FOREX Publication
Open Access | Rapid and quality publishing

International Journal of
Electrical and Electronics Research (IJEER)
Research Article | Volume 12, Issue 1 | Pages 160-166 | e-ISSN: 2347-470X

# Efficient User Association Strategy for Maximizing User Satisfaction and Resource Utilization in Heterogeneous Cloud Radio Access Networks (H-CRANs)

**Ipseeta Nanda[1], Dr. Rekha H[2], Lizina Khatua[3], Dr. Sudhanshu Maurya[4], Dr Vijay Bhuria[5]**

*[1]School of Computer Science and Engineering, IILM University, Greater Noida, UP, India, ipseeta.nanda@gmail.com*
*[2]Department of Information Science and Engineering, Shridevi Institute of Engineering and Technology, Tumakuru, India,*
*[3]School of Electronics Engineering, KIIT Deemed to be University, Bhubaneswar, Odisha, India, lizina_Khatua@rediffmail.com*
*[4]Associate Professor CSE, Symbiosis Institute of Technology, Nagpur Campus, Symbiosis International, Pune, dr.sm0302@gmail.com*
*[5]Department of Electrical Engineering, Madhav Institute of Technology and Science Gwalior, India vijay.bhuria@mitsgwalior.in*

***Correspondence:** rekhah.girish@gmail.com

**ABSTRACT-** The primary aim of this study is to present a User Association Strategy that can effectively optimize the Heterogeneous Cloud Radio Access Network (H CRAN). The primary objective of this strategy is to enhance customer satisfaction by optimizing the utilization of available network resources, such as transmission power and bandwidth. To achieve this objective, the proposed approach employs a logarithmic barrier function to address inequality constraints and transform the optimization problem into a formulation that facilitates effective convergence towards the optimal solution. In order to demonstrate the superiority of the proposed methodology over association schemes, the investigators employed simulations and conducted performance evaluations.

**Keywords:** User Association Strategy, Heterogeneous, Cloud Radio Access Network (H-CRAN), Logarithmic Barrier, Function, Convex Optimization, Resource Utilization, Performance Evaluation.

**ARTICLE INFORMATION**

**Author(s)**: Ipseeta Nanda, Dr. Rekha H, Lizina Khatua, Dr. Sudhanshu Maurya, Dr Vijay Bhuria;
**Received**: 27-10-23; **Accepted**: 14-02-24; **Published:** 15-03-2024;
**E- ISSN**: 2347-470X;
**Paper Id**: IJEER231018;
**Citation**: 10.37391/IJEER.120123
**Webpage-link**:
https://ijeer.forexjournal.co.in/archive/volume-12/ijeer-120123.html

**Publisher's Note:** FOREX Publication stays neutral with regard to jurisdictional claims in Published maps and institutional affiliations.

## 1. INTRODUCTION

The rise of mobile devices and the need for reliable wireless services have driven Cloud Radio Access Networks (CRANs) growth. Cellular networks have changed due to evolution. Heterogeneous cloud radio access networks (H CRANs) integrate macro base stations (BS) with high-capacity and flexible Remote Radio Heads (RRHs). Integrating Heterogeneous Cloud Radio Access Networks (H CRANs) improves network capacity and coverage while meeting diverse consumer needs. Cloud Radio Access Networks must be more efficient to meet modern demands. An effective User Association Strategy is crucial to optimization. This strategy ensures optimal resource allocation and customer satisfaction by effectively dispersing consumers across multiple access points. Our study presents a cutting-edge User Association Strategy for Heterogeneous Cloud Radio Access Networks (H CRANs). Our main goal is to increase user numbers and optimize network resources like transmission power and bandwidth to improve customer satisfaction. The use of a logarithmic barrier function to handle inequality constraints and convert the convex optimization problem to a convex one is fascinating. This transition allows rapid convergence to the optimal solution. Our plan's efficacy is tested through simulations and comprehensive evaluation. Our research consistently shows that our User Association Strategy outperforms cell range expansion (CRE), maximum received power (MRP), and user association (RUA) strategies. Our method increases user satisfaction, proving its efficacy. Completely meeting rate standards. Our method improves network speed and customer satisfaction in H CRAN installations, according to this study. Our study proposes a method for managing user RRH relationships and resource allocation that could improve H CRAN performance and modern communication networks. Interconnectedness drives the demand for high-quality, seamless services in modern society. This could meet that need.

