


Network capacity improvement in 5G by using dynamic fractional frequency reuse (FFR)

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Received: 22 December 2022 / Accepted: 18 March 2023

Published online: 3 April 2023

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Abstract

The FFR approach reduces interference between macrocells and small cells/femtocells, which are installed within macrocell's range. Dense deployment and unplanned installation of small cells and femtocells has a detrimental impact on the performance of the system as a result of the interference. Thus, the FFR concept distributes resources to maintain interference. However, some small cells/femtocells may suffer from shortage resources. In this work, dynamic FFR mechanism has been proposed. The scheme maximizes small cell/femtocell network's capacity. The strategy aims to boost small cell/femtocell network's capacity and system throughput. The fundamental goal of this research is to maximize the dedicated radio resources, which are allocated to small cells/femtocells, based on a predetermined cost function. According to the cost function, which is computed for all sub-regions, the proposed dynamic FFR will allocate more radio resources to small cells/femtocells, which suffer from lack resources. The highest degree of the cost function of a certain sub-region would have the largest amount of small cells/femtocells. The sub-region with the lowest cost function would receive fewer radio resources for small cell/femtocell UEs. The throughput is utilized as a metric for the purpose of evaluating the proposed strategy. MATLAB simulation is conducted for that reason. The results show that the proposed technique outperforms the fixed FFR.

Keywords Throughput · FFR · 5G · Small cells

Abbreviations

FFR	Fractional frequency reuse
5G	Fifth generation networks
BS	Base station
ICI	Inter-cell interference
UDN	Ultra-dense networks
UE	User equipment
LTE	Long term evolution
4G	Fourth generation network
SFR	Soft frequency reuse
SINR	Signal to interference plus noise ratio
LMDS	Local multipoint distributed service
LOS	Line of sight
MUE	Macrocell user equipment
TTI	Transmission time interval

1 Introduction

Fifth-generation (5G) wireless systems are the current generation of mobile network technology, and they would offer improved spectral efficiency, better data throughput, and more design and implementation options [1]. This has raised the demand for faster mobile data traffic because of the increase needs for mobile data, which requested by devices such as smartphones and tablets. The operators of mobile networks are frequently confronted with the challenge of installing base stations (BSs) with robust capacity in addition to small cells. The coverage of these BSs should be able to accommodate the unpredictability of the requirements that will be placed on them by future User Equipments UEs.

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The spectral efficiency and the cost of implementing as well as operating 5G networks are two areas that need further improvement. Inter-Cell Interference (ICI) is considered as a critical challenge in 5G networks due to the tendency toward ultra-dense networks (UDN) in the next generation of networks, which is where we are headed. ICI problem causes a reduction in the capacity at the cell-edge regions in a cellular communication systems. As a result, the spectral efficiency would also be reduced. Accordingly, cellular systems would have a couple frequency allocation mechanisms. In the first mechanism, BSs send signals on a variety of frequencies, and the band width that is utilized by each sector is equal to 25%. The reuse factor in this case is 25%, and it is referred to as Frequency Reuse Factor 3 (FRF3). This strategy can significantly reduce the co-channel interference that occurs between neighboring cells; however, it does so at the expense of the efficiency of the spectrum. This method has been implemented within the Global System for Mobile Communication (GSM). Frequency Reuse Factor 1 (FRF1) is the name given to the configuration in which all cells in a 3G or 4G network share the same carrier frequency and bandwidth. This maximizes the utilization of available spectrum but comes at the expense of increased interference from neighboring cells [2].

Fractional Frequency Reuse (FFR) is a strategy that can be used to trade off with the previously mentioned frequency reuse techniques. With this strategy, every cell in the center area of the network can transmit on the same frequency, and the majority of the network's resources will be allocated to this area. However, the area around the cell's edge would operate in distinct frequencies in order to alleviate the interference [2, 3]. This strategy can be used to trade off with the previously mentioned frequency reuse techniques. FFR separates the coverage region of the BS to inner and outer sub-regions, and then implements distinct FRFs in each of these zones in order to mitigate the interference and boost the average spectral efficiency.

The interference problem has been the subject of previous research, which has resulted in the development of potential solutions. These strategies include utilizing several antennas, regulating the amount of power used for propagation, and dividing the used spectrum. The method of dividing the available spectrum would be the essential emphasis of this study. The design of FFR concept has been attracted the attention of researchers in the academic and industrial sectors. After splitting the BS region into center/inner zone and edge/outer zone, the primary goal of introducing FFR is to utilize a variety of reuse factors value for (UE) that is positioned in the inner zone and UE that is positioned in the outer zone [4, 5]. The interference challenge is classified into two essential types. The co-interference is experienced with elements that are belongs to the same tier of network. The cross-interference

is experienced with elements that are belongs to different tier of network.

