A Novel Downlink Power Setting Scheme For Macro-Femto Heterogeneous Networks

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Abstract. In heterogeneous networks containing macro cells and femto cells, power setting is one of the effective techniques to reduce downlink inter-cell interference. In order to diminish inter-cell interference level of the systems and improve system spectrum efficiency, a novel adaptive power setting scheme is proposed and evaluated with other conventional power setting schemes by simulation. Simulation results show that the proposed scheme can improve the edge and average spectrum efficiency of femto cell significantly when there are few indoor macro UEs and reduce system inter-cell interference when there exist macro users close to the femto cell.

Keywords: power setting, heterogeneous network, power control, inter-cell interference, femto.

1 Introduction

Femto cell i.e. Home eNB (HeNB) comes into the spotlight due to its commercial potential [1-2]. It uses an access point (AP) regarded as a small base station (BS) which is connected to service provider's internet network. HeNB is the home base station with low cost and ordinary subscribers can buy and set it by them easily.

Although femto cell solves the coverage problem involving indoor users, there are still lots of problems to be solved in wireless network, which the most important is the interference problems. Since many service providers do not have enough frequency resource to provide services, macro cells and HeNB cells might use the same frequency resources. Consequently, when a macro user exists nearby a HeNB, the receiving signal of macro users will be interfered from the HeNB transmission signals. Similarly in downlink transmission, because of the interference, the SINR will be becomes lower and the data rate of macro user also reduces. [3-5].

In order to maintain the performance of macro users, the interference problem is a critical problem from the view point of service providers. Moreover, the notified users

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of the HeNB will be connected HeNB access point, so that only the owner of the HeNB could get benefits from the HeNB. Thus, non-authorized macro users nearby the HeNB access point can't access to the HeNB and suffer from significant interference from the HeNB even if the received signal power of the HeNB is larger than that of their current serving macro eNB [6-7]. In previous research on reduction of inter-cell interference for heterogeneous networks, a technique of setting eNB's transmit power receives considerable attention [8]. However, all the existing power setting schemes are setting HeNB's transmit power statically and not considering whether there are victim macro users close to the HeNB or not.

In this paper, a novel adaptive power setting scheme for a HeNB is proposed and verified by simulation. The adaptive scheme tries to reduce the inter-cell interference to the nearby victim macro users if they exist. On the other hand, the proposed scheme tends to improve the edge and average spectrum efficiency of the femto cell when there are few macro users close to the HeNB. Because of coverage problem, the macro eNB can't consider to control the power.

The rest of the paper is organized as follows. System model is presented in section 2. Conventional power setting schemes are introduced in section 3. And a new power setting scheme is proposed in section 4. Simulation results and analysis is presented in section 5. And a conclusion is drawn in Section 6.

2 System Model

We consider a simple Macro-Femto heterogeneous network scenario, where several HeNBs are deployed in a Macro cell. The scenario is illustrated in Fig.1, in which 2 HeNBs are shown for simplicity. HeNBs use the same frequency band as the Macro eNB. Therefore, for user equipment (UE), there are two kinds of downlink interference. One kind of downlink interference is from neighboring non-serving MeNB. The other kind is from neighboring non-serving HeNBs.

As in a 3GPP Long Term Evolution (LTE) system, transmission of downlink control channel signal employs the whole frequency bandwidth. In this paper, we consider UE's receive performance based on the whole frequency bandwidth.

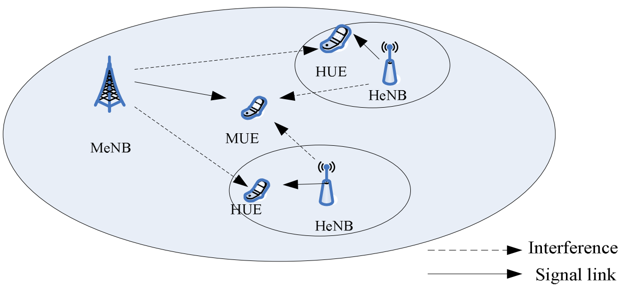

Fig. 1. Macro-Femto HetNet scenario

For a UE, we can obtain it's receive power as following:

$$R_{UE} = P_{SeNB} - PL_{SeNB\_UE} \tag{1}$$

Where R_{UE} is receive power of a UE in dB; P_{SeNB} is transmit power of its serving eNB in dB; PL_{SeNB_UE} is pathloss between the serving eNB to the UE in dB.

