Interference Management in Small Cell System

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Abstract—The rapid increase in quality performance and high data rate make the small cell an attractive solution in the next generation of a cellular mobile network. The Femtocell is a small cell that can boost services to four or five users in low price, and it can guarantee high data rate and capacity within the indoor residential. The Macrocell is a base station with high power that can cover up to 200 miles of cell radius. The propagative of Femtocell over macrocell can cause interference between them as they use the same spectrum. In our paper, first we explain interference management algorithms; such as power control algorithm, Fractional Frequency Reuse (FFR) algorithm and resource scheduling algorithm. Also, we propose an algorithm for interference management that combines the fixed power control algorithm, Dynamic Fractional Frequency Reuse (DFFR) algorithm, and resource scheduling algorithm to mitigate the interference. Simulation results show that the proposed algorithm improves the signal to interference plus noise ratio (SINR), throughput and reduces the interference from neighbor cells.

Index Terms— Femtocell, interference management, capacity.

I. INTRODUCTION

Nowadays the next generation of cellular mobile network [1], [2] improves the mobile services and industries by introducing new technologies such as small cells [3]. Small cells have many forms such as Pico, micro and Femtocell [4]. Femtocell is a cellular network access point that connects devices by using residential DSL, cable connections or wireless technologies.

Interference management is one of the remarkable areas in the 5G research field [5]. The propagative of femtocell over macro cell can cause interference between them as they use the same spectrum. There are many techniques for interference management such as: cognitive [6], Femto-aware management [7], [8], clustering of Femtocells [9], power control [10], frequency allocation (FFR) [11], [12] and resource scheduling algorithm [13], [14]. In our paper we describe the traditional combination algorithm [15], [16], that combines between the fixed power control algorithm and (FFR) algorithm to improve SINR. Then we propose an algorithm that combines between the dynamic fractional frequency algorithm, the fixed power control algorithm, and the resource scheduling algorithm which can select the best frequency allocation in the cell which can increase the SINR, throughput and reduces the interference from neighbor cells. The throughput for user can be calculated periodically by using adaptation process. In our proposed algorithm, we optimize the performance metrics such as (average user throughput, cell edge throughput, Packet Loss Ratio, and capacity).

There are different published related works for interference management techniques in Heterogeneous Network deployment. In [11] power control algorithm is combined with beamforming to rise the beam power in the desired direction. In [12], the Fractional Frequency Reuse (FFR) in the cellular network enhances the coverage for the user. In [13], the traditional combination between the Fractional Frequency Reuse (FFR) and fixed power control algorithm leads to enhance the SINR, and the total throughput. In [14] the dynamic Fractional frequency reuse mechanism can select the best frequency allocation between the outer and inner regions. In [15], the resource scheduling algorithm can optimize the performance parameters of throughputs. (See Fig. 1).

The organization of the paper is as follows: The Introduction that shows interference management techniques have been discussed. Research Method explains our system model. Simulation results are demonstrated in the Result and Discussion section. Finally, concludes the paper.

II. RESEARCH METHOD

There are many interference management techniques; we will discuss the power control algorithm & the frequency allocation algorithm and the resource scheduling algorithm

Power Control Algorithm: The Power control approach can be united with beamforming to prevent power collapse in space or alternately we could raise the power of beam in the desirable direction. When the femtocells are initially deployed, a configuration process must occur for the femtocells to adjust typically the parameters of the network. There are three different types of power configurations [16], the fixed power method, the constant radius method, and the target SINR method. In our system we will use the fixed power method due to its simplicity which commissions a fixed power value for every Femto Base Station (FBS) but it requires continuous recalculation.

Resource scheduling Algorithm: The resource scheduling algorithm [16], used to optimize the performance parameters in terms of throughputs for example average user throughput, cell edge throughput, and Packet Ratio loss (PRL). Several resource algorithms are available such as proportional fair (PF) and round robin

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(RR). PF and RR algorithms are employed to schedule data transfer between users. In PF is used for distribute the resource between users to get a high data rate which depend on priority. In RR is one of the simplest scheduling algorithms as it deals with all users with equal priorities and distributes system resources to all users. This results in achieving the equally distribution and low throughput among all the users.

