Efficient Radio Resource Management in Cell-less Wireless Communication Systems

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Abstract — In this paper, the particle swarm optimization (PSO) method with dynamic generation of biasing factors is used to determine the optimal particle size, maximize cell spectral efficiency (CSE) and balance the load in 5G networks. This work studies two distinct interference scenarios: in the first approach, CSE is calculated with varying numbers of users, when different radio services are used by each tier (when several radio access technologies are used), and when interference is received by the consumer only from the same tier base stations (BSs). In the second approach, interference is created when all levels use the same radio services and interference from BSs belonging to the same tier and other tiers is received by the consumer. Simulation results show that the cell-less network performs better than the cellular network in terms of maximizing CSE and balancing the load.

Keywords — 5G, cell-less network, particle swarm optimization, radio resource management

1. Introduction

Several technologies have been employed to control interference in mobile communications [1]. Coordinated multi-point (CoMP) transmission and other techniques have been proposed to cope with ultra-dense network (UDN) constraints, such as ping-pong handover, inter-cell interference, network congestion, and convergence issues. Unfortunately, they were unable to address issues like computing complexity, signal overhead, or practical advantages that fall short of theoretical gains [2].

In heterogeneous networks (HetNet), interference is a challenging issue due to lower signal plus interference-to-noise ratio (SINR). In order for co-channel deployment in HetNet to be effective, extremely efficient interference management is necessary, since low SINR may lower the value of spectral efficiency (SE) [3]. Next generation HetNets must employ new interference management strategies due to the quick development of new technologies, including small cell deployment, enhanced radio access technology and new backbone communications [4].

Base stations (BSs) and radio units (RUs) allocate resources in a sub-optimum manner, due to internal competition for those resources. This competition stems from the design of cellular networks, which has to evolve towards the cell-less architecture in next generation radio access networks (NG-RAN) used in 6G applications [4]. Cell-less networks combine the idea of virtualization, centralization, multi-input multi-output (MIMO), softwarization, and cooperative radio resource management (RRM). A central controller is required to ensure network-wide cooperation. Some attempts have been made to utilize centralized processing for network collaboration purposes, relying on such techniques as cloud/centralized RAN (C-RAN) [2].

By relying on the cell-less concept, a network may meet numerous requirements of 6G use cases, as it will be offering an improved capacity, more effective resource allocation, and enhanced security [4]. Such networks are important for 6G applications in smart cities and industrial automation, as these need high data rates and a simultaneous connection of numerous devices. The networking system's capacity can be significantly increased by controlling interference [4].

Numerous studies have already demonstrated that the cell-less approach may increase the networks' system capacity by collaborating with nearby base stations [5]. Cell-less communication offers dynamic coverage of user equipment (UE) and UE does not have to connect to BS. Therefore, frequent handovers between cells are not required and traffic loads may be dispersed uniformly between several BSs. As UE connects with a group of BS, better energy efficiency and coverage parameters may also be attained [6].

A cell-less network follows the same design as cell-free massive MIMO architecture, with the exception that the user is only served by a subset of the network's BSs. The choice of BSs that serve a given user is based on a user-centric process, where each user has an individual set of cooperating BSs [7]. However, in cell-free massive MIMO, all access points (APs) in the network may be used to serve a given user simultaneously [8].

In wireless communication systems, RRM controls the radio resources, such as power, co-channel interference, time-frequency channels, and other radio transmission parameters [9]. RRM relies on a variety of methods to make the most efficient use of the limited number of radio units. These techniques allow the resources to dynamically modify user access in response to radio environment changes. Hence RRM has a big impact on network performance, densified networks require effective interference management, calling for careful allocation of resource blocks (RBs), APs, and power to ensure satisfactory system performance and user experience metrics [2].

Dynamic partitioning and allocation of radio resources (RR) in the frequency and time domains improves spectrum utilization. Therefore, the system's capacity is improved. Recent studies have shown growing interest in integrating backhaul considerations into resource allocation and interference management solutions for HetNets [10]. RRM is more challenging in hyper dense HetNets environments. Due to the sheer number of devices and the existence of different levels, this environment is impacted by both co-tier and cross-tier interference. Another crucial RRM challenge is to attain peak data rates with effective resource utilization, when spectrum availability is mostly limited. It is the goal of the RRM technique to optimize SE and simultaneously manage interference [11].

The RRM method uses a resource allocation technique consisting in distributing resources to users across various BSs. All available resources of nearby BSs are taken into account when allocating resources to UE. In the cell-less architecture, user association is based on the biasing idea, i.e. the user is not always associated with the closest BS with the highest SINR level. Biasing involves management and optimization techniques used to ensure seamless connectivity and efficient use of network resources in HetNets. Biasing-based user association is essential for balancing the load in cell-less networks.

The aim of this paper is to use a RRM algorithm combined with the cell-less networking technique and the particle swarm optimization (PSO) algorithm in order to greatly enhance system capacity, improve cell spectral efficiency (CSE), and improve load balancing in the network.

The main contributions of this paper are summarized below:

- we propose a cell-less network with an effective RRM technique in order to enhance CSE, reduce interference, and balance the load evenly across all BSs,
- we use the PSO technique to generate the biasing factors in order to determine the optimal particles and calculate CSE for two interference cases in cell-less and cellular networks.

