Auto-Configuration Downlink Transmission Power Approach For Femtocell Base Station

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Summary

Femtocells are being incorporated into heterogeneous networks in order to increase the network capacity. However, intensive deployment of femtocells results in undesired interference, which lowers the system's performance. Controlling the femtocell transmission power is one of of the aspects that can be addressed in order to mitigate the negative effects of the interference. It may also be utilized to facilitate the auto-configuration of the network's conductance, if necessary. This paper proposes the use of an auto-configuration technique for transmission power. The suggested technique is based on the transmission power of macrocells and the coverage provided by femtocells. The simulation findings show that the network's capacity has increased, and the amount of interference has decreased.

Keywords:
Interference, femtocell, microcell, power control.

1. Introduction

In recent years, the massive development of mobile applications has boosted the need for data services. A significant quantity of data and voice services is also requested by users who are confined to indoor locations, such as office buildings or shopping malls. In addition to providing sophisticated technological capabilities and services, Long Term Evolution (LTE) is a broadband network that is now in use. However, because of the penetration loss and the extended distance between User Equipment (UE), which is located in an indoor environment, and the macrocell, the coverage provided by the macrocell may be insufficient and fail to fulfill the needs of UEs. As a consequence, the concept of Home eNodeB (HeNodeB), also known as femtocell or femto base station (FBS), is conceived and implemented in order to overcome the signaling insufficiency in the inside environment. Affecting the wireless industry, femtocells attract the attention and interest of both consumers and businesses. The femtocell increases the coverage of the inside environment while also offloading traffic from the macrocell. Femtocells are low-power, low-cost cellular networks that operate at a low power and cost. In addition, femtocells may be installed by end users themselves. Furthermore, it connects to the operators' networks via the utilization of licensed airwaves and backhaul connections [1][2][3]. Moreover, the femtocell has a high spectrum efficiency, which is one of the characteristics that may be attained to increase the throughput of the user equipment. In 3GPP LTE, Orthogonal Frequency Division Multiple Access (OFDMA) is a chosen downlink transmission technique that is used for downlink communication. In terms of the physical layer, the Physical Resource Block PRB is the fundamental unit that is given to each UE that is connected. A fundamental challenge when establishing femtocell and macrocell coexistence environments is the interference between cells, which is a major source of concern. Interference will be encountered as a result of the co-channel deployment, which will result in the performance of the system being limited [4]. As a result, a practical solution to mitigating interference and resolving this difficulty is required, particularly in the case of dense femtocell deployment. End customers are responsible for setting up and installing femtocell networks, which is a preferable option since it reduces the burden on network operators.

Femtocell power control is one of the most popular ways and strategies that have been proposed to relieve and prevent interference in heterogeneous networks. It is also one of the most difficult to implement. Despite the fact that the dense and unplanned deployment of adjacent femtocells would produce interference among femtocells, the femtocell power is modest since it serves and covers a small area such as private residences and apartments. Nonetheless, a technique for managing the femtocell transmission power is encouraged to be examined in order to lessen the impact of interference among neighboring deployed femtocells, which has been seen in the literature. Many other approaches of dealing with this problem have been presented in earlier studies.

In [5], authors had published the results of an extensive survey that was performed to uncover issues related to interference between femtocells. Interference reduction and avoidance in two-tier femtocell networks had been presented in detail. Paper [6], a femtocell is seen as an agent responsible for allocating an appropriate power transmission level on the basis of Q-Learning. A stochastic

