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A Joint Hybrid Resource Allocation Framework for Enhanced Performance in Cloud Radio Access Networks

Mr. Y. HARINATH[1], S.M. NIGAMA SREE SAI[2]
[1]Assistant Professor Dept. of C.S.E, Anantha Lakshmi Institute of Technology and sciences Anantapur-515721
[2]PG Scholar, Dept. of C.S.E, Anantha Lakshmi Institute of Technology and sciences Anantapur- 515721

Abstract: The fifth-generation (5G) mobile network aims to support high data rates and massive connectivity, driven in part by small cell technology. The Cloud Radio Access Network (C-RAN) has emerged as a promising architecture to address the increasing resource demands of a growing user base by separating base station functions into centralized baseband units (BBUs) and distributed remote radio heads (RRHs). Despite its advantages, C-RAN introduces challenges in efficiently allocating resources to dynamic and heterogeneous users. This paper proposes a hybrid resource allocation framework that enhances system efficiency while meeting varying user demands in C-RAN environments. The approach integrates centralized control with multi-agent-based decision-making, where a centralized controller within the BBU pool collaborates with virtual base stations (VBSs) acting as agents in a multi-agent system (MAS). Resource allocation decisions are made by jointly considering real-time resource requests from agents and historical demand predictions generated by the centralized controller. Simulation results demonstrate that the proposed method outperforms conventional random and fixed allocation schemes in terms of resource utilization, fairness, and reduction of unmet user demands. By effectively combining real-time and historical information, the proposed strategy ensures improved long-term resource planning and adaptability, making it a robust solution for dynamic C-RAN systems.

Key Words: Cloud Radio Access Networks, Resource Allocation, Multi-Agent Reinforcement Learning, Centralized Optimization, Radio Resource Management 5G and Beyond Networks.

1.Introduction

The rapid growth of mobile users and connected devices has significantly increased data traffic, making it difficult for conventional networks to meet dynamic resource demands. Cloud Radio Access Network (C-RAN) addresses this challenge by separating base station functions into centralized Baseband Units (BBUs) and distributed Remote Radio Heads (RRHs), enabling flexible and efficient resource management through virtualization. In this architecture, Virtual Base Stations (VBSs) are dynamically allocated resources from the BBU pool based on traffic conditions. However, maintaining an optimal balance is critical, as over-allocation leads to resource wastage, while under-allocation results in poor Quality of Service (QoS).

In this paper, present a combined centralized and multiagent-based resource allocation scheme for C-RAN. The main contributions of this paper are summarized in the following:

- We first design the C-RAN environment to formulate our resource allocation problem for both multi-agent and centralized systems.
- We propose a combined resource allocation scheme where the centralized controller and multiple VBS agents take part in allocating resources based on user demand. The main objective is to allocate computational resources to each VBS such that the allocation solution meets the user requirements for a longer duration.

The process system introduces a hybrid resource allocation approach that combines centralized control with a multi-agent system (MAS). In this framework, Virtual Base Stations (VBSs) act as agents that make real-time decisions based on current network conditions and user requirements, while the centralized controller in the BBU pool utilizes historical data and global network insights to guide long-term planning. The integration of these two mechanisms enables better coordination, improved resource utilization, reduced unmet demand, and enhanced fairness among users. The project also includes simulation-based evaluation, where the proposed method is compared with traditional random and fixed allocation techniques, demonstrating its effectiveness and suitability for next-generation C-RAN environments.

2.Litarature Survey

Y. Cui et al. (2024), Developed a multi-agent reinforcement learning-based resource slicing strategy for vehicular networks. The approach models each network entity as an agent and optimizes resource sharing among users. The results showed improved network throughput and better QoS in highly dynamic environments.

R. Firouzi et al. (2024) Introduced a delay-sensitive resource allocation mechanism for IoT systems in O-RAN architecture. The method uses a two-level slicing approach to allocate both communication and computation resources efficiently, ensuring low latency and reliable QoS for time-critical applications.

