UDP, IPv4, IPv6, OSPF, BGP, etc.), and support for creating bespoke mobility models and QoS architectures, among other things.
The INET offers modules that serve as a bridge between the simulation and the actual network interfaces in the host operating system, enabling the simulation of genuine applications and protocols. In these modules, the simulation displays the actual interface packets, which are then forwarded to the actual network interface. For emulation to work, the OMNeT++ must be set up as a real-time event scheduler that is in sync with the system clock **(Nardini et al., 2020)**. The iCanCloud and Simu5G framework, which is based on OMNET++, will be used to construct the cloud BBU and RRH to replicate the CRAN.

4.1 iCanCloud Framework Architecture

iCanCloud has been developed on top of the platform OMNeT++. The infrastructure of the network relies on the simulation platform simulator INET. The modules included in the simulation kernel in iCanCloud simulate the working of specific elements. The modules are classified based on functions. The modularity in the simulation platform structure in iCanCloud is made up of three major sections: cloud manager, cloud infrastructure and user model, as shown in **Fig. 6 (Castañé et al.,2012).**

Fig. 6 describes the modular architecture of the iCanCloud framework, which is used for simulating cloud computing environments. This architecture plays a crucial role in modeling and evaluating C-RAN, particularly in terms of resource management, virtualization, and dynamic workload distribution.

1. User Model: which represents the cloud users and their virtualized applications. Users submit jobs to the cloud, which are processed by allocated virtual machines (VMs) includes resource demand modeling, which helps simulate realistic cloud workload behavior.
2. Cloud Infrastructure Model: consists of physical servers (compute nodes) hosting multiple virtual machines (VMs) which includes key modules such as:
   - Memory Management Module: Manages memory allocation for VMs.
   - CPU Module: Allocates processing power for computational tasks.
   - Network Module: Handles communication between VMs and other infrastructure components.

These modules ensure efficient resource utilization and help in performance evaluation.

3. Cloud Manager Model: acts as the central controller for managing cloud resources which handles VM provisioning, dynamic allocation, and load balancing. This model includes:
    - Job Scheduler: Assigns cloud jobs to available VMs based on workload and capacity.
    - Hypervisor Scheduler: Coordinates VM execution and resource allocation at the hardware level.

    This modeule support dynamic provisioning of virtual machines to optimize system performance.
4. Hypervisor Module: that ensures seamless interaction between hardware and virtualized environments and manages resource isolation, preventing performance degradation due to resource contention.

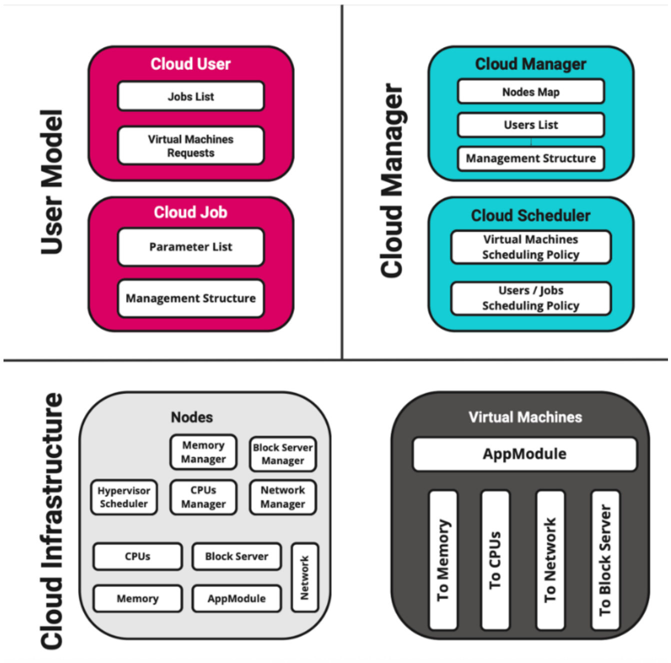

Figure 6. Modular Architecture of iCanCloud.

4.2 Simu5G Framework Architecture

Fig. 7 illustrates the Radio Access Network (RAN) cellular network architecture in Simu5G **(Nardini et al., 2020)** and emphasizes on the core components and their connections. The RAN is composed of many cells that are served by its base station (BS). In 5G systems, the BSs are named gNodeBs (gNBs), which are in charge of connections with users and data exchange. The gNBs are the 5G cells through which users (UA or UEs) send their data to reach the core network. The Core Network (CN) is responsible for processing user traffic and routing data to the appropriate destinations. The User Plane Functions (UPFs) within the CN handle packet forwarding and establish connections between the RAN and external data networks.

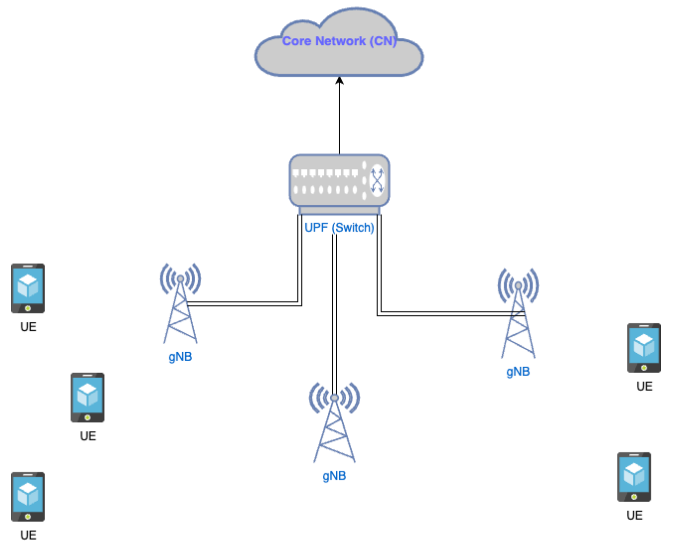

Figure 7. Architecture of generic RAN cellular network.

The GPRS Tunneling Protocol (GTP) is used for data forwarding, ensuring seamless communication between the RAN and CN. The X2 interface allows base stations to communicate with each other. This interface is used to support handover procedures, enabling seamless connectivity when a UE moves from one gNB to another. The 5G New Radio's RAN and CN data planes are simulated by Simu5G. Protocols for management and signaling are not currently part of the implementation, but they can be easily added by the interested parties. The NrUe and gNodeB composite modules, which simulate a UE and a gNB with NR characteristics, are the main components of the Simu5G library. **Fig. 8** shows their interior structure.

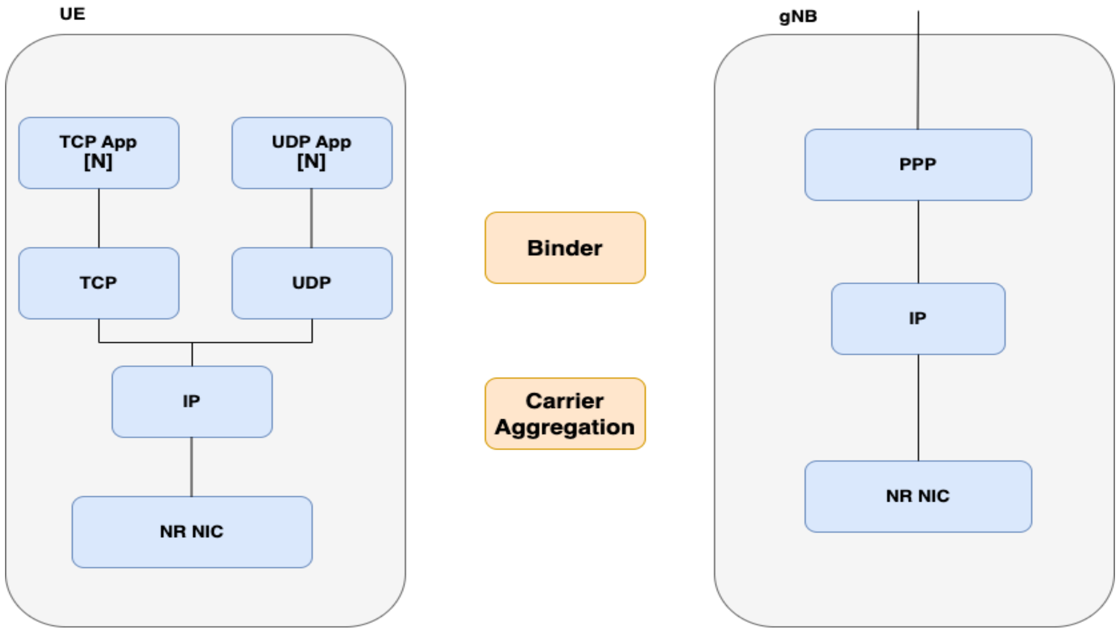

Figure 8. Main modules of the Simu5G model library.