The remaining aspects of this work are organized according to the following way. A literature review is presented in the following section. The conceptual model of the system is provided in the third section. In the fourth section, the proposed scheme is broken down into its component parts in depth. The fifth section contains specific information regarding the experiment, which is conducted to evaluate the proposed strategy. A conclusion is given in the last section of this manuscript.

2 Literature review

In this section related works to the FFR concept will be presented. The authors of [6] suggested an adaptive frequency reuse method for femtocell networks with the intention of preventing interference occurrence. In order to make the most of the sub-channels that are assigned to each small cell, it is necessary to divide the sub-channel into primary sub-channels and secondary sub-channels, based on the information provided by the system. The major sub-channels are given to the small cells that are most appropriate for them, and the secondary sub-channels are given to small cells only when there is no interference with the femtocells that are located nearby. Also, in order to manage interference in densely and unplanned distributed small cells, a clustering-based strategy is proposed in [7]. The degree of interference caused by each individual femto-cell is used to categorize the femtocells into one of several distinct groups. In [8], a plan for the equitable distribution of resources is suggested, which makes use of the FFR framework. The plan's purpose is to achieve the highest possible level of spectral efficiency while simultaneously minimizing the interference brought by small cells. It will basically be impossible for the small cells to use the same frequency as the neighboring UEs that are being served by the serving BS. Two different algorithms are considered in [9]. One of them is called the genetic algorithm. The other algorithm is called the graph-annealing algorithm. Accordingly, authors in [9] utilize those algorithms to split the spectrum into center sub-region and edge sub-region. The goal of doing so is to increase the mean capacity of the whole cell while simultaneously lowering the likelihood of an outage, in particular for the users that are located in the sub-region along the perimeter of the cell. The authors of [10] proposed a strategy, which is called the dynamic frequency reuse (DMFR) system. The number of UEs present in each region of the cell determines how the DMFR algorithm splits the spectrum among the various regions of the cell. The authors of [11] provide a strategy that dynamically assigns radio resources depending on

the location of femtocells throughout the network. The main idea behind the suggested strategy is to let the small cells utilize the all assigned bandwidth when UEs of macrocell BS are absent in its dominant region. In [12], FFR mechanisms were analyzed and assessed using a set of predetermined metrics. Moreover, the SFR mechanism was optimized and considered to accomplish a considerable balance between the scheme’s fairness requirements and its capacity requirements.

In [13], FFR mechanism is suggested to enhance the data throughput in the outer sub-region while monitor the balance between the highest data throughput as well as the mean data throughput of the entire cell with data throughput in outer sub-region area. The authors of [3] and [14] have presented FFR with transmission power allocation strategy. Accordingly, their results demonstrate a noticeably improved in the performance of cell-edge area. Additionally, the authors suggested the concept of capacity density and bandwidth density in LTE network. Though in [15] FFR was presented as a solution to the challenge of inter cell interference (ICI) in LTE network. The authors of this study examined different FFR strategies, which are FFR and Soft Frequency Reuse SFR. They made a comparison between them and the frequency reuse strategy that is used in LTE networks. A distance-dependent frequency reuse scheme with random macro base station placements has been introduced in [16]. The author of this study has formed new formulas for signal to interference plus noise ratio (SINR). They considered difference power requirements for BS transmission in order to optimize the network capacity. In spite of this, SFR has a higher interference level but greater spectral efficiency when compared to FFR. This is because the spectrum that is designated for the cell edge can be dedicated for inner zone when it is not being utilized at the cell outer area [17]. The reason for this is due to the fact that the spectrum is not being used at the cell edge.

Moreover, authors in [18] proposed a novel strategy. Their mechanism aimed to enhance the capacity of the network. It also aimed to allocate appropriate subband for new installed small cell BS. The mechanism split the available bandwidth into seven sequence subbands. Also, the extend of a particular macrocell BS is split into 3 sectors as well as 3 layers. The seven subbands would be properly distributed among different sectors and layers. Thus, any new small cell BS will operate in different subband contrast to its zone. In [19], a novel strategy was proposed. The proposed strategy depend on the distribution of the UEs and their path loss. The basic approach is to divide active users into different group. A proposed coverage probability expression is derived based on the received path loss from different users. The result will influence the decision of the area and bandwidth division. Moreover, a Stienen’s

cell based SBS implementation was considered in [20]. The goal of this deployment is to enhance the signal to interference ratio in terms of downlink. In addition, the SFR concept is integrated within the deployment to alleviate the ICI for macrocell BSs. According to stochastic geometry a novel formula was formed for coverage probability. The resulted expression provided four distinct possibilities of cell deployment.

