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Downlink beamforming in a two-tier macro femtocell network with decentralized spectrum allocation and partitioning

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Abstract

In order to reduce cross-tier interference in downlink beamforming settings, this paper analyses several spectrum allocation and partitioning strategies. Beamforming increases SIR, allowing more femtocells to share the microcell's spectrum, which increases spectrum efficiency. To select whether femtocells should utilize the entire or partitioned spectrum with acceptable control overhead, we first construct a simple centralized system as the optimal solution and then offer a feasible decentralized approach. In this paper, we examine two distinct probabilistic femtocell base station (HeNB) selection methods with the goal of optimally capitalizing on sparse information about the received signal strength. We control the outage probability for a microcell user under two different selection policies—equal selection and interference weighted selection. We show via performance assessment that our decentralized method greatly outperforms a standard cochannel deployment scheme in terms of outage probability and cell capacity. We also demonstrate that our suggested strategy improves upon the spectrum partitioning scheme with a fixed ratio, while maintaining a level of cell utility that is competitive with the centralized scheme.

Introduction

Mobile operators are taking notice of femtocell deployment as a high-bandwidth, low-cost option for the next generation of wireless networks. In order to improve indoor coverage, femtocells use IP networks to backhaul incoming traffic while using little power. Femtocells offer mobile convergence services through the broadband backhaul in long-term evolution (LTE) networks, and they operate in the licensed spectrum controlled by a mobile operator. Capacity expansion, improved coverage, and lower handset power consumption are just a few of its advantages [1]. However, the cross-tier interference between microcells and femtocells, as well as the co-tier interference, presents additional control issues when microcell and femtocell networks coexist at the same frequency. While research on co-tier interference management is substantial [2–7], addressing interference between tiers remains an important technological issue [1,8].

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Uplink capacity in overlayed macro-cell/microcell code division multiple access (CDMA) systems has been studied in previous works on a two-tier network [9,10]. For independently installed femtocell networks, this can be an unrealistic assumption [8]. Managing cross-tier interference between pre-existingmicrocell and femtocell networks [1,8] is a critical technological implementation challenge in a two-tier network. Femtocells should be planned so as to reduce the low-level interference [11,12] so as to have little effect on the performance of the current microcell network. via put performance of cochannel deployment of femtocells and microcells has been extensively explored via simulations in [13], particularly with regard to cross-tier interference. One way to reduce cross-tier interference is to use separate frequency bands for microcell and femtocell networks [14]. However, sharing the same spectrum is preferred due to the limited availability of radio resources and the complexity of spectrum distribution.

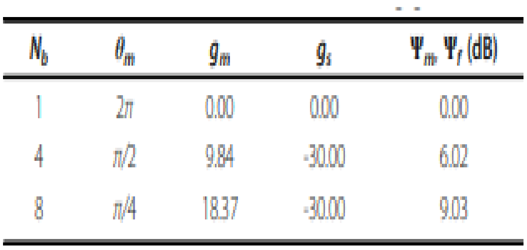
a model of the system

We think of a two-tiered network with a microcell network and many femtocell networks. The microcell network consists of a single microcell ephemeral eNB (MeNB) and a single macrocell user (MUE) within a cell radius of Rm. Each femtocell network has a radius of Rf (Rf Rm), where Kt represents a group of Heterogeneous Network Base Stations. For purposes of privacy and security, femtocells are thought to provide restricted access to a small group of authorized subscribers located within a building within radio range of the femtocell. A femtocell user (HUE i) is presumed to be connected to each HeNB i. Femtocells are placed on top of the current macrocell infrastructure and use the same frequencies as the macrocells below. Spectrum limitations force both femtocells and microcells to partly or entirely reuse the same frequency spectrum, which may cause interference with other networks. Cross-tier interference occurs when a femtocell network interacts with a microcell network, while co-tier interference is created by neighbour boring femtocells. Due of the little impact of noise on an interference-limited network, we shall disregard it as background thermal noise in simple city. In this work, we split severely interfering femtocells with the goal of reducing cross-tier interference between microcells and femtocells in the downlink. Beamforming transmission, which we use, boosts the power of the targeted signal while simultaneously dampening unwanted noise. We assume that the base stations (Meknes and HeNBs) have beamforming antennas but the user equipment's (MUEs and HUEs) do not.