5. PROPOSED CLOUD RADIO ACCESS NETWORK

This section explains the implemented method and procedures based on the OMNET ++ simulator, which is made up of the BBU pool, fronthaul, and RRH, as shown in **Fig. 9**.

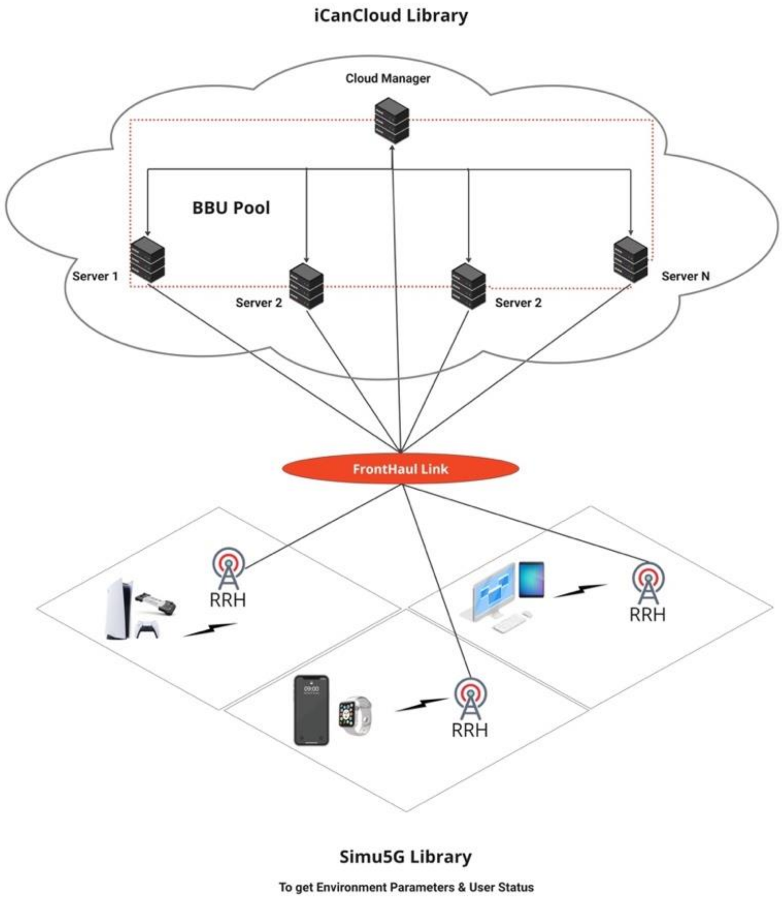

Figure 9. General Model of the Proposed C-RAN.

The geographic area is separated into multiple cells, each of which has a single RRH in accordance with C-RAN. A person positioned inside a cell (particularly close to the cell's edge) may be simultaneously covered by multiple RRHs, depending on the coverage area of the various nearby RRHs. Every cell is designated as a virtual machine (VM) to a particular cluster, which is made up of the collection of VMs ascribed to the same BBU according to mobility, application, distance, or a combination of these criteria. A general flowchart for the implementation is shown in **Fig. 10**.

5.1 System Model for User-RRH Association (Cell Site)

The implementation of the suggested RRH cells, which are made up of several User Equipment's (UEs) and Remote Radio Heads (RRHs) that are individually referred to as gNBs nodes with their own coverage area, is covered in this section. Additionally, UEs shift and eventually cross cell boundaries, altering their serving gNB. **Fig. 11** shows model of the User-RRH cell site example.

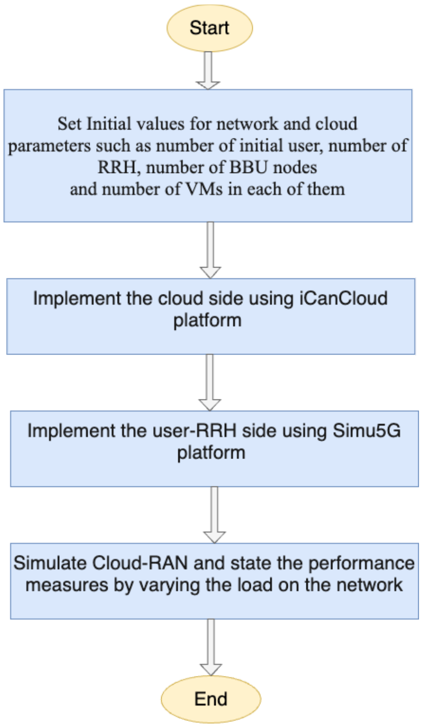

Figure 10. A general Flowchart for the Proposed C-RAN.

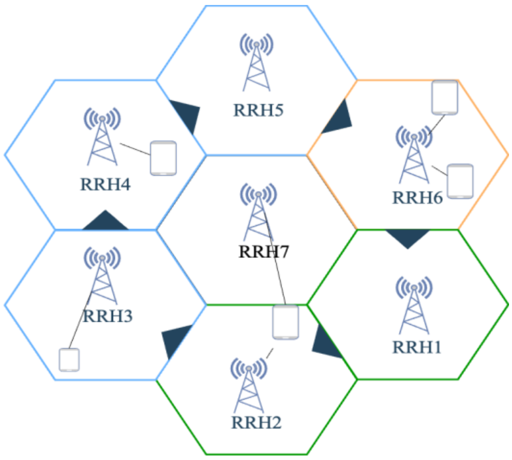

Figure 11. RRH-User Association in the C-RAN.

5.2 System Model for the Cloud Side (BBU Pool)

The cloud site consists of number of clusters (Compute Nodes) that contain several Baseband Units (BBUs) nodes that simulate the workloads through number of virtual machines under the control of cloud managers. **Fig. 12** shows a block diagram about the structure of cloud BBU model.

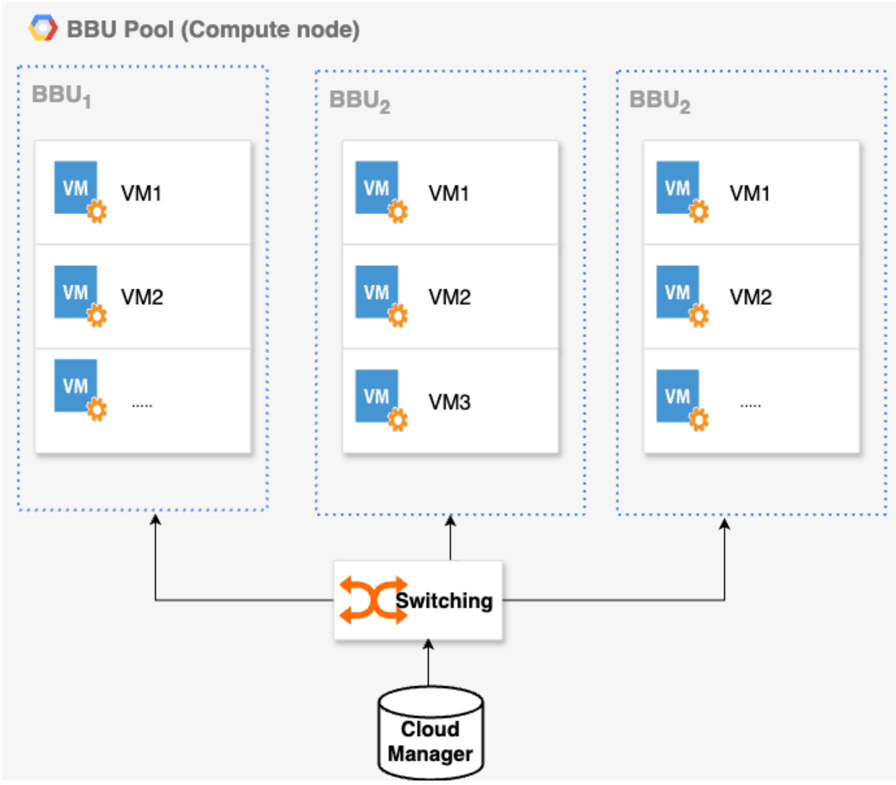

Figure 12. An overall picture about the cloud BBU Pool of the C-RAN.