Similarly, we can obtain its suffering interference power as following:

$$I_{UE} = \sum_i P_{NSeNB,i} - PL_{NSeNB,i\_UE} \tag{2}$$

Where I_{UE} denotes interference power suffered by a UE in dB; $P_{NSeNB,i}$ is transmit power of the ith non-serving eNB in dB; PL_{NSeNB,i_UE} is pathloss between the ith non-serving eNB to the UE in dB.

Then the signal-to-interference plus noise-ratio (SINR) of a UE can be given as following:

$$SINR_{UE} = 10^{R_{UE}/10} \Big/ (10^{I_{UE}/10} + 10^{\sigma_n^2/10}) \tag{3}$$

Where σ_n^2 is the noise power at UE receiver in dB.

From above deviation, it is can be shown that there are several factors affect the SINR performance of a UE. These factors are transmitting power of neighboring non-serving eNBs, pathloss between the neighboring non-serving eNBs and the UE, and its receiver power from its serving eNB. In order to reduce interference and improve the receive performance of the UE, we need to either improve receiver power of the UE, or decrease the transmit power of its neighboring eNBs. However, decreasing transmit power of the neighboring eNBs may lead into problems, such as low system throughput, poor UE experience and shrunk cell coverage.

3 A Conventional Power Setting Scheme

As mentioned above, adjusting neighboring eNB's transmitting power is one of techniques to reduce interference level of the HetNet systems. As transmit power of a macro eNB determines its cell coverage, it is impossible for a macro eNB adjusts transmit power for purpose of interference reduction. On the other hand, a home eNB may serve few UEs indoor. We consider the power setting algorithms for a HeNB.

A conventional power setting scheme is that an eNB adjusts transmit power according to the objective SINR of its associated UEs. Assuming there is only one HUE associated with the HeNB, the transmit power of the HeNB can be given as follows.

$$P_{HeNB} = \max\left(P_{\min}, \min\left(PL_{HeNB\_HUE} + R_{HUE}, P_{\max}\right)\right) \tag{4}$$

Where P_{HeNB} denotes the transmit power of HeNB in dB; PL_{HeNB_HUE} is the pathloss between HeNB and the home UE (HUE) in dB; $P_{\max}$ and $P_{\min}$ are the maximum and the minimum transmit power limit of a HeNB in dB; respectively, R_{HUE} denotes the receive power of HUE in dB and can be obtained as following.

$$R_{HUE} = 10\log_{10}\left(10^{I_{HUE}/10} + 10^{\sigma_n^2/10}\right) + T \tag{5}$$

Where I_{HUE} denotes the interference power suffered by HUE; T is target SINR of the HUE.

As can be seen from the equation (4) and (5), a HeNB can adjust transmit power by setting the target SINR of its associated HUE. If the target SINR is set as a large value, the close-by non-associated UEs will suffer much heavy interference and may even experience radio link failure. On the contrary, if the target SINR is set as a low value, the nearby non-associated UEs will suffer the least interference from the HeNB. However, with a low target SINR, the HUE has to receive signal with a much low data rate.

4 New Power Setting Scheme

In order to diminish system interference level and improve cell throughput when there is no nearby victim non-associated UEs, we propose a new power setting scheme. In our proposed scheme, a HeNB may detect if there is a MUE close to it and estimate its pathloss to the closest MUE. There are some papers researches the calculation of pathloss between a HeNB and its close-by non-associated MUE [9-10].

