

FIXED COORDINATED BEAMFORMING WITH FAIRNESS TECHNIQUE IN HETNETS

Sirada Samomob^{1*}, Monthippa Uthansakul¹, Thossaporn Chanpuek², and Pongnarin Sriploey²

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Abstract

Heterogeneous networks consist of different base stations and levels of transmission power. Thus, beamforming interference is caused to the users in other base stations. Currently, a base station considers the weights by evaluating the maximum value of SINR at each user. However, the pico users still receive a weak signal. Therefore, we propose a technique to select the weighting which introduces a similar SINR between the user in a pico base station and the user in the macro base station. The SINR threshold of the macro user is defined as a condition to select the optimum weights. Moreover, we compare the proposed method with normal fixed coordinated beamforming. The simulation results show that the pico users receive the higher SINR and throughput.

Keywords: Coordinated beamforming, HetNets, fairness, SINR

Introduction

Currently, mobile phones are increasingly used in daily lives. For example, they are used for calling, sending messages, and entertainment such as online games, music streaming, and video streaming. These applications require a huge data bandwidth. In some situations, a base station cannot support a sufficient bandwidth. To solve the

problem, heterogeneous networks (HetNets) which deploy small cells into a large cell's coverage area are considered. These networks can provide higher data bandwidths in the city and in poor signal areas.

The concept of HetNets consists of applying different base stations to improve the performance of a wireless network (Khandekar

¹ School of Telecommunication Engineering, Institute of Engineering, Suranaree University of Technology, Nakhon Ratchasima, 30000, Thailand. E-mail: M5840731@g.sut.ac.th; mtp@sut.ac.th

² Program in Industrial Education, Nakhon Ratchasima Rajabhat University, Nakhon Ratchasima, 30000, Thailand. E-mail: thossaporn.c@nrru.ac.th; pongnarin.s@nrru.ac.th

* Corresponding author

et al., 2010). In addition, HetNets are flexible and have low installation costs because small cells are installed in urban areas in which there are many people but the limited space means that a large cell cannot be installed. As to the benefit of HetNets, inter-cell interference occurs as a result of the same frequency being utilized in the large base station and a small base station. This problem affects users in terms of low received signal-to-interference-plus-noise (SINR).

Recently, many solutions for the inter-cell interference problem have been proposed. One of these techniques is the fractional frequency reuse technique which mitigates the inter-cell interference by dividing and reusing the frequency resources. Another popular technique is adaptive beamforming which adapts the radiation pattern by depending on the interference levels (Hamza *et al.*, 2013). The concept of adaptive beamforming is to form a main beam to the desired direction and form a null to the interference direction. However, when using adaptive beamforming in HetNets, a base station requires knowledge of all the users' locations in the network. Then, a base station provides a higher performance of beamforming since each base station selects a suitable weight for its users. Moreover, a base station reduces the inter-cell interference by pointing its null to users in other base stations.

From the literature, there are many ways for solving inter-cell interference by using coordinated beamforming. Coordinated beamforming solves inter-cell interference in cluster HetNets which are considered for different environments such as a stadium or an urban area. Besides, a bottleneck problem of coordinated beamforming is improved by utilizing a reference signal (Nagaraj *et al.*, 2014).

Coordinated beamforming solves inter-cell interference by adopting the average channel gain in order to consider a suitable base station for each user (Oguejiofor and Zhang, 2016). This paper studies an effect of inter-cell interference from other clusters which cannot exchange the channel information. The results show that coordination leads to higher effectiveness than no coordination (Belschner *et al.*, 2015).

Coordinated beamforming can point a main beam to the desired user and point nulls to the interference signal by adjusting the weighting coefficients at an individual antenna. Weight selection can be divided into 2 groups. The first group is a method to select the weights without predefining the weight coefficients. For instance, the authors have improved the zero-forcing method by limited feedback for decreasing information exchange between base stations, as presented in Li *et al.* (2010). Coordinated beamforming reduces downlink co-channel interference from a macro base station to a pico user using zero-forcing in order to define the weight coefficients (Li *et al.*, 2013). The authors have presented beamforming using the zero-forcing method and block diagonalization for coordinated multi-point (CoMP) transmission which can improve the sum rate of the users (Khan and Lee, 2012). However, this method does not work in some situations due to the limitations of the existing hardware. The zero-forcing method is suitable for a perfect channel, but it is not practical.