6. POWER CONSUMPTION AND USER ASSOCIATION MODEL

The study referenced in **(Beloglazov et al., 2012)** illustrates that power consumption in physical machines can be represented by a linear relationship with CPU usage. It also highlights that a fully idle physical machine typically consumes around 70% of its total power capacity. Using Eq. (1), defines power consumption as a function of CPU utilization.

$$P(v) = n \times P_{max} + (1 - n).P_{max} \times v \quad (1)$$

where v is the CPU usage, n is the proportion of power used by an idle physical server, and P_{max} is the maximum power of a server while it is operating. Due to workload fluctuation, CPU usage varies over time, and v(t) is a function of time. Eq. (2) can be used to define overall energy usage. This model states that CPU use determines energy consumption.

$$E = \int_t P\big(v(t)\big)dt \quad (2)$$

Also, the assumptions about RRH, user connection and their initial association will describe here, look at a C-RAN design with m tiny RRHs spread out widely around the network. M and N can be used to represent the set of RRHs and users, where M = {1, 2, ..., m} and N = {1, 2, ..., n}. The fronthaul link connects each RRH to the BBU pool. The user-RRH association is managed by the BBU pool using the data that users provide at each time stamp.
A circle with a radius of R can be used to represent the coverage area, and it is believed that all small RRHs have the same transmission range. Unfortunately, an RRH's capacity determines how many users it can support at any given time **(Xia et al., 2017).**

All the network's data, including the BBU controller, is contained in the BBU pool. The network data is regularly updated based on user reports received from the relevant RRHs. The position coordinates and coverage area of each RRH are likewise known to the controller. The BBU controller runs the algorithms required for association and handover choices before sending them to the RRHs.
The association indicator between user and RRH can be denoted by $\sigma i, j,$ which represents whether user i is associated to RRH j or not

$$\sigma_{i,j} = \begin{cases} 1 \; if \; user \; i \; associated \; with \; RRH \; j; \; \forall j \in M \\ 0 \qquad\qquad\qquad\qquad otherwise, \end{cases} \tag{3}$$

Based on proximity, the users will first be assigned to an RRH. In particular, the RRH that is nearest to the user will be linked to that user. The Euclidean distance formula can be used to determine the distance between user i and RRH j, represented by Di,j, as shown below:

$$D_{i,j} = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2} \tag{4}$$

Upon entering the network, the user may get signals from several RRHs. Therefore, it is first linked to the RRH that is closest to the user.

7. PROPOSED ALGORITHM FOR BBU RESOURCE ALLOCATION, USER ASSOCIATION AND SLEEP-MODE CONTROL

To strengthen the technical depth and reproducibility of our proposed simulation-based C-RAN architecture, we present a unified algorithmic framework that encompasses user-RRH association, BBU resource allocation, and a lightweight energy-saving sleep-mode mechanism for BBUs. We also present a formal optimization objective based on energy consumption to guarantee the efficient and scalable BBU resource allocation and user association. The optimization problem is subject to constraints considering system capacity, load balancing, and energy-efficient sleep mode control.
Optimization Objective:

Minimize total energy consumption E:

$$min \sum_{b \in B} (P_{idle} + (P_{max} - P_{idle}).u_b(t) \tag{5}$$

Where:

- B: Set of BBUs
- $u_b(t)$: Utilization of BBU b at time t
- P_{idle}: Power in idle state
- P_{max}: Power at full load

Subject to Constraints:

1. User Demand Constraint:

$$\sum_{j \in M} \sigma_{ij}.D_i \leq C_j, \forall i \in N \tag{6}$$

Where $\sigma_{ij} \in \{0,1\}$ indicates association, D_i is user demand, and C_j is RRH capacity.

2. BBU Load Constraint:

$$\sum_{u \in VMs_b} L_u(t) \leq L_b^{max}, \forall b \in B \quad (7)$$

3. Sleep Mode Triggering:

If $L_b(t)<\theta_{idle}$ for T_{idle}, then b enters sleep mode

This model forms the foundation for the dynamic algorithm presented below.

Algorithm: Integrated C-RAN Resource Management
Input:

- $N=\{n_1,u_2,...,n_n\}$: Set of users
- $M=\{m_1,m_2,...,m_m\}$: Set of RRHs
- $B=\{b_1,b_2,...,b_k\}$ Set of BBUs
- SNR_{ij}: Signal-to-noise ratio between user n_i and RRH m_j
- Cj: Fronthaul capacity of RRH m_j
- Di: Traffic demand of user n_i
- $L_b(t)$: Load on BBU b at time t
- Thresholds θ_{active},θ_{idle} ; time parameters T_{idle},T_{wake}

Output:

- User-RRH assignments
- BBU activation states
- Dynamic energy-aware resource allocation

Step-by-Step Procedure:

1. User-RRH Association
   For each user n_i:
   Evaluate SNR_{ij} for all $m_j \in M$
   Assign n_i to the RRH r_j with the highest SNR_{ij}, ensuring $\sum Di \leq Cj$
2. RRH Clustering and Workload Aggregation
   Group nearby RRHs into clusters
   Calculate total workload for each cluster
3. BBU Allocation
   Activate minimum number of BBUs in each cluster based on workload
   Allocate VMs to BBUs for load balancing
4. BBU Sleep-Mode Control
   For each BBU b:
   a. If $L_b(t)>\theta_{active}$, set state to Active
   b. If $L_b(t)<\theta_{idle}$ for $\geq T_{idle}$, set state to Sleep
   c. If in Sleep and $L_b(t)\geq\theta_{active}$, trigger wake-up after T_{wake}
5. Repeat
   Repeat the above steps every time slot T to adapt to changing user mobility and traffic demand

8. C-RAN IMPLEMENTATION WITH OMNET++

We examine a C-RAN environment with a specific number of tiny RRHs dispersed at random across a region measuring 1100(m) x 800(m) x 50(m). Every RRH has the same coverage area, which overlaps with that of its nearby RRHs. By default, there are ten RRHs spread out at random throughout the simulated area. Every RRH is a tiny cell that manages user connections and sends information to the cloud-based BBU pool. With a modified random walk, we have assumed that the user can only navigate through the straight paths. There are 50 users by default. The simulation scenario for the RRH-User interaction paradigm is shown on **Fig. 13**. To ensure reproducibility and clarity, the main simulation parameters used for the C-RAN implementation are summarized in **Table 1**. These parameters were selected based on standard 5G/6G network assumptions and aligned with the Simu5G configuration environment.

Table 1. Simulation Parameters.

Parameter	Symbol / Unit	Value / Description
Simulation area	—	1100 m × 800 m × 50 m
Number of RRHs	N_{RRH}	10
Number of Ues	N_{UE}	50
RRH coverage radius	R	120 m
Bandwidth	B	20 MHz
Carrier frequency	f_c	3.5 GHz
Number of BBUs per compute node	—	150
Virtual Machines per BBU	—	3
Maximum BBU processing capacity	—	3 000 MIPS
Average user request size	—	1500 requests/session
CPU power limit	P_{max}	200 W
Idle power ratio	P_{idle}/P_{max}	0.7
Simulation duration	—	2 hours
Number of simulations runs	—	3 (averaged results)

Every scenario in the simulation runs three trials with different seeds, and the results were averaged to improve the reliability of the outcome. The above parameters create the environment in which the proposed energy-efficient C-RAN model will be tested.

