Interference Management with Relay-Based Clustering Method on Ultra Dense Networks of Femto-Macrocellular Network

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***Abstract*—Ultra Dense Networks (UDN) which is one of the key technologies for 5th Generation (5G) Cellular Networks is intended to increase the capacity and coverage of the cellular networks. Densely deployment of femtocells in UDN mitigates signal attenuations experienced by indoor users, but potentially increases co-tier and cross-tier interferences as the consequence of spectrum sharing with other femtocells and its associated macrocells. The interference problems in such network become worst when the femtocells are located on the cell edge of its macrocells. In this paper, we design interference management of femtocells located in the cell edge of macrocell area for uplink transmissions. We propose interference management to reduce the interference effects of the femtocells located in the cell edge area of macrocell using a relay-based clustering method. The simulation results show that the proposed method (relay-based clustering) can improve SINR and system throughput compared to the conventional system, i.e., the system without relay-based clustering. We applied the sectored macrocell on the observed macrocell having 6 sectors in the simulation experiments. When we are targeting the SINR value of 20 dB, the SINR value is below 20 dB for conventional systems in sectors 1 and 2 are 86% and 87 %, respectively. However, the probability of the SINR in a system using the relay-based clustering method that does not reach the target in both sectors 1 and 2 are 71% and 74% correspondingly. These results are in line with the expectation that the relay-based clustering method can improve the performance of femtocells in the cell edge area.**

Keywords—Ultra dense networks (UDN), cross-tier interference, co-tier interference, interference management, relay-based clustering

I. Introduction

Wireless data traffic is increasing dramatically, especially traffic coming from users of wireless cellular communication services. Nowadays above 70% of users are indoors [1]. However, users who are indoors often are experiencing weak signal, because the signal from the transmitting antenna at the Base Transceiver Station (BTS) was attenuated by the walls of the room, doors, and windows.

Ultra dense networks (UDN) technology offers a solution for the indoor users experiencing poor connection inside the building. UDN is also known as one of the key technologies for the 5th generation (5G) that promises to increase the data capacity and coverage area of cellular networks [2]. Femtocells that are deployed densely on the UDN network can solve the problem of signal attenuation for users who are residing inside a building or indoors. Femtocell consists of three access modes including close, open, and hybrid modes. The closed mode is used for users who are registered to the femtocell. Open mode allows all users to use femtocell. In hybrid access mode, some femtocells can serve unregistered users [3].

However, one of the problems when deploying femtocells are interference. This is because femtocell shares the same radio resources with macrocells. One type of interference that can occur is between femtocells and macrocells, it is called as cross-tier interference. Another type of interference is interference among femtocells which is called as co-tier interference. The limited availability and sharing of the frequency spectrum cause this interference can occur. The condition of femtocell will get worse when they are located on the cell edge area of macrocell [4]. The femtocell interferences on the UDN network can occur on both uplink and downlink transmissions. To solve this problem, many literatures are available proposed for interference management in the area of Ultra Dense Networks (UDN), just few to mention as in [5-8].

The authors in [5] proposed an algorithm of linear pre-coders and decoders to minimize the number of Mean Square Errors (MSE). Pre-coders and decoders were designed using pilot-assisted channel estimation to improve the accuracy of channel status information. Another method in the literatures about interference management for UDN as well as for other networks is using power control techniques [6-10]. Reference [6] analyzes three macrocells, where one macrocell is in uplink transmission, while the other two macrocells are in downlink transmission. To solve the problem of interference in a two-tier cellular network, the authors in [6] used a power control method. The simulation results show that the power control method can significantly increase the SINR performances compared to without power control. However, the scenario that they considered has not been considered as UDN.

In this paper, we design interference management of femtocells located on the edge cell area of macrocell for reducing the interference effects of the cell edge area. We focus on the uplink transmission based on Single Carrier Frequency Division Multiple Access (SC-FDMA). This paper proposes a relay-based clustering method for interference management. First, we deploy relays statically on neighboring macrocells. The relay will recruit their members based on closest distance. Then, radio resources are allocated to users by considering Signal-to-Interference plus Noise Ratio (SINR) with certain criteria. Thus, the users in the groups on certain relays do not need to transmit large power to the eNB, so that interferences coming from users on the cell edge to the femtocells in the neighboring macrocell can be minimized.

The rest of this paper is organized as follows. The system models and our relay-based clustering method are presented in Section II. The simulation scenario, simulation parameters, and simulation results are described in Section III. Finally, the conclusion of this paper is given in Section IV.