The second group is the method to select the weights from predefined weighting coefficients using a suitable algorithm. For instance, coordinated beamforming has been presented to mitigate the downlink co-channel interference from a macro base station to a femto user (Kim *et al.*, 2013). From that work, the uplink sounding reference signal is used to decrease the feedback signal from the base station. The weighting coefficients are selected by estimation of a signal to leakage and noise ratio (SLNR) and signal to noise ratio (SNR) in order to find the optimum beamforming vector from the codebook (Huang *et al.*, 2011). In this paper, the weighting coefficients are selected from the codebook at the base station (Baracca *et al.*, 2012). Thus, the base station can select the optimum weights which provide the best transmitted data. Moreover, this can be applied to coordinated multi-point joint processing (CoMP-JP). Sometimes, the weighting coefficients obtained from this method are not the optimum weights. Nonetheless, the advantage of this method is that the weighting coefficients are practical. Therefore, this paper uses the predefined weights method and then

selects the suitable weights for all users in the HetNet.

As the different levels of transmission power lead to a poor SINR for users in the small base stations, there has been much research attempting to solve the unfair SINR for each user. For example, the authors have presented an algorithm to solve the SINR by balancing and improving the worst user-rate for the coordinated multi-cell system as proposed by Park *et al.* (2013). The SINR balancing can be adapted to be used in cognitive radio networks for improving the SINR of the secondary user and ensures the interference leakage to the primary user is less than the required criteria (Cumanan *et al.*, 2010). The authors have proposed a low complicated algorithm for finding the optimal beamforming in which the users obtain a balanced SINR. This algorithm is based on zero-forcing and leakage (Tang *et al.*, 2017). Therefore, the predefined threshold of the SINR at the macro user is proposed in this research work to improve the SINR at the pico user. This is for fairness for the pico user.

The System Model

Figure 1 illustrates the model of the HetNets and consists of 1 macro base station and 4 pico base stations in the coverage area of the macro base station. We assume that each base station

has 1 user and all base stations use the same frequency considered in the case of the downlink. Note that herein the symbol M is the short term for the macro base station and the symbol p is the short term for the pico base stations. In addition, the symbols U_M and U_p are the macro user and the pico user, respectively. The received signal of the macro user can be expressed as follows:

$$y_{U_M} = \sqrt{P_M} \mathbf{H}_{U_M}^M \mathbf{W}_{U_M} x_{U_M} + \sum \sqrt{P_p} \mathbf{H}_{U_M}^p \mathbf{W}_{U_p} x_{U_p} + n_{U_M} \quad (1)$$

Likewise, the received signal of the pico user is obtained:

$$y_{U_p} = \sqrt{P_M} \mathbf{H}_{U_p}^M \mathbf{W}_{U_M} x_{U_M} + \sqrt{P_p} \mathbf{H}_{U_p}^p \mathbf{W}_{U_p} x_{U_p} + \sum_{p \neq p} \sqrt{P_p} \mathbf{H}_{U_p}^p \mathbf{W}_{U_p} x_{U_p} + n_{U_p} \quad (2)$$

where $\mathbf{H}_{U_M}^M$ and $\mathbf{H}_{U_p}^M$ are the downlink channel matrices from the macro base station to their own user and the pico user, respectively; $\mathbf{H}_{U_M}^p$, $\mathbf{H}_{U_M}^p$, and $\mathbf{H}_{U_p}^p$ are the downlink channel matrices from the pico base station to their own user, the macro user, and from the other pico base stations, respectively; $\mathbf{W}$ is the beamforming vector which is the weight that has been defined; and n is the additive white Gaussian noise. The signal to noise

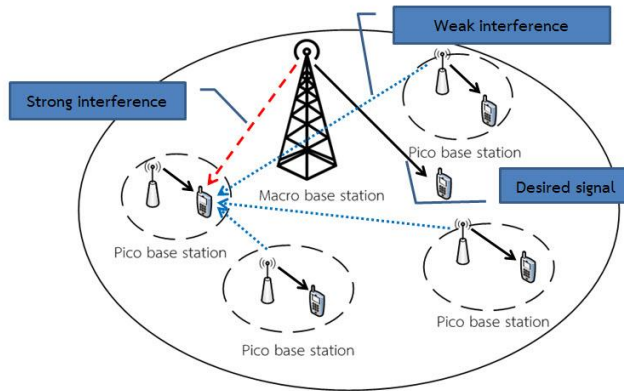


Figure 1. Macro base station and pico base stations for downlink transmission of HetNets

ratio can be express as follows $\rho_M = P_M / \sigma_n^2$, $\rho_p = P_p / \sigma_n^2$ where σ_n^2 is the noise power.