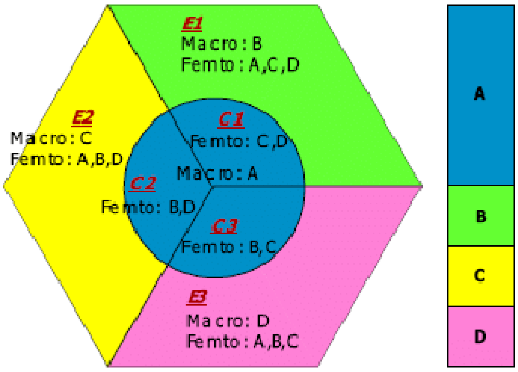

Fig. 1. FFR

Average user throughput [17]: As the distance between all users and the base station is not equal so the user which located near to the base station will get high SINR, and throughput while the user which located far from the base station will get low SINR and throughput so the average user throughput parameter must be calculated.

Cell edge throughput [18]: when the user become in the cell edge will have a inter cell interference from the neighboring cell and signal strength is weak as a consequence of the distance from the base station so the user which located in the edge of the cell have a very poor signal strength and data rate so the user must keep a minimum data rate to avoid call drop.

Packet Loss Ratio (PLR) [19]: is defined as the ratio of the number of lost packets to the total number of sent packets during the simulation.

III. System Model

A. The System Model of the Proposed Alogrithm

Fig. 2 shows the system model of the proposed algorithm.

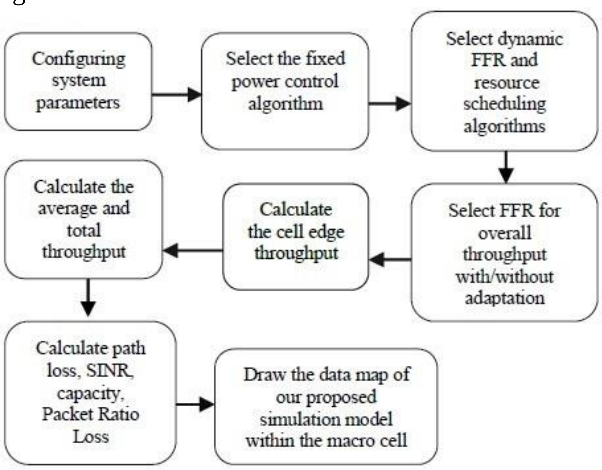

Fig. 2. System model

B. The Implementation Steps of Our Proposed Alogrithm

After configuring the system parameters (Number of Macro users, Number of Femto users, Number of Femtocells, Number of Macro cells), the fixed power control technique is applied. Then FBS power is calculated which determine whether the user can be attached to the femto or the macro base station. Next, we apply dynamic FFR technique then apply the resource scheduling technique and calculates the priority. In order to calculate the optimal inner cell region and frequency allocation in the cell. The technique swears the cell into two regions; inner region and outer region. For each FA, the mechanism calculates total throughput, path loss, capacity and SINR for all users. We calculate the average user throughput, the cell edge throughput, Packet Loss Ratio (PLR), and the priority function for all users. This procedure is repeated in order to take into account user's mobility for adaptation process. We select the FFR for overall throughput with/without adaptation. We draw the data map of our proposed simulation model within the macro cell range. Finally, we analyze the results from the system.

According to Fig. 3, we draw the data map of our proposed simulation model.