The concept of frequency reuse in the millimetre wave band (mm-wave) was initially presented in [21]. It was utilized in the local multipoint distributed service (LMDS) band at 28GHz. In addition to the use of polarization and sectorization to increase system capacity in this band, the author has demonstrated a frequency reuse range of anywhere from one to eight per cell. Table 1 summarized the proposed strategies in the literature review.

In this particular piece of research, the objective of FFR optimization is to achieve the highest possible cell-edge zone data rate and the highest possible mean UEs’ data rate. Because of the significant path loss and the attenuation caused by the atmosphere, signals on the band are extremely sensitive to whether or not they have a clear line of sight (LOS) [22]. This is because of the increasing interference. The network would experience a huge spike in ICI as a direct result of the increased interference from neighboring cells. Also, the utilization of FRF1 will lead to significant ICI, particularly in the cell-edge area, which will result in a decline in the performance of the network in terms of throughput [23]. Because of this, interference coordination is required in order to deal with the excessive interference and enhance the network’s performance. This particular FFR division strategy makes use of FFR3 and FFR1 to its advantage by dividing the cell coverage into two distinct zones: the inner and the outer zones. In addition, the spectrum is segmented into an primary band for the inner zone and an Secondary band for the outer zones.

Table 1 Literature review summary

Reference	Mode	Deployment	Target
[6]	Semi-static	HetNet	Interference mitigation
[7, 8]	Static	HetNet	Interference mitigation
[9]	Static	HetNet	Average capacity
[10]	Dynamic	Traditional cell	Interference mitigation
[11]	Dynamic	HetNet	Outage probability
[12]	Static	HetNet	Fairness
[13]	Static	Traditional cell	Throughput
[14]	Static	Traditional cell	Power allocation
[15]	Static	Traditional cell	Interference mitigation
[16, 18]	Static	HetNet	Capacity
[19, 20]	Static	HetNet	Coverage probability

Based on that, a scheme for dynamic FFR is proposed in this paper. Enhancing the network’s small cell/femtocell capacity is central to the proposed concept, which is the objective of the proposed strategy. The fundamental concept that underpins the suggested strategy is to allocate the portion of the macrocells that contains more small cell/femtocells with fewer radio resources. This is done with the intention of reusing non-utilized resources for the small cell/femtocells, which are placed in the same portion of the macrocell. Accordingly, the proposed mechanism would boost small cell/femtocell network capacity, mitigate the co-tier interference, and improve the utilization of the resources.

3 System model and problem formulation

3.1 System model

In this work, random deployment of small cells has been taken into consideration. The coordination between group’s members of small cells, which are deployed in a particular macrocell, is done through Femto-Gateway. In this scenario, S1 interface is used for the communication between Femto-Gateway and distributed smallcells. The concept of FFR is adopted in this work. As a result, macrocell BS’s region would be divided into four sub-regions. The inner region and the three outer regions. Accordingly, the spectrum is split into four sub-bands. Each sub-band is dedicated for a particular sub-region. Figure 1 depicts the the sub-regions and the sub-bands according to FFR concept.

The path loss between UEs, which are attached to a macrocell BS, and their serving macrocell BS is modeled as follows [24]:

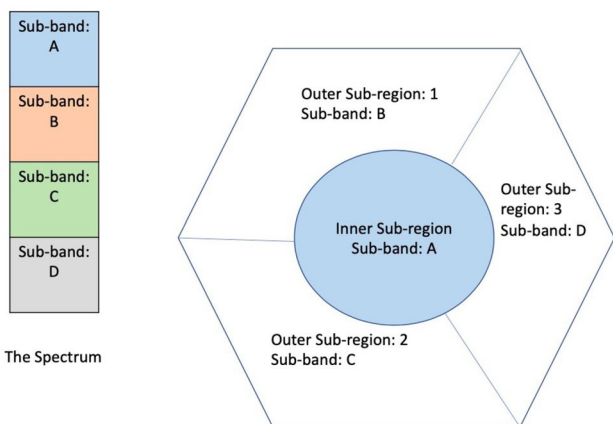


Fig. 1 FFR

$$P_{dB} = 15.3 + 37.6 \log_{10} (D) \tag{1}$$

where (D) represents the distance between UE and its serving macrocell BS. Also, the path loss of small cell when its UE is expressed according to the following [24]:

$$P_{dB} = 38.46 + 20\log_{10} (D) + 0.7d_{2D, In} + 18.3x^{((x+2)/(x+1)-0.46)} + W * L_{iw} \tag{2}$$

where, W represents the number of the walls that are reside between small cells and their UEs, and x denotes to the floors’ number. Also, because small cells are implemented in indoor environments, L_{iw} represents the walls of the building that introduce penetration loss. The internal walls causes penetration loss and it is represented by $0.7d_{2D, In}$ and it is in meters.

The received SINR for UE i of macrocell BS i on subcarrier s , is given by [25]:

$$SINR_{i,s} = \frac{\Psi_{m,s} G_{i,m,s}}{\sum_{m'} \Psi_{m',s} G_{i,m',s} + \sum_F \Psi_{F,s} G_{i,F,s} + D_0 \Delta t} \tag{3}$$

where $\Psi_{m,s}$ is the transmission power, which is propagated by the serving macrocell BS m on subcarrier s and $\Psi_{m',s}$ is the transmission power, which is propagated by neighbor macrocell BS m' on subcarrier s . The gain of the channel is represented by $G_{i,m,s}$, m represents the macrocell BS, which serves UE i with the received subcarrier s . Also, $G_{i,m',s}$ represents the gain channel, which received from neighboring macrocell BS and interferes the original signal. m' is neighboring macrocell BS, i is the UE, and s is the subcarrier. Also, the scenario of receiving interference from small cells, which are deployed in macrocell region, to macrocell’s UE i is considered. $\Psi_{F,s}$ represents smallcell’s F , which transmits power on subcarrier s , and $G_{i,F,s}$ represents gain of the delivered subcarrier s . Subcarrier’s spacing is represented by Δt . In addition, D_0 indicates the white noise power spectral density.

The received SINR for small cell in this case for its UE j on subcarrier s is calculated as follows [25]:

$$SINR_{j,s} = \frac{\Psi_{F,s} G_{j,F,s}}{\sum_m \Psi_{m,s} G_{j,m,s} + \sum_{F'} \Psi_{F',s} G_{j,F',s} + D_0 \Delta t} \tag{4}$$

where $\Psi_{F,s}$ represents the level of transmitted power for a particular femtocell F assigned to a subcarrier s , and $\Psi_{m,s}$ represents the level of propagated power for the serving macrocell BS m , which is assigned to subcarrier s . $G_{j,F,s}$ represents the gain os subcarrier s for small cell BS F and UE j . $G_{j,F',s}$ is the gain of subcarrier s , which transmitted by small cell BS F' and received by UE j . The channel gain of an UE is calculated according to the following formula [25]:

$$G = 10^{-P/10} \tag{5}$$

The expected capacity of UE u with a particular subcarrier s is calculated according to the following formula [25]:

$$\eta_{u,s} = \Delta f \log_2(1 + \alpha \text{ SINR}_{u,s}) \tag{6}$$

here α is the BER. In this research, its level is assumed to be 10^{-6} . The total throughput of the cell is calculated as follows [25]:

$$\varepsilon = \sum_u \sum_s \beta_{u,s} \eta_{u,s} \tag{7}$$

here $\beta_{u,s} = 1$ once a subcarrier s is assigned to UE u ; otherwise it would be assumed as $\beta_{u,s} = 0$.

The problem optimization is formulated in the next sub-section. Its objective is to maximize the overall throughput.

3.2 Problem formulation

ε_f indicates the overall throughput of small cells, which is denoted by femtocell in this work. Also, ε_m represents the total throughput of macrocell.

$$\tau_f = \sum_f \sum_s \beta_{u_f}^s \eta_{u_f}^s \tag{8}$$

$$\tau_m = \sum_m \sum_s \beta_{u_m}^s \eta_{u_m}^s \tag{9}$$

In (8) and (9), $\beta_{u_f}^s$ and $\beta_{u_m}^s$ indicates that a particular subcarrier is allocated to UE, which is attached to small cell BS, or UE of macrocell BS. If $\beta_{u_f}^s$ or $\beta_{u_m}^s = 1$, it indicates that a particular subcarrier is allocated to UE of small cell BS or UE of macrocell BS.