The equation used for selecting the weighting coefficients can be expressed as follows:

$$\mathbf{W} = \arg \max |\text{SINR}|^2 \quad (3)$$

The SINR of the macro user can be calculated from

$$\text{SINR}_{U_M} = \frac{\rho_M |\mathbf{H}_{U_M}^M \mathbf{W}_{U_M}|^2}{\sum \rho_p |\mathbf{H}_{U_M}^p \mathbf{W}_{U_p}|^2 + 1} \quad (4)$$

Likewise, the SINR of the pico user can be calculated from

$$\text{SINR}_{U_p} = \frac{\rho_p |\mathbf{H}_{U_p}^p \mathbf{W}_{U_p}|^2}{\rho_M |\mathbf{H}_{U_p}^M \mathbf{W}_{U_M}|^2 + \sum_{p \neq p} \rho_p |\mathbf{H}_{U_p}^p \mathbf{W}_{U_p}|^2 + 1} \quad (5)$$

From Equation (3), the users receive the maximum SINR, but the SINR of the macro user is higher than that of the pico users. This is not fair for the pico users who receive a poor SINR. Therefore, the threshold is defined to constrain the SINR of the macro user which is higher than that of the pico users.

The Proposed System

As mentioned above, the SINR of the macro user is higher than the SINR of the pico users. Since the macro base station has transmission power higher than the pico base stations, it is possible that nearby users receive an interference signal when the beams are formed to the desired users. Therefore, this paper proposes the defined threshold of the SINR of the macro user. The expectation is an increase of the SINR of the pico users when compared to a case in which the threshold is not defined.

Figure 2 illustrates the operating system that can be described as follows. The weighting coefficients of each base station are defined and the information is exchanged. In this paper, the weighting coefficients are defined as the angle spread from 0 to 180 degrees by increments of 30 degrees. Then, the base stations calculate the expected SINR using the different weights. The base station will check the weights which can make the SINR of the macro user less than the defined threshold. As there are a lot of weights which can make the SINR of macro user less than the threshold, the SINR of the pico users in the 4 pico base stations will be combined. Therefore, the weights are selected from 2 conditions. First, the SINR of the macro user is not higher than the threshold. Second, the total SINR of all the pico users is the maximum value.

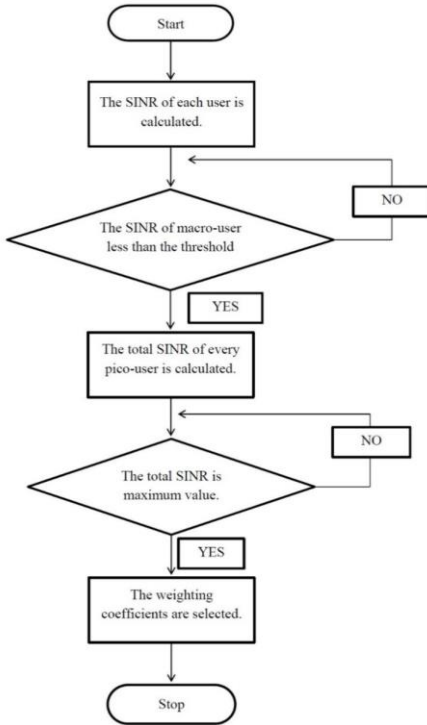


Figure 2. Flowchart of the system's operation

Simulation Result

This section illustrates and compares the results between the cases of a defined threshold and

an undefined threshold. The SINR and throughput of the system are considered.

Figure 3 shows the SINR of the macro user when varying the threshold from 5 to 20 dB. The SINR of the macro user is consistent with the defined threshold. Figure 4 shows the results when varying the threshold from 5 to 20 dB and focuses on the SINR of the pico users. The results show that the SINR of the pico users increases when the threshold decreases. Additionally, the SINR of the pico users is higher than in the case of the undefined threshold. From the results, it can be seen that the threshold affects the SINR of the pico users.