In this image **(Fig. 13)**, the communication between the User Equipments (UEs) and the Remote Radio Heads (RRHs) in the Simu5G simulation setup is explained pictorially. Simu5G can dynamically distribute users to the cell of the closest RRH based on the strength of the signal when users change between the coverage areas of different RRHs. Handover actions are generated when every user moves out of the coverage area of an RRH for continuous connectivity. In Simu5G, every user data received at RRHs will be processed in the central BBU pool, which dynamically allocates resources. Simu5G and the OMNeT++ simulator evaluate the efficiency of the network in delivering requests from users.

In the proposed framework, Simu5G and iCanCloud were integrated in such a way that the hybrid co-simulation approach facilitates simultaneous data sharing between the wireless and cloud environments. Simu5G functions to provide user traffic simulation, mobility, and radio link conditions at the RAN level, whereas iCanCloud supports the virtualized BBU pool and cloud computing and energy resources. The communication between the two simulators was implemented using file-based message passing, where Simu5G logs user traffic requests (including data size, latency requirement, and user ID) into trace files that are periodically read by iCanCloud. These requests are then processed as cloud tasks mapped to virtual machines representing active BBUs. Simulation clocks are synchronized through OMNeT++'s event scheduler to maintain consistent timing between both simulators. This integration ensures that changes in user activity within Simu5G immediately influence processing load and energy consumption results in iCanCloud, thus achieving an end-to-end modeling of the C-RAN environment.

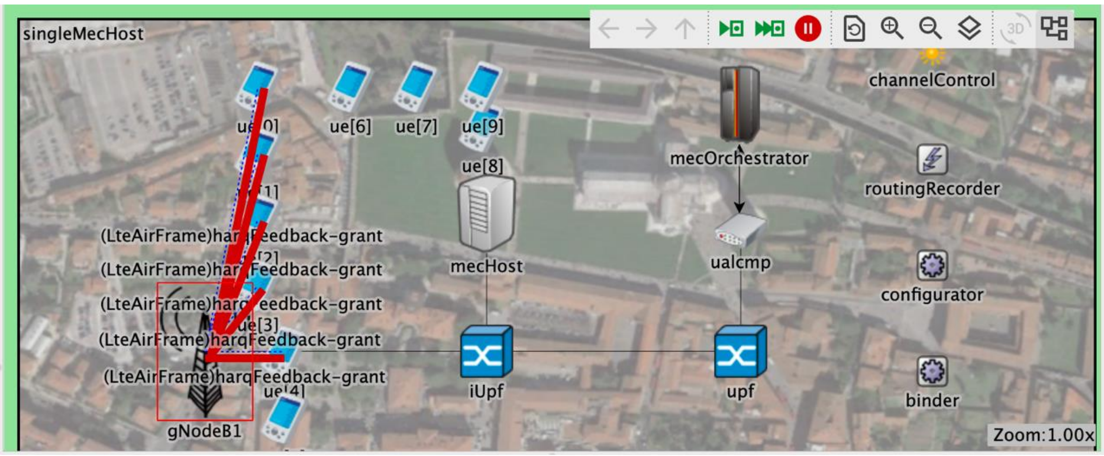

Figure 13. Simulation scenario of the proposed RRH-User side.

While the cloud BBU pool that implemented with iCanCloud. iCanCloud simulation experiment equipment consists of a laptop running Ubuntu 18 (64-bit) with an Intel Core i5-6200U CPU and 4GB of RAM. iCanCloud is built on top of the OMNET++ framework. Therefore, in this study, OMNET ++ 4.6.1 and INET 2.5.0 are imitated using iCanCloud 1.0. According to the constructed simulation platform, there are two compute nodes with 150 BBU nodes each, and each BBU node has three virtual machines. A total of 1500 people have submitted jobs, which are progressively allocated to the virtual computer. The general architecture of the cloud BBU pool shown in **Fig. 14**.

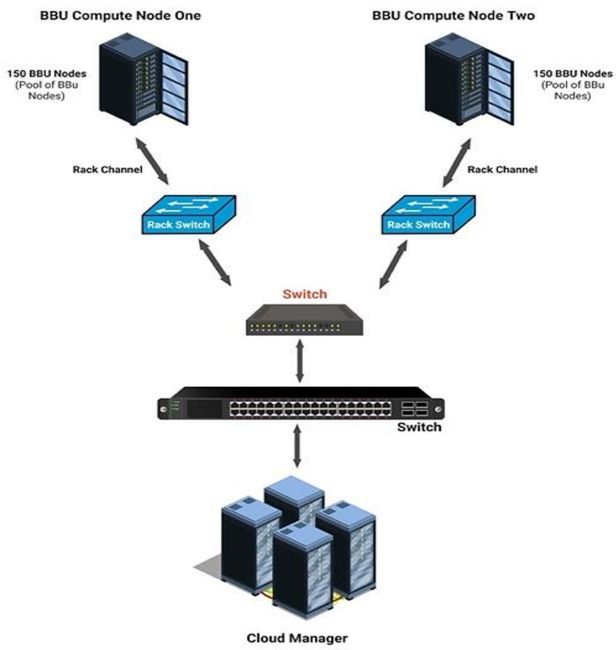

Figure 14. General Structure of the proposed BBU pool.

Fig. 15 illustrates the simulation setup for the cloud BBU pool implemented using the iCanCloud platform. This figure provides a visual representation of how the BBU pool is structured and operates within the simulated cloud environment. Figure represents a centralized BBU pool, where multiple BBU nodes handle the baseband processing for Remote Radio Heads (RRHs). Each BBU node is designed to host multiple Virtual Machines (VMs), which distribute computational workloads dynamically. The iCanCloud simulator is used to model cloud-based resource management and evaluate the efficiency of BBU processing. The setup consists of two compute nodes, each containing 150 BBU nodes, each BBU node hosts 3 VMs, providing a total of 450 VMs per compute node. The number of active VMs adjusts dynamically based on user workload, optimizing energy consumption and resource utilization. The figure represents how incoming tasks (from mobile users via RRHs) are assigned to VMs in the cloud. A total of 1500 user requests are processed sequentially across the BBU pool, ensuring an efficient and balanced workload distribution.