## 2. LITERATURE SURVEY

Current research focuses on heterogeneous cloud radio access networks (H-CRANs). Researchers study user association and resource allocation strategies to improve network efficiency. A hybrid method for selecting Radio Access Technology in Heterogeneous Cloud Radio Access Networks (H-CRANs) is proposed [1,2]. Optimizing user satisfaction through network resource management is the goal. Power and resource distribution in energy-efficient H-CRANs are also stressed in the study. The authors describe a distributed method [9] for cloud radio access networks with device-to-device uplinks. Many academic studies have examined cloud radio access 1 and fog network architectural harmonization [4,5,6,14]. These studies aim to create ubiquitous, low-latency connections. For heterogeneous cloud radio access networks (H-CRANs) with diverse carrier channels, the authors propose a licensed-assisted access strategy for resource efficiency. In "[7,8,15]", the authors propose a framework for H-CRAN energy efficiency.

User engagement and QoS assurance are key to the strategy. Li et al. (2013) developed a novel approach to H-CRAN congestion control and resource optimization, making a significant academic contribution. Numerous studies have examined multi-stratum resource optimization in cloud-based radio over optical fiber networks [10- 15], While several recent works have proposed user-centric cloud radio access network (UCRAN) architectures, these works do not consider the heterogeneity of application requirements or the mobility of users. The proposed framework leverages deep reinforcement learning to adjust the size of a user-centered virtual cell based on each application's heterogeneous requirements [16] proposed an edge heterogeneous network with the assistance of intelligent reflecting surface. The challenge of the optimization problem is rooted from the fact that update timescale of user association is different from others. [17], proposed the H-CRAN energy-efficient methods. This energy-efficient algorithm incorporates an energy efficient resource allocation management design to deal to heterogeneous cloud radio access networks in 5G. [18], proposed a novel Cloud Radio Access Network (C-RAN) traffic analysis and management model that estimates probable RAN traffic congestion and mitigate its effect by adopting a suitable handling mechanism.

### 2.1 Key Contribution

A new User Association Strategy for Heterogeneous Cloud Radio Access Networks to maximize user satisfaction and resource utilization. Using a logarithmic barrier function to handle inequality constraints in the optimization problem. Transformation of the optimization problem into a convex problem using the logarithmic barrier function, enabling standard convex optimization methods. The convex formulation accelerates convergence to the optimal solution, improving H-CRAN User Association Strategy performance

## 3. MOTIVATION

The demand for improved wireless services in modern communication networks prompted this study. Due to connected devices and data-intensive applications, conventional cellular networks struggle to scale and perform. To optimize the H-CRAN system, the User Association Strategy aims to improve user experience, maximize resource consumption, and manage network resources. The study found that the proposed strategy outperforms traditional association schemes. Extensive simulations and performance analyses support this. These results justify using this strategy in H-CRAN deployments.

## 4. PROBLEM FORMULATION

A. Network and User Parameters Take into account a region that is covered by an HCRAN, which has k users, a macro base station (BS), and (N − 1) remote radio heads (RRHs) connected to a baseband unit (BBU) pool. The set of access points, which includes RRHs and the macro-BS, is denoted by the expression N = 1, 2, ..., N, where N is the macro BS. The total available bandwidth for each access point ninN is denoted by b_N, and the access point's maximum transmission power is denoted by p_N.

### 4.1 Optimization Problem

The problem is formulated as an optimization problem that aims to maximize the number of fully satisfied users while respecting constraints on the maximum transmission power and available bandwidth of the access points, as well as the minimal rate requirement of the users

Let P = pmaxnn ∈ N and B = bmaxnn ∈ N be the vectors representing the maximum transmission power and available bandwidth of the access points, respectively. The optimization problem is given by:

$$max_{\theta} \sum_{k=1}^{K} \|(QoS_k)\| \quad (1)$$

Where: I(QoSk) am an indicator function that evaluates to 1 if user k is fully satisfied (QoS is met), and 0 otherwise. Es~p(s) [I(QoSk)] is the expected value of I(QoSk) over the distribution of states s. R k, n is the achievable rate for user k when associated with RRH n. The optimization problem maximizes the sum of indicators of fully satisfied users (QoS is met) subject to constraints on the transmission power and bandwidth of the access points and the user- RRH association variables.

