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DYNAMIC POWER TUNING FOR DOWNLINK INTERFERENCE MITIGATION IN HETEROGENEOUS LTE NETWORK

R. Sharanya, R. Gunasundari and K. Jayanthi
Department of ECE, Pondicherry Engineering College, Puducherry, India
E-Mail: rmsh027@gmail.com

ABSTRACT

Heterogeneous Long Term Evolution (LTE) network comprising femtocells leads to cross-tier interference that arises between macrocells and femtocells in both uplink and downlink degrading the performance of the cellular system. The downlink interference from the femtocell to Macro User Equipments (MUE) being the most serious interference case is focused in this work. A power tuning technique has been proposed to mitigate this interference taking into consideration the number of User Equipments present in the interfering femtocells along with the information received from the interfered MUE. Simulation results show that this scheme mitigates the interference to the MUE effectively while the total transmission power of femtocells also reduce in the process of interference mitigation which is an added benefit obtained effortlessly in the dense deployment of femtocells.

Keywords: LTE, femtocell, heterogeneous network, power tuning.

1. INTRODUCTION

The heavily growing data needs from the mobile users for real time services like gaming, VoIP, video-conferencing and other such services has led to the evolution of a new wireless standard called Long Term Evolution (LTE). LTE stands as a promising solution to meet the above requirements by incorporating OFDMA technique in the downlink providing 100 Mbps data rate and SC-FDMA technique in the uplink providing 50 Mbps data rate. The main goal of this emerging LTE is to increase the speed and capacity of the wireless data networks.Most of the traffic demand is from the indoor users but the signal between the user and the macro base station undergoes path loss and shadowing effects while penetrating through the walls thus degrading the service to the users. Heterogeneous network includes the addition of various small cells like picocells, femtocells and relay nodes to macrocell to enhance the system capacity and coverage by overcoming the dead zone problems. Femtocells which are user deployed are highly expected to be in usage because of its low cost and easy deployment.

Femtocells offer increased spectrum efficiency, improved capacity and good power savings. Therefore to meet the data needs of indoor users and to improve the capacity in LTE system, these femtocells are added into the existing macrocells forming heterogeneous LTE network.

Femtocells, also called home base station or Home evolved NodeB (HeNB), are low-power, low-cost wireless access points that gets connected to the mobile operator's network by means of the prevailing user's broadband connections such as cable, Digital Subscriber Line (DSL) or optical fiber. Femtocellsoperate in the licensed spectrum and can be deployed with the macrocell network in the same or different frequencies. Usually co-channel deployment is preferred due to the lack of frequency resources. These femtocells that are deployed in an unplanned manner which uses the same frequency causes serious interference to the Macro User Equipments (MUEs) that comes into its coverage area. Femtocells operate in three different modes namely Open Access Mode in which all MUEs can get access from the femtocells, Closed Subscriber Group (CSG) mode in which the registered users alone can get access from the femtocells and Hybrid Access Mode in which the registered MUEs will be given priority to unregistered users. Hence, the interference is serious in the CSG mode, wherein an unregistered MUE enters the femtocell coverage area. Since these MUEs are subjected to downlink interference caused by the femtocell, several methods have been proposed to mitigate this. 3GPP and Femto Forum have proposed several interference control methods of transmit power control [1], [2] and time domain based inter-cell coordinated scheduling solutions [3], [4]. Power control techniques for interference mitigation in heterogeneous OFDMA system have been discussed in [5]. Other techniques on power control in a two-tier OFDMA system is dealt in [6] and [7]. Frequency scheduling [8] and dynamic resource partitioning [9], [10] schemes for interference mitigation in OFDMA systems have also been done. This research work focuses on mitigating the downlink interference that takes place from femtocells to the Macro User Equipments (MUEs) without compromising the guaranteed service quality.