Third-best spectrum-splitting proportion and single-source algorithm

Heterogeneous femto-microcell networks are vulnerable to severe performance loss due to cross-tier interference generated by neighbouring active users. Spectrum sharing and spectrum partitioning are two methods for reducing interference. While the quantity of cross-tier interference is reduced by using partitioned spectrum, the amount of usable spectrum is decreased. When users pool their spectrum resources, they benefit from more available frequencies but are subject to more disruptive cross-tier interference. Hybrid spectrum utilization, which takes advantage of both kinds of spectrums, is also an option. Significant cross-tier interference may be experienced by UEs when they are placed close to an active cross-tier transmitter, such as a MUE close to active HeNBs or a HUE close to an active Men. The spectrum must be split in half to prevent this from happening. Less than half of it, shared spectrum Both microcell and femtocell networks utilize the same frequency without interfering with one another. The remaining spectrum is "partitioned," meaning it is reserved for use by femtocell networks. This article addresses two issues related to reducing cross-tier interference. The difficulty of deciding which HeNBs should utilize the partitioned spectrum is called the spectrum allocateton problem. To determine how much spectrum should be shared and how much should be partitioned, we must solve the spectrum

table 1 Number of beams and beamforming gain



N_b	θ_m	g_m	g_s	Ψ_m, Ψ_f (dB)
1	2π	0.00	0.00	0.00
4	$\pi/2$	9.84	-30.00	6.02
8	$\pi/4$	18.37	-30.00	9.03

partitioning issue. We shall examine in depth how the channel input from each HeNB i is necessary for optimum spectrum allocation in Section. We first determine the optimal spectrum partitioning ratio, v p, as a function of the fraction of a cell's spectrum that is partitioned, | Kp|, using an analytical method.

Distributed Systems for Allocating and Partitioning the Spectrum

Here, we provide a system for the distributed allocation and division of the spectrum. Each HeNB in our method may choose to utilize either the whole or partitioned spectrum, with just the barest minimum of cross-tier feedback.

Distributed algorithm

Aside from HUE and HeNB SIR measurement tests, the decentralized spectrum allocation algorithm requires. In Algorithm 2, we outline a decentralized approach to allocating spectrum, and in Figure 3, we outline the methods for sending and receiving control signals. i MeNB uses beamforming transmission to send a pilot signal in the first test. HUE i tells its connected HeNB i that it is part of F1 if it has the necessary SIR q f ; otherwise, it tells its connected HeNB i that it is part of F2. In the second experiment, MUE sends out an omnidirectional pilot signal, and HeNB i calculates the intensity of the interference it causes by measuring the strength of the signal it receives from MUE. Cross-tier interference is communicated from HeNB i to MUE ii. iii. MUE measures SF1 and communicates it to the HeNBs in F1. In this part, we will discuss two different HeNB selection strategies, the equal selection policy and the inter ference weighted selection strategy, and how they affect the cross-tier feedback from MUE to HeNBs. To comply with the equal. Selection policy, MUE must broadcast SF1 information to all F1 HeNBs through the backhaul. When using the interference weighted selection approach, however, MUE modifies the strength of the transmitted pilot signal such that PS:= PtSF1. As a result of the previous cross-tier handshake, each HeNB I knows the channel response hi between MUE and HeNB I, allowing HeNB I to estimate I in ii, allowing HeNB I to recover SF1 from the received signal of PS. Each HeNB I chooses whether to employ the complete spectrum or the partitioned spectrum with a probability ps. Instead of the heavy lifting of gathering channel status information at the MUE, each HeNB uses a probabilistic decision process instead. In Section 4.2, we detail the steps necessary to derive PS from SF1.