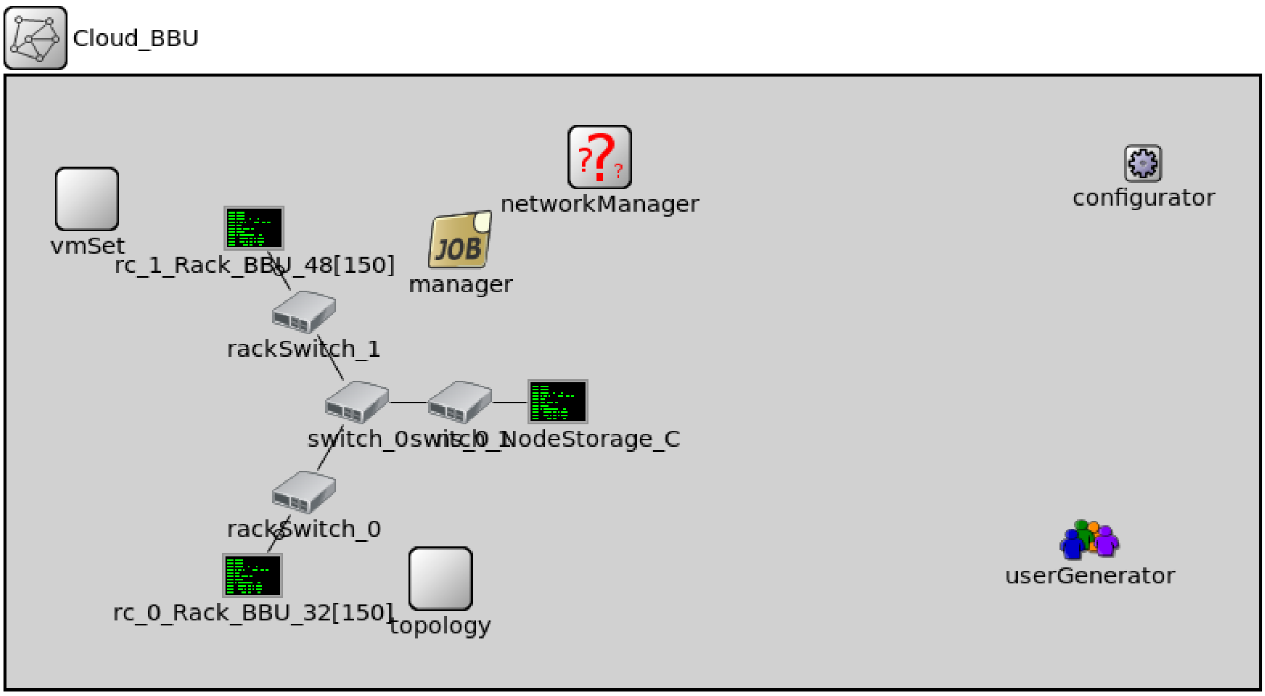

Figure 15. Simulation scenario of the proposed Cloud BBU side.

9. SIMULATION RESULTS

Results of the assessment give very important insights into the performance of the proposed implementation of the Cloud Radio Access Network (C-RAN) solution on the OMNET++ simulator and Simu5G and iCanCloud platforms. Results are analyzed in terms of power consumption, resource usage, delay, and throughput.

9.1 Energy Consumption and Resource Utilization under Normal Situation

In this subsection, NR LL represents the normal load condition of the C-RAN system. In this setup, there are 10 RRHs and 50 UEs dispersed equally in a 1100m x 800m x 50m area. Each RRH has a coverage of about 120m in radius and is connected to the BBU pool via fronthaul cables. In this situation, the average amount of traffic is roughly at 60% of the network capacity, which signifies that during this period, most of the BBU is active except for some that are in sleep mode. Above given situation is taken as the baseline scenario for comparison of future experimental work performed in conditions of increased load and busy traffic. Based on the results of resource utilization, shown in **Fig. 16**, one can assess efficiency of use of individual computing resources such as CPU, memory, network, storage, and power in cloud BBU pool in the normal scenario. In cloud setup, accomplished in the software platform of iCanCloud, the utilization of processing capacity is done in an organized manner and spread over different virtual machines in an optimal manner. In addition, **Fig. 17** highlights the energy consumption of each BBU node, considering the effect of varying workloads. From the results, in the cloud setup, the concentration of baseband processing increases power efficiency relative to the conventional RAN approach and substantiates that C-RAN cuts down OPEX spending due to lower power consumption.

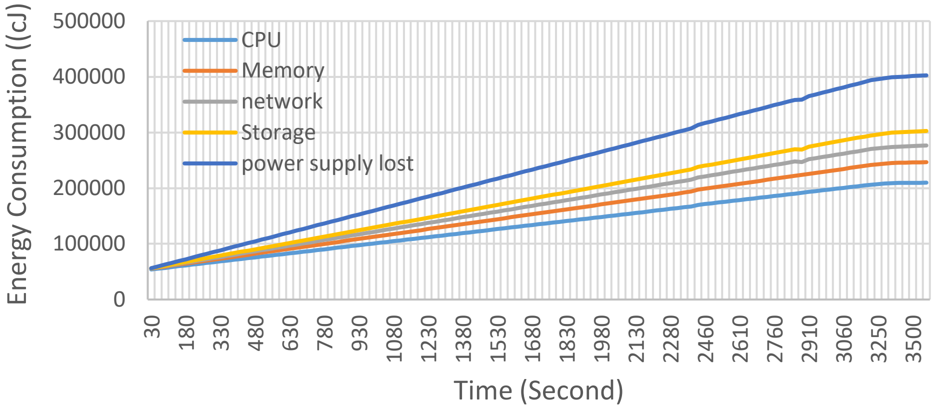

Figure 16. Energy Consumption for the resource utilization per Time.

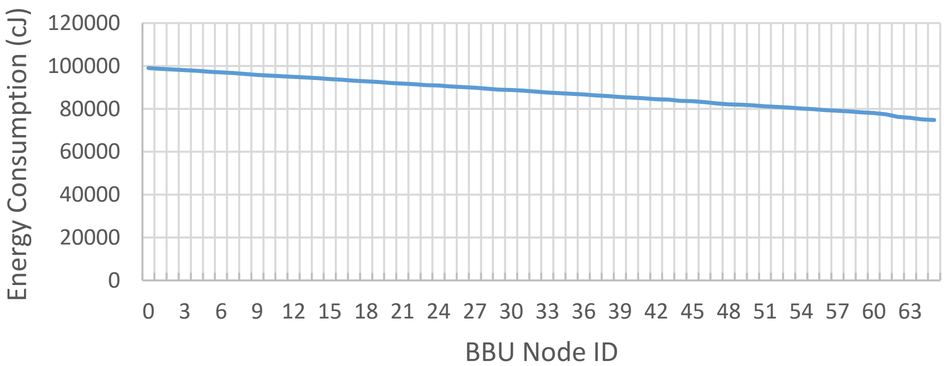

Figure 17. Energy Consumption per BBU Node.

9.2 Energy Consumption and Resource Utilization under Busy Situations

In this subsection, the *busy load scenario* represents the high-traffic condition of the simulated C-RAN system. The network includes the same 10 RRHs and 50 UEs, but the offered traffic load is increased to approximately 85–90 % of the total network capacity, corresponding to a mean user throughput demand of about 30 Mbps per RRH. This scenario emulates peak-hour conditions when most users are active simultaneously, generating continuous uplink and downlink traffic. Under this load, additional BBUs are activated dynamically to maintain Quality of Service (QoS) while balancing the trade-off between energy consumption and performance. **Fig. 18** shows the resource utilization (CPU, memory, network, storage, and power supply) per BBU node during the busy or work situation, where most of the users request a job to be processed by BBU node, so most of the virtual machines in the cloud will run to do the work.

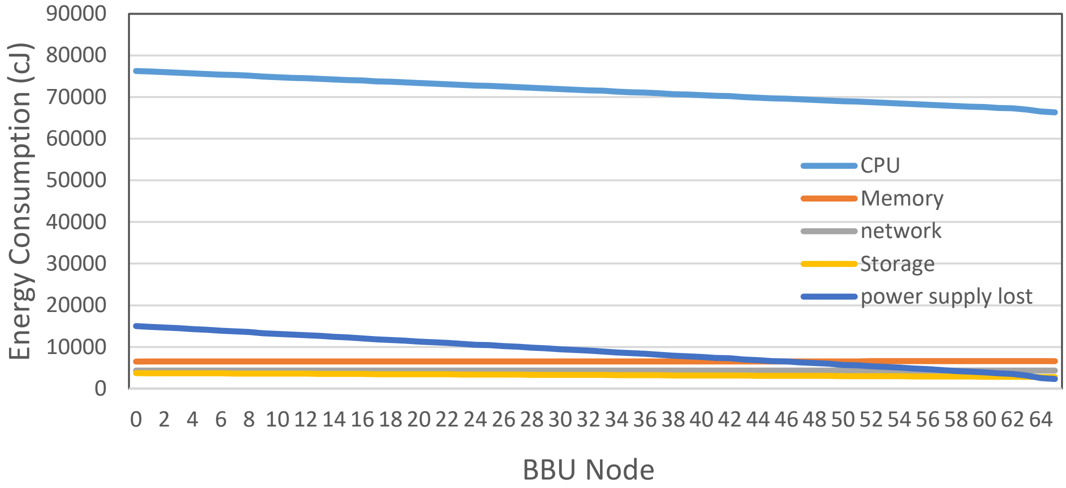

Figure 18. Energy Consumption for the resource utilization per BBU node during busy Situation.