In this work, the area of a certain macrocell would be divided into four sub-regions as well as the spectrum is divided into four sub-bands. Macrocell's UEs and small-cell/femtocell's UE, which are positioned in the same sub-region, would be operate in different sub-bands. Sub-bands that are assigned to small cell/femtocells, which are installed in sub-area X , is indicated by f_x . The problem would be presented as follows:

$$\underset{F_x}{\text{maximize}} \quad (\tau = \tau_m + \tau_f) \tag{10a}$$

$$\text{subject to} \quad \sum_{u_m=1}^{n_m} \sum_s P_m^s \beta_{u_m}^s = P_m \tag{10b}$$

$$\sum_{f \in X} \sum_s P_f^s \beta_{u_f}^s = P_f \tag{10c}$$

$$\sum_{u_m=1}^{n_m} \beta_{u_m}^s = 1, \quad \forall s \tag{10d}$$

$$\sum_{f \in X} \beta_{u_f}^s = 1, \quad s \in F_x \tag{10e}$$

$$\beta_{u_m}^s, \beta_{u_f}^s \in [0, 1], \quad \forall [m, f] \tag{10f}$$

the total number of UEs as a macrocell BS is represented by n_m . The temperature of propagated power of macrocell BS is represented by P_m . Also, P_f represents the transmission power of small cell/femtocell. In addition, P_m^s represents the allocated power by macrocell BS with subcarrier s . P_f^s represents the power that is allocated by small cell BS for subcarrier s .

Constraints (10d), (10e) assures that a particular subcarrier is only allocated to a single UE of macrocell BS or small cell BS. This problem is NP-Complete problem and its solution will not be apparent. Thus, a strategy is suggested in the next section.

4 Proposed solution

This work introduces a dynamic technique to boost the average throughput of the macrocell by enabling the macrocell to more efficiently allocate its resources and thereby boost the throughput of the small cells/femtocells. The fundamental idea behind FFR is to divide the prominent area of the macrocell into four separate sub-regions. This is done to reduce the cross-tier interference as well as co-tier.

The spectrum is allocated among the four sub-regions of the macrocell, as shown in Fig. 1. Nevertheless, the spectrum is divided in exactly the same way across all four sub-regions. The objective of the proposed dynamic technique is to improve the FFR by splitting the spectrum into four sub-bands in a dynamic way according to predetermined cost function. This function indicates the number of operated small cells/femtocells for each sub-region. Basically for a particular sub-region, particular sub-band is allocated for macrocell's UEs, which are positioned at the same sub-region. To reduce the potential interference, the remaining three sub-bands are assigned for the small cells/femtocells, which are located in the same sub-region.

N is a set, which comprises all installed small cells/femtocells in the network, so $N_1^n = [s_1, s_2, s_3, \dots, s_n]$. Also, S_{total} is the total number of deployed small cells/femtocells, so $S_{total} = N$. In addition, the macrocell range is divided into four different sub-regions, which are $[A, B, C, D]$. Accordingly, A represents the inner sub-region, which is the center cell area. Also, the outer three sub-regions are represented by $[B, C, D]$. Moreover, the spectrum is split

into four distinct sub-bands. Each sub-region of the macrocell has its own sub-band, which also includes a certain amount of installed small cells/femtocells.

Accordingly, sub-bands, which are A_{M_s} , B_{M_s} , C_{M_s} , D_{M_s} are allocated to macrocell's UEs that are positioned in sub-regions A , B , C , D , respectively. In addition, the following sets $\delta_1^{an} = [s_{a1}, s_{a2}, s_{a3}, \dots, s_{an}]$, $\delta_1^{bn} = [s_{b1}, s_{b2}, s_{b3}, \dots, s_{bn}]$, $\delta_1^{cn} = [s_{c1}, s_{c2}, s_{c3}, \dots, s_{cn}]$, and $\delta_1^{dn} = [s_{d1}, s_{d2}, s_{d3}, \dots, s_{dn}]$ represent the set of small cells/femtocells that are installed in the sub-regions A , B , C , D , respectively. The following sub-bands, which are A_s , B_s , C_s , D_s , would be allocated to small cells/femtocells that are installed in the A , B , C , D sub-regions, respectively.