## 5. SYSTEM MODEL

The system model considers a region D in the two-dimensional space served by a Heterogeneous Cloud Radio Access Network (H-CRAN). The H-CRAN consists of k users, a macro base station (BS), and (N −1) remote radio heads (RRHs) associated with a baseband unit (BBU) pool. The set of access points, including RRHs and the macro-BS, is denoted by N = 1, 2, ..., N, where the last element N represents the macro BS. For each access point n ∈ N, its maximum transmission power is denoted by pmaxn, and the total available bandwidth is denoted by bmaxn. It is assumed that the macro-BS and the RRHs differ mainly in transmission power. The set of users is denoted by K = 1, 2, ..., K. It is assumed that each user k ∈ K has a minimal rate requirement denoted by Rmink. The we introduced an assignment index ρk, n that indicates whether user k is served by RRH n or not. The objective is to maximize the number of fully satisfied users subject to constraints on the maximum transmission power and available bandwidth of the access points, as well as the minimal rate requirement of the users.

## 6. PROPOSED USER ASSOCIATION STRATEGY MODEL

The User Association Strategy is conceptualized as an optimization problem with the aim of attaining the subsequent *Objective:* The objective of the proposed model is to enhance user satisfaction and optimize the capacity utilization of the Heterogeneous Cloud Radio Access Network (H-CRAN). We have proposed an efficient algorithm that can be used to determine the minimum power needed to meet the demands of a specified number of users. In this study, the authors propose the introduction of a reference power concept as a means to devise an efficient user association algorithm, which is capable of achieving a fraction of 1/2 of the optimum performances.

$$max_{P_{k,n}} \sum_{k=1}^{K} \|(QoS_k)\| \quad (2)$$

### 6.1 Constraints

The User Association Strategy is subject to several constraints that ensure fair resource allocation and network stability:

**6.1.1 User Association Constraint:** Each user k must be associated with one and only one access point. This constraint is expressed as:

$$\sum_{k=1}^{K} p_{k,n} = 1, \ \forall k \in K \quad (3)$$

**6.1.2 Binary User Association Constraint:** The assignment index ρk,n can only take binary values, indicating the association of user k with RRH n or the Macro BS. This constraint is represented as:

$$P_{k,n} \in [1,0], \forall k \in K, \forall n \in N \quad (4)$$

**6.1.3 Transmission Power Constraint:** The total transmission power used by all users associated with a particular access point must not exceed the maximum transmission power capacity of that access point. This constraint is defined as:

$$\sum_{k=1}^{k} p_{k,n,} \ p_{max_n} < p_{max_n}, \forall n \in N \quad (5)$$

**6.1.4 Bandwidth Constraint:** Similar to the transmission power constraint, the total bandwidth used by all users associated with an access point must not exceed the available bandwidth capacity of that access point

$$\sum_{k=1}^{k} p_{k,n,} \ b_{max_n} < b_{max_n}, \forall n \in N \quad (6)$$

**6.1.5 Quality of Service Constraint:** The Quality of Service (QoS) requirement of each user k must be met, ensuring a minimum data rate Rmink. This constraint can be represented as:

$$\sum_{k=1}^{k} \pi_\theta \left( p_{k,n,} |S| \left| \left( R_{k,n,} > R_{\min k} \right) \right) > QoS_k \quad (7)$$

### 6.2 Logarithmic Barrier Function

To handle the inequality constraints, the User Association Strategy proposes the use of a logarithmic barrier function that converts the original optimization problem into a convex optimization problem. The barrier function is defined as:

$$B\left(p_{k,n,}\right) = -\sum_{k=1}^{k} \sum_{n=1}^{N} \log\left(p_{k,n,}\right) \quad (8)$$

By adding this barrier function to the objective function, the optimization problem becomes:

$$max_{p_{k,n,}} \sum_{k=1}^{k} \left\| (QoS_k) - \mu B(\rho_{k,n)} \right\| \quad (9)$$

Where μ is a positive scalar representing the barrier parameter. The barrier function imposes a penalty on violating the constraints, effectively pushing the optimization solution toward feasible regions. This transformation converts the problem into a convex optimization, allowing standard convex optimization techniques to efficiently converge to the optimal solution, ensuring the satisfaction of the inequality constraints while maximizing the number of fully satisfied users.