This paper is arranged as follows. Section 2 presents the related works on cell-less techniques. Section 3 explains the proposed cell-less system model and configuration. Section 4 describes the operation of the RRM technology in a cell-less network. In section 5, an explanation is given of the process for creating dynamic biasing factors using PSO. Section 6 presents a simulation of the cell-less model and, finally, Section 7 concludes the paper.

2. Related Works

In [12], the authors described a centralized radio access network (C-RAN) method against the background of time-division duplex (TDD) techniques, empowering a cell-less experience for UE located in the covered areas. UE utilized a certain number of sub-frames from different cells to form a customized cell-less frame, using a flexible method. New queuing models and mathematical analysis methods were identified to optimize low delay and power control targets.

In article [13], the authors developed a dynamic cell-free (or cell-less) network to simplify user signal processing in a network with multiple devices and access points (APs). The architecture divides APs into subgroups, each functioning as a virtual AP with a distributed antenna system (DAS). They introduced an inter-user-interference (IUI)-aware DAS's receive diversity combining strategy and a successive interference cancellation (SIC)-enabled signal to detection approach.

Paper [14] introduces a user-centric cooperation scheme known as Voronoi coordinated multi-point (CoMP), used in a cell-less architecture to mitigate interferences. Users are assigned to small base stations (SBS) clusters, ensuring they are served by the nearest SBS, which maximizes their power while minimizing interference. In [15], a solution to reduce interference in multi-cell domains and optimize inter-cell spectrum utilization using the cell-less technique is proposed. In C-RAN architectures, this approach enhances efficiency by handling data from multiple cells and dynamically manages radio resource allocation.

In [16], the authors introduced a new method of improving energy efficiency in cell-less radio access networks by temporarily switching APs to sleep mode during the interference management phase. this approach uses two-step sleep modes, focusing on load-based conditional criteria and intelligent control over underutilized APs. The system ensures a consistent performance enhancement and efficient power savings during peak traffic hours. Article [17] presents a framework for optimizing the overall throughput of next generation wireless networks (NGWN) that use the multi-carrier cell-less non-orthogonal multiple access (MC-CL-NOMA) architecture. The framework uses scenario data to feed an ensemble metaheuristic technique in order to carry out this task.

In paper [18], the authors presented a multi-architecture coexistence (MACO) network model enabling the deployment of a cell-less architecture with legacy networks to achieve better cost-efficiency, smooth compatibility alignment, and performance enhancement by using the existing architecture for partially deployed cell-less networks, and facilitating network migration towards the ideal entire cell-less RAN. In [19], a new RRM scheme is introduced that combines time and frequency domain schedulers for URLLC and eMBB UE. A UE ranking algorithm is developed to increase scheduling efficiency in large-scale networks with an optimized scheme to reduce delay for URLLC UEs and overcome challenges for eMBB users, ensuring efficient resource utilization in high-density scenarios.

Paper [20] proposes a dynamically changing cell-less wireless network architecture that deals with the high complexity of fully-centralized cell-less architecture in an ultra-dense network (UDN) deployment scenario. It also covers the use of non-orthogonal multiple access (NOMA) to meet the demand for huge wireless connection and applies artificial intelligence (AI)-based techniques to effectively create AP clusters.

Finally, in [21], the authors present the cluster-then-match (CtM) technique that jointly decides on user assignment and point-of-access (PoA) management. Following the human-centric networking paradigm, these determinations take into consideration not only the network's efficiency but also the level of electromagnetic field exposure that humans experience. Energy use is taken into account as well.

3. System Model and Configuration

PSO is utilized to generate dynamic bias values in HetNets. The proposed system consists of cellular and cell-less networks. We use a downlink 4-tier heterogeneous network with n BSs. Tier 1 stands for conventional macrocells, tier 2 stands for picocells, tier 3 stands for femtocells, and tier 4 stands for RU. Set $N = \{1, 2, 3, \ldots, n\}$ denotes the total number of BSs in this network, where the first element represents the macrocell and other cells (pico, femto, and RU) are represented by the remaining elements. CSE is calculated by using the PSO algorithm, where PSO is used to generate dynamic bias values in HetNets.

RRM application is managed and improved by the cell-less-enabled RAN controller. With system capacity optimization being the main objective, the proposed cell-less networking technique would dynamically adjust to the state of the network [4].

Two different interference cases for the proposed plane in two steps are considered:

1) The first scenario involves calculating CSE with a variable number of users in a situation in which each tier uses a different radio service (it usually occurs when several radio access technologies are used) and where the user receives only interference from BS in the same tier.
2) The second scenario involves calculating CSE with a variable number of users in a situation in which all tiers use the same radio resources and the user experiences interference from the same tier and other tier BSs. The PSO technique is utilized to calculate CSE in the two interference cases, both in cellular and cell-less networks.

A cell-less and a conventional cellular network are shown in Figs. 1–2. A mobile terminal in the cell-less network does not associate with any BSs, but a terminal in the conventional cellular network always associates with one and only one BS. The terminal in this scenario may communicate with one or more BSs in a flexible manner. The results show that the cell-less network outperformed the cellular network as the CSE value improved.