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approximation technique is presented in [7], in which a femtocell practices eavesdropping on adjacent macro UE (MUE) communicating with a macrocell in order to evaluate feedback approximation, and then femtocells adjust their downlink transmission power depending on those estimates. According to [8], the authors provided a unique approach for adjusting the transmission power of femtocells. According to the article, it is necessary to differentiate between indoor and outdoor users, and the femtocell calculates the appropriate transmission power based on this classification. It is suggested in [9] to use a quadratic programming framework, as well as a cost index method. According to the proposed framework, estimate of path losses between neighbouring femtocells is used to regulate the transmission power of femtocells in a manner that minimizes interference between the cells. Also, in [10], the estimate of data traffic quantity is taken into consideration in order to develop an autonomous transmission power adjustment mechanism while also maintaining the best coverage that a femtocell can provide. According to [11], the radio environment maps (REM), which is a database tool that stores collective information among distributed UEs and base stations, is employed in order to decrease co-channel interference by managing the transmission power of femtocells. Based on signaling interaction between femotcells and macrocells, the authors of [12] suggested that femtocells could adjust their own transmission power levels by interacting with their surroundings. However, the connection between femtocells and macrocells, which is required in order to coordinate the interference issue, is indirect, resulting in excess signaling and adverse impacts on the performance of the system. As a result, femtocells adjust their transmission power in accordance with cognitive radio (CR) principles in order to increase system capacity while decreasing interference.

It is suggested in this paper that femtocells use an independent downlink transmission power strategy to communicate with one another. Femtocells would be able to modify their downlink transmission power depending on their coverage, and this power is calculated based on the coverage and transmission power of macrocells in the area.

The remainder of this work is arranged in the following manner. The system model is discussed in detail in the second part. The third section outlines the steps involved in implementing the suggested method. Section four presents and discusses the simulation findings of the suggested scheme's effectiveness, which are displayed and explained. The last section of this paper includes the conclusion.

2. System Model

In this paper, a dense co-channel deployment of a femtocell system within a single macrocell coverage is taken into consideration. As seen in figure 1, the co-interference between femtocells is presented. In this paper, a LTE-Advanced heterogeneous network, which composes a macrocell and femtocells that are operating in an indoor environment. Femtocells are linked to one another by the Femto-gateway (FGW) entity, which communicates with the femtocells over the S1 Interface protocol. Dense deployment of femtocells is being studied in order to enhance network performance and capacity. Calculating the path loss between a macrocell and its associated MUEs, as well as calculating the path loss between a femtocell and its associated FUEs, are both utilized to estimate the SINR for MUEs and FUEs, respectively, when estimating the SINR for MUEs. The path loss for outdoor microcell UE is calculated as follows [13]:

$$PathLoss_{dB} = 15.3 + 37.6\, log_{10}\,(R) \qquad (1)$$

While the path loss model for indoor UEs is given as follows [13]:

$$PathLoss_{dB} = 15.3 + 37.6\, log_{10}\,(R) + L \qquad (2)$$

(R) represents the distance between the transmitter and the receiver in meter. L represents the penetration loss caused by the wall.

The received SINR is modeled as follows [14]:

$$SINR_{i,s} = \frac{\gamma_{m\ ,s}\ G_{i,m,s}}{\sum_{m'} \gamma_{m',s}\ G_{i,m',s} + \sum_{F} \gamma_{F,s}\ G_{i\,,F,s} + N_0\, \Delta f} \qquad (3)$$

the transmitting power for serving macrocell m on subcarrier s and the transmitting power for adjacent macrocells m' on subcarrier s are represented by $\gamma_{m\ ,s}$ and $\gamma_{m',s}$, respectively. The channel gain is indicated by $G_{i,m,s}$, where m represents serving macrocell, i represents macrocell's UE, and s represents received subcarrier. The channel gain $G_{i,m',s}$ indicates interfering signal received from adjacent macrocell, where m' represent adjacent macrocell, i represent UE, and s represents the subcarrier. Also, in case of receiving interference from femtocells, which are adjacent to macrocell's UE i, $\gamma_{F,s}$ indicates femtocell's F transmission power on subcarrier s, and $G_{i,F,s}$ indicates gain of received subcarrier s. Spacing of subcarrier is indicated by Δf and white noise power spectral density is indicated by N_0 .

Also, the channel gain of an UE is expressed by [14]:

$$Gain = 10^{-PathLoss/10} \qquad (4)$$

The estimated capacity of any UE u on any subcarrier s is given as follows [14]:

$$C_{u,s} = \Delta f \, log_2 \left(1 + \alpha \, SINR_{u,s}\right) \qquad (5)$$

here α indicates BER. In this work, its target is considered to be 10^{-6} . The cell overall throughput model is expressed as follows [14]:

$$Throughput = \sum_{u} \sum_{s} \beta_{u,s} \; C_{u,s} \qquad (6)$$

where $\beta_{u,s} = 1$ if particular subcarrier s is allocated to UE u; otherwise it is set to be $\beta_{u,s} = 0$.