In this paper, the co-channel deployment of femtocells with macrocells is examined through simulations. A new femtocell power tuning technique has been proposed to mitigate the downlink interference based on the information received from the interfered MUEs while taking into account the number of Femto User Equipments (FUEs) present in the interfering femtocells. The power tuning of the femtocells in the process of interference mitigation also helps to minimize the power consumption with the dense deployment of femtocells. Thus the proposed scheme provides double benefit such that the proposed logic effectively mitigates the interference component as well as optimizes the power consumption.

The reminder of this paper is structured as follows: in section II, dynamic power allocation to the femtocells is briefly reviewed. Then the proposed dynamic power tuning scheme is explained in section III. The simulations and results are discussed in section IV. Section V concludes the paper.

2. EXISTING DYNAMIC POWER ALLOCATION

A dynamic power allocation to the femtocells for effective interference mitigation is discussed here. A downlink interference scenario is shown in Figure-1. As shown in this figure, although the MUE is close to the HeNB, it is not allowed to access the femtocell, because it is not the member of the HeNB's CSG users. Since the MUE is far from the MeNB, it experiences substantial interference from the HeNB, which results in its lower performance. To avoid this, the transmit power of the HeNB downlink should be set appropriately so that the interference to the macro user is tolerable. This method consists of updation of power to the interfering femtocells based on the information received from the interfered MUEs.

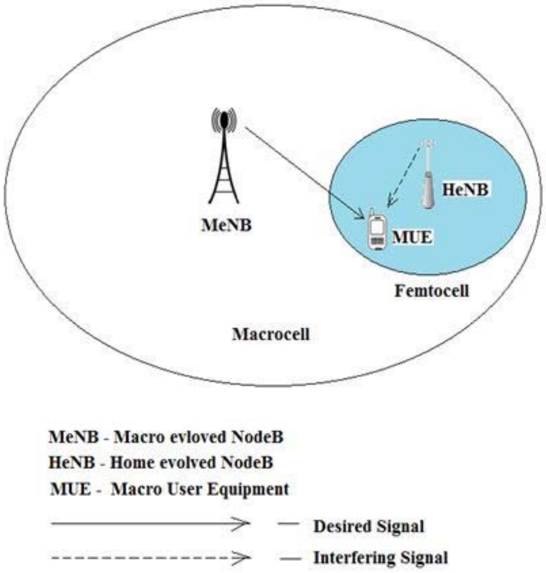

Figure-1. Downlink interference scenario.

This information from the MUEs contains the interference it receives from the femtocells. The interfering femtocells will then update their power based on the information it receives using the following formula [17].

$$HeNB_{power} = \frac{(P_{total} + Int_{total})}{\text{Total HeNBs}} - Int_{HeNB} \qquad (1)$$

where,

$HeNB_{power}$-Transmission powerof the femtocells

P_{total} -Totaltransmission power of interfering femtocells

Int_{total} - Total interference caused by the femtocells

Int_{HeNB} - Interference offered by that HeNB

Total HeNBs – Total number of femtocells present in the system

The MUEs measure the total interference it receives which includes the interference from the neighbouring six macro base stations (MeNBs), interference from the femtocells along with the thermal noise. When the received total interference exceeds the limit of -100dBm [17], the MUEs find that they are being interfered by the femtocells. The MUEs then informs the Macro Base Station about the interfering femtocells. The femtocells receive the information from the MeNBs and start to collect information from the interfered MUEs. The interfered femtocells will update their power based on the above given formula. Through this the interference to the MUEs gets reduced reflecting in the increased throughput of the MUEs along with the increased average system capacity of the macrocell.

3. PROPOSED DYNAMIC POWER TUNING SCHEME

In this section, the proposed power tuning scheme is discussed in detail. Taking into account the interference scenario in Figure-1, when a MUE get close to the femtocell, it would receive strong downlink interference signal from the HeNB. Normally, the MUE will try to initiate the cell reselection [11] or handover procedure [12]. If the HeNB is working in CSG mode and the MUE is not a member of the CSG users, the MUE will be refused to access the femtocell. However, the MUE would report the RSRP (Reference Signal Received Power) with the corresponding cell's PCID (Physical Cell Identity) and CQI (Channel Quality Indicator) message to the MeNB, which indicates which HeNB is interfering with the MUE.