Figure 5 shows the results when varying the threshold from 5 to 20 dB to focus on the throughput of the macro user and the total throughput. Figure 6 shows the results when varying the threshold from 5 to 20 dB to focus on the throughput of the pico users. The results

show that the throughput of the macro user and the total throughput are consistent with the defined threshold, whereas the throughput of the pico users increases when the defined threshold decreases. From the results, it can be seen that the threshold affects the throughput of the pico users because the SINR value is calculated from the desired signal divided by the interference from other base stations and the noise. From Equations (4) and (5), the weights are taken into account for the desired signal and the interference signal. Therefore, the defined threshold becomes the condition for selecting the weights. The SINR of the macro user from this method may not be the best signal, but it can provide a communication. In the case of the SINR of the macro user being higher than that of the pico users, this possibly occurs when the pico users directly receive the interference from the macro base station. However, these conditions can make the

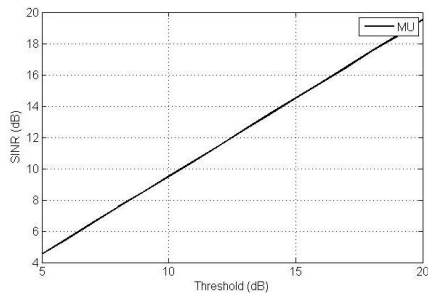


Figure 3. SINR of the macro user when varying the defined threshold

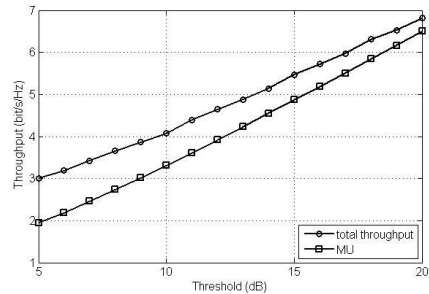


Figure 5. Throughput of the macro user when varying the defined threshold

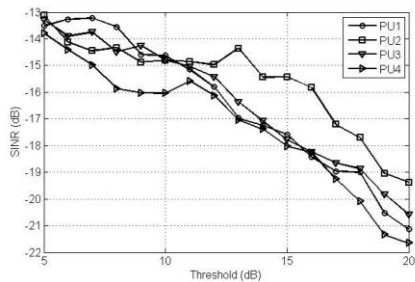


Figure 4. SINR of the pico users when varying the defined threshold

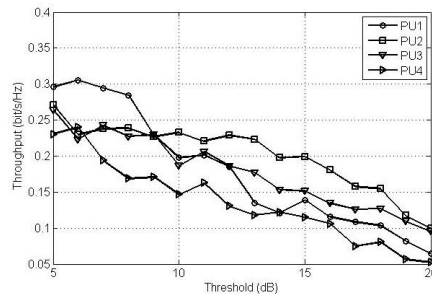


Figure 6. Throughput of the pico users when varying the defined threshold

interference from the macro base station decrease. As a result, the SINR and throughput of the pico users are higher than in the case of the undefined threshold.

We also studied the SINR and throughput of users at the macro and pico base stations when varying the number of beams. The number of beams varies from 4 to 13 beams. Figures 7 and 8 show the SINR and the throughput of users, respectively, when the threshold is not defined. The SINR and throughput of the pico users are lower than those of the macro user, even if the number of beams increases. However, the increasing number of beams slightly affects the SINR and throughput of the pico users.

Likewise, Figures 9-14 show the SINR and throughput of users when the threshold is

defined as 4.3, 10.3, and 22.7 dB. From the results, the SINR and throughput are slightly increased when the number of beams increases, since increasing the number of beams can increase the probability of the interference signal. It can be seen that the number of beams is 7 and 13 in which the SINR and throughput are similar.

The proposed technique can improve the SINR and throughput of the pico users. It means that the defined threshold of the macro user affects the SINR and throughput of the pico users but the increasing number of beams slightly affects the SINR and throughput of the pico users.