Then the HeNB can set transmit power by adjusting the target SINR of its associated HUE according to its pathloss to the closest MUE.

Thus, the target SINR of an associated HUE can be given as equation (6).

$$T = T_{\min} + \Delta \tag{6}$$

Where $T_{\min}$ denotes the minimum limit of the target SINR of a HUE; Δ denotes an adaptive factor and can be given as follows.

$$\Delta = \max\left(\alpha(PL_{HeNB\_MUE} - PL_{HeNB\_MUE,\min}),0\right) \tag{7}$$

Where PL_{HeNB_MUE} is the estimated pathloss between the HeNB to its closest MUE; $PL_{HeNB\_MUE,\min}$ is a predetermined minimum threshold of the pathloss from the HeNB to MUE; α denotes coefficient for mapping rang of pathloss to the range of target SINR of the HUE.

Then, the receive signal power at HUE can be obtained by substituting equation (6) into equation (5). And the transmit power of the HeNB can be obtained by substituting equation (5) to equation (4).

From equation (6) and equation (7), we can see that the proposed new power setting scheme can adjust the target SINR of the associated HUE dynamically according to the pathloss difference of actual value to a minimum threshold. If the closest MUE is far from the HeNB, the adaptive factor Δ will be large as PL_{HeNB_MUE} is much greater than the minimum threshold $PL_{HeNB\_MUE,\min}$. In this case, the target SINR of the HUE is accordingly set as a large value and the transmit power of the HeNB will be high. It is reasonable the HeNB can transmit with a large power to increase its cell throughput when there is no close MUE. If the closest MUE is near the HeNB, the adaptive factor Δ will be small or even zero because PL_{HeNB_MUE} is approaching to the minimum threshold $PL_{HeNB\_MUE,\min}$. Then the target SINR of the HUE is accordingly set as a low value approaching to the minimum limit $T_{\min}$ to enable the associated HUE not to suffer a radio link failure. And the transmit power of the HeNB will be low to protect the closest MUE to keep a radio link connect to its serving MeNB.

5 Simulation and Analysis

In order to verify performance of our proposed power setting scheme, computer simulation is conducted. Furthermore, the conventional power setting scheme, i.e. PS1, and scheme of HeNB's transmit power being the maximum limit, i.e. no power setting, are simulated. In PS1, the target SINR is set as a lower value of -4 dB to protect nearby non-associated MUEs. In the simulation, we consider a cellular system containing 7 macro cells with 3 sectors in a macro cell [11]. Simulation scenario is illustrated in Fig.2. HeNBs are modeled as a Dual-stripe and deployed in a sector of the center macro cell.

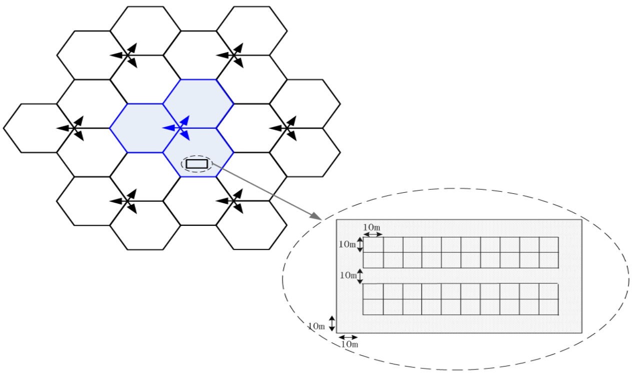

Fig. 2. simulation scenario

In the following figures, $P_{\_in}$ represents the probability of MUEs being indoors. PS1 is the conventional power setting scheme with fixed -4dB target SINR and PS2 denotes our proposed power setting scheme. NO PS is the scheme that HeNB transmit downlink control signal with the maximum power.

Fig.3 and Fig.4 are curves of UEs' SINR of the proposed power setting scheme when 35% of macro UEs being indoors.