3.Proposed System

The proposed system introduces a hybrid resource allocation framework for Cloud Radio Access Networks (C-RAN) by combining centralized control with a Multi-Agent System (MAS) to efficiently manage dynamic resource demands. In this approach, the centralized controller maintains global network knowledge and historical data, while distributed agents (virtual base stations) collect real-time demand information from users. The Hybrid Multi-Objective Genetic Resource Allocation Algorithm is applied to optimize resource distribution based on multiple objectives such as minimizing unfulfilled demand, maximizing resource utilization, and ensuring fairness among

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users. The system dynamically prioritizes requests and allocates resources adaptively rather than following a rigid allocation strategy. Genetic optimization enhances decision-making by exploring optimal allocation patterns under varying conditions. The interaction between centralized intelligence and decentralized agents improves responsiveness and scalability. The proposed model supports real-time applications such as IoT, smart healthcare, and autonomous systems. It significantly reduces resource wastage and improves Quality of Service (QoS). Overall, the system provides a robust and efficient solution for next-generation 5G and beyond network environments.

4.System Architecture

System architecture defines the structure and interaction of components in a system. In a C-RAN resource allocation setup, it shows how user requests are processed, resources are managed, and allocation algorithms operate together.

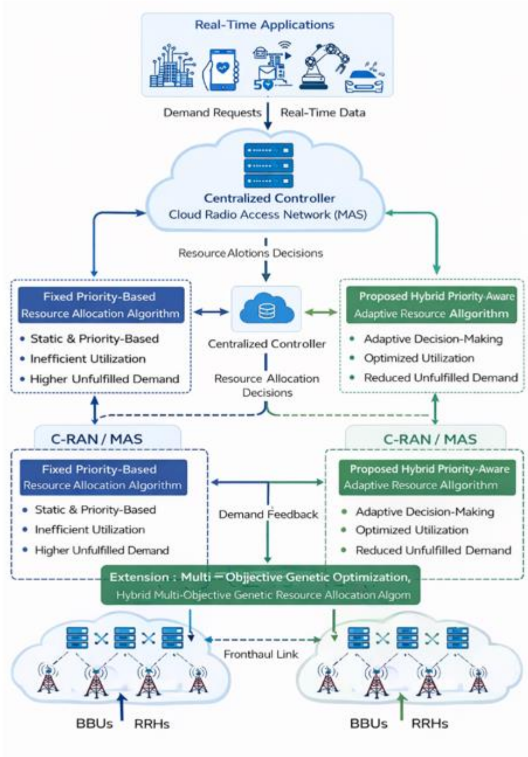

Fig 1: System Architecture

A well-designed architecture ensures efficient resource use, scalability, modularity, and real-time performance for applications like IoT and smart communication networks.

5.Methodology

The proposed methodology follows a hybrid centralized–multi-agent resource allocation framework designed for Cloud Radio Access Networks (C-RAN). Initially, the system collects real-time resource requests from multiple users along with available CPU, memory, and storage capacities. A centralized controller aggregates this information and forms the global system state.

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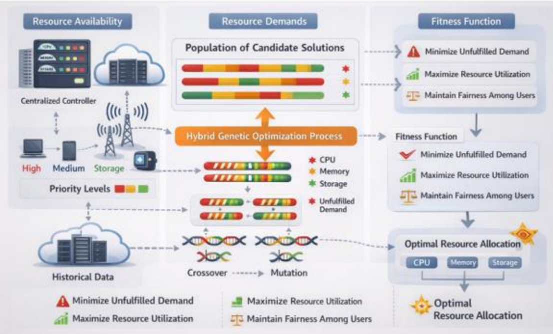

Fig 2: Hybrid Genetic Resource C-RAN Allocation

Multiple candidate allocation solutions are then generated to represent different possible resource distribution strategies. Each solution is evaluated using a multi-objective fitness function that considers resource utilization, fairness among users, priority levels, and unfulfilled demand. Genetic operators such as selection, crossover, and mutation are applied to evolve the population toward optimal solutions over successive iterations. In parallel, priority-based rules guide the allocation of critical requests to ensure service quality for high-priority users. Finally, the system selects the best-performing solution, achieving an efficient, balanced, and adaptive resource allocation strategy.