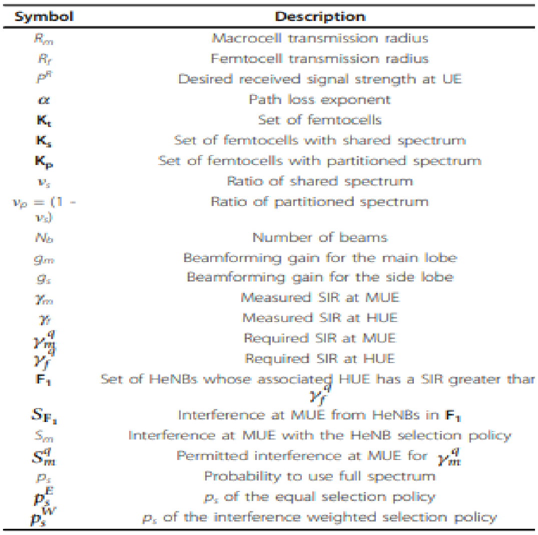
Evaluation of Performances

Here, we take into account the typical number of HeNBs making full use of the spectrum and utilize simulations to determine the spectrum's efficiency. The likelihood of outages in the centralized, decentralized, and spectrum-free schemes is examined. We also look at the connection between cell functionality and the ratio of common spectra. For the sake of our simulations, we set |Kt| equal to 100, assuming that each microcell site has 100 femtocells. Our calculations are based on a centrally positioned Men with a 500-meter transmission range (Rm). The Rf transmission range of each HeNB inside the microcell site is 20 meters. We have performed extensive simulations over several randomly generated topologies and shown the average outcomes here. We used wm = 10 for the MUE utility weight and wf = 1 for the HUE utility weight. Beamforming sharpness of the main lobe is represented by the number of beams in a MeNB or HeNB, which may be Nb Î 1, 4, or 8.

$$\left(\text{i.e., } \theta_m = \frac{2\pi}{N_b}\right).$$

The beam gains of the main lobe and the side lobe are denoted by gm and gs, respectively, in dB scale and the average beamforming gain in the twotier network by Ψ(Nb). The path loss exponent parameters a’s for MUE and HUEs are uniformly distributed in [3,5]a . We set the UE noise figure at -174 dBm/Hz and the spectrum bandwidth at 20 MHz which follow the 3GPP LTE specifications. The system parameters and notations are summarized in Table 3.

table 3 Definition of notations



Symbol	Description
R_m	Macrocell transmission radius
R_f	Femtocell transmission radius
P^R	Desired received signal strength at UE
α	Path loss exponent
$\mathbf{K_t}$	Set of femtocells
$\mathbf{K_s}$	Set of femtocells with shared spectrum
$\mathbf{K_p}$	Set of femtocells with partitioned spectrum
ν_s	Ratio of shared spectrum
$\nu_p = (1 - \nu_s)$	Ratio of partitioned spectrum
N_b	Number of beams
g_m	Beamforming gain for the main lobe
g_s	Beamforming gain for the side lobe
γ_m	Measured SIR at MUE
γ_f	Measured SIR at HUE
γ_m^q	Required SIR at MUE
γ_f^q	Required SIR at HUE
$\mathbf{F_1}$	Set of HeNBs whose associated HUE has a SIR greater thar γ_f^q
$S_{\mathbf{F_1}}$	Interference at MUE from HeNBs in $\mathbf{F_1}$
S_m	Interference at MUE with the HeNB selection policy
S_m^q	Permitted interference at MUE for γ_m^q
p_s	Probability to use full spectrum
p_s^E	p_s of the equal selection policy
p_s^W	p_s of the interference weighted selection policy