In the proposed scheme, the power updation of the femtocells is done based on two entities,

i) The information received from the interfered MUEs

ii) Number of Femto User Equipments (FUEs) present in the femtocells causing interference.

After finding that the BS causing interference is a HeNB, the MeNB will send an interference message to the MUE. The MUE then forwards this message to the interfering HeNB. Since there is no X2/S1 interface between MeNBs and HeNBs as specified in Release 8/9, the interference message need to be forwarded by the MUE to the HeNB. The process of forwarding interference messages has been discussed in [13], [14] and [15].

The proposed power tuning scheme adjusts the transmission power of the femtocells when receiving the interference message from the interfered MUEs. The scheme is illustrated in Figure-2.

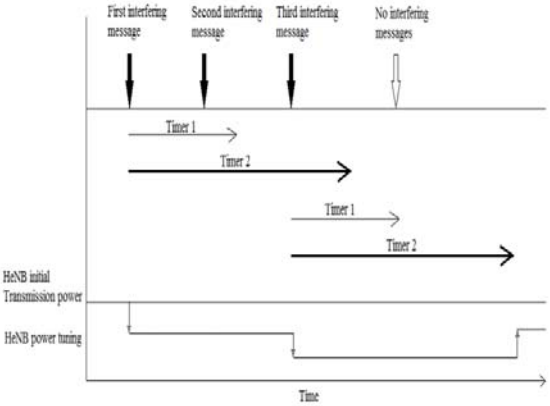

Figure-2. Power tuning illustration of HeNB.

In this scheme, in order to adjust the rise and fall of the transmit power of the HeNB, two timers are used namely Timer 1 and Timer 2. The HeNB sets its Timer 1 and Timer 2 when it receives the first interference message from the MUE. Once the timers are set, all the HeNBs causing interference would update their power based on the interference message and then diminish their transmission power based on the number of User Equipments, they contain. If the number of User Equipments present in those interfering HeNBs is more than one, the HeNBs reduce their transmission power by 4dBm and if the number of User Equipments is only one, then the HeNBs would reduce their transmission power to 10dBm which is sufficient to provide service for that single User Equipment.Timer 1 is used to monitor unnecessary reduction in the transmission power of the HeNBs wherein the HeNBs will not reduce their transmission power even if they receive new interfering messages from MUE until Timer 1 runs out. But the HeNBS could not keep on work on their decreased transmission power. Hence, Timer 2 determines when the transmission power of HeNBs has to rise again. The value of Timer 2 is taken to be smaller than that of Timer 1 because the HeNBs still may be causing interference to the MUE.

Figure-2 clearly shows that the HeNB will not respond to newly arriving interfering messages until Timer 1 runs out. When the HeNB receives interfering message after Timer 1, it would undergo power control after initiating the timers again and this process goes on with time. The flowchart shown below clearly demonstrates the proposed power tuning scheme.

4. SIMULATION RESULTS

The simulation model and results are discussed in detail here. The following Figure-4 shows the snapshot of the simulation scenario with HeNBs, MeNB and Macro User Equipments (MUEs). The circles represent the HeNBs and the squares denote the MUEs with a MeNB at the centre of circle.

The downlink SINR and the system capacity are calculated using the following formulas.