II. System Model

This paper considers three macrocells based-OFDMA networks, which have different radio resources (reuse factor of 3). Uplink transmission is considered in both femtocell and macrocell networks. Since we aim to analyze the effect of interference on the cell edge area of macrocell, a number of femtocells are densely deployed in the cell edge area of one of those three macrocells in which the femtocell serves one user at certain period of time. Meanwhile, there is no femtocells deployed in two other macrocells. Femtocells are assumed to use the same radio resources with neighboring macrocells (reuse factor of 2). At the neighboring macrocells are randomly deployed a number of macrocell user equipment (MUE). MUE communicates with their respective macrocells, i.e., in uplink transmissions. By this model, interference between femtocells and macrocells can occur, i.e., cross-tier interference. In addition, there will be likely interferences occurring among the femtocells located at the same macrocell, it is known as co-tier interference. This model system is illustrated in Fig. 1. When femtocell user equipment (FUE) transmits an uplink signal to Home Enhanced node B (HeNB), at the same time macro user equipment (MUE) also transmits an uplink signal to e Node B (eNB). In this case, the HeNB of the observed femtocells suffered cross-tier interference caused by the MUE of their neighboring macrocells. Likely at the same time, co-tier interference occurs among the femtocells due to the usage of same radio resources. The interference that occurs in the femtocell-macrocell network is described in Fig. 1. The blue dashed line indicates co-tier interference, while the red dashed line indicates cross-tier interference. Solid black line indicates the desired signal from user equipment (FUE or MUE) to HeNB or eNB.

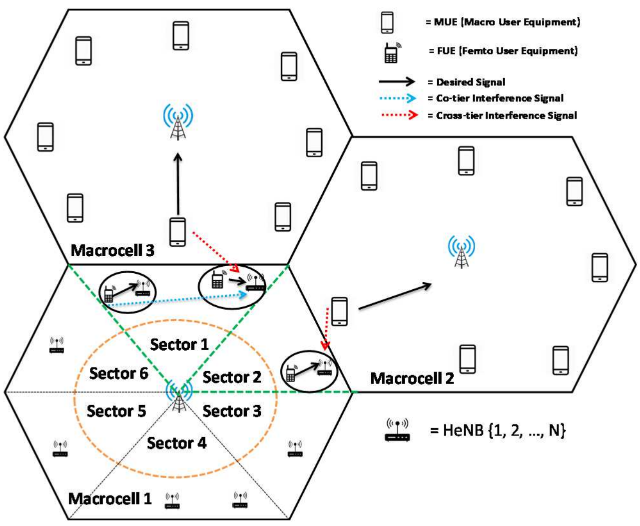

Fig. 1. Conventional System Model Based on Sector Division.

The second scenario is the scenario of interference management with relay-based clustering which is depicted in Fig. 2 and explained in sub-section 2 (C). This scenario is designed to mitigate the interference of femtocells located in the cell edge area. The technique used is the relay-based clustering method. First, the observed macrocell area is divided into six sectors. In each sector, it is randomly deployed 33 femtocells. However, the analysis of this scenario only focuses on sectors 1 and 2. Femtocells in sector 1 are located adjacent to the edge of macrocell 3, while femtocells in sector 2 are located adjacent to the edge of macrocell 2. Then, relays are deployed statically on neighboring macrocells. The relay will recruit its group members based on the closest distance. It is assumed that the maximum number of users can be connected through a relay is 3 MUEs.

A. Channel Model

The propagation characteristics of the radio channel are necessary for the planning of a good mobile cellular communication system. In this paper, we use two types of channels model. First, we use a channel model (path loss) for macrocells in urban areas. Then, we use a channel model for femtocells located indoors. These two-channel models can be formulated as below.

Channel model for femtocells in urban areas can be written by (1) [11] below.

$$PL_{femto}\,(dB) = 15.3 + 37.6\,log_{10}(d) \qquad (1)$$

The channel model for macrocells in urban areas can be formulated by (2) [12] as follow.

$$PL_{macro}\,(dB) = 127 + 30log_{10}\left(\frac{d}{1000}\right) + L_{ow} \qquad (2)$$

where d denotes the distance between the user (FUE or MUE) to the HeNB or eNB in meters and L_{ow} is the penetration loss which its value is 6 dB [12].

B. Signal to Interference and Noise Ratio (SINR)Analysis

In this paper, Signal to Interference and Noise Ratio (*SINR*) is calculated to determine the signal quality of femtocells. When the HeNB is serving its user (FUE), the observed HeNB suffers cross-tier interference from MUE, because the femtocell shares the same radio resources with neighboring macrocells, and at the same time it also suffers co-tier interference from other femtocells due to they share the same radio resources. *SINR* can be calculated as the ratio of the expected signal received by HeNB from served FUE to the unexpected signal from MUE and other FUE (in other

HeNB coverage) plus noise. Therefore, the *SINR* equation can be calculated as below in (3) [6].

$$SINR = \frac{P_{rx}}{\sum_{x=1}^{n} I_x + \sum_{y=1}^{m} I_y + N} \quad (3)$$

where

P_{rx}: power transmitted from expected FUE to HeNB (in mWatt or Watt)

I_x: co-tier interference of another femtocell (in mWatts or Watt)

I_y: cross-tier interference from MUE to HeNB (in mWatt or Watt)

N: power noise (in mWatt or Watt)

n and *m*: the number of co-tier and cross-tier interferences, respectively.