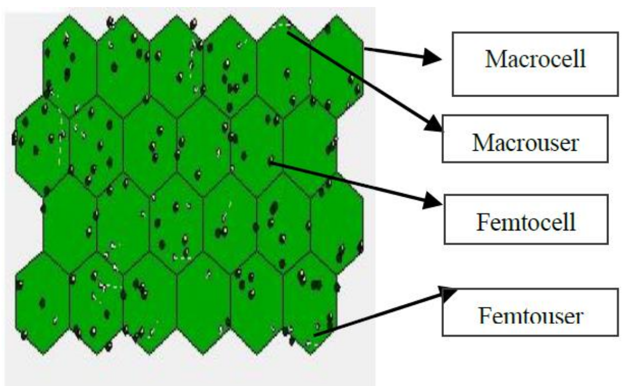

Fig. 3. The data map of our proposed algorithm

C. Equations

The SINR of a macro-user (x) at sub-carrier (k) (taking into account the impact of both the adjacent macro cells and overlaid femtocells) can be calculated as [20], [21]:

$$SINR_{x,k} = \frac{P_{M,k} G_{M,x,k}}{N_0 f_s + \sum_F P_{F,k} G_{F,x,k} + \sum_{M'} P_{M',k} G_{M',x,k}} \quad (1)$$

where

$P_{M,k}$ is the power transmission of Macro serving station (M) at subcarrier (k).

$G_{M,x,k}$ is the gain between the Macro serving station (M) and user (x) at subcarrier (k).

$P_{M',k}$ is the power transmission of neighboring Macro station (M') at subcarrier (k).

$G_{M',x,k}$ is the gain between the neighboring Macro station (M') and user (x) at subcarrier (k).

N_0 is the power density of white noise.

f_s is the sub-carrier frequency.

$P_{F,k}$ is the power transmission of Femto serving station (F) and subcarrier (k).

$G_{F,x,k}$ is the gain of the Femto serving station (F) and user (x) at subcarrier (k).

The SINR of a Femto user (y) at sub-carrier k can be calculated as [20], [21]:

$$SINR_{y,k} = \frac{P_{F,k} G_{F,y,k}}{N_0 f_s + \sum_M P_{M,k} G_{M,y,k} + \sum_{F'} P_{F',k} G_{F',y,k}} \quad (2)$$

where

$P_{F,k}$ is the power transmission of Femto serving station (F) at subcarrier (k).

$G_{F,y,k}$ is the gain between the Femto serving station (F) and user (y) at subcarrier (k).

$P_{F',k}$ is the power transmission of neighboring Femto station (F') at subcarrier (k).

$G_{F',y,k}$ is the gain of neighboring Femto station (F') and user (y) at subcarrier (k).

$G_{M,y,k}$ is the gain of Macro serving station (M) and user (y) at subcarrier (k).

Path loss heavily relies on the environment and the technology of the network. Regarding this paper, an urban environment is considered, thus the path loss for a macro-user at distance *R* from the transmitter and frequency of 2GHz is given by:

$$\text{PL (dB)} = 15.3 + 37.6\log R + L_{OW} \quad (3)$$

where the term L_{ow} is added for an indoor macro user to denote the penetration loss of the external wall. Similarly, the suggested model according to [15] for the case of an indoor and outdoor Femto-user is estimated, taking into account the penetration loss due to exterior and interior walls. Values of 7 and 15 dB are a good estimation of the penetration loss for internal and external walls, respectively.

The capacity for a macro-user (x) at subcarrier (k) can be calculated as [22], [23]:

$$C_{x,k} = \Delta f \log_2(1 + \propto SINR_{x,k}) \quad (4)$$

The capacity for a femto-user (y) at subcarrier (k) can be calculated as [22], [23]:

$$C_{y,k} = \Delta f \log_2(1 + \propto SINR_{y,k}) \quad (5)$$

where α is a constant for a target bit error rate (BER) can be calculated as:

$$\propto = -1.5/\ln(5\ BER) \quad (6)$$

The overall throughput of macro cell (M) for a macro-user (x) at subcarrier (k) can be calculated as [24]:

$$T_x = \sum_x \sum_k \beta_{x,k} C_{x,k} \quad (7)$$

where $\beta_{x,k}$ is the sub-carrier assignment for macro-user (x) at sub-carrier (k).

The overall throughput of femto cell (f) for a femto-user (y) at subcarrier (k) can be calculated as [25]:

$$T_y = \sum_y \sum_k \beta_{y,k} C_{y,k} \quad (8)$$

where $\beta_{y,k}$ is the sub-carrier assignment for femto-user (y) at sub-carrier (k).