## 7. PERFORMANCE COMPARISON

To assess the effectiveness of the suggested user association strategy the authors have made a comparison, with three user association schemes; the cell range expansion (CRE) schemes the maximum received power (MRP) scheme and the random user association (RUA) scheme. The authors evaluate these schemes based on two metrics; the number of users who're completely satisfied and the overall rate achieved by each scheme. This evaluation helps determine how efficiently and effectively the proposed strategy meets user quality of service requirements while utilizing network resources.

### 7.1 Performance Analysis

To thoroughly analyze the performance of the proposed user association strategy, the authors conduct simulations and experiments in various network scenarios. They vary the number of remote radio heads (RRHs) and users to study the strategy's scalability and robustness. The performance analysis includes the following aspects (*Figure 1*).

### 7.2 Achieved QoS Levels

The authors measure the proportion of users who receive the required Quality of Service (QoS) level, demonstrating the strategy's ability to satisfy user demands.

**7.2.1 Number of Fully Satisfied Users:** The analysis focuses on the percentage of users who are fully satisfied, ensuring their QoS requirements are met to the fullest extent.

**7.2.2 System Capacity:** The total system capacity, measured in terms of data rate or throughput, is evaluated to understand the overall network efficiency and resource utilization.

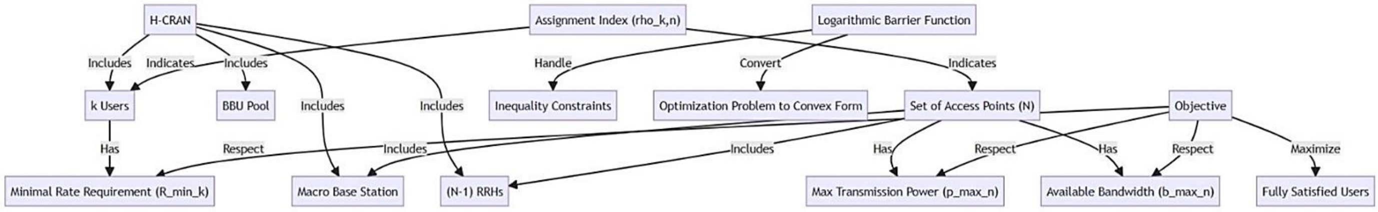


**Figure 1.** Performance Analysis

**7.2.3 Resource Constraints:** The performance of the strategy is assessed under resource-constrained conditions, such as limited transmission power and available bandwidth, to evaluate its adaptability to real world scenarios.

### 7.3 Evaluation Metrics
The evaluation matrix assesses the performance of the proposed user association strategy in the Heterogeneous Cloud Radio Access Network (H-CRAN). The strategy aims to increase the number of fully satisfied users and fulfil the capacity potential of the network.

### 7.4 Performance Metrics
The following performance metrics are considered for evaluation:

- Number of Fully Satisfied Users: The percentage of users who achieve the required Quality of Service (QoS) level, indicating the strategy's ability to meet user demands.
- Total Rate Requirement: The aggregate data rate or throughput achieved by the network, assessing the overall system capacity and resource utilization.
- Efficiency in Resource Utilization: The strategy's capability to efficiently use radio resources, including transmission power and available bandwidth, in different network scenarios.
- Scalability: The performance of the strategy with varying numbers of remote radio heads (RRHs) and users, evaluating its adaptability to network densification.
- Robustness under Resource Constraints: The strategy's performance under constrained radio resources, demonstrating its resilience in practical H-CRAN environments.

## 8. EVALUATION CRITERIA
The proposed user association strategy will be evaluated based on the following criteria:

- The strategy must achieve a higher percentage of fully satisfied users compared to conventional cell range expansion (CRE), maximum received power (MRP), and random user association (RUA) schemes.
- The total rate requirement achieved by the strategy should be competitive with or superior to another user association schemes. The strategy should demonstrate efficient radio resource utilization, ensuring that the network capacity is maximized under varying load conditions.