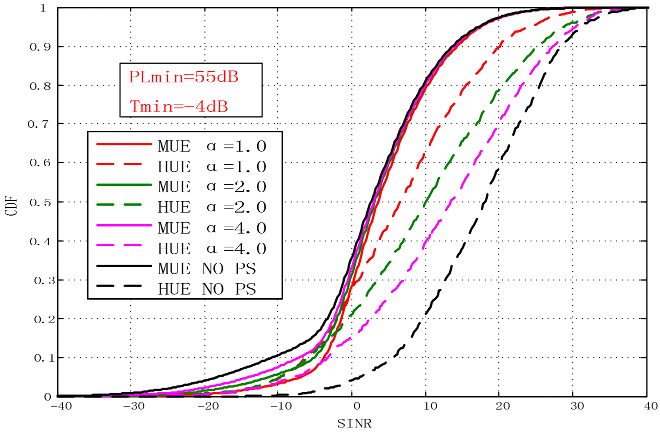

Fig. 3. CDF curve of SINR with different coefficient α

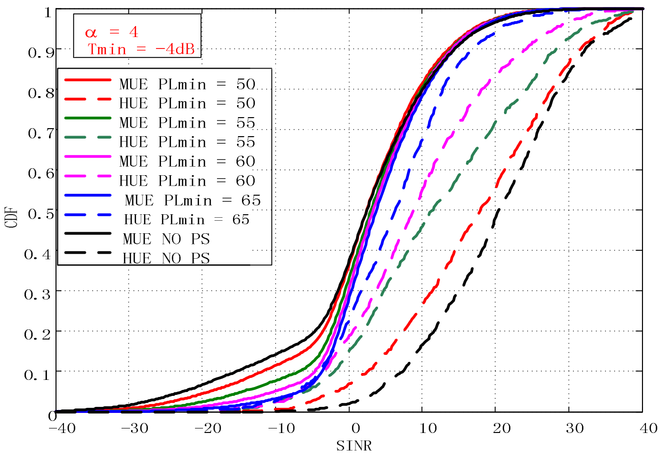

Fig. 4. CDF curve of SINR with different $PL_{HeNB\_MUE,\min}$

In Fig.3 with the minimum pathloss threshold $PL_{HeNB\_MUE,\min}$ invariant, the probability of HUEs with high SINRs increases when coefficient α increases. In the meantime, the probability of MUEs with low SINR also increases. In Fig.4 with α fixed invariant, the probability of HUEs with high SINRs decreases with the increase of $PL_{HeNB\_MUE,\min}$. Meanwhile, the probability of MUEs with low SINR also decreases. As can be seen from Fig.3 and Fig.4, $PL_{HeNB\_MUE,\min}$ and α have different effects on the system performance, $PL_{HeNB\_MUE,\min}$ is supposed to protect MUEs close to the HeNB and α is supposed to improve the throughput of HUEs when there is no nearby MUEs.

Fig.5 and Fig.6 illustrate SINR performance of different power setting schemes with different probability of MUEs being indoors. It is shown form the both figures that the proposed scheme has the similar probability of MUEs in low SINR range with the scheme of setting HUE's target SINR as -4dB. On the other hand, the proposed scheme has a much great probability of HUEs in high SINR range compared with the fixing target SINR scheme, especially when 11% of MUEs are randomly distributed indoors.