The average throughput can be calculated as [26]:

$$T_{avg} = \frac{\sum_{i=1}^{n} T_i}{n} \quad (9)$$

where

T_i is the overall throughput for i^{th} user.

n is the total no of users.

The cell edge throughput (A_k) can be calculated as [27]:

$$A_k = \sum_j W_j X_{j,k} \quad (10)$$

where

$X_{j,k}$ is the received information on sub-carrier (k) from adjacent cell (j), it takes value 1 for cell edge and 0 otherwise.

W_j is the weight with respect to adjacent cell (j).

In the PF algorithm [28], the priority function is

$$P = \frac{T^{\alpha}}{R^{\Delta}} \quad (11)$$

where T is the overall throughput.

R is the average data rate.

$\Delta, \propto$ are the fairness distribution parameter (delta (Δ), alfa ($\propto$).where in PF will be delta ($\Delta = 1$), alfa($\propto = 1$) but in RR will delta ($\Delta = 1$), alfa($\propto = 0$).

The Packet Loss Ratio can be calculated as [28]:

$$PLR = \frac{\sum_{i=1}^{n} Pr_i - \sum_{i=1}^{n} Ps_i}{\sum_{i=1}^{n} Ps_i} \quad (12)$$

where Pr_i is the total number of transmitted packets.
Ps_i is the total number of received packets.

IV. Simulation Result

A. Simulation Parameters

We simulate the performance of our technique using the simulation parameters shown in Table I.

TABLE I. SIMULATION PARAMETERS

Simulation Parameters	Value / Range
Macro cell Transmission Power	46 dBm
Femto cell Transmission Power	15 dBm
Macro cell Radius	250 m
Femto cell Radius	8 m
Bandwidth	20 MHz
Subcarrier spacing	15 KHz
Modulation	64 QAM
Fading channel type	Rayleigh fading
No. of Femto cells	120
No. of Macro cells	15
No. of Macro Users	40
No. of Femto Users	100
No. of neighboring Macro cells	14
No of subcarriers	30 subcarriers
The thermal power density of white noise	-174 dBm/hz

According to Fig. 4, the relation between total throughput and SINR for femto-user and Macro-user for our proposed algorithm. We note that the throughput value of Femto-user is greater than of Macro user. For Example, at SINR = 9 dB, the throughput will be 3 Mbps for Macro-user and 8 Mbps for Femto-user.

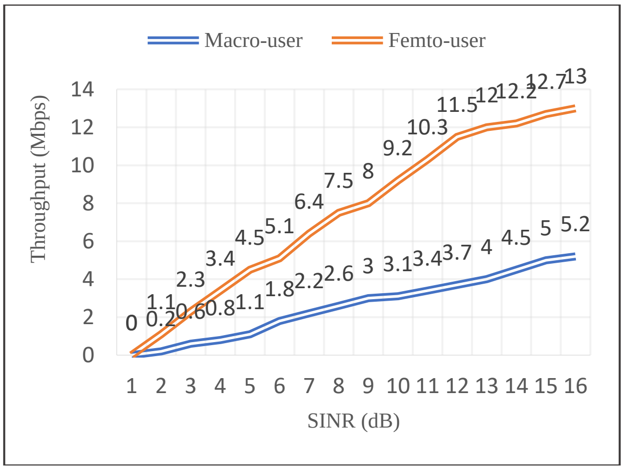

Fig. 4. SINR & total throughput for macro-users & femto-users

According to Fig. 5, the total throughput performance of our proposed algorithms, with the number of femtocells. As the number of femtocells increases, the throughput decreases. Our proposed technique (DFFR with fixed power control) gives highest throughput than the performance of (FFR with fixed power control) technique [5]. The proposed algorithm enhances total cell throughputs and SINR that reduces interferences with neighbor cells.