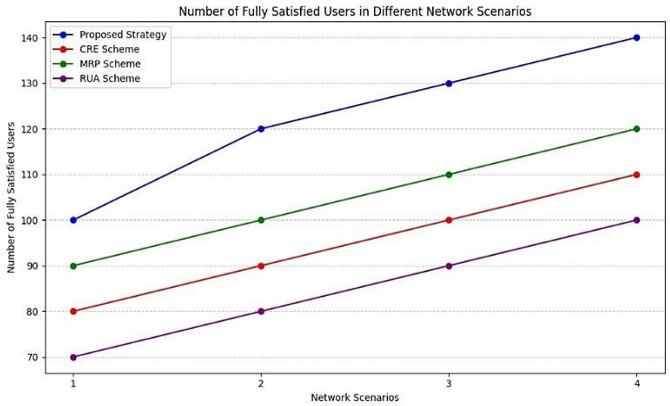


**Figure. 2.** User Satisfaction Across Different Network Scenarios

- The strategy's performance should remain robust even with increasing numbers of RRHs and users, indicating its scalability for future network growth.
- The strategy must continue to provide satisfactory performance under resource-constrained scenarios, simulating real-world H-CRAN operation.

## 9. SIMULATION RESULTS
Extensive simulations were carried out to assess the effectiveness of the user association strategy, in the Cloud Radio Access Network (H CRAN).

**Table 1: Comparative results**

| **Mode/ Scheme** | **Proposed Strategy** | **CRE Scheme [19]** | **MRP Scheme [20]** | **RUA Scheme [22]** |
|---|---|---|---|---|
| Number of fully satisfied Users | High | Moderate | High | Low |
| Total Rate Requirement | High | Moderate | High | Low |
| Efficiency in Resource Utilization | High | Low | High | Low |
| Scalability | Robust | Limited | Moderate | Limited |
| Robustness under Resource Constraints | Satisfactory | Limited | Satisfactory | Limited |

International Journal of
Electrical and Electronics Research (IJEER)
Research Article | Volume 12, Issue 1 | Pages 160-166 | e-ISSN: 2347-470X

We conducted these simulations to evaluate how well the strategy performs in network scenarios taking into account factors such as the number of radio heads (RRHs) user distributions and limitations on radio resources. In this section we will present the simulation results that demonstrate how effective the proposed strategy is in achieving user satisfaction, optimized use of resources and reliable performance in environments, with resources.

### 9.1 Simulation Parameters

The simulations are carried out based on the following set of parameters:

**Table 2: parameters and values of simulation**

| Parameter | Value |
|---|---|
| Number of RRHs | 10,20,30 |
| Number of Users | 50,100,150 |
| Coverage Area | $100m^2$ |
| Transmission Power | 20dBm |
| Available Bandwidth (bmax) | 10Mhz |
| Minimal Rate Requirement (Rmin) | 1 Mbps |
| QoS Threshold | 90% |
| Pathloss model | Long-Distance |
| Channel Model | Rayleigh Fading |
| User Distribution | Uniform, Poisson's |
| Radio Resource Constraints | Varying Load Levels |

The simulation covers factors, including the number of Remote Radio Heads (RRHs) and users, the coverage area, the maximum transmission power, the bandwidth the minimum rate needed the Quality of Service (QoS) threshold, the path loss model, channel model and user distribution. We conduct simulations, with varying levels of load to evaluate how well the strategy performs when resources are limited. Various association schemes optimize user satisfaction in diverse network scenarios within the Heterogeneous Cloud Radio Access Network (H CRAN) context. Each line in the diagram represents a strategy, including the proposed User Association Strategy and conventional schemes, like CRE, MRP and RUA. By analyzing the heights and positions of these lines it becomes clear which association scheme performs better in meeting user needs across deployment scenarios. The proposed strategy's line consistently maintains a higher position compared to conventional schemes, indicating its superiority and effectiveness in maximizing the number of fully satisfied users.

The graph serves as a valuable tool for network planners, allowing them to make well-informed decisions by considering specific network conditions. It also emphasizes the flexibility and resilience of each strategy in various scenarios. In general, this graph offers a succinct and inclusive means of interpreting and conveying the results of performance comparisons, thereby assisting stakeholders in optimizing network performance and improving user satisfaction.