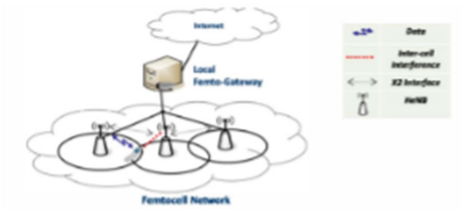

Fig. 1 An Overview of Femtocell Networks [15].

3. Auto-Configuration Transmission Power Proposed Mechanism for Femtocell

In this section, a method for reducing the impact of co-channel interference in OFDM-LTE transmission schemes is provided. When femtocells are densely deployed in macrocell coverage, they cause cross-tier interference, which is interference between the macrocell and the femtocell, as well as co-tier interference, which is interference between nearby femtocells. The deployment of small cell networks in areas such as an enterprise building or a building containing neighboring apartments enhances the negative impact of co-tier interference on system performance, and as a result, the performance of the system degrades significantly. The transmission power of neighbouring femtocells is a significant component that may influence the amount of interference that is experienced. The simple plug-and-play femtocell configuration by the user is sensitive to interference. Radio resources, locations, and transmission power all affect radio circumstances, therefore improving the efficacy of auto-configuration is a critical problem. In this paper, the performance associated with power configuration is presented. When compared to the coverage of a macrocell, the femtocell has a shorter range. The radius of a macrocell may range from a few hundred meters to several kilometers in length. Femtocells, on the other hand, have a range of 5 to 50 meters in their radius of operation. Aside from that, the number of UEs connected to a femtocell is small when compared to the number of UEs connected to a macrocell. In order to achieve low transmission power, a femtocell transmits at a low level of power. For example, the transmission power of femotcells is fixed at 21 dBm, whereas the transmission power of macrocells is set at 46 dBm. For dense and unplanned deployments of femtocell networks, transmission power for femtocells may be obtained from macrocell transmission power by considering the radius and coverage area of both the femtocell and macrocell. This ensures that co-interference is maintained between the two cell types. As a result, a femtocell would be able to dynamically adjust its transmission power depending on its coverage range, resulting in an increase in transmission power as the coverage range was expanded.

It is assumed that N be the set that comprises all positioned femtocells in a particular macrocell extend . $N = [f1, f2, f3, \ldots fn]$. Each femtocell fi has predefined radius ri based on its surrounding environments such as building or apartment. Accordingly, R indicates the set of radius that is matching to N. $R = [r1, r2, r3, \ldots rn]$. Furthermore, P denotes the set of transmission power for each femtocell fi. $P = [p1, p2, p3, \ldots pn]$. Pm denotes the macrocell transmission power. Also, Rm represent the serving macrocell radius.

Also, Macrocell's transmission power is predominately set to be proportional to its radius. As a consequence, femtocells are encouraged to adjust their transmission power in accordance with their radius and coverage in order to prevent wasting energy and to mitigate the impact of interference on neighboring femtocells while also conserving power. By dividing the P_m over $log10(Rm)$, we attain Y as follows:

Let,

$$X_m = log_{10}(R_m), and \; X_{f_i} = log_{10}(r_i) \qquad (7)$$

Then,

$$Y = \frac{P_m}{X_m} \quad (8)$$

Y denotes the proportion between macrocell downlink transmission power and its radius. Therefore, Y can be utilized to derive femtocell downlink transmission power pi for each femtocell $fi \in N$ according to the following forumla:

$$p_i = Y \times X_{f_i} \qquad (9)$$

Now, femtocell base station is able to set the downlink transmission power based on the equation (9).

4. Simulation Results

The system model is discussed in detail in the second section of this paper. In accordance with this, the MATLAB simulation tool is used to simulate the system model that has been supplied, using the simulation settings stated in Table I.