The number of small cells/femtocells and their locations within each sub-region are both consistent, although the number of macrocell's UEs varies from sub-region to sub-region. Therefore, the proposed dynamic FFR enables the macrocell to partition the entire spectrum into four sub-bands based on the number of small cells/femtocells for each sub-region. Therefore, the objective of the suggested dynamic FFR mechanism is to boost the total capacity of the network by boosting the capacity of the small cells/femtocells.

Then, the proposed dynamic FFR scheme would process the following steps. The entire spectrum would be split among all four sub-regions A , B , C , D fairly. Afterward, each sub-region i should recognize its own cost function. The cost function for each sub-region i is defined as follows:

$$\beta_i = \frac{\delta_{in}}{S_{total}} \quad (11)$$

where δ_{in} indicates the number of small cells/femtocells that are installed in a particular sub-region i . S_{total} indicates the total number of small cell/femtocell BSs, which are considered in the network.

Accordingly, the dedicated radio resources τ is split fairly between the four sub-regions. Thus, the allocated radio resources for every sub-region is configured as follows:

$$I_{M_s} = \tau \times (0.25) \quad (12)$$

where I_{M_s} is the allocated sub-band portion of the spectrum for macrocell's UEs, which are positioned at sub-region i . Consequently, the small cells/femtocells, which are positioned at sub-region i , would schedule their associated UEs to one of the other three different sub-bands, so I_s would be one of the rest sub-bands such as $[I'_{M_s}, I''_{M_s}, \text{ or } I'''_{M_s}]$. If $I = A$, so $I' = B$, $I'' = C$, and $I''' = D$.

Now, cost function β_i would be applied to configure an adequate amount of resources for each sub-band for

both I_{M_s} and I_{F_s} in sub-region i . The rate of cost functions fluctuates depending on quantity of small cells/femtocells, which are positioned in each sub-region i , hence the cost function's rate of a sub-region i will be increased when more small cells/femtocells are installed in sub-region i . Accordingly, the rate of a cost function β_i for a particular sub-region i represents the serviceable percentage degree of the available spectrum, which is needed for increasing the capacity of the small cells/femtocells network. The satisfied sub-band I_s that need to be assigned for small cells/femtocells that are stalled in sub-region i can be computed as follows:

$$\psi_{S_i} = \tau \times (\beta_i) \quad (13)$$

where ψ_{S_i} represents the maximum amount of radio resources and sub-bands, which can be allocated for small cells/femtocells that are installed in sub-region i . The proposed dynamic FFR scheme enables the system to configure both β_i and ψ_{S_i} , so that it is applicable to compute an adequate I_{M_s} and I_s for sub-region i . The objective of the suggested dynamic FFR strategy is to boost the capacity of small cells/femtocells network. Subsequently, I_s is increased by decreasing I_{M_s} for sub-region i .

At the beginning when the system run and operated, both I_{M_s} and I_s are the same for sub-region i and also for all other sub-regions of a macrocell's range. Afterward, the first action is to sort the degree of the cost function in a descending way for all sub-regions. Then, the sub-region with highest degree of cost function β_i match the satisfied value of radio resources ψ_{S_i} with the actual value of assigned radio resources I_s until it satisfies the following formula:

$$I_s \geq \psi_{S_i} \quad (14)$$

The predetermined expression would be met by enforcing the cost function on I_{M_s} for the subsequent iterations according to the following expression:

$$I_{M_s}(1+t) = I_{M_s}(t) - [I_{M_s}(t) \times \beta_i] \quad (15)$$

where t indicates the iteration time. This step would be iterated until the condition is satisfied. The remain radio resources would be configured as follows:

$$\theta = I_{M_s}(t) - I_{M_s}(1+t) \quad (16)$$

and it would be appended to $\gamma(1+t)$. Then,

$$\gamma(1+t) = [\gamma(t)] - [I_{M_s}(1+t)] + [\theta] \quad (17)$$

here $\gamma(1+t)$ is partitioned among other three sub-regions. Once the term is met, the following highest β_i would be recognized and all the aforementioned steps would be reiterated till it reaches the last sub-region that has least

value of β . The pseudo code of the suggested dynamic FFR strategy is presented in Algorithm 1.