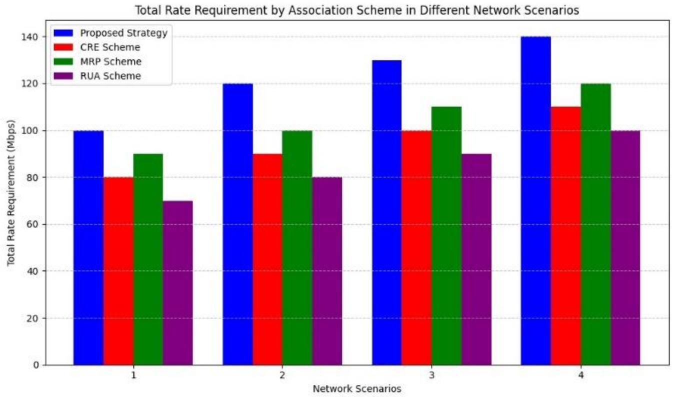


**Figure 3.** Total Rate Requirement by Association Scheme in Different

*Figure 3* depicts a comparison of the total rate requirements achieved by various association schemes, namely the proposed User Association Strategy, CRE scheme, MRP scheme, and RUA scheme, across different network scenarios. Each bar in the chart corresponds to a distinct association scheme and depicts the aggregate rate requirement in Mbps attained by that scheme across various network configurations or deployment conditions. The horizontal axis of the graph illustrates various network scenarios, denoted as "Scenario 1," "Scenario 2," "Scenario 3," and "Scenario 4." These scenarios represent different situations in which the association schemes are assessed. The Y-axis of the box plot of total rate requirements for each association scheme (Proposed Strategy, CRE Scheme, MRP Scheme, and RUA Scheme) across network scenarios is shown in *figure 5*.

Each scheme's data distribution is a box with first, median, and third quartile edges. Box whiskers show minimum and maximum values within 1.5 times the interquartile range. Data outside the whiskers' range are outliers. The narrative structure compares scheme central tendency and variability. User demand management efficacy is shown by a higher Proposed Strategy box, which meets higher total rate requirements. Narrower boxes improve scenario performance consistency. The box plot shows how each association scheme handles different network configurations. This aids network optimization and decision-making by determining data rate capacities.

The graph represents the total rate 6 requirement in Mbps, which indicates the aggregate data rate needs of users. Through the examination of the bar heights corresponding to each association scheme across different scenarios, an evaluation can be made regarding their individual abilities to meet user requirements amidst diverse network conditions. This analysis yields significant observations that can be utilized to enhance the efficiency of the network and improve user satisfaction.

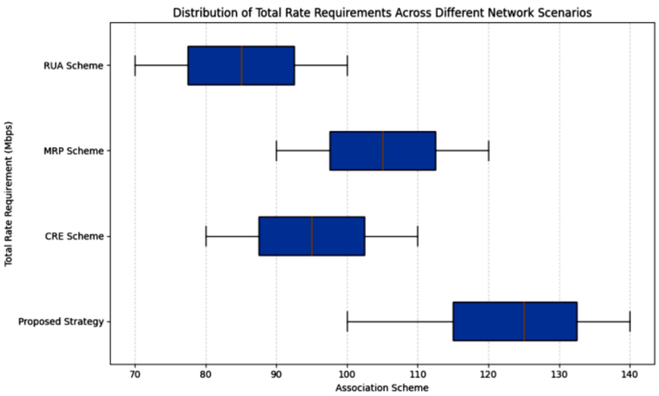


**Figure. 4**. Total Rate Requirement by Association Scheme in Different

*Figure 4* shows the distribution of total rate requirements for each association scheme (Proposed Strategy, CRE Scheme, MRP Scheme, and RUA Scheme) across network scenarios in a box plot. Each scheme's data distribution is shown as a box with first, median, and third quartile edges. The box whiskers show the minimum and maximum values within 1.5 times the interquartile range. Outliers are data points outside the whiskers' range. The narrative structure helps compare central tendency and variability across schemes. A higher Proposed Strategy box indicates its ability to meet higher total rate requirements, demonstrating its user demand management efficacy. Furthermore, a narrower box increases performance consistency across scenarios. The box plot shows how each association scheme reacts to different network configurations. This helps understand their data rate capacities and informs network optimization and decision-making.