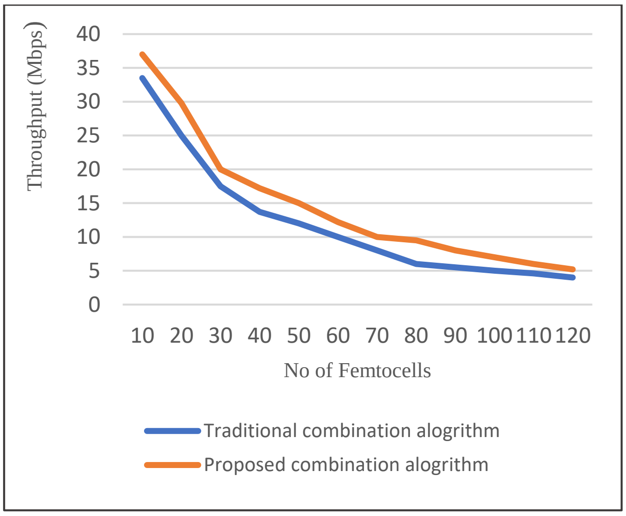

Fig. 5. The relationship between the number of femtocells and the total throughput

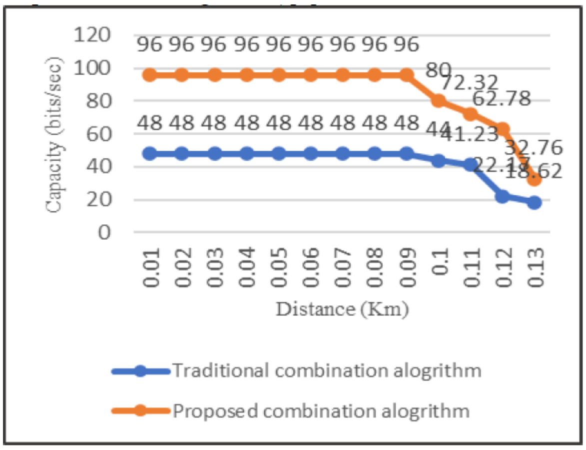

Fig. 6. The relation between the distance and the capacity of DFFR and FFR

According to Fig. 6, We present the system capacity based on the number of users supported using our proposed algorithm (dynamic fractional frequency reuse (DFFR) with fixed power algorithm) comparing to the traditional algorithm (fractional frequency reuse (FFR) with power control algorithm)[5].

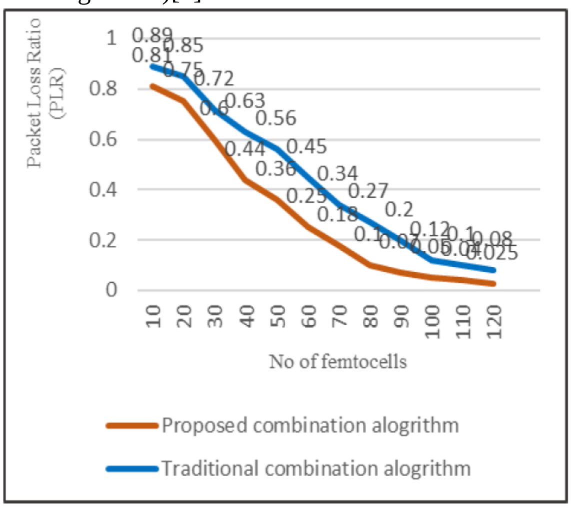

Fig. 7. The relation between the Packet Loss Ratio and the no of femtocells

According to Fig. 7, we present the relationship of Packet loss Ratio with the number of femtocells supported using our proposed algorithm (dynamic fractional frequency reuse (DFFR) with fixed power algorithm) comparing to the traditional algorithm (fractional frequency reuse (FFR) fixed power algorithm) [5]. Our proposed combination algorithm gives better result than the traditional combination algorithm.