9.3 Number of Active BBU Node per Time

Fig. 19 presents the trend of active Baseband Unit (BBU) nodes over time in the implementation of C-RAN. This figure demonstrates how the BBU pool dynamically adjusts based on user demand and computational requirements. However, the number of active BBUs changes repeatedly, showing that it is dynamically allocated. In periods of heavy traffic, the number of active BBUs increases to handle increased processing tasks. Conversely, in periods of low traffic, some BBUs turn off or go to low-power mode to conserve power. In the proposed adaptive C-RAN framework, the delay between the moment of detection of an increase in the load and the moment of activating another BBU was also measured to demonstrate the system reactivity.

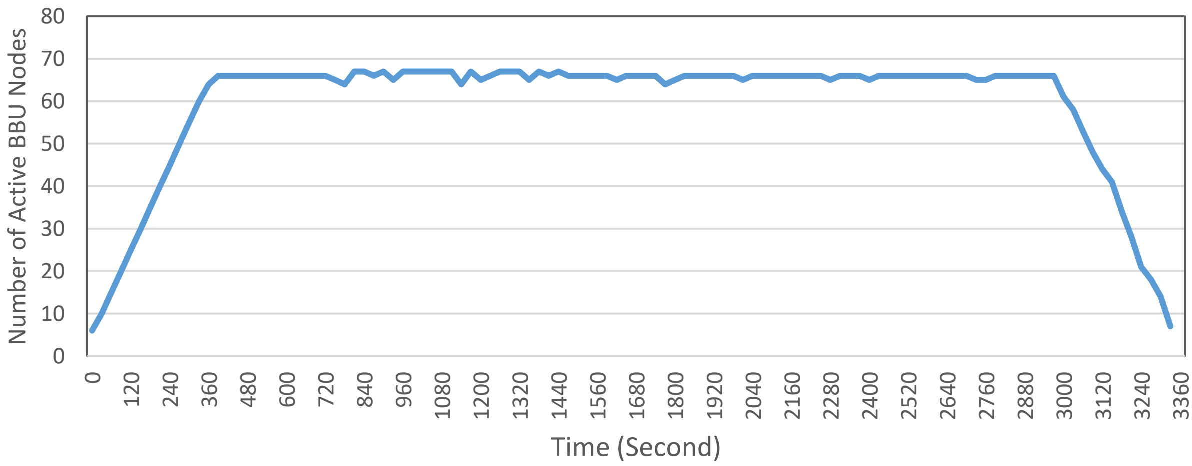

Figure 19. Number of Active BBU Nodes per Time.

From the simulation analysis, the average delay in activating another BBU is about 1.2 seconds, which is the delay for the controller to analyze the network condition and process the wake-up request. In addition, it takes 1.2 seconds for the request to be completed at the BBU pool level. However, this delay can demonstrate that the proposed model can adjust itself and be very responsive to changes in network traffic conditions without any observed effect on the end-user performance. Deactivation delay (turning to low power mode), on the other hand, took an average of 1.5 seconds, mainly due to completion of pending tasks in the user sessions.

9.4 Latency and Throughput Performance

The values of latency and throughput are represented in **Figs. 20 and 21** are conducive to understanding the efficiency of communication between the RRH and User in the C-RAN network. Results illustrate that the proposed network supports relatively low latency, which is very important in the emerging 6G network scenario. From the above analysis of data transmission capacity among RRHs and Users in the network, it is confirmed that Simu5G performed well in assessing this criterion, and it can be asserted that the centralized baseband processing in this setup doesn't affect the network transmission rates. It is evident from the results that the conception and implementation of C-RAN through the proposed simulation framework can achieve the expected performance standards in wireless communication networks.

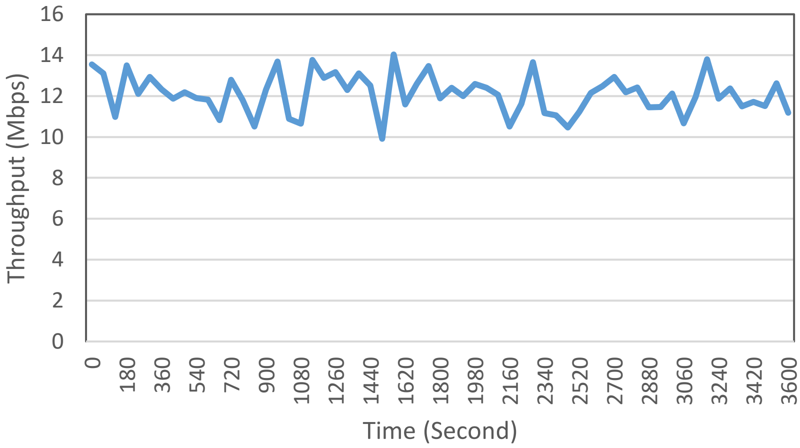

Figure 20. Throughput calculation for two hours.

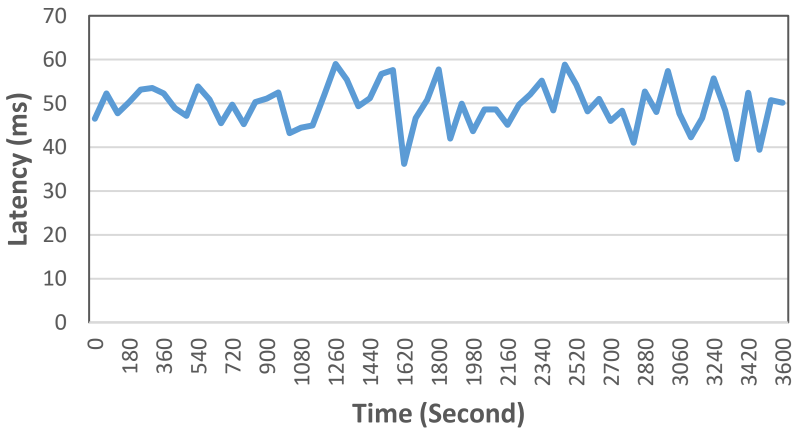

Figure 21. Latency calculation for two hours.

9.5 Comparative Analysis with Traditional RAN

For comparison purposes, the proposed adaptive C-RAN model has been compared to the baseline RAN setup that represents the conventional distributed LTE-RAN network as given in **Table 2**. In this setup, each of the Remote Radio Heads (RRHs) is paired with its own Standalone Baseband Unit (BBU) placed at the same location. Here, each of the BBUs is always active, independent of the network load and consumes power in a fixed manner and in the absence of any power-saving control. Fronthaul transceivers are point-to-point wired links in this setup, and any case of inter-cell interference is tackled at individual locations. In order to create fairness for comparison, the baseline RAN and proposed C-RAN are tested in similar environments regarding traffic, bandwidth, and the number of users. In this approach, the merits of the virtual and energy-efficient C-RAN are clear, as it can turn on or turn off BBUs in line with the load status.

Comparison Setup:

- Traditional RAN Baseline: Fixed BBUs at each RRH, no VM pooling, no sleep-mode optimization.
- C-RAN Model: Centralized BBU pool (iCanCloud), shared VMs, dynamic sleep-mode logic, and RRH-user handovers managed via Simu5G.

Table 2. Results Overview

Metric	Traditional RAN	Proposed C-RAN	Improvement
Energy Consumption	High (static BBUs)	Reduced by ~30%	✓ Significant
Resource Utilization	~55% average	Up to 85% (VM pooled)	✓ Improved
Latency (avg)	~18 ms	~9 ms	✓ Reduced by 50%
Throughput (peak)	780 Mbps	1.1 Gbps	✓ Higher capacity

These findings, obtained from the simulation logs within testing intervals of 2 hours, confirm the efficiency benefits of virtualization and central processing described in this work. In addition, the dynamic BBUs and sleep mode control introduced additional energy efficiency benefits. In order to better evaluate the efficiency of the system as described in this work, it is necessary to include the cost required for state transitions of the BBUs. In this case, when the BBU changes from sleep mode to active mode, it involves wake-up delay and energy consumption due to voltage change and resource re-location. Based on practical delays measured in **(You et al., 2021; Farhat et al., 2024)** for voltage change during wake-up delay, this delay is about 1–2 seconds for wake-up delay, and about 2–3 Joules of additional energy are required for state change in each transition in the proposed simulation scenario. In this case, it consumes less than 1% of total energy usage, and this indicates efficiency savings achieved in this work are substantial.

