Dynamical Resource Allocation Using Modified Artificial Bee Colony Algorithm in 5G C-RAN

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Table of contents

List of Figures

List of Tables

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Abstract

Faced with increasing traffic demand brought by the fifth generation (5G) system, Cloud Radio Access Network (C-RAN) becomes one of the promising candidates of next generation Radio Access Network (RAN) architectures. Unlike the conventional RAN architectures, C-RAN divides the original Base Station (BS) into two parts: Baseband Units (BBU) and Remote Radio Head (RRH), in which centralized management of BBUs and scalable deployment of RRHs will be fulfilled.

Swarm intelligence (SI), which derives from the study of swarm behavior of social insects, is the collective behavior of decentralized, self-organized systems, natural or artificial. the artificial bee colony algorithm (ABC) algorithm is one of SI algorithms, which is an optimization algorithm based on the intelligent foraging behavior of honey bee swarm.

In this research, a dynamical resource allocation scheme in 5G C-RAN based on modified ABC algorithm was designed. The logical mappings of BBU-RRH and RRH- User Equipment (UE) change depending on traffic load and network conditions. The resource allocation problem of C-RAN was formulated as a mixed integer nonlinear problem with a number of constraints. Then, a modified ABC algorithm is developed as a SI-based approach to build the mappings of BBU-RRH and RRH-UE. The performance of the proposed scheme in comparison to two resource allocation schemes was evaluated and the results of simulation demonstrated that proposed scheme was capable to maintain a high level of QoS while maximizing the throughput and minimizing power consumption.

Keywords: C-RAN, Resource allocation, Swarm intelligence, BBU, RRH, 5G

Chapter 1
Background

1.1 C-RAN

Wireless communications are faced with a huge growth in traffic demand accompanying the explosion of the Internet and smart devices in recent years. This increasing demand faced by mobile operators in the explosive growth of data traffic, mainly due to the popularity of mobile devices, streaming audio and video services and other Internet-related services. To satisfy this more and more increasing demand of data transmission, the mobile network technologies must be able to increase their capacities.

At first glance, the new generation networks are proposed with a greater number of cells while reducing the size of cells, to increase the density of the network and take the interference account in at the same time. Time Division Duplex (TDD) systems introduce not negligible fluctuations of traffic in both Downlink (DL) and Uplink (UL). Capacities of network are increased by adding more cells into existing networks creating more complex Heterogeneous and Small cell Networks (HetSNets), and integrating techniques such as Multiple Input Multiple Output (MIMO), which allow a number of antennas to simultaneously serve clients using the same time-frequency resources [1][2][3].

Therefore, the future architectures of network should be designed in hierarchical structures with several sizes of cells. However, the hierarchy may increase the interference between cells at the same time. Moreover, the power consumption to deploy and organize the heterogeneous cells may increase Simultaneously.

Furthermore, huge amounts of data are becoming an overwhelming part of the traffic, while the associated income is shrinking [4][5]. Therefore, there is an increasing challenge in the operation of the upcoming 5G networks, especially for multimedia systems, services and applications [6][7].

At the same time, power consumption in RAN remains a challenging issue. In traditional RAN architectures only about 15–20% of BSs operating in the current RAN architecture are loaded more than 50% [9][10], which causes a huge energy wastage in current RAN. Moreover, when cell is shrinking, energy consumption of BBU becomes dominant. Hence, it is crucial to optimize energy efficiency (EE) in the BBU.

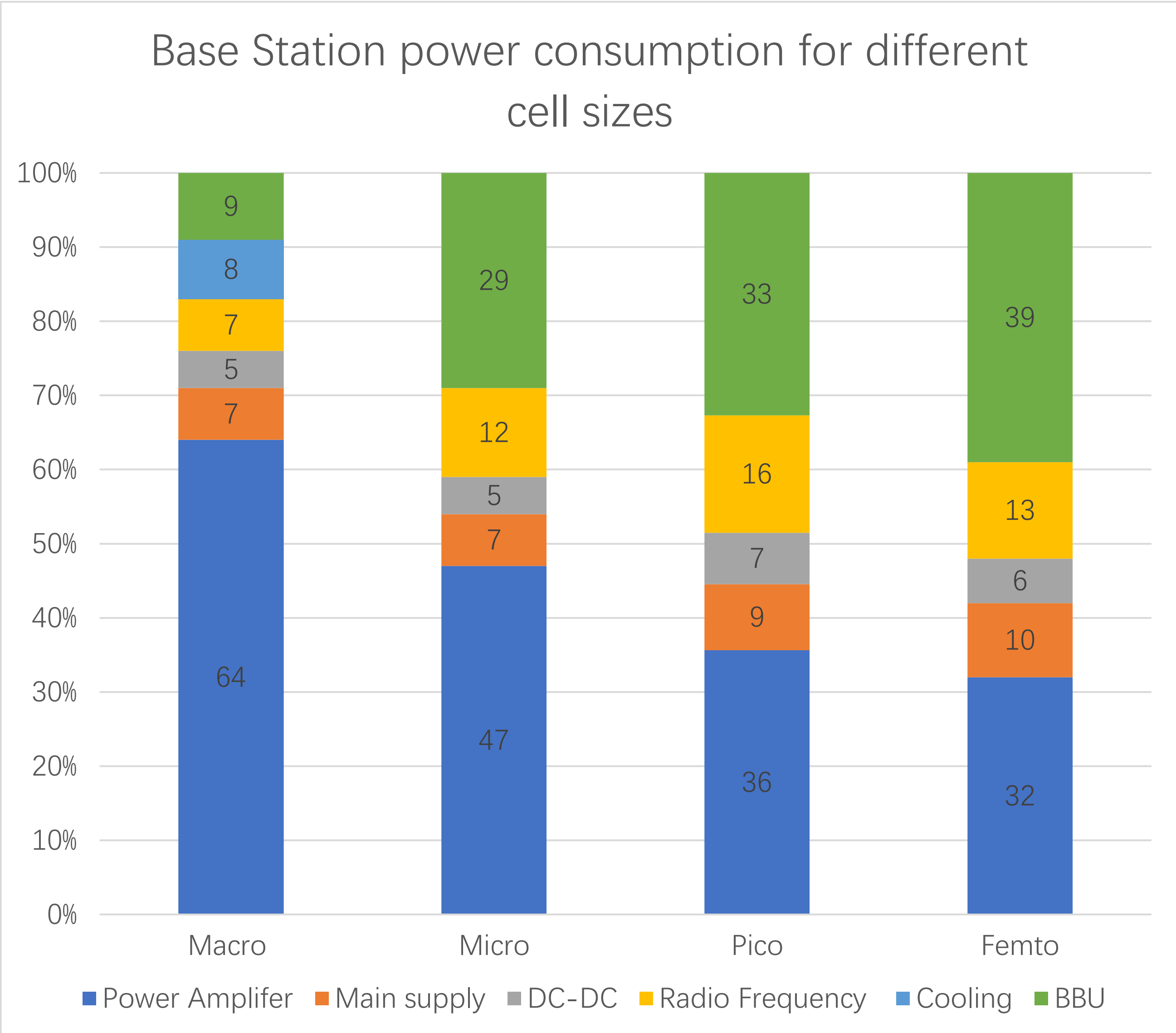

Figure 1 Power consumption of different sizes of cells

In order to meet challenges mentioned above, C-RAN becomes one of the promising candidates of next generation access network architectures. Unlike the traditional RAN, C-RAN consists of two parts: BBU and RRH. BBU is responsible for baseband processing, which implements the functionality of the MAC layer. And RRH, which only integrates the