6.Design and Construction

The system is designed with a centralized controller and distributed agents to manage resource allocation in a C-RAN environment. It integrates modules for data collection pre-processing, and optimization. The core component is a hybrid multi-objective genetic algorithm that constructs candidate allocation solutions and refines them using selection, crossover, and mutation.

i)Uploading Dataset: This module generates or uploads synthetic demand data (CPU, Memory, Storage, priority) to simulate user requests in a C-RAN environment. It initializes system capacities and serves as the foundation for resource allocation experiments.

ii) Data Pre-processing: The data is cleaned, structured, and normalized into standard formats. Missing values and inconsistencies are handled to ensure compatibility with allocation algorithms.

iii) Model Development: Three approaches are implemented: Fixed Allocation, Hybrid Allocation and a Multi-Objective Genetic Algorithm. The hybrid model improves adaptability, while the genetic approach enhances optimization, fairness, and resource utilization.

iv) Prediction Module: This module processes test data through pre-processing and applies the hybrid model to allocate resources based on priority and availability, producing final allocation results.

v) Performance Evaluation: Algorithms are compared based on unfulfilled demand. The hybrid model outperforms the fixed method, and the genetic approach further optimizes resource usage and fairness.

Priority handling and real-time updates are incorporated to ensure adaptive decision-making. The architecture enables efficient interaction between modules, ensuring scalable, flexible, and optimized resource distribution.

7.Results and Discussion

The proposed Hybrid Multi-Objective Genetic Resource Allocation method outperforms the Fixed Priority-Based approach by dynamically adapting to changing workloads and optimizing resource distribution based on priority,

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fairness, and availability. As a result, it improves resource utilization, reduces unmet demand, and minimizes resource wastage, leading to more efficient and reliable allocation.

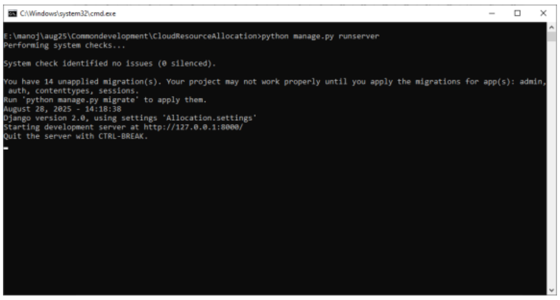

Fig 3: Project Deployment

Fig 3 is the python web server started and now open browser and enter URL as http://127.0.0.1:8000/index.html and then press enter key to get below page.

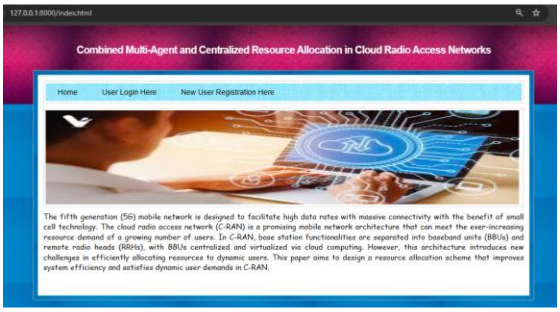

Fig 4: Home Page

Fig 4 illustrates the main interface of the C-RAN system, featuring Home, User Login, and New User Registration options. These functions provide simple navigation and secure access to the system's resource allocation services.