The definitions of the first and second interference cases are as follows:

$$\mathrm{SNIR}_{i,j} = \frac{p_i \, g_{ij}}{\sum l \in A, \;\; i \neq j \, p_l \, g_{il} + \sigma^2}\,, \tag{1}$$

$$\mathrm{SNIR}_{i,j} = \frac{p_i \, g_{ij}}{\sum l \in B, \;\; i \neq j \, p_l \, g_{il} + \sigma^2}\,, \tag{2}$$

where p_i is the transmitted power of BS j, g_{ij} is the channel gain incorporating path loss and shadowing between user i and BS j, A is the collection of all BSs in the same tier, B is the collection of all BSs in all tiers, σ^2 is the noise power.

The transmission rate is modeled using the truncated Shannon bound (TSB) model, in the following manner:

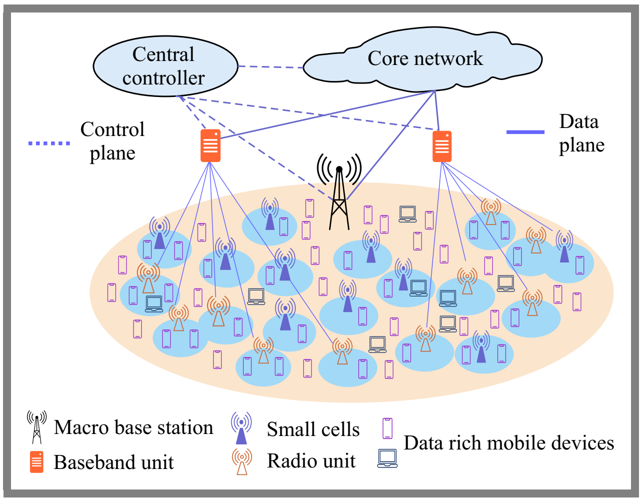

Fig. 1. Cellular network architecture.

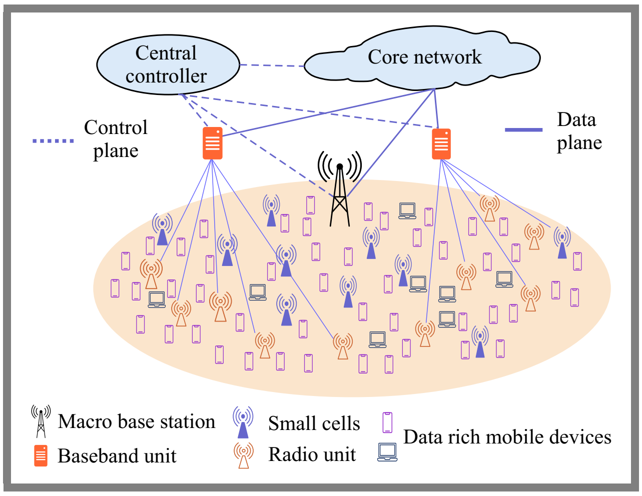

Fig. 2. Cell-less network scheme.

$$T_h = \begin{cases} 0, & \mathrm{SINR} < \mathrm{SINR_{min}} \\ \alpha \log_2(1 + \mathrm{SINR}), & \mathrm{SINR_{min}} < \mathrm{SINR} < \mathrm{SINR_{max}} \\ T_{h_{\max}}, & \mathrm{SINR} > \mathrm{SINR_{max}} \end{cases} \tag{3}$$

where α is the attenuation factor, $\mathrm{SINR_{max}}$ is the maximum value of SINR achieving the highest throughput, T_h is the achieved throughput in bps/Hz, $\mathrm{SINR_{min}}$ is the minimum SINR value that is necessary to guarantee the expected QoS and $T_{h_{\max}}$. As stated in [22], TSB parameters are $\alpha = 0.65$, $\mathrm{SINR_{min}} = 1.8$ dB, $\mathrm{SINR_{max}} = 21$ dB, and $T_{h_{\max}} = 4.5$ bps/Hz.

4. RRM Technique with Cell-less Network

Resource allocation is a process that allocates network resources for wireless communication. The distribution of resources across BSs is particularly important in HetNets, where relay nodes are also a component of the network. The distribution of resources is based on the operating band mode and includes access to, as well as direct links between UEs and BSs [11]. Several parameters, mostly controlled at the

BS level, are important for allocating resources. These include the number of users, quantity of available resources, buffer size, and interference. Multiple BSs/RUs are distributed across the network's coverage area. These BSs/RUS are connected via a high-speed backhaul network, allowing them to communicate and coordinate with each other.

A central control unit (CCU) manages the coordination of resources and their allocation to the BSs/RUs. The CCU has a global overview of the network, including its location, channel conditions, and resource requirements of all users. UEs are associated with one or more BSs based on such factors as signal strength, load balancing, and quality of service (QoS). UEs send their channel state information (CSI) and QoS requirements to the BSs/RUs. The CCU uses an advanced algorithm to process CSI and QoS data received from the UEs. These algorithms consider such factors as interference, user priority, channel conditions, and overall network load to optimize resource allocation.

Resources (e.g. time and frequency power) are dynamically allocated to UEs by assigning them to appropriate BSs/RUs. Time and frequency resources are assigned to users based on their demands and QoS requirements. BSs/RUs use such techniques as joint transmission to minimize interference and maximize the data rate. The transmit power of BSs and user devices is adjusted to optimize coverage and reduce interference. This helps maintain a balance between power consumption and signal quality. The network continuously monitors performance and adapts resource allocation as needed. Figure 3 shows a cell-less network with the RRM technique applied.