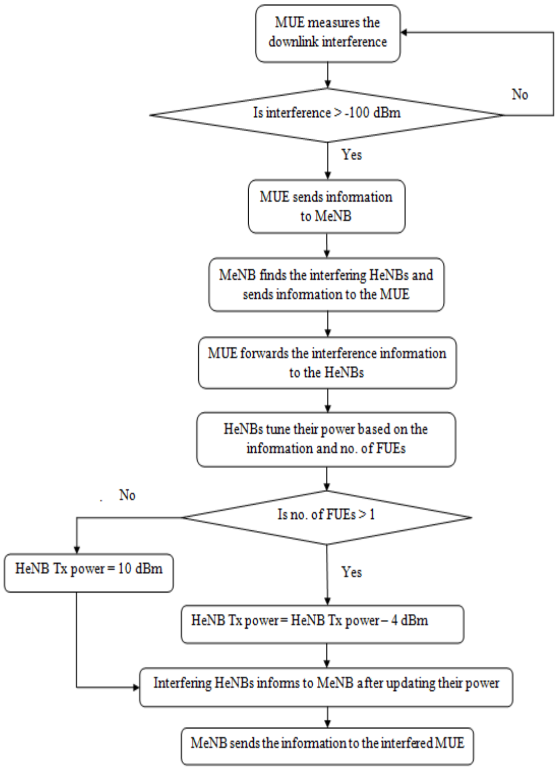

Figure-3. Flowchart for the proposed power tuning scheme.

$$SINR_{MUE\text{-}downlink} = \frac{P_{t,m}\cdot x_0^{-\alpha_1}}{\sum_1^{n_m} P_{t,m}\cdot x_i^{-\alpha_1} + \sum_1^{f} P_{t,f}\cdot l^{-\alpha_2}\cdot 10^{\frac{-\xi}{10}} + wN_0} \quad (2)$$

where,

$P_{t,m}$ -Transmission power of MeNB
x_0 -Distance between the MeNB and Macro User Equipment
x_i - Distance between MUE and ith MeNB
n_m - Number of MeNBs
f - Number of HeNBs
l - Distance between the MUE and HeNB
α_1 - Path loss exponent at macrocell
α_2 -Path loss exponent at femtocell

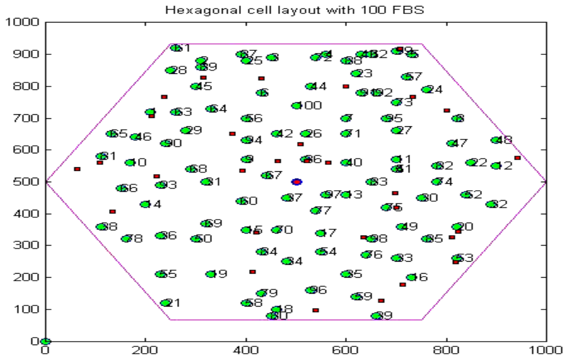

Figure-4. Simulation scenario snapshot.

β - Penetration loss
w - Bandwidth
N_0 - Power spectral density of thermal noise

Downlink capacity=w.log$_{2.}$(1+SINR$_{\text{MUE-downlink}}$) (3)

where,

SINR$_{\text{MUE-downlink}}$ - Signal to Interference plus Noise Ratio in the downlink.

The simulation parameters employed for this study is obtained from [16, 17, 18] and is tabulated in Table-1.

Table-1. Simulation Parameters.

Parameter	Value
Cellular Layout	Hexagonal 7 cell layout
Inter-cell distances of MeNBs	500 m
Femtocell radius	10 m
Thermal noise	-174 dBm/Hz
Bandwidth	20 MHz
Transmission power	MeNB: 46 dBm HeNB: 10-23 dBm
Carrier frequency	2.5 GHz
Number of MUEs in a cell	1
Number of UEs in a femtocell	Maximum: 4
Timer 1 limit	50 ms
Timer 2 limit	100 ms
HeNB transmission power	Fall: 4 dBm Rise: 3 dBm

The simulation has been carried out for 50 iterations for convergence and the results are as follows. The average system interference and total transmission power of HeNBs are compared for dynamic power allocation scheme, power tuning based on FUE which adjusts the transmission power of HeNBs taking into account the number of User Equipments it contains and the proposed dynamic power control scheme.