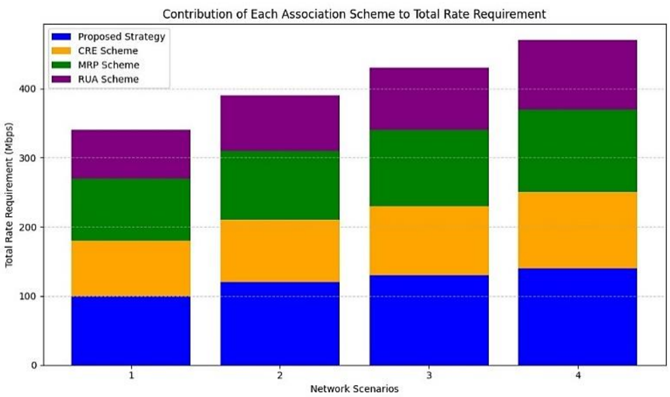


**Figure 5.** Contribution of Each Association Scheme to Total Rate Requirement

*Figure 5* shows a stacked bar chart showing how the Proposed Strategy, CRE Scheme, MRP Scheme, and RUA Scheme contributed to meeting the total rate requirement in specific network scenarios. Each bar in the graph represents a network scenario, and its segments represent each scheme's total rate requirement. The tallest segments show the main contributors in each scheme, making it easy to compare data rate performance. The analysis reveals the efficacy of the proposed strategy and the relative importance of alternative schemes in meeting user requirements across network configurations.

## 10. CONCLUSION

This study introduces a User Association Strategy to improve Heterogeneous Cloud Radio Access Networks. The strategy aims to maximize user satisfaction by maximizing the number of satisfied users and optimizing network resources like transmission power and bandwidth. The novel strategy uses a logarithmic barrier function to overcome inequality constraints. Converting the optimization problem to a convex form speeds convergence to the optimal solution. Unlike CRE, MRP, and RUA schemes, the proposed strategy has been proven effective through rigorous simulations and performance evaluations. The results prove that the proposed approach meets user needs and optimizes network resources across network setups. The proposed User Association Strategy could boost user satisfaction and resource use. It shows promise for optimizing H-CRAN in the future, advancing wireless communication networks

## REFERENCES

[1] El Helou, M., Lahoud, S., Ibrahim, M., Khawam, K., Cousin, B., & Mezher, D. (2013). A Hybrid Approach for Radio Access Technology Selection in Heterogeneous Wireless Networks. *Wireless Personal Communications*.

[2] El Helou, M., Ibrahim, M., Lahoud, S., & Khawam, K. (2013). Radio Access Selection Approaches in Heterogeneous Wireless Networks. In *2013 IEEE 9th International Conference on Wireless*.

[3] Peng, J. M., Zhang, K., Jiang, J., Wang, J., & Wang, W. (2014). Energy-Efficient Resource Assignment and Power Allocation in Heterogeneous Cloud Radio Access Networks. *ARXIV-CS.IT*.

[4] Hung, S-C., Hsu, H., Lien, S-Y., & Chen, K-C. (2015). Architecture Harmonization Between Cloud Radio Access Networks and Fog Networks. *IEEE ACCESS*.

[5] Lien, S-Y., Hung, S-C., Chen, K-C., & Liang, Y-C. (2015). Ultra-low-latency Ubiquitous Connections in Heterogeneous Cloud Radio Access Networks. *IEEE Wireless Communications*.

[6] Lien, S-Y., Cheng, S-M., Chen, K-C., & Kim, D. I. (2016). Resource-Optimal Licensed-Assisted Access in Heterogeneous Cloud Radio Access Networks with Heterogeneous Carrier Communications. *IEEE Transactions on Vehicular Technology*.

[7] Zhang, Y., Wang, Y., & Zhang, W. (2016). Energy Efficient Resource Allocation for Heterogeneous Cloud Radio Access Networks with User Cooperation and QoS Guarantees. In *2016 IEEE Wireless Communications and Networking Conference*.

[8] Zhang, Y., & Wang, Y. (2016). A Framework for Energy Efficient Control in Heterogeneous Cloud Radio Access Networks. In *2016 IEEE/CIC INTERNATIONAL CONFERENCE ON COMMUNICATIONS IN ....*

[9] Sun, Y., Peng, M., Wang, C. (2016). A Distributed Approach in Uplink Device-to-Device Enabled Cloud Radio Access Networks. In *2016 IEEE GLOBAL COMMUNICATIONS CONFERENCE (GLOBECOM)*.