5. Using PSO for Dynamic Biasing

PSO is one of the sub-fields of artificial intelligence (AI) dedicated to solving optimization problems [23]. PSO algorithms are utilized for discovering the best solution after initializing a set of random particles, by monitoring two extreme values. The particles self-update, yielding the global best particle ($gbest$) and the personal best position ($pbest$).

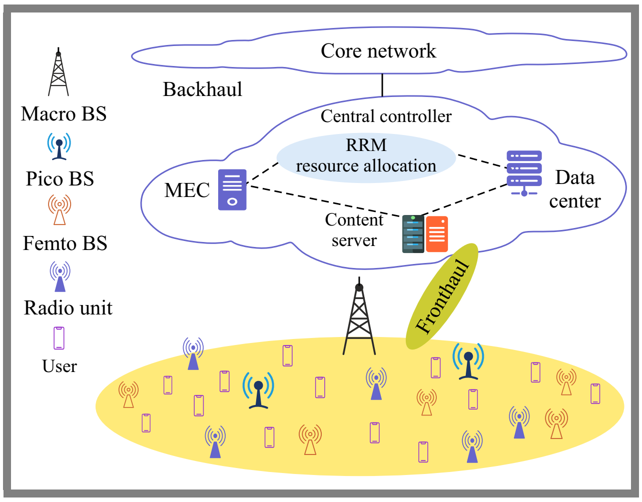

Fig. 3. RRM technique in a cell-less architecture.

All neighbors with extreme values are local extremums. The method employs the whole population but just a subset of them as neighbors [24], [25].

Dynamic biasing is a viable approach allowing to determine the ideal biasing values, as it relies on its strong resilience, quick convergence, and low complexity [26]. Fast convergence speed and a minimal number of controlling parameters are just some of the benefits of utilizing PSO. The main parameters required for PSO are as follows:

1) Swarm size N,
2) Initial position x and initial velocity v,
3) Inertia weight w,
4) The individual and social cognitive c_1 and c_2,
5) Uniformly distributed random numbers r_1 and r_2 in the range $[0, 1]$,
6) Number of iterations T.

In PSO, a swarm of particles randomly generates their initial positions and velocities within predefined bounds. Then, each particle's position and velocity are calculated in a D-dimensional space to find the optimal solution [27]. Each particle i of the swarm has a position and a velocity that can be expressed as follows:

$$V_i = [V_{i1}, V_{i2}, \ldots, V_{iD}]\,, \quad i = 1, 2, \ldots, N\,, \tag{4}$$

$$X_i = [X_{i1}, X_{i2}, \ldots, X_{iD}]\,, \quad i = 1, 2, \ldots, N\,. \tag{5}$$

Each particle updates its velocity and position based on the following equations:

$$\begin{aligned} V_{id}(t+1) = w\,V_{id}(t) + c_1\,r_1\big(pbest_{id}(t) \\ -X_{id}(t)\big) + c_2\,r_2\big(gbest_d(t) - X_{id}(t)\big)\,, \end{aligned} \tag{6}$$

$$X_{id}(t+1) = X_{id}(t) + V_{id}(t+1)\,. \tag{7}$$

The following is used to compute CSE:

$$\text{System throughput} = \sum_{k=1}^{N}\sum_{j=1}^{M} D_{ki}\,Th_{h_{ki}}\,, \tag{8}$$

$$\text{CSE} = \frac{\text{System throughput}}{N} \times \frac{1}{BW}\,, \tag{9}$$

$$D_{ki} = \begin{cases} 1, & \text{if a user } i \text{ is connected to } BS_k \\ 0, & \text{if a user } i \text{ is not connected to } BS_k\,, \end{cases}$$

where N is the number of total BSs, m is the number of users, BW is the bandwidth. PSO's task is to find the optimal particle to maximize CSE and to identify procedures for producing dynamic biasing values. A specific algorithm is shown in Fig. 4, illustrating how PSO is applied to find the biasing values to balance the load and maximize CSE.

6. Simulation Results

The results are obtained, in the course of this study, using a Matlab snapshot simulation. We consider a cellular network

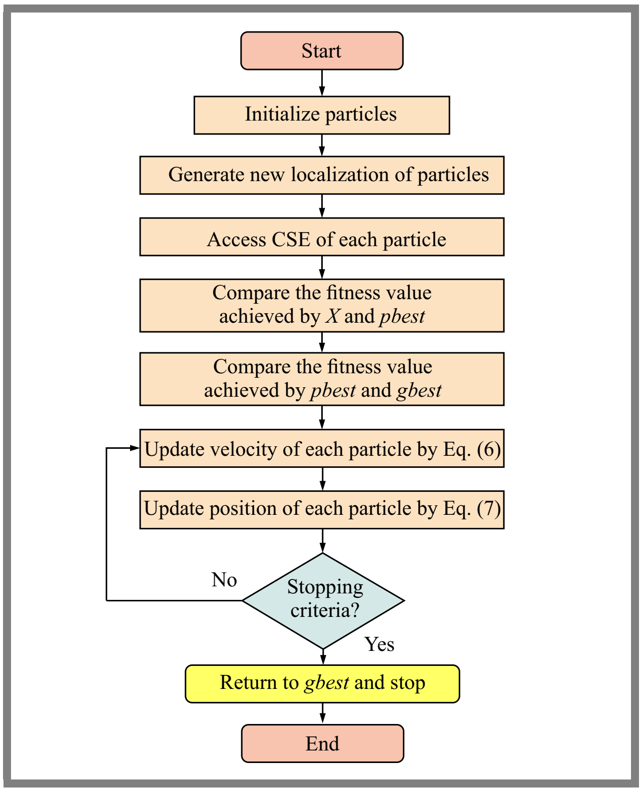

Fig. 4. PSO method used for generating dynamic biasing values.

and a cell-less network, each consisting of 30 BSs (one macro BS, two pico BSs, 17 femto BSs and 10 radio units). The best performance is obtained with a swarm size of 500 particles representing the number of users. The associated path loss model for radio units used in the simulations is retrieved from [28]. The simulation parameters are summarized in Tab. 1, while PSO-related parameters are displayed in Tab. 2.