Algorithm 1 Proposed Dynamic FFR

```

1:  $N_1^n = [s_1, s_2, s_3, \dots s_n]$ 
2:  $S_{total} = n$ 
3:  $\tau$ 
4:  $\zeta = \tau * (0.10)$ 
5:  $\delta_1^{an} = [s_{a1}, s_{a2}, s_{a3}, \dots s_{an}]$ 
6:  $\delta_1^{bn} = [s_{b1}, s_{b2}, s_{b3}, \dots s_{bn}]$ 
7:  $\delta_1^{cn} = [s_{c1}, s_{c2}, s_{c3}, \dots s_{cn}]$ 
8:  $\delta_1^{dn} = [s_{d1}, s_{d2}, s_{d3}, \dots s_{dn}]$ 
9: for  $i \leq 4$  do
10:    $\beta_i = \frac{\delta_{in}}{S_{total}}$ 
11:    $I_{Ms} = \tau \times (0.25)$ 
12:    $I_{Fs} = \tau \times (0.25)$ 
13:    $\psi_{S_i} = \tau \times (\beta_i)$ 
14: end for
15: for  $i \leq 4$  do
16:   while  $I_S(t) \leq \psi_{S_i}$  do
17:     if  $I_{Ms}(t) \geq \zeta$  then
18:        $I_{Ms}(1+t) = I_{Ms}(t) - [I_{Ms}(t) \times \beta_i]$ 
19:        $\theta = I_{Ms}(t) - I_{Ms}(1+t)$ 
20:        $\gamma(1+t) = [\gamma(t)] - [I_{Ms}(1+t)] + [\theta]$ 
21:
22:        $I_S(1+t) = \frac{\gamma(1+t)}{3}$ 
23:     end if
24:   end while
25: end for

```

5 Results

A simulation of the modeled system, which was presented in the third section of this work, was carried in order to evaluate the proposed mechanism. The MATLAB tool

was used to construct the simulation. The system follows the real-time run based on channel models, which are presented in this work. The resources allocation also follows the Round Robin scheduling strategy. Thus, the scheduling decision is made every Transmission Time

Table 2 Simulation parameters

Parameters	Value
(Radius _m)	500 m
(Radius _f)	5 m
Multiple access	OFDMA
Tx power of macrocell P _m	46 dBm
Tx power of small cell/femtocell P _f	21 dBm
Walls loss L _{ow} (outdoor)	15 dB
Walls loss L _{iw} (indoor)	7 dB
Spacing between subcarriers	15 kHz
White noise power density	– 174 dBm/Hz
Scheduling strategy	Round Robin

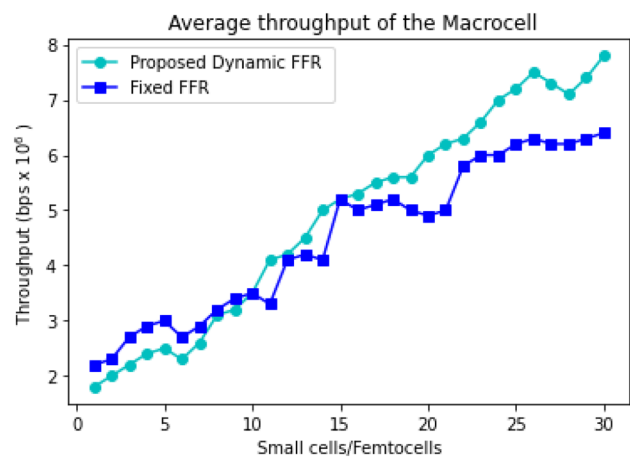


Fig. 2 The cell average throughput

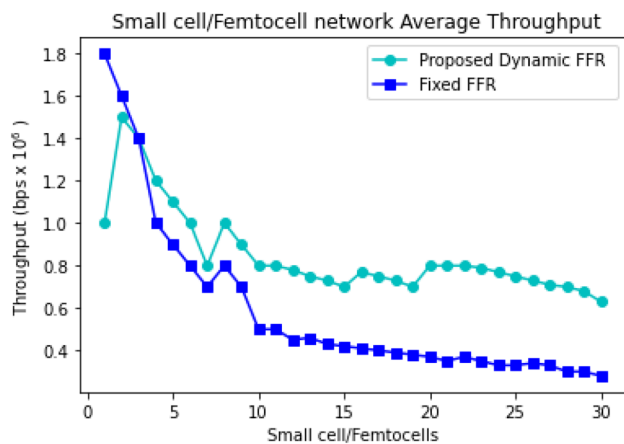


Fig. 3 The femtocell network throughput

Interval (TTI). TTI equals 1 ms. Also, the variables including cost function of the proposed mechanism would be reconfigured each time a new small cell BS is inserted into the system. The process of small cell BS insertion is vary depend on iterations of TTI. In this system, a new small cell BS is inserted into the system every 1000 TTIs. The simulation parameters that were taken into consideration for this experiment were summarized in Table 2.