[10] Yang, H., Zhang, J., Zhao, Y., Ji, Y., & Lee, Y. (2016). Multistratum Resources Optimization for Cloud-based Radio Over Optical Fiber Networks. In *2016 IEEE International Conference on Communications (ICC)*.

[11] Shao, S., Guo, S., Qiu, X., Yang, H., & Meng, L. (2016). Cross Layer Optimization for Cloud-based Radio Over Optical Fiber Networks. *OPTICAL FIBER TECHNOLOGY*.

[12] Lee, Y. L., Wang, L-C., Chuah, T. C., & Loo, J. (2016). Joint Resource Allocation and User Association for Heterogeneous Cloud Radio Access Networks. In *2016 28TH INTERNATIONAL TELETRAFFIC CONGRESS (ITC 28)*.

[13] Li, J., Peng, M., Yu, Y., & Ding, Z. (2016). Energy-Efficient Joint Congestion Control and Resource Optimization in Heterogeneous Cloud Radio Access Networks. *ARXIV-CS.IT*.

[14] Yang, H., Zhang, J., Ji, Y., He, Y., & Lee, Y. (2016). Experimental Demonstration of Multi-dimensional Resources Integration for Service Provisioning in Cloud Radio Over Fiber Network. *SCIENTIFIC REPORTS*.

International Journal of
Electrical and Electronics Research (IJEER)
Research Article | Volume 12, Issue 1 | Pages 160-166 | e-ISSN: 2347-470X


[15] Zhang, Y., Wang, Y., & Fan, B. (2017). SDN Based Optimal User Cooperation and Energy Efficient Resource Allocation in Cloud Assisted Heterogeneous Networks. *IEEE ACCESS*.

[16] Kasi, S. K., Hashmi, U., Ekin, S., Abu-Dayya, A., & Imran, A. (2023). D-RAN: A DRL-Based Demand-Driven Elastic User-Centric RAN Optimization for 6G & beyond. *IEEE Transactions on Cognitive Communications and Networking*.

[17] Wang, Z., Wei, Y., Feng, Z., Yu, F., & Han, Z. (2023). Resource Management and Reflection Optimization for Intelligent Reflecting Surface Assisted Multi-Access Edge Computing Using Deep Reinforcement Learning. *IEEE Transactions on Wireless Communications*.

[18] G, M., Deshmukh, P. M., Kumar N. L., U., Macedo, V. D. J., B, V. K., N, A., & Tiwari, A. (2023). Resource Allocation Energy Efficient Algorithm for H-CRAN in 5G. *INTERNATIONAL JOURNAL ON RECENT AND INNOVATION TRENDS IN*

[19] Kuribayashi, H., De Souza, M. A., Gomes, D. A., Da Costa Silva, K., Silva da Silva, M., Costa, J. C. W. A., & Frances, C. R. L. (2020). Particle Swarm-Based Cell Range Expansion for Heterogeneous Mobile Networks. *IEEE Access*. https://doi.org/10.1109/ACCESS.2020.2975981

[20] Miki, N., & Kanehira, Y. (2019). Investigation on Distributed Optimization of User Association and Inter-Cell Interference Coordination Based on Proportional Fair Criteria. In *Proceedings of the Consumer Communications and Networking Conference*. https://doi.org/10.1109/CCNC.2019.8651878

[21] Jung, T., Song, I., Lee, S., Jung, S., Yoon, S., & Kang, J. (2018). Cell Range Expansion with Geometric Information of Pico-Cell in Heterogeneous Networks. In *Proceedings of the Vehicular Technology Conference*. https://doi.org/10.1109/VTCSPRING.2018.8417616

[22] Jaber, M., Onireti, O., & Imran, M. (2019). Backhaul-Aware and Context-Aware User-Cell Association Approach. In *Proceedings of the International Conference on Communications*. https://doi.org/10.1109/ICC.2019.8761585

[23] Yang, B., Mao, G., Ge, X., & Han, T. (2015). A New Cell Association Scheme in Heterogeneous Networks. In *Proceedings of the International Conference on Communications*. https://doi.org/10.1109/ICC.2015.7249219.