The cellular and cell-less networks are compared using PSO. CSE is calculated for two interference cases with a bandwidth of 20 MHz and 100 RBs. Figure 5 shows CSE for the two networks with the number of users equaling 500, both in the first and second interference scenario.

Figure 6 explains the CSE value with the number of users equaling 300 for both cases. Figure 7 describes the CSE value in the first and second interference instance, where there are 100 users. In the next step, a comparison between cellular and cell-less networks with a specific number of users in macro, femto and pico BSs as well as in radio units, under two interference scenarios with a bandwidth of 20 MHz is provided. Figure 8 shows how the users are connected to the two networks, with 500 users in the first and second interference case.

Figure 9 shows the total number of users connected to the two networks for 300 UEs and both cases, while Fig. 10 illustrates what happens when the number of users drops to 100 in the initial instance of interference, for both networks and both cases.

Next, PSO is used to compute CSE for two interference scenarios with a bandwidth of 30 MHz and RB equaling 150, in order to compare cellular and cell-less networks.

Tab. 1. Simulation parameters.

Parameter	Value
Bandwidth	20 MHz, 30 MHz
Total number of RBs	100, 150
Tx power of macro BS	46 dBm
Tx power of pico BSs	30 dBm
Tx power of femto BSs	20 dBm
Tx power of RUs	33 dBm
Carrier frequency f_c	4 GHz
Radio unit height	15 m
UE height	1.5 m
Shadowing std. dev.	8 dB (macro), 10 dB (pico), 10 dB (femto)
Macro path loss [29]	$128.1 + 37.6\log(R)$, R in [km]
Pico path loss [29]	$140.7 + 36.7\log(R)$, R in [km]
Femto path loss [29]	$127 + 30\log(R)$, R in [km]
Noise power level	–174 dBm/Hz
Scheduler	Round robin
Traffic model	Full buffer

Tab. 2. PSO parameters.

Parameter	Setting
Swarm size	500, 300, 100
Number of iterations	80
c_1	2
c_2	2
w	0.9–0.4

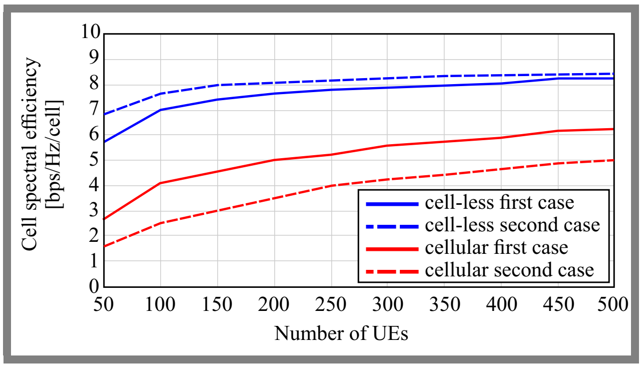

Fig. 5. CSE for different UEs in the first and second interference case.

Figure 11 shows the CSE value for the two networks in the first and second interference instance, when there are 500 users.

Based on all the evaluations conducted, one may conclude that the cell-less networking approach with the proposed

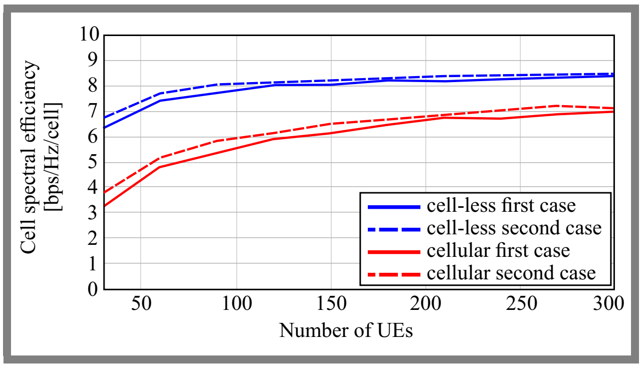

Fig. 6. CSE for different UEs in the first and second interference case.

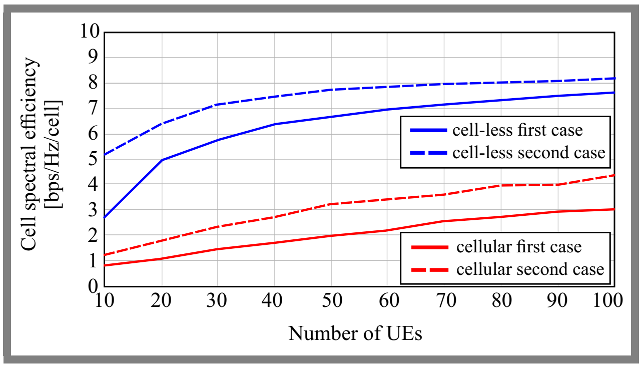

Fig. 7. CSE for different UEs for both interference cases.