Radio Frequency (RF) frontend functions, acquires, processes and transmits the signal. By combining all the BBUs on a remote cloud-based infrastructure called BBU Pool together and sharing radio resources, like illustrated in Figure 2, a number of RRHs managed by a single BBU can form a single cluster especially for reducing the cost of maintenance, the computational load and for energy saving purpose. Furthermore, besides being reliable and relatively inexpensive, solutions for the interconnection of BBUs must allow high bandwidth and flexible topology for the interconnection of RRHs.

Moreover, architecture of C-RAN allows centralized management of BBUs and scalable deployment of RRHs, a BBU can be assigned to one or more RRHs. Similarly, RRHs managed by the same BBU can form a single cluster by sharing their radio resources [10][11]. These features allow a flexibility in resources allocation and a smart centralized management on the C-RAN architecture.

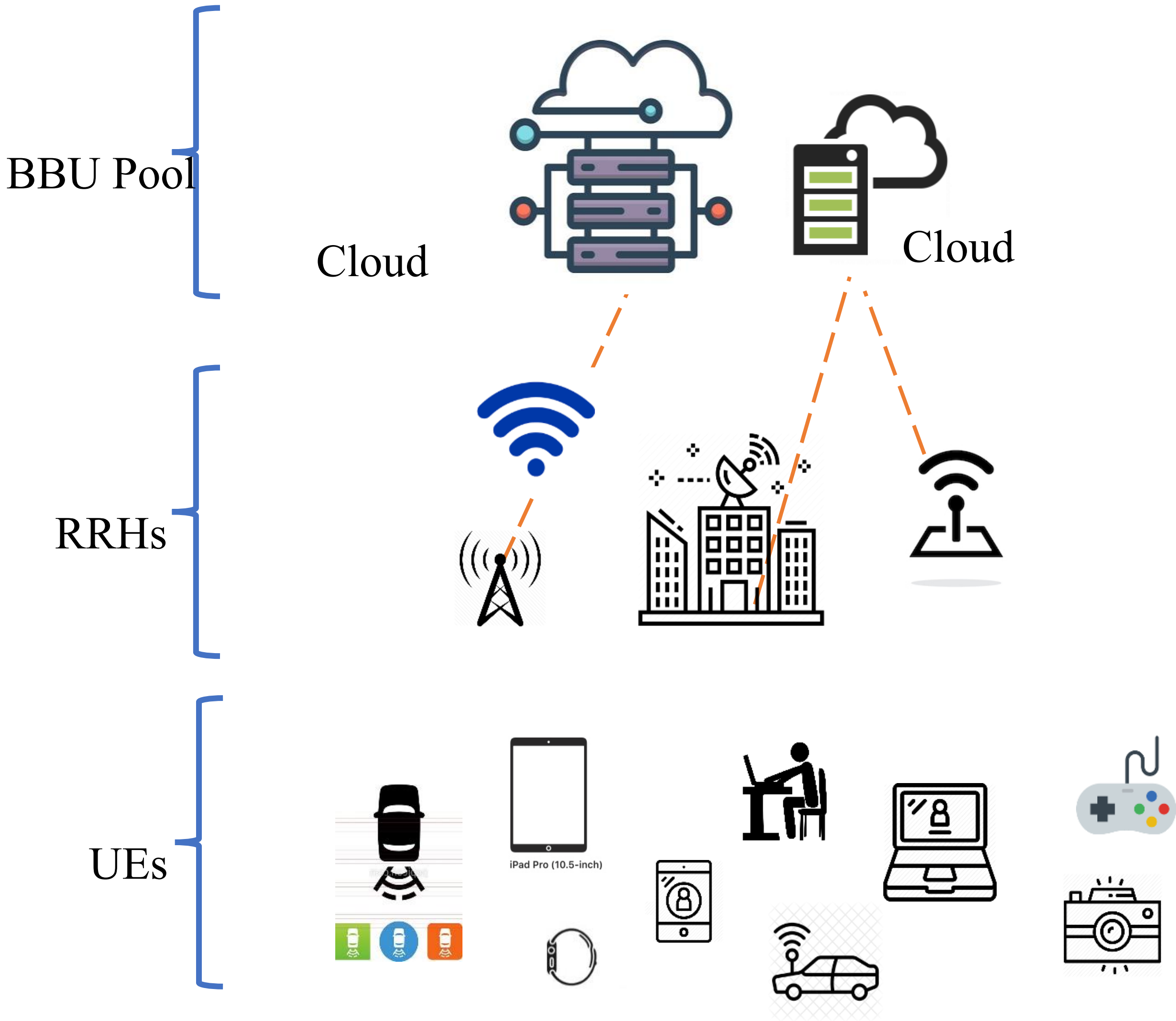

Figure 2 C-RAN architecture

1.2 SI

SI is the collective behavior of decentralized, self-organized systems, natural or artificial. SI systems are typically made up of a population of simple agents interacting locally with one another and with their environment. The inspiration often comes from nature, especially biological systems. The agents follow very simple rules, and although there is no centralized control structure dictating how individual agents should behave, local, and to a certain degree random, interactions between such agents lead to the emergence of “intelligent” global behavior, unknown to the individual agents. Natural examples of SI include ant colonies, bird flocking, animal herding, bacterial growth, and fish schooling [12].

Figure 3 SI of fish schooling. Retrieved from

http://www.iaacblog.com/programs/swarm-intelligence/

1.3 Author's contributions

In this research, a dynamical resource allocation scheme in 5G C-RAN based on modified ABC algorithm was designed. The logical mappings of BBU-RRH and RRH-UE change depending on traffic load and network conditions.

The joint BBU-RRH and RRH-UE mapping was formulated as a multi-objective optimization problem and ABC algorithm was modified to overcome this multi-objective optimization problem. According to simulation results, proposed scheme can maintain a high level of QoS while improving the throughput and reducing power consumption.

1.4 Organization of the thesis

The rest of the paper is organized as follows. In Section 2, a brief review of resource allocation scheme of C-RAN is introduced. Section 3 describes our considered C-RAN architecture and the system model. Section 4 demonstrates the formulation of BBU-RRH and RRH-UE mapping problems. In Section 5, modified ABC algorithm for resource allocation in C-RAN is introduced. In Section 6. The simulation results are presented, we conclude this work in Section 7.