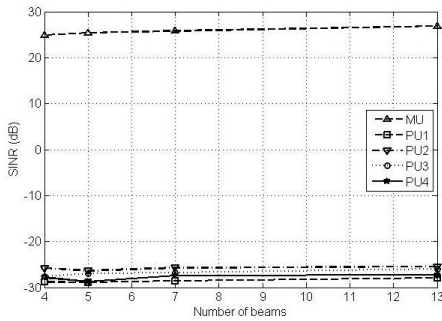


Figure 7. SINR of users when varying the number of beams. No defined threshold

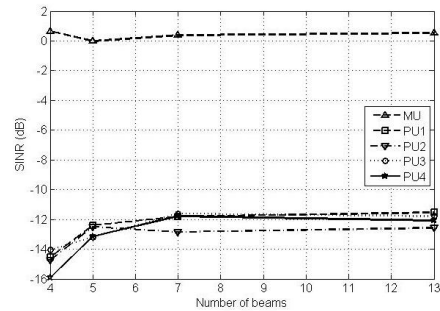


Figure 9. SINR of users when varying the number of beams. Threshold = 4.3 dB

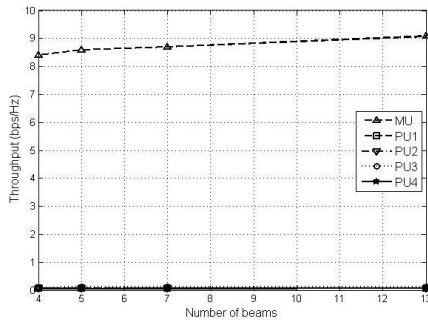


Figure 8. Throughput of users when varying the number of beams. No defined threshold

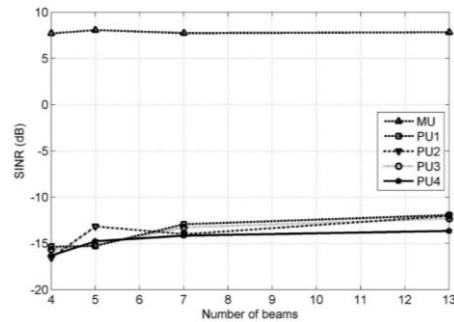


Figure 10. SINR of users when varying the number of beams. Threshold = 10.3 dB

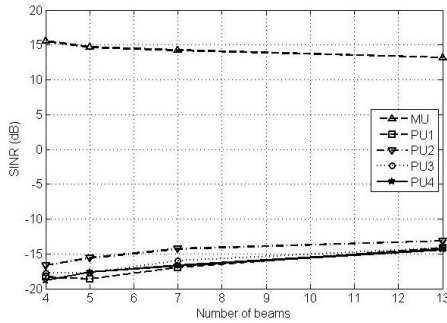


Figure 11. SINR of users when varying the number of beams. Threshold = 22.7 dB

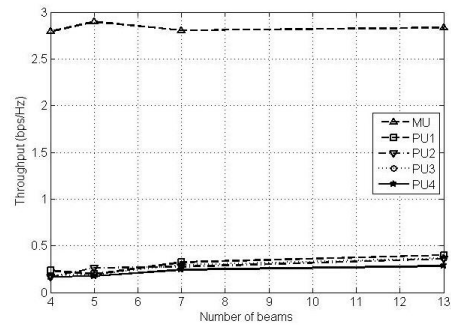


Figure 13. Throughput of users when varying the number of beams. Threshold = 10.3 dB

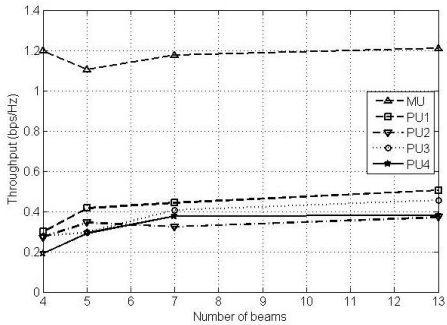


Figure 12. Throughput of users when varying the number of beams. Threshold = 4.3 dB

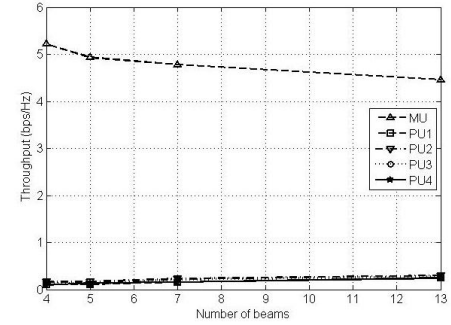


Figure 14. Throughput of users when varying the number of beams. Threshold = 22.7 dB

Conclusions

HetNets consist of different transmitting powers of base stations. That introduces an unfairness to pico users. This paper presents the weight selection which provides a fairness for the pico users. The fixed coordinated beamforming and the defined threshold are adapted to this paper. As a result, the pico users achieve the SINR and throughput higher than in the case of the undefined threshold.

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