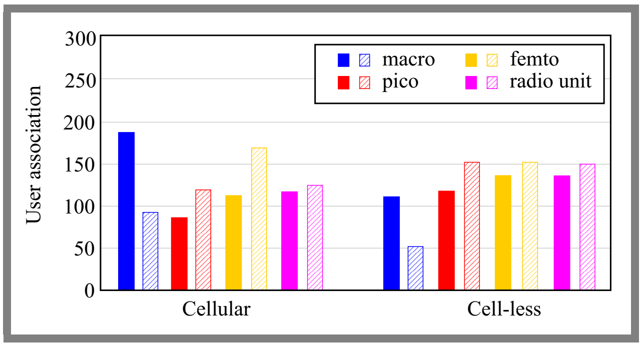

Fig. 8. Number of users linked to every tier in the first and second interference scenario.

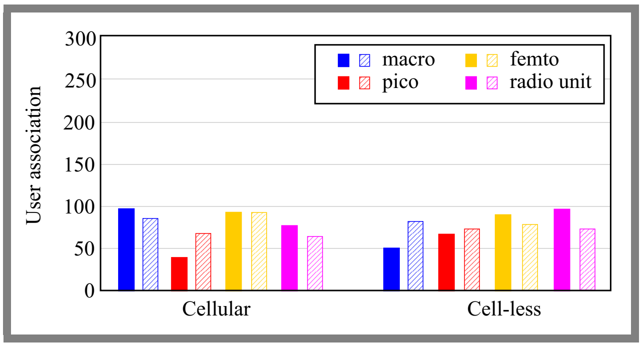

Fig. 9. Number of users linked to every tier in both scenarios.

RRM algorithm is characterized by better CSE performance when compared to cellular networks. This is the result of collaborative scheduling for resources with higher gain will create the more space to allocate resource efficiency in order to achieve higher CSE performance and interference control provided by RRM, the same time utilized to the dynamic bias generated by the PSO in both cellular and cell-less networks to maximizing the CSE. Compared to cellular networks, cell-less networks offer a higher CSE value.

In the second case, where the cellular network uses competitive scheduling to allocate resources to the user, interference is received from all tiers, resulting in severe cross-tier interference between cells that are part of various tiers. Users located at cell edges experience severe interference, which lowers CSE. The CSE value in cell-less networks is higher than in cellular networks.

Figure 6 illustrates that CSE of a cellular network will increase when the number of users drops. Reducing the number of users from 500 to 300 may help minimize network congestion and interference. Less competition for the same bandwidth across users may result in less interference for, thus enabling a more efficient use of the available resources.

In the case of radio resources, less competition results in greater CSE and higher per user data rate, when there are fewer users. The CSE value in cell-less networks remains greater than in cellular networks, even as the number of users decreases.

Figure 7 shows that when the number of users decreases, both cellular and cell-less networks experience a drop in CSE value due to under-utilization of resources. However, cell-less networks maintain higher CSE than cellular networks, because of their ability to dynamically allocate resources, better manage interference, and efficiently utilize the available spectrum, even with fewer users.

Figure 8 shows that users connect to the macro BS more frequently than to other BSs in a cellular network, as there is only one macro BS which transmits at a higher strength than pico BSs, femto BSs, and radio units. Furthermore, users connecting to the macro BS do not encounter interference from other tiers. Users in a cell-less network are dispersed equally throughout all BSs, and radio resource cooperative scheduling is used to share the load between them.

Figure 8 shows also that the number of users connected to the macro BS is lower than in the first interference scenario involving a cellular network, because the macrocell, picocells, femtocells, and RUs share the same frequency for transmission. That is caused by the reduced SINR that a user receives from the microcell, creating an imbalance in the load of the individual BSs. However, in the cell-less network, the load is distributed evenly among all BSs.

Figure 9 illustrates that a cell-less network may still balance the load across all BSs more effectively than a cellular network, even with a drop in number of users from 500 to 300, for two different types of interference, in both networks. High levels of interference from neighboring cells experienced in a cellular network may degrade performance, causing users to connect to more distant cells with lower interference but higher loads, which results in load imbalance.

Figure 10 shows that a cell-less network is still more effective at distributing the load across cells, even when the user count

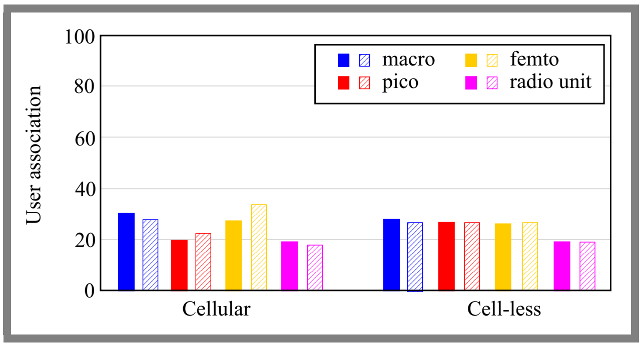

Fig. 10. Number of users linked to every tier in both scenarios.