Chapter 2
Related work

Researches regarding C-RAN have been performed globally by the scientific and industrial community over the past few years, such as s 5G PPP phase one, 5G-Crosshaul, 5G-Xhaul, i-CIRRUS and FP7 Mobile Cloud Networking projects.

Recently, SI plays an important role in solutions of network organization by modeling individuals process that locally interact among themselves, exchanging knowledge through the swarm which results in a high emergent system with a high degree of self-organization. Therefore, SI may be suitable for the efforts made toward the standardization of the next generation 5G RAN [13].

In order to improve the network performances while reducing the network power consumption, the mapping between UEs and RRHs as well as the RRHs and BBUs mapping should be logically designed. Unfortunately, existing work and studies only focus on one kind of mapping, some related works on these mapping schemes are briefly discussed hereinafter.

CDI C-RAN was proposed by [14], in which a semi static approach was proposed based on the concept of cell differentiation and integration. Furthermore, the load balancing problems of C-RAN system was modeled as an integer-based optimization problem, and a discrete Particle Swarm Optimization (PSO) approach was proposed to tackle the formulated load balancing optimization problem. Their simulation results proved that their proposed scheme can increase the throughput compared to a fixed C-RAM.

A dynamical clustering scheme was proposed by [15] to take the advantages of the borrow-and-lend approach. However, only BBU-RRH mapping issues have been considered.

[16] proposed an efficient joint BBU-RRH resource allocation in CRAN. The jointly RRH antenna resource management and the BBU computation capabilities were formulated as an optimization problem, a weighted minimum mean square error scheme was used to tackle the network wide beamforming vectors optimization.

In addition, the best fit decreasing scheme has been used in order to minimize the number of active BBU for energy saving purpose. The results of simulation showed that compared to existing classical schemes, their proposed scheme can have more energy efficiency.

In summary, most of resource allocation schemes in C-RAN was not able to take full advantages of C-RAN architecture. Therefore, how to maximize the advantage of C-RAN to increase the effectiveness of network still need to be considered.

Chapter 3
System model

In this paper, we consider an architecture of C-RAN with three parts: a centralized BBU pool with several BBUs on the cloud, a number of RRHs are set that allows two kinds of cells: Macro and Pico. RRHs are connected to BBU pool via a link called fronthaul, as shown in Figure 4.

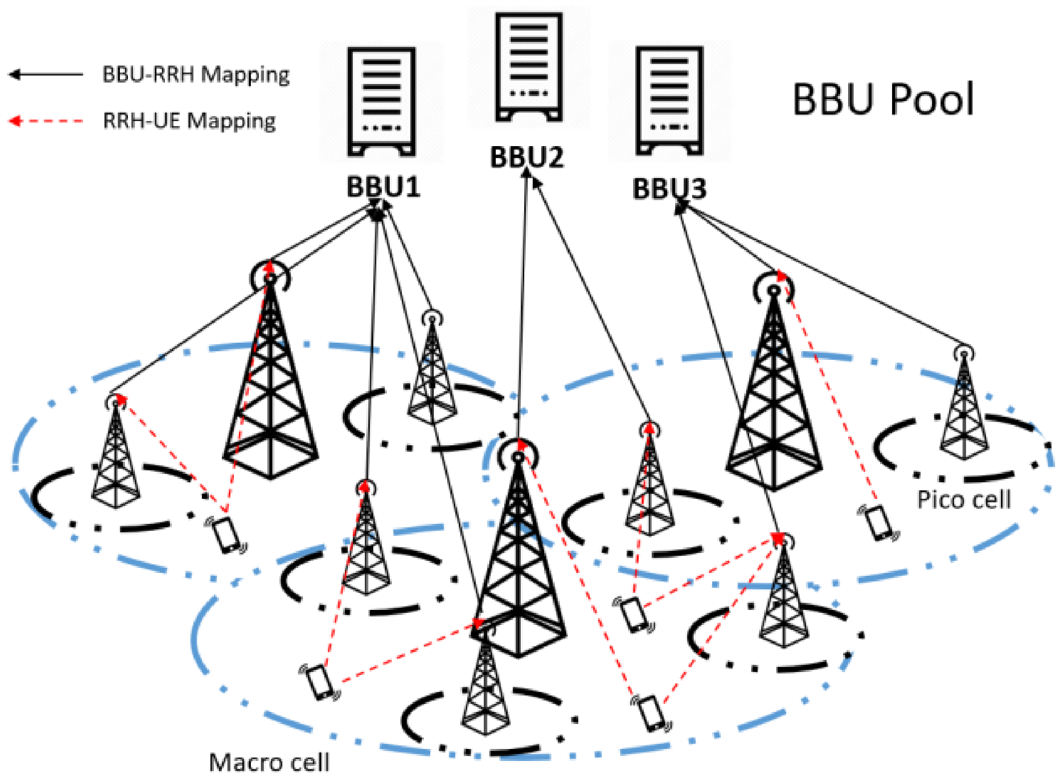

Figure 4 System model

The Macro cell allows a wide coverage while Pico cells are to increase edge speed, data capacity, network efficiency. Given to the adopted C-RAN architecture, each BBU on the BBU pool can handle one or more RRHs depending on the network load condition. Moreover, since all BBUs are migrated in the cloud in the C-RAN architecture, the deployed RRHs become less complex, more scalable and energy efficient. However, the logical mapping between centralized BBUs and distributed RRHs is not static but dynamic. It depends on the traffic load and some network conditions faced by operators.

3.1 Channel model

We define a set of Macro cells $\mathcal{M} = \{M_1, M_2 \cdots M_n\}$ and $\mathcal{P}(M_i) = \{P_1, P_2 \cdots P_m\}$ as the Pico cells belong to Macro cell M_i. Then, let us define the set $\mathcal{U}(P_j) = \{U_{j,1}, U_{j,1} \cdots U_{j,t}\}$ as the UE belonging to P_j. Assuming that the channel state information is perfect, the received signal $\mathcal{Y}_{j,k}$ of UE $\mathrm{U}_{j,k}$ can be given as:

$$\mathcal{Y}_{j,k} = h_j^k \times (d_j^k)^{-\frac{\beta}{2}} \times s_j^k + \sum_{P_o \in \mathcal{P}'(M_i)} h_o^k \times (d_o^k)^{-\frac{\beta}{2}} \times s_o^k + g_{o,k} \qquad (1)$$

Where $\mathrm{h_j^k}$, $\mathrm{d_j^k}$ and s_j^k denote the channel gain, distance and desired data from the Pico RRH P_j to the UE $\mathrm{U}_{j,k}$ respectively; $\mathrm{h_o^k}$, $\mathrm{d_o^k}$ and s_o^k are defined similarly for a given interfering Pico RRH $P_o, o \neq j$; β is the path loss exponent and $g_{o,k}$ represents the additive Gaussian noise.