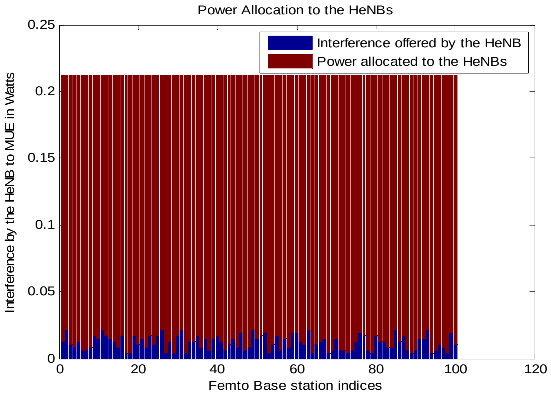

Figure-5. Proposed power allocation to the HeNBs.

Based on the proposed power tuning scheme, the power allocation to the HeNBs that cause downlink interference to the MUE are shown in Figure-5. The power allocation is done using the two factors described above.

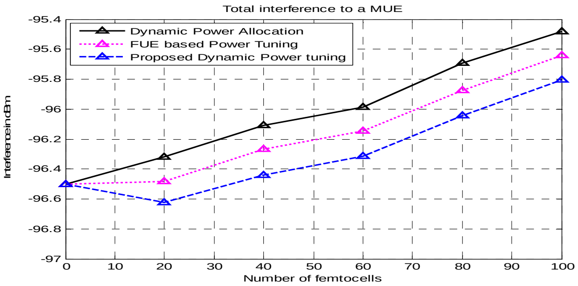

Figure-6. Average macrocell system interference.

Figure-6 represents the average macrocell system interference which includes the total interference experienced the Macro User Equipment (MUE) from the neighbouring MeNBS, HeNBS present in the macrocell and thermal noise. Figure shows that the proposed power tuning scheme reduces the interference to the MUE considerably. This is because, the proposed scheme takes into consideration the number of Femto User Equipments (FUEs) present in the interfering femtocells along with the information received from the MUE.

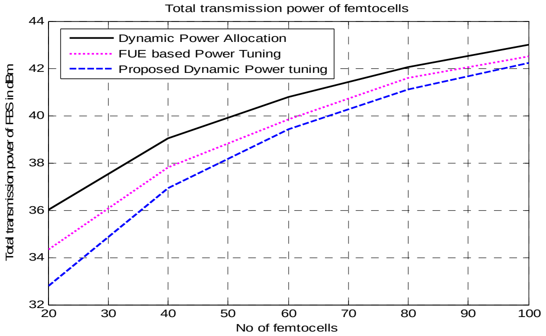

Figure-7. Total transmission power of femtocells.

The total transmission power of femtocells in is compared for all three schemes. As shown in the Figure-7, the transmission power of femtocells decreases in the proposed scheme. This is a byproduct achieved in the process of controlling interference. In a macrocell, when femtocells are deployed densely the total power consumption of the entire system increases. This decrease in the transmission power of the femtocells in the process of interference mitigation would be efficient when more number of femtocells is deployed.

5. CONCLUSIONS

The downlink interference mitigation between femtocells and macrocells in co-channel deployment in LTE has been carried out by implementing a novel dynamic power tuning scheme. The performance of the system is compared in terms of interference, capacity and transmission power of the femtocells. From the results, the proposed scheme is better at mitigating the downlink interference from the femtocells to the Macro User Equipments (MUEs) which subsequently increases the capacity of the system. Moreover, when the femtocells are deployed in a dense fashion, the proposed scheme would work efficiently which promotes reduced energy consumption of the system. The interference from the femtocells to the MUEs is reduced by tuning the power of the interfering femtocells. This ensures that the proposed logic eventually culminates into green engineering, which is the need of the hour.

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