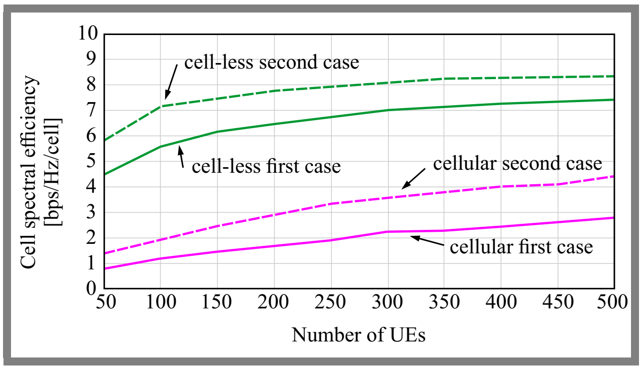

Fig. 11. CSE for different UEs in the first and second interference case

is lowered to 100, but a cellular network still suffers from load imbalance. Figure 11 illustrates a drop in the CSE value observed in the two networks, in line with Eq. (9), since the enormous bandwidth in the cell-less network may result in more significant channel state changes, thus inducing fluctuations which, in turn, cause a drop in CSE and lower signal quality.

The system shows better performance as the user count increases, making better use of the available bandwidth and resources, which may result in higher CSE through optimization. The drop in CSE observed as the bandwidth increases may be the result of a higher number of users in the cellular network competing for the limited capacity, which increases interference. In a cell-less network, the CSE value is larger than in a cellular network.

The results will be different if the PSO algorithm is not used. This is explained in paper [26], where the authors used static biasing and PSO. After comparing the results, it turned out compared that dynamic biasing relying on PSO outperformed static biasing in terms of maximizing CSE and load balancing. Finally, by converting cellular networks to cell-less networks, it will be possible to enhance CSE, decrease interference, reduce network congestion, balance the load across all BSs, and enhance the system's overall performance.

7. Conclusion

In this paper, two distinct interference scenarios were used to compare cell spectral efficiency, for different numbers of users, in cellular and cell-less networks. Particle swarm optimization was applied to determine the optimal particle allowing to maximize CSE and to dynamically generate biasing parameters. 20 MHz and 30 MHz bandwidths were used for CSE calculations in both networks. The benefit of such an approach is that when the bandwidth increases, the number of RBs increase as well, which facilitates CSE value calculations. The result is that when both bandwidths are used, the CSE value increases in the cell-less network.

Simulation-based findings demonstrate that interference management and cooperative RRM scheduling are capable of increasing CSE in cell-less networks, while dynamic biasing is capable of achieving the highest CSE possible and balancing the load between all BSs in cell-less networks.

References

[1] S.A. Ahmed, S.A. Ayoob, and A.O. Al Janaby, "On the Performance of Multi-user Massive MIMO over mm Wave Channels", *2021 7th International Conference on Contemporary Information Technology and Mathematics (ICCITM)*, Mosul, Iraq, 2021 (https://doi.org/10.1109/ICCITM53167.2021.9677730).

[2] S. Pietrzyk *et al.*, "Open Cell-less Network Architecture and Radio Resource Management for Future Wireless Communication Systems", (https://patents.google.com/patent/US20220210794A1), 2023.

[3] A.O. Al Janaby, A. Al-Omary, S.Y. Ameen, and H. Al-Rizzo, "Tracking and Controlling High-speed Vehicles via CQI in LTE-A Systems", *International Journal of Computing and Digital Systems*, vol. 9, no. 6, pp. 1109–1119, 2020 (https://doi.org/10.12785/ijcds/090609).

[4] F. Kooshki *et al.*, "Efficient Radio Resource Management for Future 6G Mobile Networks: A Cell-less Approach", *IEEE Networking Letters*, vol. 5, no. 2, pp. 95–99, 2023 (https://doi.org/10.1109/LNET.2023.3263926).

[5] H.A. Ammar *et al.*, "Downlink Resource Allocation in Multiuser Cell-free MIMO Networks with User-centric Clustering", *IEEE Transactions on Wireless Communications*, vol. 21, no. 3, pp. 1482–1497, 2021 (https://doi.org/10.1109/TWC.2021.3104456).

[6] S. Kim, S. Park, H. Ji, and B. Shim, "AOA-TOA Based Localization for 5G Cell-less Communications", *2017 23rd Asia-Pacific Conference on Communications (APCC)*, Perth, Australia, 2017 (https://doi.org/10.23919/APCC.2017.8304042).

[7] T. Al-shami, "Design of Innovative Access Protocols for Cell-less Architectures", Ph.D. Thesis, University of York, 2020 (https://etheses.whiterose.ac.uk/28469/).

[8] G. Interdonato *et al.*, "Ubiquitous Cell-free Massive MIMO Communications", *EURASIP Journal on Wireless Communications and Networking*, vol. 2019, art. no. 197, 2019 (https://doi.org/10.1186/s13638-019-1507-0).

[9] A.O. Al Janaby, "5G Downlink Throughput Enhancement by Beams Consolidating at Vacant Traffic", *Journal of Communications Software and Systems*, vol. 15, no. 4, pp. 311–316, 2019 (https://doi.org/10.24138/jcomss.v15i4.690).

[10] N. Wang, E. Hossain, and V.K. Bhargava, "Backhauling 5G Small Cells: A Radio Resource Management Perspective", *IEEE Wireless Communications*, vol. 22, no. 5, pp. 41–49, 2015 (https://doi.org/10.1109/MWC.2015.7306536).