Therefore, the SINR $\Upsilon_{j,k}$ perceived by the UE $\mathrm{U}_{j,k} \in \mathcal{U}(P_j)$ is given:

$$\Upsilon_{\mathrm{j,k}} = \frac{|\mathrm{h_j^k}|^2 \times (\mathrm{d_j^k})^{-\beta}}{\sigma_{\mathrm{j,k}}{}^2 + \sum_{\mathrm{P_o} \in \mathcal{P}'(\mathrm{M_i})} |\mathrm{h_o^k}|^2 \times (\mathrm{d_o^k})^{-\beta}} \qquad (2)$$

The achievable rate(bit/s/Hz) can be given as:

$$C_{j,k} = B \times log2(1 + \Upsilon_{j,k}) \quad (3)$$

$$B = W_j \times \omega_j \quad (4)$$

Where ω_j is spectral efficiency, W_j is the spectrum bandwidth in the RRH P_j.

3.2 Power consumption model

Unlike the conventional RAN power consumption model, power consumption model of C-RAN should take three parts into account: power consumption of BBU pool, power consumption of RRH and power consumption of fronthaul.

Power consumption of fronthaul is given as:

$$P^{FH} = \nu_j \times \sum C_{j,k} \tag{5}$$

where ν_j is the scaling factor of the fronthaul.

Like models proposed by [18], power consumption of RRH can be given as data dependent power P^{DD}, which is expended to transmit signals and data independent power P^{ID}, which is consumed by electronic components.

$$P^{DD} = \frac{1}{n_j} \times \sum (d_j^k)^2 \tag{6}$$

$$P^{ID} = P^{RRH}_{active} + P^{RRH}_{sleep} \quad (7)$$

$$P^{RRH} = P^{DD} + P^{ID} \quad (8)$$

Where $n_j \in (0,1)$ is efficiency of power amplifier.

Therefore, the power consumption model of our system is given in Eq. (9):

$$P = \sum P^{BBU} + \sum (P^{RRH} + P^{FH}) \quad (9)$$

Chapter 4
Problem formulation

4.1 Constraints derivation

According to prior assumptions the channel capacity $C_{j,k}$ is given in Eq. (3) and the per-fronthaul capacity constraint (C1) can be expressed as:

$$(C1)\sum C_{j,k} \leq C_j^{FH} \quad (10)$$

Where C_j^{FH} is the maximum capacity of the fronthaul link on RRH P_j.

$$(C2)\sum (d_j^k)^2 \leq \varepsilon \quad (11)$$

Where ε is the threshold value of the maximum available power in the fronthaul.

Let us consider packet processing task at each BBU can be described as a M/M/1queue and service time at each BBU follows the exponential distribution with the mean $\frac{1}{\mu_{j,k}}$ and the computing capability constraint (C3) is given as:

$$(C3)\sum \mu_{j,k} \leq C_{BBU} \tag{12}$$

Our goal is to maintain a high level of QoS while maximizing the throughput and minimizing power consumption. Therefore, our problem can be formulated as maximizing function below:

$$\mathcal{F}(C,P) = \alpha \times \sum C_{j,k} + (1-\alpha) \times P, \alpha \in [0,1] \tag{13}$$

Chapter 5
Modified ABC algorithm

5.1 ABC algorithm

The ABC algorithm was one of swarm intelligence approach introduced by Karaboga [17] to overcome numerical optimization problems. This algorithm is based on the intelligent foraging behavior of honeybee swarm that consists of three parts: Employed bees, Onlookers and Scouts. Employed bees go to their food source and share information with Onlookers, Onlooker choose the food source according to information from Employed bees, the employed bee whose food source has been abandoned becomes a scout and starts to search for finding a new food source. Finally, the best food source will be chosen.

Figure 5 Honeybee swarm. Retrieved from

https://www.honeyhut.co.za/honey-bees-bees-hive-bee-hive-53444low/

However, the convergence rate of original ABC algorithms is relatively slow under a large scale of C-RAN, therefore we introduce Global best solution (Gbest) to increase convergence rate of ABC algorithm.

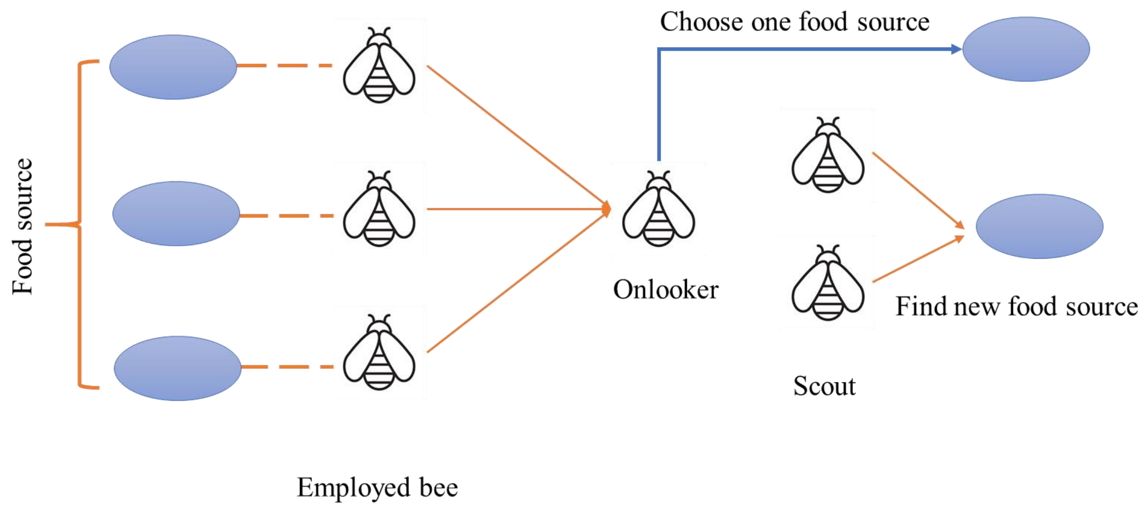

Figure 6 ABC algorithm

5.2 Multi-objective optimization

In our scheme, RRHs are set as Employed bees, which are associated with food source.

In Employed bee phase, Employed bee generates a new assignment $\mathcal{G}_{new}$ of RRH and UE, BBU and RRH in the neighborhood of its present position $\mathcal{X}_i$ by taking advantages of Gbest $\mathcal{G}_{best}$.

$$\mathcal{G}_{new} = \mathcal{X}_i + \Phi_i(\mathcal{X}_i - \mathcal{G}_{best}) \tag{14}$$

Where Φ_i is is a random number within $[-1,1]$.