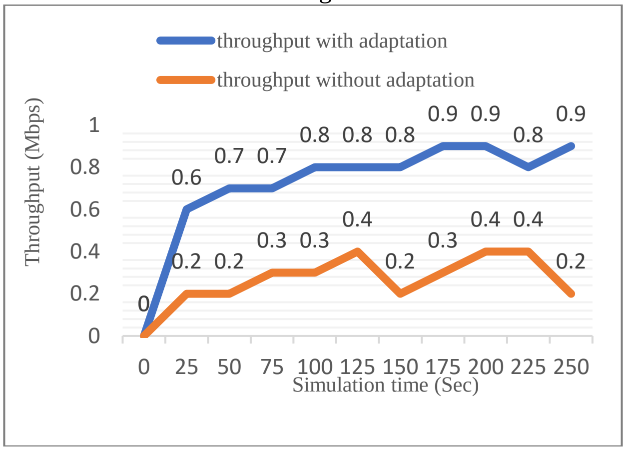

Fig. 8. Cell total throughput with simulation time

According to Fig. 8, we present the total throughput of all the users in the network [9],[11] with the simulation time. For our proposed algorithm When we apply the process without adaptation, we consider the user mobility is constant so the frequency allocation and the inner cell radius will be constant but when we apply our simulation with adaptation process that mean the frequency allocation and inner cell radius will calculate periodically. The adaptation process leads to high throughput. For comparison purposes, the graph also shows the throughput with adaptation is higher performance than the throughput without adaptation.

According to Fig. 9, PF and RR scheduling techniques [25], are used to optimize the performance metrics such as (average user throughput, cell edge throughput, Packet Loss Ratio) in our proposed algorithm. In the average user throughput, for low velocity PF performs better than RR but when the velocity increases RR is better than PF.

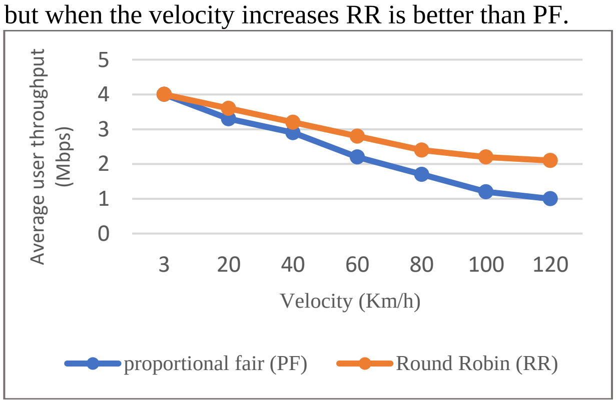

Fig. 9. The relation between the average user throughput & velocity

According to Fig. 10, in the cell edge throughput metric, while the user velocity increases, under the PF technique the cell edge throughput falls rapidly. Under the RR technique [19] the cell edge throughput falls slowly at high velocities but still boost a low data rate.

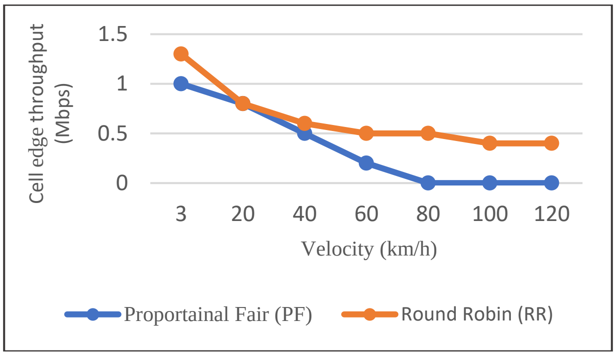

Fig. 10. The relation between the cell edge throughput & velocity

V. Conclusion

We propose an algorithm that combines the fixed power control technique, Dynamic FFR algorithm by using adaptation process and resource scheduling techniques (PF and RR). Our Proposed algorithm improves the SINR & throughput and reduces the interference from neighbor cells. It can select the best frequency allocation in the cell which can increase the SINR & the total cell throughput and optimize the performance metrics such as (average user throughput, cell edge throughput, Packet Loss Ratio and capacity).

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

The first author designed the interference management technics, simulation results and wrote the paper. All authors had approved and analyzed the final results and the final version.

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