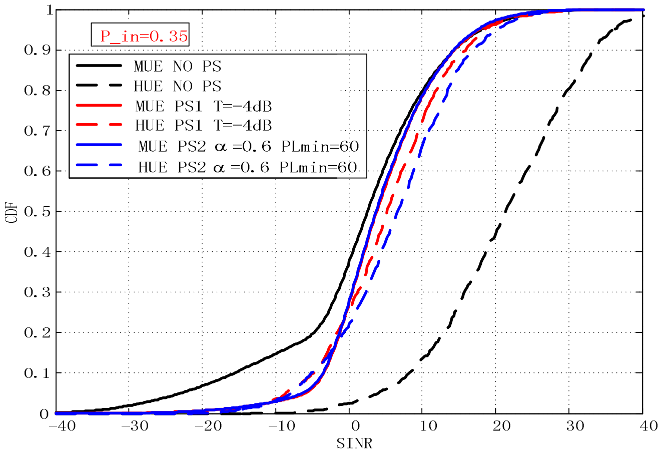

Fig. 5. CDF curve of SINR with 35% of macro UEs being indoors

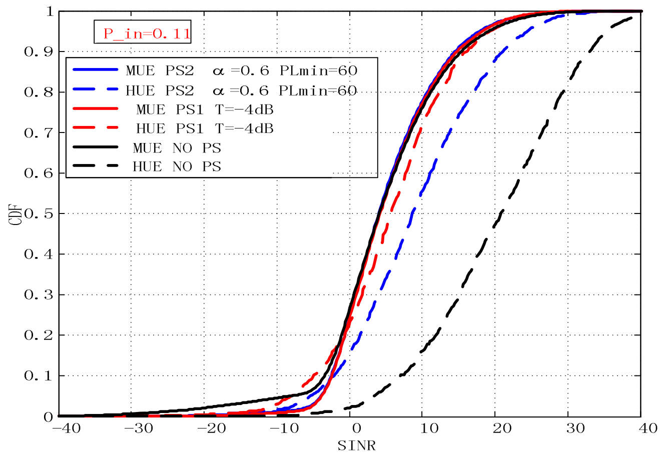

Fig. 6. CDF curve of SINR with 11% of macro UEs being indoors

Performance of different power setting schemes in terms of spectrum efficiency (SE) and the outage probability is listed in Table 1 and Table 2.

As can be seen from the tables, the proposed scheme has similar outage performance with the fixed target SINR scheme while has much higher edge and average throughput for the femto cell. Simulation parameters are in table 3.

Table 1. Performance of different power setting scheme with 35% MUE indoors

Throughput	NO PS	PS1	PS2
Outage for MUE (assuming -6dB)	18.25%	5.01%	5.37%
Outage for HUE (assuming -6dB)	0.58%	8.17%	8.21%
Edge HUE SE [bps/Hz]	1.10 (100%)	0.10 (-90.90%)	0.13 (-88.18%)
Ave HUE SE [bps/Hz]	3.57 (100%)	1.52 (-57.42%)	1.69 (-59.17%)

Table 2. Performance of different power setting scheme with 11% MUE indoors

Throughput	NO PS	PS1	PS2
Outage for MUE (assuming -6dB)	5.83%	1.84%	2.18%
Outage for HUE (assuming -6dB)	0.58%	8.12%	4.04%
Edge HUE SE [bps/Hz]	1.0 (100%)	0.12 (-88%)	0.22 (-78%)
Ave HUE SE [bps/Hz]	3.49 (100%)	1.57 (-55.01%)	2.06 (-40.97%)

Table 3. Simulation parameters for HeNB deployment

Parameter	Assumption
Carrier bandwidth	10 MHz
Femto Frequency Channel	same frequency and same bandwidth as macro layer
Cell Radius	10 m
Min separation UE to femto	3m
Number of Tx antennas at femto	1
Femto antenna pattern	Omni antenna elements
Femto antenna gain	5 dBi
Min/Max Tx power femto	-10/20 dBm
Maximum number of femto UE per femto	1

6 Conclusions

In a heterogeneous system deployed with macro eNBs and home eNBs, a macro UE may move to a position close to a home eNB. However, the macro UE can’t access to the home eNB as the home eNB serves for a closed subscribe group. In this case, the macro UE will suffer heavy interference from the home eNB and may loss radio link connect to the serving macro eNB. An adaptive power setting scheme is proposed in this paper to diminish inter-cell interference to macro UEs and improve the edge and average spectrum efficiency of the femto cell when there is no macro UE surrounding the home eNB. Simulation results show that the proposed scheme can reduce inter-cell interference to the macro users close to the femto cell and improve the throughput of femto cell significantly especially when few MUEs being indoors.

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