Then, Employed bees share the value $\mathcal{F}_i$ of Eq. (13) to Onlooker.

In Onlooker phase, Onlooker select the best solution according to goodness probability given by Eq. (15).

$$\wp_i = \frac{\mathcal{F}_i}{\sum_{t=1}^{m} \mathcal{F}_t} \tag{15}$$

If the value $\mathcal{F}_i$ is not improved at the end of cycles, in Scouts phase, Scouts randomly generate an assignment of RRH and UE, BBU and

RRH.

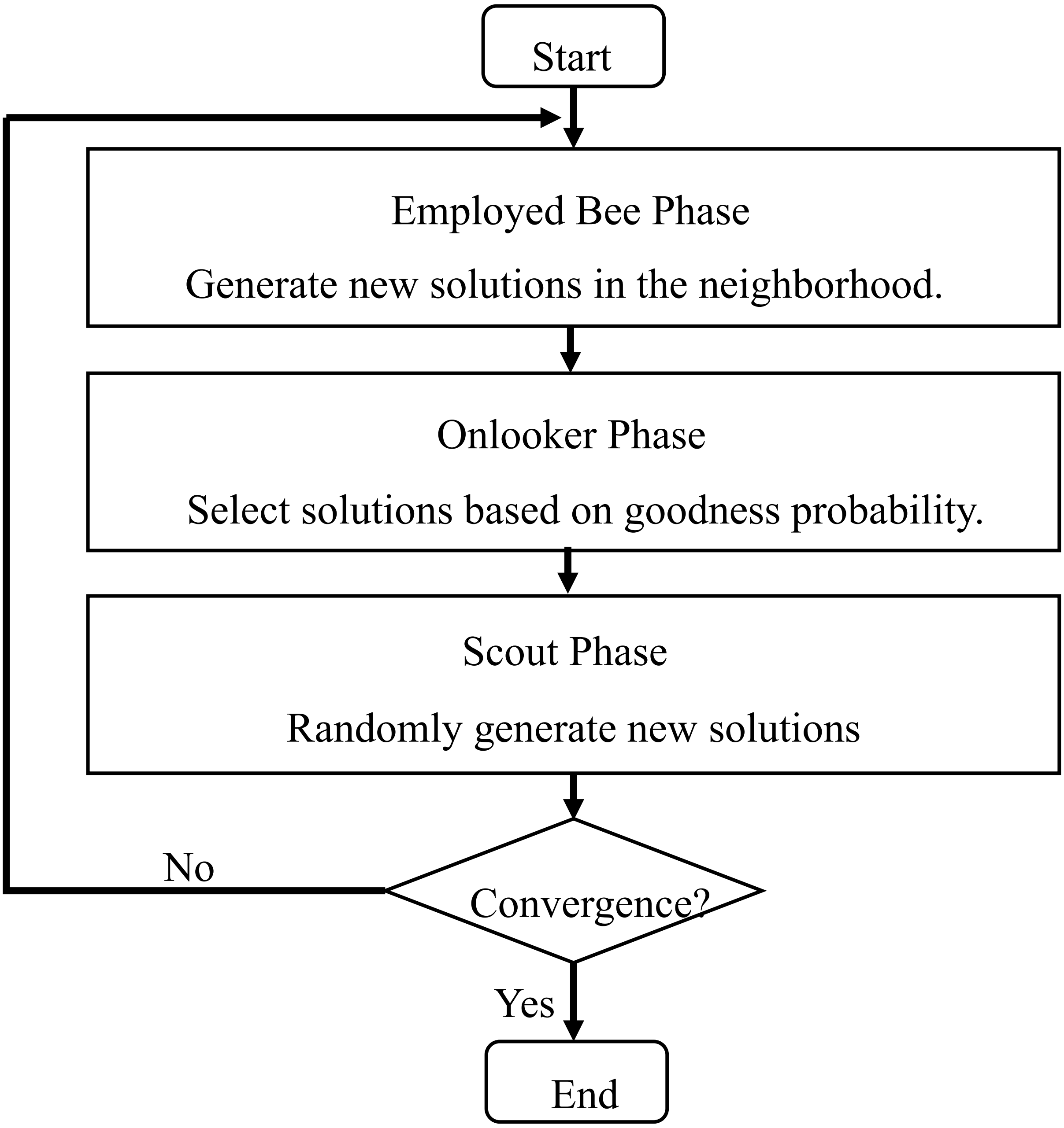

Figure 7 Chart of ABC algorithm

Table 1 Modified ABC algorithm

Algorithm Modified ABC algorithm

Begin

1. Initialization:

2. Generate the initial food source.

3. Repeat:

For each UE, do:

4. Launch the employee bee phase, generate an assignment of RRH and UE based on Gbest.

5. Launch the onlooker bee phase, evaluate the goodness probability Eq. (15).

6. **If** the fitness of Eq. (13) is not improved, **then** launch the scout bee phase.

7. **Until** convergence.

8. Set not assigned RRH to sleep.

9. Repeat:

For each active RRH, do:

10. The same as UE.

11. Until convergence.

12. Set not required BBU to sleep.

End

Chapter 6
Simulation

In this section, we present the simulation results to show the effectiveness of our BBU-RRH and RRH-UE mapping schemes.

Our results are compared with the scheme Borrow-and-Lend proposed by Chen [15] and CDI C-RAN [14]. We consider the same network load, the same amount of downlink packets arrival rate (packets/s) generated by all the UEs in each cell.

Table 2 Simulation parameters

Parameter	Value
Cell radius	500 m
System bandwidth	15 MHz
Carrier frequency	5 GHz
Log normal shadowing	−8 dB
Penetration loss	−20 dB
Noise power density	−174 dBm/Hz
Number of BBUs	5
Number of RRHs	49