Table 1: Simulation Parameters

Parameters	***Value***
Macrocell Radious	500 m
Femtocell Radious	5 m
Frequency	2 GHz
Macrocell Transmission Power	46 dBm
Predefined Femtocell Transmission Power	18 dBm
Bandwidth	20 MHz
Spacing between Subcarriers	15 KHz
White Noise Power Density	-174 dBm/Hz

Also, femtocell network model which is known as (5 × 5 grid model) [16] is adopted in this work. In this model, a building includes about 25 neighboring apartments is considered. Each apartment covers area of 100 m^2 . (5 × 5) grid model is shown in Fig.2. Each part of the macrocell area contains one building, and it is randomly paced. Also, throughput is used as a comparative metric when the number of femtocells is varied.

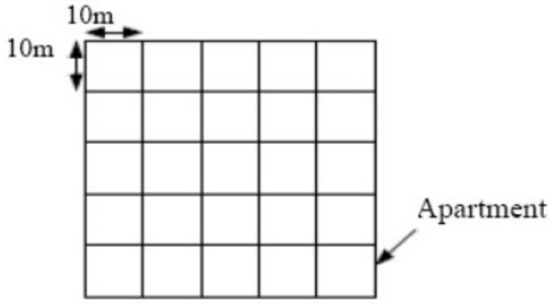

Fig. 2 Grid Model [15].

The suggested technique is compared to a fixed transmission power mechanism and a mechanism that has been presented in [17], and it is denoted as constant-range in this study. The constant-range technique supports femtocells in adjusting their transmission power autonomously while taking into account the transmission power of macrocells in order to alleviate the cross-interference caused by the deployment of OFDMA co-channels in the network. The transmission power adjustment of the constant-range technique is dependent on a number of parameters, including path loss, femtocell radius, antenna gain, and the distance between the femtocell and the macrocell . In this way, the transmission power of a femtocell can be expressed as follows:

$$P_F = min(P_M + G_\theta - PL_M(D) + PL_F(r), P_{max}) \ (10)$$

where PM indicates the macrocell transmission power. $G\theta$ represents the antenna gain. $PL_M(D)$ denote the macrocell path loss at distance D. Also, $PL_F(r)$ represents the femtocell path loss at radius r.

Figure 3 shows an illustration of the average throughput of a macrocell. The macrocell offloads the indoor UEs that are connected to it to femtocells. Therefore, it has been shown that the network operates better when additional femtocells are included. With an increase in the number of femtocells, a significant fluctuation in the cell's average throughput is seen; at the same time, the constant-range method outperforms both the fixed scheme and the proposed system in terms of throughput performance. When additional femtocells are added to the network, the proposed strategy outperforms all of the others in terms of overall performance and reliability.

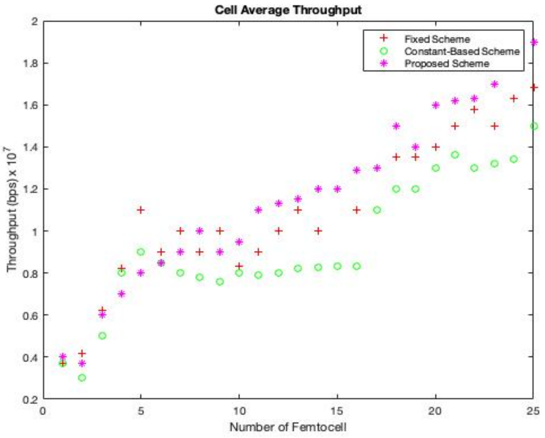

Fig. 3 Cell Average Throughput.

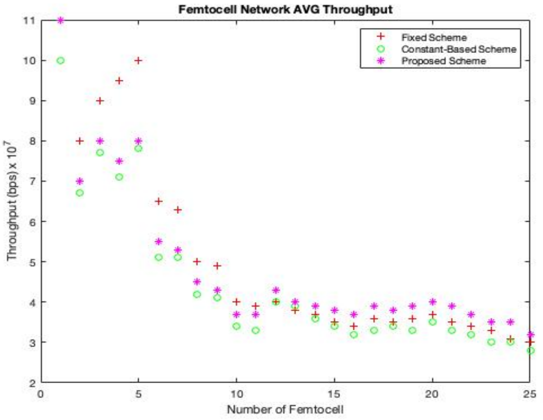

Fig. 4 Femtocell Network Throughput.