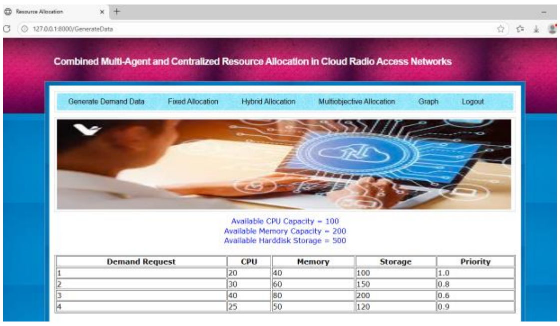

Fig 5: Resources Demand Priorities

Fig 5 shows the initial resource allocation setup with available resources and multiple demand requests. The Fixed Allocation method assigns resources using a predefined strategy and determines the resulting unfulfilled demand.

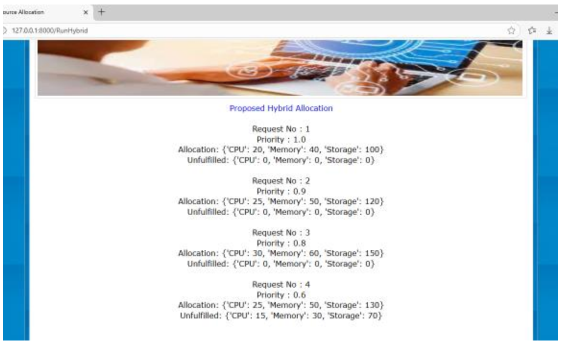

Fig 6: Proposed Model

Fig 6 illustrates the results of the proposed hybrid allocation algorithm, which efficiently distributes resources by fully satisfying high-priority requests while partially serving lower-priority demands

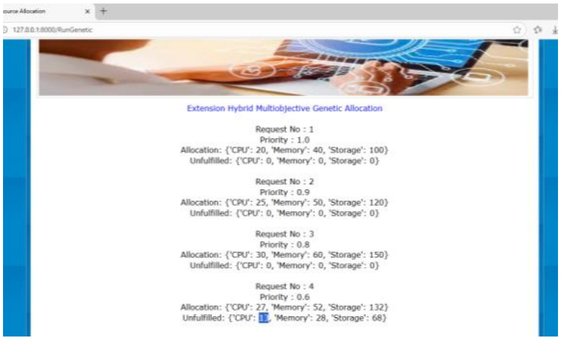

Fig 7: Extension model

Fig. 7 displays the results of the Hybrid Multi-Objective Genetic Allocation approach, which optimizes resource distribution to further reduce unfulfilled demand while fully satisfying high-priority requests.

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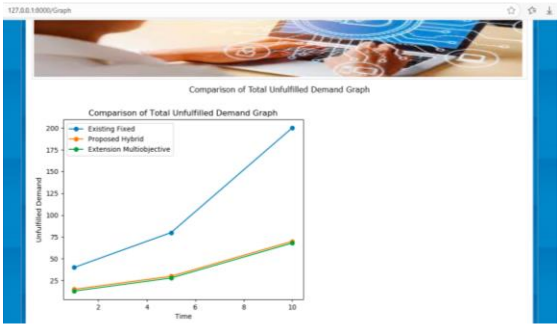

Fig 8: Comparison

Fig. 8 illustrates the comparison of unfilled demand over time for the Existing Fixed Allocation, Proposed Hybrid Allocation, and Extension Multi-Objective Allocation algorithms. The graph shows that the Extension Multi-Objective Allocation consistently achieves the lowest unfilled demand, demonstrating superior resource allocation performance.

8.Conclusion and future scope

This study proposed a Hybrid Multi-Objective Genetic Resource Allocation framework for Cloud Radio Access Networks (C-RAN) to improve resource management efficiency. The proposed approach dynamically allocates CPU, memory, and storage resources based on demand, priority, and fairness considerations. Experimental results show that it significantly reduces unfulfilled demand compared to the traditional Fixed Priority-Based method. The model achieves better resource utilization while ensuring fair distribution among users. The integration of genetic optimization further minimizes resource wastage and improves allocation performance. Overall, the proposed framework provides a flexible, efficient, and scalable solution for modern cloud-based network environments.