The distance-based allocation method, which divides femtocells into inner and outer kinds depending on their distance from MeNB, is first compared to the centralized and decentralized spectrum allocation schemes. Spectrum is divided into inner and outside femtocells, with the latter using the former. Due to the lack of consideration for beamforming settings in prior hybrid spectrum methods, we use the distance-based strategy with beamforming in [23]. Figure 5 depicts the CDF (cumulative distribution function) of |Ks| when q m = 0 dB, and Figure 6 depicts the average number E[|Ks|] of HeNBs that utilise the whole spectrum. If the beamforming is more precise, then more HeNBs will be able to share the spectrum with the microcell network, increasing the value of |Ks|. For a particular beamform ing gain, the 'Centra lized' centralized algorithm has the maximum |Ks|. Both the equal selection policy (labeled 'Decentralized Equal') and the interference weighted selection policy (labeled 'Decentralized Weight') are examples of decentralized systems whose |Ks| are very close to that of the centralized scheme. The 'Dis tance-based' approach uses a set distance threshold and the average channel model without knowledge of the current channel state, hence it has a smaller number of E[|Ks|]. Using interference cancellation using MIMO and beamforming communication methods, we can reduce interference. However, the outage performance is still severely impacted by cross-tier interference if all HeNBs share the macrocell spectrum without interference mitigation, and this is true even with beamforming transmission. Figure 7 depicts MUE's outage performance with and without cross-tier interference mitigation. Here we show the 'Without IM' version of the cochannel deployment with beam forming transmission, where all HeNBs use the same microcell spectrum. The chance of an outage in MUE increases to between [10-1] and [10-2] if a spectrum partitioning technique is not used. By distributing most likely severely interference-generating HeNBs to the partitioned spectrum, our decentralized allocation and partitioning techniques effectively lower the outage probability. It also demonstrates that an increase in beamforming gain reduces the likelihood of an outage. Note that the distance-based scheme does not suffer an outage either due to its conservative spectrum sharing approach, i.e., lesser number of |Ks|, and the centralized scheme does not experience an outage at all due to the utilization of all the co-tier and cross-tier channel information.

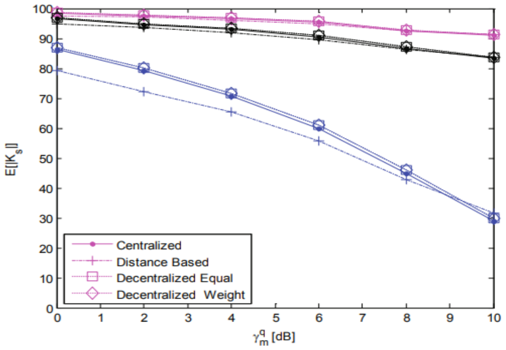


figure 1 Average number of sharing HeNBs versus required SIR at MUE.

Figure 1 highlights the relationship between the SIR requirement and the outage probability and the ensuing E[|Ks|]. In the 'Without IM' scheme, all HeNBs utilize the cochannel with the microcell network, which results in the very disruptive cross-tier interference. When Nb = 4, the chance of a 'Without IM' outage is close to 10-1, but at Nb = 8, it drops to 10-2. It demonstrates that the outage probability is much reduced thanks to interference mitigation, particularly when the decentralized weight strategy is used. In most cases, the frequency of the outage increases as the SIR requirement becomes more stringent. Figure 1 shows that when q m increases, the out-of-age probability reduces in the proposed method, denoted by E[|Ks|]. Because of this, we see that as E[|Ks|] becomes larger—that is, as q m decreases—the likelihood of an outage rises. Figure 9 displays the cell capacity at MUE q m with Nb = 1, and Figure 10 displays the utility performance according to the requirement SIR. Our decentralized spectrum splitting strategy is compared to a centralized approach with fixed ratios of vs = 0.5 and 0.9. when illustrated in Figure 1, when q m rises, the capacity of each UE grows logarithmically, yet |Ks| shrinks. As a result, there is a little rise in cell capacity as q m increases. When compared to the centralized strategy, our probabilistic spectrum allocation and partitioning techniques perform similarly in terms of cell capacity and utility. However, the cell capacity and utility of the fixed spectrum parti toning scheme with s = 0.5 and 0.9 are lower than those of our systems. Cell capacity and utility are both lowest in the 'Without IM' scheme because to the extreme cross-tier interference that occurs.

conclusion

To reduce cross-tier interference in downlink beamforming situations, we offer spectrum allocation and partitioning techniques. With efficiency and equity in mind, we analytically computed the ideal ratio of spectrum partitioning to optimize cell utility. Our distributed method needs less cross-tier feedback because of the probabilistic aggregation of cross-tier interference. In terms of overall cell capacity and utility, our simulation findings demonstrate that the proposed decentralized method with the interference weighted HeNB selection criteria is on par with the centralized system. The cross-tier interference issue in a large-scale two-tier network is also efficiently resolved by the employment of reduced cross-tier control overhead.

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