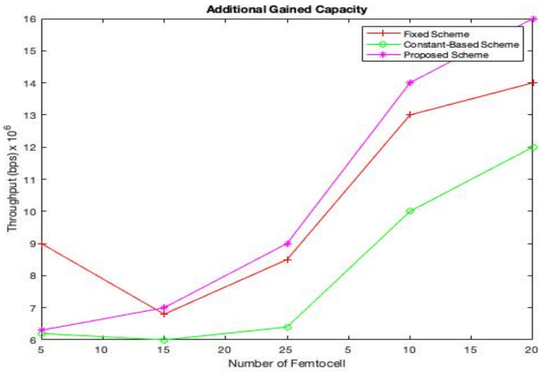

Fig. 5 Estimated Appended Throughput.

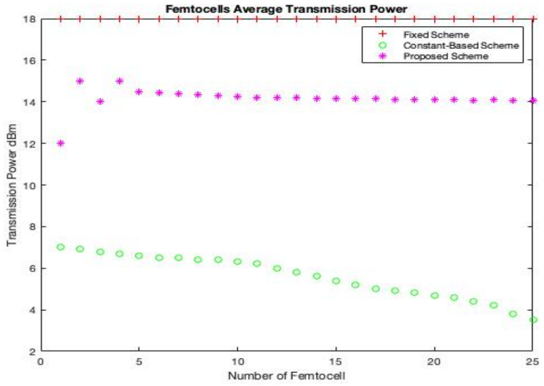

Fig. 6 Femtocell Average Transmission Power.

Figure 4 depicts the average throughput of a femtocell network. Macrocell throughput is completely ignored. As a result, the unwanted impact of co-interference, which is induced by dense deployment of neighboring femtocells, can be detected, and the system's performance is degraded as a result of this co-interference. A fixed transmission power strategy achieves high performance when just a small number of femtocells are inserted, as shown by experiments. However, when the number of inserted femtocells is increased, both the constant-range and proposed techniques outperform the fixed transmission power scheme in terms of performance, and they relieve interference better than the fixed transmission power scheme in terms of interference reduction. It is possible that the high level of transmission power of the fixed system may cause greater interference on neighbouring femtocells, resulting in a decrease in network performance.

As shown in Figure 5, the increased throughput that is achieved as a consequence of the insertion of femtocells has been calculated. The extra capacity shown in this figure varies depending on the number of femtocells that have been inserted. According to the results, the proposed scheme is the most effective scheme for delivering more extra capacity to the network, particularly when more femtocells are integrated into the system. Figure 6 also shows the average transmission power level of femtocells, which is a useful indicator of their performance. As a result, the transmission power level provided by the proposed method is neither higher than that of the fixed transmission power plan nor lower than that of the constant-range scheme. The proposed transmission power strategy, on the other hand, provides the greatest performance and has the potential to mitigate the adverse effects of interference more effectively than the other two methods.

5. Conclusion

Femtocells are being offered as a way to increase the capacity of the network while also improving its performance. Although femtocells have several advantages, the extensive and unplanned deployment of femtocells increases the amount of interference, which lowers their benefits. Controlling the femtocell's downlink transmission power is one of the recommended strategies that is being examined in order to mitigate the adverse effects of the interference. Specifically, in this study, we suggested a technique that supports femtocells in setting their transmission power depending on their nearby coverage in order to reduce excessive power consumption while also mitigating the negative impact of interference between neighboring femtocells. Therefore, a simulation is conducted to validate the suggested scheme's efficiency. Comparing the proposed scheme to the fixed transmission power scheme and the constant-range scheme, the simulation results show that the suggested method has the potential to provide more capacity. Furthermore, when compared to other schemes, it is the most effective in alleviating interference. More additional features would be examined in future development, such as increasing the capacity by increasing the power level depending on the received SINR value in order to improve the capacity, but with care for interference mitigation.

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