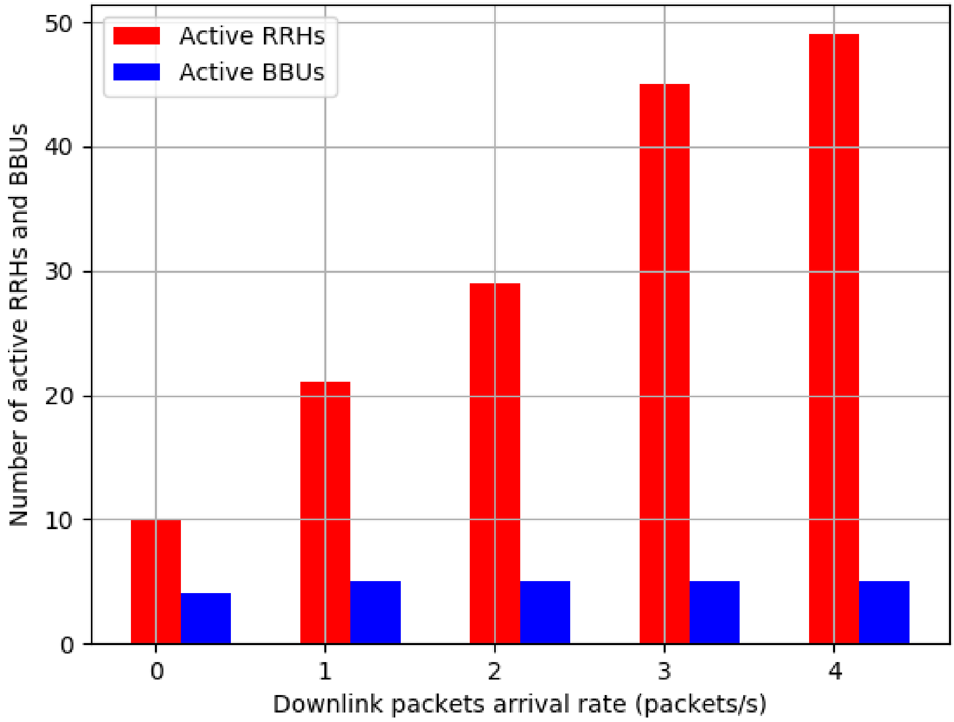

Figure 8 Number of active RRHs and BBUs (CDI C-RAN)

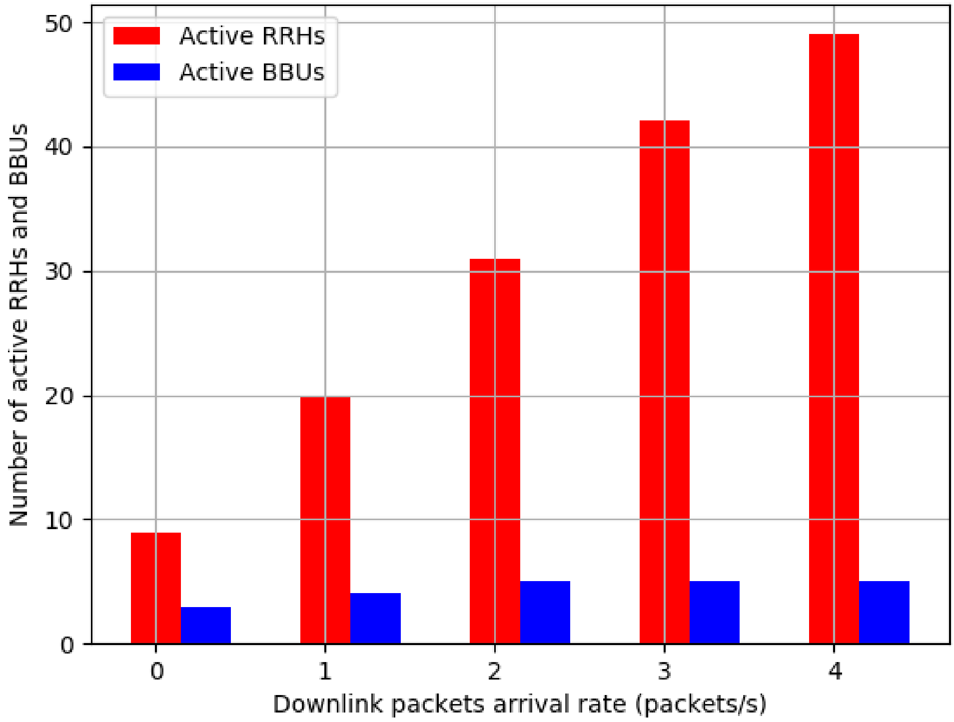

Figure 9 Number of active RRHs and BBUs (Borrow-lend)

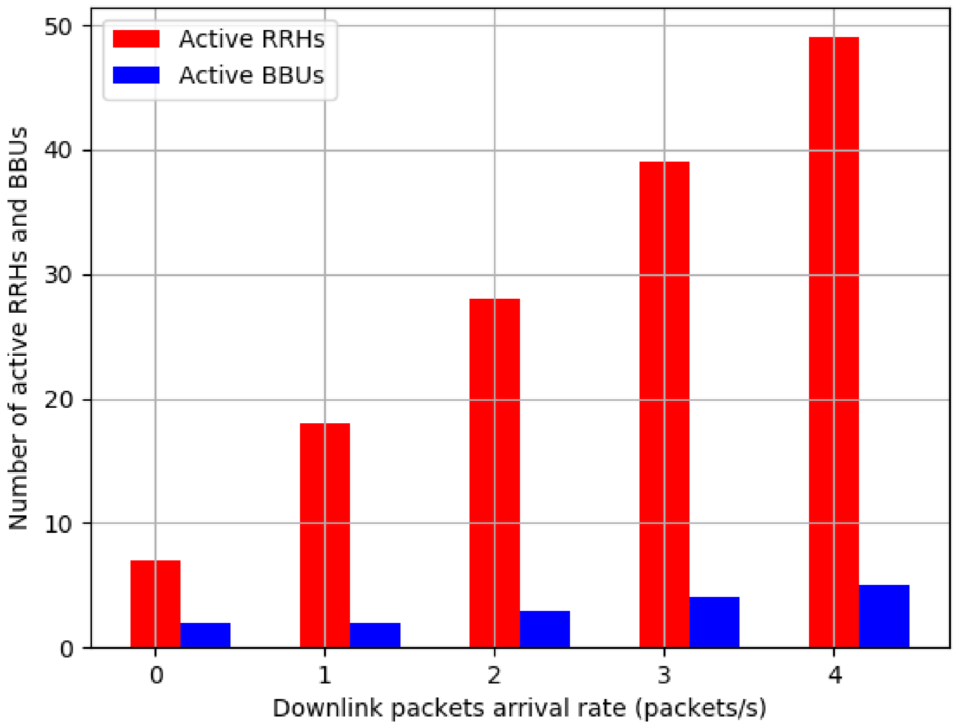

Figure 10 Number of active RRHs and BBUs (Modified ABC)