Future Scope: Future work can incorporate real-time C-RAN datasets and advanced machine learning techniques for predictive resource allocation. The framework may also be enhanced using other optimization algorithms and evaluated in large-scale distributed environments.

References

1.A. Checko, H. L. Christiansen, Y. Yan, L. Scolari, G. Kardaras, M. S. Berger, and L. Dittmann, "Cloud RAN for mobile networks—A technology overview," *IEEE Commun. Surveys Tuts.*, vol. 17, no. 1, pp. 405–426, 1st Quart., 2015.

2.K. Chen and R. Duan, "C-ran the road towards green ran," China Mobile Res. Inst., Beijing, China, Tech. Rep., 2011, vol. 2.

3.R. T. Rodoshi, T. Kim, and W. Choi, "Resource management in cloud radio access network: Conventional and new approaches," *Sensors*, vol. 20, no. 9, p. 2708, May 2020.

4.D. Pompili, A. Hajisami, and H. Viswanathan, "Dynamic provisioning and allocation in cloud radio access networks (C-RANs)," *Ad Hoc Netw.*, vol. 30, pp. 128–143, Jul. 2015.

6.R. Tasnim Rodoshi, T. Kim, and W. Choi, "Deep reinforcement learning based dynamic resource allocation in cloud radio access networks," in *Proc. Int. Conf. Inf. Commun. Technol. Converg. (ICTC)*, Oct. 2020, pp. 618–623.

7.B. Niu, Y. Zhou, H. Shah-Mansouri, and V. W. S. Wong, "A dynamic resource sharing mechanism for cloud radio access networks," *IEEE Trans. Wireless Commun.*, vol. 15, no. 12, pp. 8325–8338, Dec. 2016.

8.J. Xu, Z. Dziong, Y. Luxin, Z. Huang, P. Xu, and A. Cabani, "Intelligent multi-agent based C-RAN architecture for 5G radio resource management," *Comput. Netw.*, vol. 180, Oct. 2020, Art. no. 107418.

9.M. Morcos, T. Chahed, L. Chen, J. Elias, and F. Martignon, "A two-level auction for resource allocation in multi-tenant C-RAN," *Comput. Netw.*, vol. 135, pp. 240–252, Apr. 2018.

10.L. Ferdouse, A. Anpalagan, and S. Erkucuk, "Joint communication and computing resource allocation in 5G cloud radio access networks," *IEEE Trans. Veh. Technol.*, vol. 68, no. 9, pp. 9122–9135, Sep. 2019.

11. X. Liu, Y. Chen, and L. Wu, "Deep reinforcement learning for resource management in C-RANs with dynamic user mobility," *IEEE Trans. Wireless Commun.*, vol. 21, no. 8, pp. 6425–6438, Aug. 2022.

12.J. Li, Z. Zhao, and H. Zhang, "Federated learning for intelligent resource allocation in 5G C-RAN," *IEEE Wireless Commun. Lett.*, vol. 11, no. 2, pp. 315–319, Mar. 2022.

13. M. Zhao, J. Zhou, and K. Yang, "Multi-agent reinforcement learning for resource allocation in C-RAN," *IEEE Access*, vol. 11, pp. 20345–20355, 2023.

14.F. Rezazadeh, L. Zanzi, F. Devoti, S. Barrachina-Munoz, E. Zeydan, X. Costa-Pérez, and J. Mangues-Bafalluy, "A multi-agent deep reinforcement learning approach for RAN resource allocation in O-RAN," 2023, *arXiv:2307.02414*.

15.R. J. Tallarida and R. B. Murray, "Area under a curve: Trapezoidal and simpson's rules," in *Manual of Pharmacologic Calculations*. Cham, Switzerland : Springer, 1987, pp. 77–81.