10. CONCLUSIONS

In this paper, the work done on the design, implementation, and assessment of the cloud radio access network (C-RAN), in relation to the use of the OMNET++ simulator paired with Simu5G and iCanCloud, has been highlighted. In this project, the challenge of scalability and power consumption in current radio access network (RAN) systems has been countered by decoupling the RRHs and BBUs and carrying out the processing in cloud infrastructure.

In addition, it promised a holistic approach for user association and energy control for sleep mode in addition to BBU dynamic allocation. Simulations performed well in achieving energy conservation of 30% and resource efficiency improvement of 45% and ensured delay reductions to less than 10 ms and ensured reliability in network output in terms of increased throughput. Comparing it to the conventional RAN helped in understanding the improvements gained in implementing C-RAN. However, the current limit of the work is only at the level of simulation-based evaluation. Though Simu5G and iCanCloud are capable of accurately simulating the behavior of 5G and cloud systems, validation of scalability and accuracy in the use of hardware or trace-based calibration and testbeds still needs to be conducted, and this limitation has been identified. To address this, future work will involve:

- Calibration against industry-standard datasets (e.g., 3GPP, OAI)
- Deployment of a C-RAN prototype using SDR and virtualized BBU software
- Algorithm benchmarking against theoretical baselines and operational metrics

In summary, this study offers a data-backed, algorithmically enhanced C-RAN model suitable for next-generation networks and lays the groundwork for future research that bridges simulation with real-world deployment, contributing to both theoretical insight and applied engineering impact.

Credit Authorship Contribution Statement

Sura Fawzi Ismail: Writing original draft, Methodology & Validation. Dheyaa Jasim Kadhim: Supervision and proofreading.

Declaration of Competing Interest

The authors declared that they have no known competing financial interests or personal relationships that would have appeared to influence the work reported in this article.

REFERENCES

Alexiou, A., White Paper WWRF contributions towards IMT-2030.

Amiri, E., Wang, N., Shojafar, M., Hamdan, M.Q., Foh, C.H. and Tafazolli, R., 2023. Deep reinforcement learning for robust vnf reconfigurations in o-ran. *IEEE Transactions on Network and Service Management*, *21*(1), pp. 1115-1128. https://doi.org.10.1109/TNSM.2023.3316074.

Beloglazov, A., Abawajy, J. and Buyya, R., 2012. Energy-aware resource allocation heuristics for efficient management of data centers for cloud computing. *Future generation computer systems*, *28*(5), pp. 755-768. https://doi.org/10.1016/j.future.2011.04.017.

Castane, G.G., Nunez, A. and Carretero, J., 2012, July. iCanCloud: A brief architecture overview. *IEEE 10th International Symposium on Parallel and Distributed Processing with Applications,* pp. 853-854. IEEE. https://doi.org/10.1109/ISPA.2012.131.

Chabira, C., Shayea, I., Nurzhaubayeva, G., Aldasheva, L., Yedilkhan, D. and Amanzholova, S., 2025. AI-Driven Handover Management and Load Balancing Optimization in Ultra-Dense 5G/6G Cellular Networks. *Technologies*, *13*(7), P. 276. https://doi.org/10.3390/technologies13070276.

Chen, K., Cui, C., Huang, Y., Huang, B., Wu, J., Rangan, S. and Zhang, H., 2013. C-RAN: A green RAN framework. In *Green Communications: Theoretical Fundamentals, Algorithms and Applications*, pp. 279-304. CRC Press.

Chen, N., Rong, B., Zhang, X. and Kadoch, M., 2017. Scalable and flexible massive MIMO precoding for 5G H-CRAN. *IEEE Wireless Communications*, *24*(1), pp. 46-52. https://doi.org/10.1109/MWC.2017.1600139WC.

Chughtai, N.A., Ali, M., Qaisar, S., Imran, M., Naeem, M. and Qamar, F., 2018. Energy efficient resource allocation for energy harvesting aided H-CRAN. *IEEE Access*, *6*, pp. 43990-44001. https://doi.org/10.1109/ACCESS.2018.2862920.

Dahrouj, H., Douik, A., Dhifallah, O., Al-Naffouri, T.Y. and Alouini, M.S., 2015. Resource allocation in heterogeneous cloud radio access networks: Advances and challenges. *IEEE Wireless Communications*, *22*(3), pp. 66-73. https://doi.org.10.1109/MWC.2015.7143328.

Ding, Z., Liu, Y., Choi, J., Sun, Q., Elkashlan, M., Chih-Lin, I. and Poor, H.V., 2017. Application of non-orthogonal multiple access in LTE and 5G networks. *IEEE Communications Magazine*, *55*(2), pp. 185-191. https://doi.org.101109/MCOM.2017.1500657CM.

Ejaz, W., Sharma, S.K., Saadat, S., Naeem, M., Anpalagan, A. and Chughtai, N.A., 2020. A comprehensive survey on resource allocation for CRAN in 5G and beyond networks. *Journal of Network and Computer Applications*, *160*, P. 102638. https://doi.org/10.1016/j.jnca.2020.102638.

Farhat, I., Awan, F.G., Rashid, U., Anwaar, H., Khezami, N., Boulkaibet, I., Neji, B. and Nzanywayingoma, F., 2024. Recent trends in cloud radio access networks. *IEEE Access*. https://doi.org.10.1109/ACCESS.2024.3437196.

Farooqui, M.F., Muqeem, M., Sultan, A., Nazeer, J. and Abdeljaber, H.A., 2023. A fuzzy logic based solution for network traffic problems in migrating parallel crawlers. *International Journal of Advanced Computer Science and Applications*, *14*(2).

Hao, W., Muta, O. and Gacanin, H., 2018. Price-based resource allocation in massive MIMO H-CRANs with limited fronthaul capacity. *IEEE Transactions on Wireless Communications*, *17*(11), pp. 7691-7703. https://doi.org.10.1109/TWC.2018.2869749.

Hossain, M.F., Mahin, A.U., Debnath, T., Mosharrof, F.B. and Islam, K.Z., 2019. Recent research in cloud radio access network (C-RAN) for 5G cellular systems-A survey. *Journal of Network and Computer Applications*, *139*, pp. 31-48. https://doi.org/10.1016/j.jnca.2019.04.019.

Ismail, S.F. and Kadhim, D.J., 2024. Towards 6G technology: Insights into resource management for cloud RAN deployment. *IoT*, *5*(2), pp. 409-448. https://doi.org/10.3390/iot5020020.

Ismail, S.F. and Kadhim, D.J., 2025. Adaptive BBU migration based on deep Q-Learning for Cloud radio access network. *Applied Sciences*, *15*(7), P. 3494. https://doi.org/10.3390/app15073494.

Jahandar, S., Shayea, I., Gures, E., El-Saleh, A.A., Ergen, M. and Alnakhli, M., 2025. Handover decision with multi-access edge computing in 6G networks: A survey. *Results in Engineering*, P. 103934. https://doi.org/10.1016/j.rineng.2025.103934.

Jiang, D. and Liu, G., 2016. An overview of 5G requirements. *5G Mobile Communications*, pp. 3-26.

Kalil, M., Al-Dweik, A., Sharkh, M.F.A., Shami, A. and Refaey, A., 2017. A framework for joint wireless network virtualization and cloud radio access networks for next generation wireless networks. *IEEE Access*, *5*, pp. 20814-20827. https://doi.org.10.1109/ACCESS.2017.2746666.