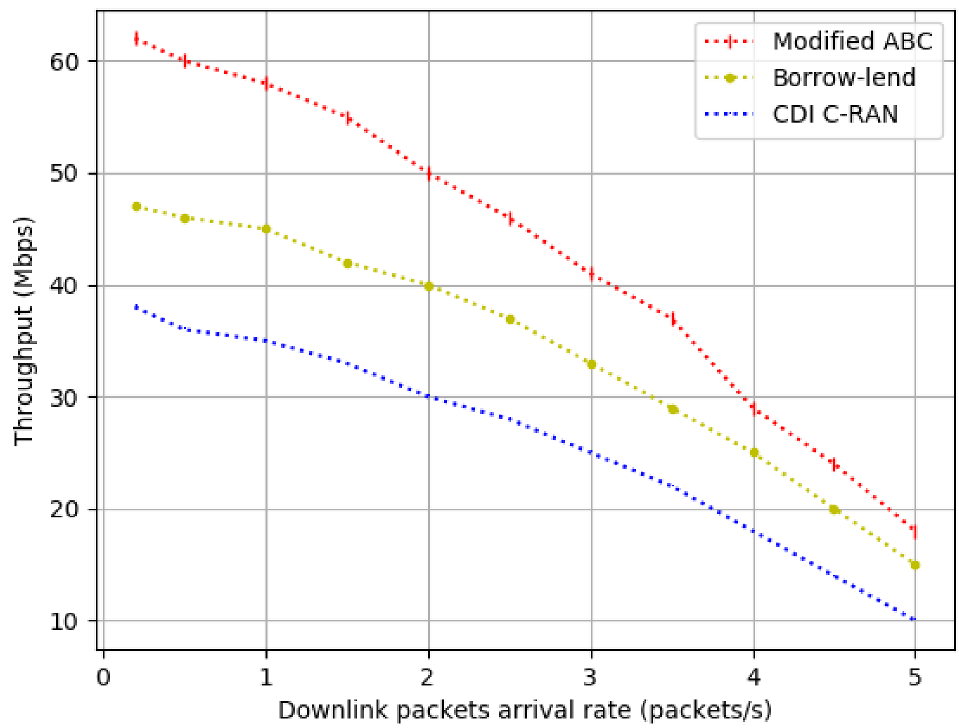

Figure 11 Network throughput

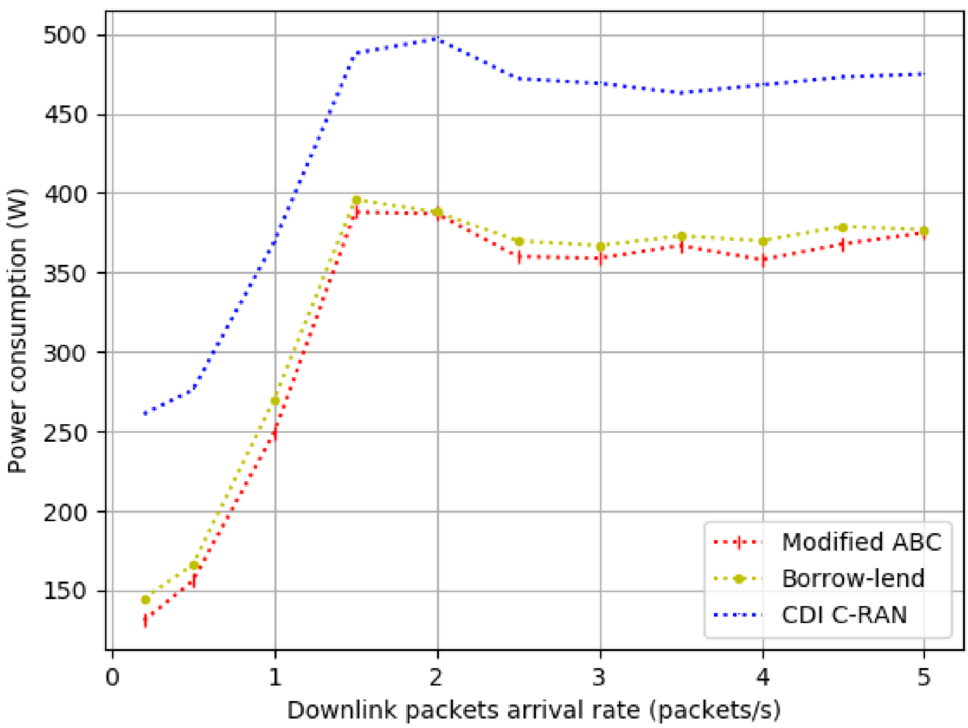

Figure 12 Power consumption

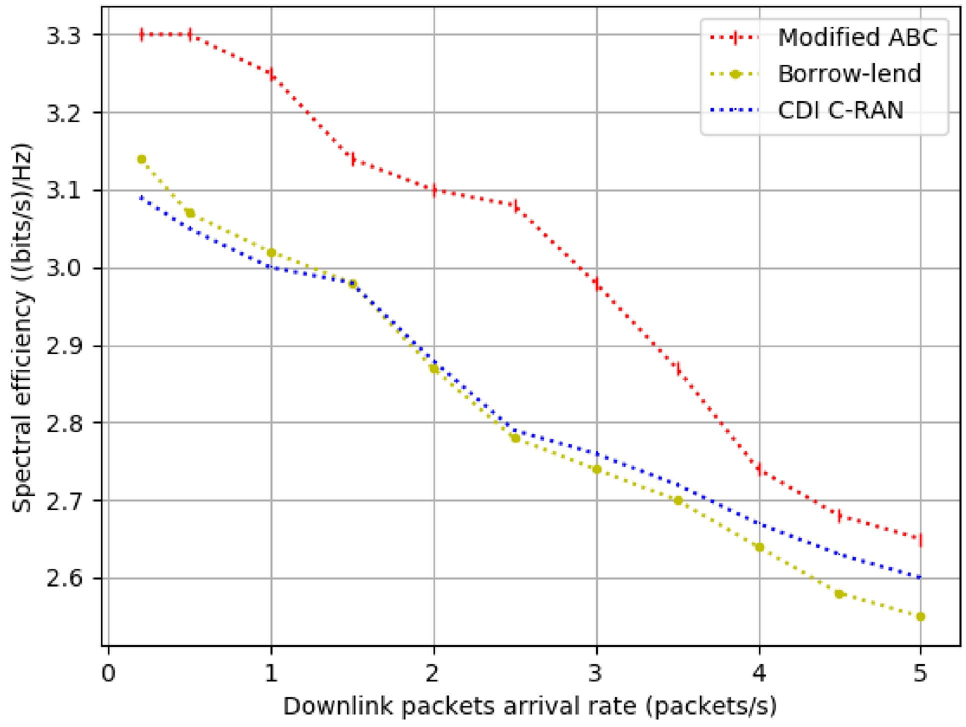

Figure 13 Spectral efficiency

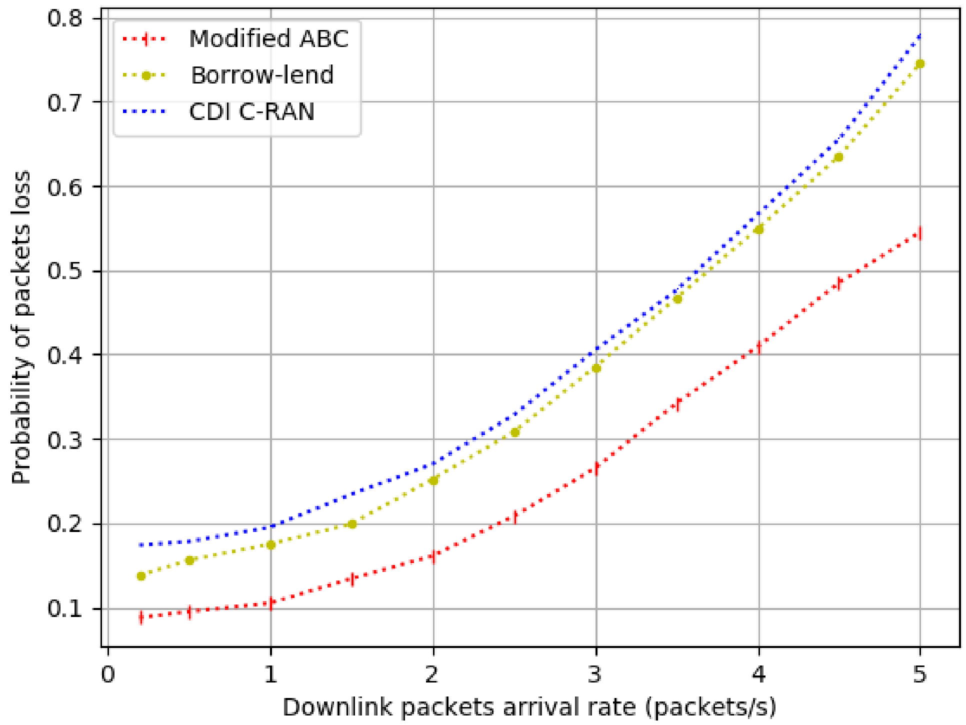

Figure 14 Packets loss

From the simulation results, it can be observed that our scheme can have more throughput and less power consumption than the compared schemes. Moreover, our propose scheme have well performance in spectral efficiency and probability of packets loss.

Chapter 7
Conclusion and Future work

In this research, we completed the formulation of BBU-RRH and RRH-UE mapping and evaluate the performance of the proposed scheme in comparison to two resource allocation schemes. The results of simulation demonstrated the effectiveness of our proposal.

As a future work, the effect of interference in heterogenous network should be considered for the overall performance of C-RAN.

Reference

[1] M. Morcos, J. Elias, F. Martignon, T. Chahed, L. Chen, On efficient radio resource calendaring in cloud radio access network, Comput. Networks (2019) 106862.

[2] H. Park, Y. Lim, Energy-Effective power control algorithm with mobility prediction for 5G heterogeneous cloud radio access network, Sensors 18 (9) (2018) 2904.

[3] H. Raza, A brief survey of radio access network backhaul evolution: part i, IEEE Commun. Mag. 49 (6) (2011).

[4] C.V.N. Index, Global mobile data traffic forecast update, 2015–2020 white paper, http://goo.gl/ylTuVx. (2016).

[5] A. Djedouboum, A.A.A. Ari, A. Gueroui, A. Mohamadou, Z. Aliouat, Big data collection in large-scale wireless sensor networks, Sensors 18 (12) (2018) 4474.

[6] A. Aissioui, A. Ksentini, A.M. Gueroui, T. Taleb, Toward elastic distributed SDN/NFV controller for 5G mobile cloud management systems, IEEE Access 3 (2015) 2055–2064.

[7] L. Zhou, J.J. Rodrigues, H. Wang, M. Martini, V.C.M. Leung, 5G Multimedia communications: theory, technology, and application, IEEE Multimedia 26 (1) (2019).

[8] M.L. Memon, M.K. Maheshwari, N. Saxena, A. Roy, D.R. Shin,

Artificial intelligence-based discontinuous reception for energy saving in 5G networks, Electronics (Basel) 8 (7) (2019) 778.

[9] N. Nikaein, E. Schiller, R. Favraud, R. Knopp, I. Alyafawi, T. Braun, Towards a Cloud-native Radio Access Network, in: Advances in Mobile Cloud Computing and Big Data in the 5G Era, Springer, 2017, pp. 171–202.