In this work, the installation of the small cell/femtocell BSs within the building is decided on a completely arbitrary basis, and it is installed at indoor environment. Each individual small cell/femtocell that is being used in an indoor environment is linked to at least one UE. After the installation of a new small cell/femtocell in the system, the macrocell will unload at least one indoor UE onto the newly installed small cell/femtocell, where it will be considered and treated as small cell/femtocell's UEs. This happens each time a new small cell/femtocell is introduced to the system that's being monitored. The throughput is considered as the basic metric that is utilized to make a comparison between the fixed FFR and the proposed dynamic FFR. A single macrocell and multiple simultaneously associated small cells/ femtocells are taken into account in this simulation.

Figure 2 depicts the overall throughput of the cell as an average, which may be seen in its entirety. The conventional FFR approach functions quite well even when there are only a few small cells/femtocells are performed and utilized. On another hand, when a major amount of small cells/femtocells are applied, the performance of the suggested technique is improved because more resources are allocated for small cells/femtocells. According to the figure fixed FFR perform better than proposed dynamic FFR when the number of associated small cells are few because the resources will remain the same for all four sub-regions of the entire macrocell. When the

number of small cells/femtocells is increased, it means that the resources would be distributed and allocated effectively across all sub-regions. In this case, the sub-bands that are allocated to a group of small cells/femtocell, which are positioned in a particular sub-region, would have more radio resources. As a result, the total throughput of the network would be increased.

According to Fig. 3, which illustrates the throughput of the network that is made up of a group of small cell/femtocells, it is possible to notice the unfavorable effects of the interference that occurs between small cells/femtocells in the network. This is the case even though the interference is only temporary. It is abundantly clear that the amount of small cells/femtocells that are actually implemented will have a direct bearing on the extent to which the promised benefits of installing small cells/femtocells are realized. This is because of the fact that the actual number of small cells/femtocells in use will be directly relative to the number of small cells/femtocells that are implemented. The data rate of the small cells/femtocells network suffers when there is a dense deployment of small cell BSs in an area where their placement was not predetermined and it would be negatively impacted. On another hand, in contrast to the FFR, the strategy that has been proposed has a greater chance of successfully preserving the capacity. In addition, the capacity growth that is forecasted to occur as a consequence of adding small cells/femtocells to a system experiences a reduction.

6 Conclusion

The FFR concept was designed with the goal of lowering interference levels among macrocell BSs. In addition, it mitigate interference level, which is generated by deploying small cells/femtocells within macrocells's range. A random and dense deployment of small cells/femtocells has a unfavorable impact on the performance of the system as a result of the interference. Therefore, the FFR concept is adopted to distribute the resources where the interference could be maintain. However, some small cells/femtocells in certain sub-region might suffer from the lack of the allocated resources. In this work, dynamic FFR mechanism has been proposed. The objective of the suggested strategy is to maximize the capacity of small cells/femtocells. The proposed strategy intends to boost the capacity of the femotcells network, which will lead to an increase in the system's overall throughput. Providing small cells/femtocells with additional radio resources on the basis of a set cost function is the primary objective of this project. Depending on the cost function, which is configured for all sub-regions, the proposed dynamic FFR will allocate

more radio resources to small cells/femtocells, which suffer from the lack of resources. The sub-region, which has the highest level of cost function, indicate that it has the largest number of installed small cells/femtocells. As a direct consequence of this, a sub-region with lowest level of cost function would be given less radio resources, which would be allocated to UEs of small cells/femtocells. The throughput is utilized as a metric for the purpose of evaluating the proposed strategy. In addition, a simulation in MATLAB is executed for this purpose. The performance of the fixed FFR is surpassed by the performance of the suggested strategy. Intercellular interference between macrocells is something that will be looked at in future research. To find a solution to the issue, a heuristic search strategy would need to be developed.

Author contributions Supervision, project administration, conceptualization, methodology, investigation, resources, data curation, writing-original draft preparation, writing-review and editing, funding acquisition, the author has read and agreed to the published version of the manuscript.

Funding The author declares that no funds, grants, or other support were received during the preparation of this manuscript.

Availability of data and materials There is no associated data or the data will not be deposited.

Declarations

Conflict of interest The author has no competing interests to declare that are relevant to the content of this article.

Ethics approval and consent to participate Not applicable.

Consent for publication Not applicable.

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