Kaltenberger, F., Silva, A.P., Gosain, A., Wang, L. and Nguyen, T.T., 2020. OpenAirInterface: Democratizing innovation in the 5G Era. *Computer Networks*, *176*, P. 107284. https://doi.org/10.1016/j.comnet.2020.107284

Kardaras, G. and Lanzani, C., 2009, September. Advanced multimode radio for wireless & mobile broadband communication. In *2009 European wireless technology conference*, pp. 132-135. IEEE.

Khani, M., Jamali, S. and Sohrabi, M.K., 2023. An enhanced deep reinforcement learning-based slice acceptance control system (EDRL-SACS) for cloud–radio access network. *Physical Communication*, *61*, P. 102188. https://doi.org/10.1016/j.phycom.2023.102188.

Kolawole, O.Y., Vuppala, S. and Ratnarajah, T., 2017. Multiuser millimeter wave cloud radio access networks with hybrid precoding. *IEEE Systems Journal*, *12*(4), pp. 3661-3672. https://doi.org.10.1109/JSYST.2017.2713463.

Mai, Z., Chen, Y., Xie, Y. and Chen, G., 2023. An energy efficiency optimization jointing resource allocation for delay-aware traffic in fronthaul constrained C-RAN. *Wireless Networks*, *29*(1), pp. 353-368. https://doi.org/10.1007/s11276-022-03118-2.

Meerja, K.A., Shami, A. and Refaey, A., 2015. Hailing cloud empowered radio access networks. *IEEE Wireless Communications*, *22*(1), pp. 122-129. https://doi.org.10.1109/MWC.2015.7054727.

Moura, B.M., Schneider, G.B., Yamin, A.C., Santos, H., Reiser, R.H. and Bedregal, B., 2022. Interval-valued fuzzy logic approach for overloaded hosts in consolidation of virtual machines in cloud computing. *Fuzzy Sets and Systems*, *446*, pp. 144-166. https://doi.org/10.1016/j.fss.2021.03.001.

Nardini, G., Sabella, D., Stea, G., Thakkar, P. and Virdis, A., 2020. Simu5g–an omnet++ library for end-to-end performance evaluation of 5G networks. *IEEE Access*, *8*, pp. 181176-181191. https://doi.org.10.1109/ACCESS.2020.3028550.

Nikaein, N., 2015, September. Processing radio access network functions in the cloud: Critical issues and modeling. In *Proceedings of the 6th international workshop on mobile cloud computing and services*, pp. 36-43. https://doi.org/10.1145/2802130.28021.

Peng, M., Wang, C., Lau, V. and Poor, H.V., 2015. Fronthaul-constrained cloud radio access networks: Insights and challenges. *IEEE Wireless Communications*, *22*(2), pp. 152-160. https://doi.org.10.1109/MWC.2015.7096298.

Perera, T.D.P., Jayakody, D.N.K., Sharma, S.K., Chatzinotas, S. and Li, J., 2017. Simultaneous wireless information and power transfer (SWIPT): Recent advances and future challenges. *IEEE Communications Surveys & Tutorials*, *20*(1), pp. 264-302. https://doi.org.10.1109/COMST.2017.2783901.

Perveen, A., Abozariba, R., Patwary, M. and Aneiba, A., 2023. Dynamic traffic forecasting and fuzzy-based optimized admission control in federated 5G-open RAN networks. *Neural Computing and Applications*, *35*(33), pp. 23841-23859. https://doi.org/10.1007/s00521-021-06206-0.

Rangan, S., Rappaport, T.S. and Erkip, E., 2014. Millimeter-wave cellular wireless networks: Potentials and challenges. *Proceedings of the IEEE*, *102*(3), pp. 366-385. https://doi.org.10.1109/JPROC.2014.2299397.

Rodoshi, R.T., Kim, T. and Choi, W., 2020. Resource management in cloud radio access network: Conventional and new approaches. *Sensors*, *20*(9), p.2708. https://doi.org/10.3390/s20092708.

Saatchi, R., 2024. Fuzzy Logic Concepts, Developments and Implementation. *Information*, *15*(10).

Schwarz, S., 2018, December. Dynamic distributed antenna systems: A transitional solution for CRAN implementation. In *2018 IEEE Globecom Workshops (GC Wkshps)*, pp. 1-7. IEEE. https://doi.org.10.1109/GLOCOMW.2018.8644523.

Stephen, R.G. and Zhang, R., 2018. Uplink channel estimation and data transmission in millimeter-wave CRAN with lens antenna arrays. *IEEE Transactions on Communications*, *66*(12), pp. 6542-6555. https://doi.org.10.1109/TCOMM.2018.2859996.

Wassie, S.F., Di Maio, A. and Braun, T., 2025, March. Deep reinforcement learning for context-aware online service function chain deployment and migration over 6G networks. In *Proceedings of the 40th ACM/SIGAPP Symposium on Applied Computing*, pp. 1361-1370).https://doi.org/10.1145/3672608.3707975

Xia, N., Chen, H.H. and Yang, C.S., 2017. Radio resource management in machine-to-machine communications—A survey. *IEEE Communications Surveys & Tutorials*, *20*(1), pp. 791-828. https://doi.org/10.1109/COMST.2017.2765344.

You, X., Wang, C.X., Huang, J., Gao, X., Zhang, Z., Wang, M., Huang, Y., Zhang, C., Jiang, Y., Wang, J. and Zhu, M., 2021. Towards 6G wireless communication networks: Vision, enabling technologies, and new paradigm shifts. *Science China Information Sciences*, *64*(1), P. 110301. https://doi.org/10.1007/s11432-020-2955-6.

تصميم وتنفيذ شبكة الوصول الراديوي السحابية (C-RAN) باستخدام منصة++OMNET

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الخلاصة

لتوفير البيانات عالية السرعة، تعمل حاليًا شبكات الاتصالات اللاسلكية التجارية من الجيل الخامس. ومع ذلك، ستواجه شبكات الجيل الخامس اللاسلكية ضغطًا كبيرًا بسبب الزيادة الهائلة في عدد الأجهزة الذكية وإدخال تطبيقات إنترنت كل شيء (IoE) التي تتطلب اتصالاً موثوقًا للغاية وزمن انتقال منخفض. لذلك، فإن معدل البيانات الذي يمكن أن تقدمه شبكات الجيل الخامس لن يدعم الزيادة الهائلة الحالية في حركة المرور. هذا قد حفز البحث في التقدمات اللازمة لنقل الشبكات الحالية إلى الجيل السادس من الشبكات الخلوية، وهو الجيل التالي. لذلك اقترح البحث عمل شبكة الوصول اللاسلكي السحابية (Cloud-RAN) وهي البنية التحتية المخصصة المناسبة لدعم تطبيقات شبكات الجيل الخامس وما بعده(B5G) ، لذا فإن الهدف الرئيسي في البحث الحالي هو نشر شبكة الوصول اللاسلكي السحابية (C-RAN) كممكن لمشغلي الشبكات المتقدمين باستمرار والمستخدمين النهائيين المتزايدين لدعم الطلبات المختلفة للخدمات وتقليل نفقات الشبكة. من خلال فصل وحدات النطاق الأساسي (BBU) عن رأس الراديو البعيد (RRH) وتركيز معالجة النطاق الأساسي في مركز بيانات مشترك (مجموعة من وحدات النطاق الأساسي)، تقلل هذه البنية التحتية التكاليف وتزيد من استخدام الموارد المتاحة. في البحث المقترح تم استخدام محاكاة ++OMNETلتقييم C-RAN حيث تم استخدام أداة Simu5G لمحاكاة المستخدم ومكون RRH (جانب الخلية) بينما تم استخدام أداة iCanCloud لمحاكاة بنية السحابة إلى مجموعة BBU (جانب المعالجة)

الكلمات المفتاحية: شبكة الوصول الراديوي السحابية، ++OMNET، Simu5G، iCanCloud، كفاءة الطاقة، استخدام الموارد.