[11] T. Akhtar, C. Tselios, and I. Politis, "Radio Resource Management: Approaches and Implementations from 4G to 5G and Beyond", *Wireless Networks*, vol. 27, pp. 693–734, 2021 (https://doi.org/10.1007/s11276-020-02479-w).

[12] V. Sciancalepore *et al.*, "A Service-tailored TDD Cell-less Architecture", *2016 IEEE 27th Annual International Symposium on Personal, Indoor, and Mobile Radio Communications (PIMRC)*, Valencia, Spain, 2020 (https://doi.org/10.1109/PIMRC.2016.7794957).

[13] Y. Al-Eryani, M. Akrout, and E. Hossain, "Multiple Access in Dynamic Cell-free Networks: Outage Performance and Deep Reinforcement Learning-based Design", *arXiv*, 2020 (https://doi.org/10.48550/arXiv.2002.02801).

[14] A. Shen *et al.*, "A Voronoi-based User-centric Cooperation Scheme in Cell-less Architecture", *2021 IEEE Wireless Communications and Networking Conference (WCNC)*, Nanjing, China, 2021 (https://doi.org/10.1109/WCNC49053.2021.9417317).

[15] C. Merlhe and C. Gueguen, "Dynamic Cell-less Radio Access Network Meta-scheduler for High System Capacity Increase", *2020 IEEE 21st International Symposium on "A World of Wireless, Mobile and Multimedia Networks" (WoWMoM)*, Cork, Ireland, 2020 (https://doi.org/10.1109/WoWMoM49955.2020.00031).

[16] F. Kooshki, A.G. Armada, M.M. Mowla, A. Flizikowski, and S. Pietrzyk, "Energy-efficient Sleep Mode Schemes for Cell-less Ran in 5G and Beyond 5G Networks", *IEEE Access*, vol. 11, pp. 1432–1444, 2022 (https://doi.org/10.1109/ACCESS.2022.3233430).

[17] F. de Oliveira Torres *et al.*, "Throughput Maximization for a Multicarrier Cell-less NOMA Network: A Framework Based on Ensemble Metaheuristics", *IEEE Transactions on Wireless Communications*, vol. 22, no. 1, pp. 348–361, 2022 (https://doi.org/10.1109/TWC.2022.3193328).

[18] F. Kooshki, M.M. Mowla, and A. Flizikowski, "Multi-architecture Coexistence Enabling Network Framework for 5G and Beyond Mobile Systems", *2022 IEEE Conference on Standards for Communications and Networking (CSCN)*, Thessaloniki, Greece, 2022 (https://doi.org/10.1109/CSCN57023.2022.10051097).

[19] F. Kooshki, A.G. Armada, M.M. Mowla, and A. Flizikowski, "Radio Resource Management Scheme for URLLC and eMBB Coexistence in a Cell-less Radio Access Network", *IEEE Access*, vol. 11, pp. 25090–25101, 2023 (https://doi.org/10.1109/ACCESS.2023.3256528).

[20] Y. Al-Eryani and E. Hossain, "A Dynamic Cell-less Architecture for Ultra-dense Wireless Networks", *IEEE ComSoc Technical Committees Newsletter*, 2019 (https://www.comsoc.org/publications/tcn/2019-nov/dynamic-cell-less-architecture-ultra-dense-wireless-networks).

[21] E. Chiaramello *et al.*, "Human-centric Decision-making in Cell-less 6G Networks", *arXiv*, 2024 (https://doi.org/10.48550/arXiv.2402.14344).

[22] T. Jiang, A. Papadogiannis, D. Grace, and A.G. Burr, "EU FP7 BuNGee Project Deliverable 4.1.1 Interim Simulation", European Commission FP7, 2011.

[23] L. Vanneschi and S. Silva, "Particle Swarm Optimization", *Lectures on Intelligent Systems*, pp. 105–111, 2023 (https://doi.org/10.1007/978-3-031-17922-8_4).

[24] T.M. Shami *et al.*, "Particle Swarm Optimization: A Comprehensive Survey", *IEEE Access*, vol. 10, pp. 10031–10061, 2022 (https://doi.org/10.1109/ACCESS.2022.3142859).

[25] S. Wang, F. Zhou, and F. Wang, "Effect of Inertia Weight ω on PSO-SA Algorithm", *International Journal of Online Engineering*, vol. 9, pp. 87–91, 2013 (https://doi.org/10.3991/ijoe.v9iS6.2923).

[26] T.M. Shami, D. Grace, and A. Burr, "User Association in Cell-less 5G Networks Exploiting Particle Swarm Optimization", *14th International Symposium on Wireless Communication Systems (ISWCS)*, 2017.

[27] T.M. Shami *et al.*, "Velocity Pausing Particle Swarm Optimization: A Novel Variant for Global Optimization", *Neural Computing and Applications*, vol. 35, no. 12, pp. 9193–9223, 2023 (https://doi.org/10.1007/s00521-022-08179-0).

[28] ITU, "Guidelines for Evaluation of Radio Interface Technologies for IMT-2020", Report ITU, vol. 2512, 2017 (https://www.itu.int/pub/R-REP-M.2412-2017).

[29] 3GPP, "Evolved Universal Terrestrial Radio Access (E-UTRA); Further Advancements for E-UTRA Physical Layer Aspects (release 9)", 3GPP TR 36.814 Release 9 V9.0.0, 2010 (https://portal.3gpp.org/desktopmodules/Specifications/SpecificationDetails.aspx?specificationId=2493).

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