[10] K. Khawam, S. Lahoud, M. Ibrahim, M. Yassin, S. Martin, M. El Helou, F. Moety, Radio access technology selection in heterogeneous networks, Phys. Commun.18 (2016) 125–139.

[11] M. Yassin, S. Lahoud, K. Khawam, M. Ibrahim, D. Mezher, B. Cousin, Centralized versus decentralized multi-cell resource and power allocation for multiuser OFDMA networks, Comput. Commun. 107 (2017) 112–124.

[12] Jevtić, Aleksandar and Andina de la Fuente, Diego (2007). Swarm intelligence and its applications in swarm robotics. In: "WSEAS International Conference on Computational Intelligence, Man-Machine Systems and Cybernetics ; 6 CIMMACS ; 6", December 14-16, 2007, Tenerife, España. ISBN 978-960-6766-21-3.

[13] Z.H. Fakhri, M. Khan, F. Sabir, H.S. Al-Raweshidy, A resource allocation mechanism for cloud radio access network based on cell differentiation and integration concept, IEEE Trans. Network Sci. Eng. 5 (4) (2018) 261–275.

[14] Z. H. Fakhri, M. Khan, F. Sabir, H. S. AlRaweshidy, A resource allocation mechanism for cloud radio access network based on cell differentiation and integration concept, IEEETrans. NetworkSci. Eng.5(4)(2018)261–275.

[15] Chen, Y., Chiang, W. and Shih, M., 2018. A Dynamic BBU–RRH Mapping Scheme Using Borrow-and-Lend Approach in Cloud Radio Access Networks. IEEE Systems Journal, 12(2), pp.1632-1643.

[16] K. Wang, W. Zhou, S. Mao, On joint BBU/RRH resource allocation in heterogeneous cloud-RANs, IEEE IoT J. vol. PP (99) (2017). 1.

[17] D. Karaboga, An idea based on honeybee swarm for numerical optimization, Technical Report, Technicalreport-tr06, Erinyes university, engineering faculty, computer, 2005

[18] Luong, P., Gagnon, F., Despins, C. and Tran, L., 2017. Optimal Joint Remote Radio Head Selection and Beamforming Design for Limited Fronthaul C-RAN. IEEE Transactions on Signal Processing, 65(21), pp.5605-5620.

[19] Y. Shi, J. Zhang, K.B. Letaief, Group sparse beamforming for green cloud-RAN, IEEE Trans. Wireless Commun. 13 (5) (2014) 2809–2823.

[20] H. Park, Y. Lim, Energy-Effective power control algorithm with mobility prediction for 5G heterogeneous cloud radio access network,

Sensors 18 (9) (2018) 2904

[21] M. Morcos, J. Elias, F. Martignon, T. Chahed, L. Chen, On efficient radio resource calendaring in cloud radio access network, Comput. Networks (2019) 106862.

Achievements

Yuemeng Tang, Zhenni Pan and Shigeru Shimamoto, “Dynamical Resource Allocation Using Modified Artificial Bee Colony Algorithm in 5G C-RAN” in IEICE Society Conference 2020.