In this scenario, it is assumed that the observed users (FUE) are transmitting in uplink mode to HeNB, so the calculated receiving power is at the observed HeNB. The calculation of the received power can be formulated as below in (4).

$$P_{rx}(dBm) = P_{FUE}(dBm) - PL_{femto}\,(dB) \quad (4)$$

where P_{FUE} is the transmit power of the desired FUE or other FUE in dBm. The cross-tier interference coming from MUE of neighboring macrocell is calculated as follow in (5).

$$I_y(dBm) = P_{MUE}(dBm) - PL_{macro}\,(dB) \quad (5)$$

where P_{MUE} is the transmit power of MUE in dBm.

C. Relay-Based Clustering Method

The relay-based clustering method is the second scenario in this paper as shown in Fig. 2. Similar to the first scenario, in this second scenario, three macrocells are used. Each macrocell is assigned to set of different radio resources, i.e., it uses the reuse factor of 3. In the simulation, the FUE which is located in the cell edge area of sectors 1 and 2 is transmitting uplink to HeNB. At the same time, MUEs of macrocells which is located adjacent to the FUE in both sectors 1 and 2 is also transmitting uplink to eNB. This causes the observed HeNB suffers interference due to MUE in neighboring macrocells are sharing the same radio resources. To reduce these interference effects, in macrocells 2 and 3, relays are distributed statically in the neighboring macrocells. The number of relay nodes deployed in macrocells 2 and 3 are 16 nodes. The relay will recruit its members based on the shortest distance between users and the relay. In the simulation, it is assumed that the maximum members of the relay are 3 users. Thus, the group members on the certain relays do not need to transmit larger power to the eNB as the relay.

III. Simulation Setting, Parameters, and Results

The simulation considers two scenarios. The first scenario is a conventional system as shown in Fig. 1, i.e., the system without relay-based interference management method. In this scenario, 3 macrocells are generated with a reuse factor of 3. It means that each macrocell is allocated different radio resources. Since we analyze the effect of interferences on the HeNB, we are not deploying any MUE

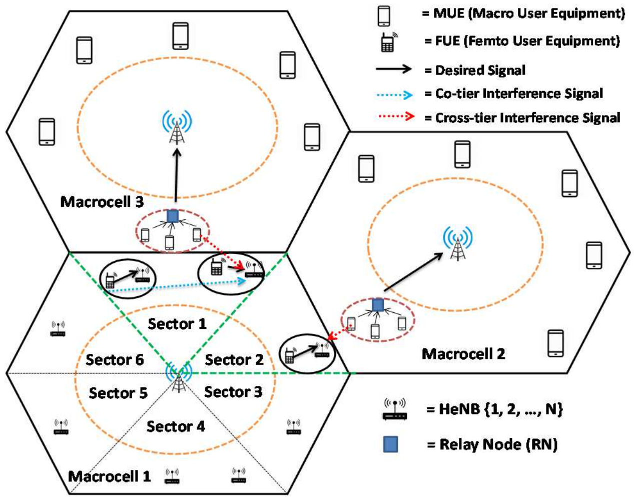

Fig. 2. System Scenario with Relay-Based Clustering Method.

in macrocell 1. The area in macrocell 1 is divided into 6 sectors. A certain number of femtocells are deployed within macrocell 1. In each sector, 33 femtocells are randomly deployed. However, the analysis of this scenario only focuses on sectors 1 and 2. In macrocells 2 and 3, femtocells are not deployed, but there are a certain number of MUE in those macrocells deployed randomly. HeNB located in the cell edge area suffers interference caused by MUEs of neighboring macrocells which is also located in the cell edge area of corresponding macrocells. To reduce the effect of interferences, the relay-based clustering method is considered to mitigate interference problems of femtocells located in the cell edge area.

A. Simulation Parameters

The designed scenarios have been implemented using MATLAB software. The simulation parameters in this paper generate three macrocells with a reuse factor of 3. Femtocell uses reuse factor 2, where it uses the same radio resources with two others neighboring macrocells. In each sector, it is randomly deployed 33 femtocells. The bandwidth used on the system is 10 MHz. The radius of circle to border inner and outer of macrocells is 750 meters. The macrocell's and femtocell's radiuses are 1000 meters and 30 meters, respectively. The simulation parameters are summarized in Table I. We apply the modulation type of 16 Quadrature Amplitude Modulation (QAM) in the system. The simulation was run for 20 times, all femtocells (33 femtocells) were observed, and the collected performance results (SINR, throughput, and BER) were averaged for 33 femtocells and for 20 simulation times.

B. Simulation Results and Discussions

Based on the designed scenario, in this section, we will discuss the results of simulation that has been carried out using MATLAB software. The discussion that will be explained is the result of a comparison between the conventional system model with system model using the relay-based clustering method. The simulation results in this paper that are collected are a Cumulative Distribution Function (CDF) graph that indicates the performance of *SINR* and throughput, meanwhile the performance parameter of Bit Error Rate (BER) is described by a Complementary Cumulative Distribution Function (CCDF) graph. Fig. 3 depicts the SINR performance versus the number of femtocells increased. In Fig. 3, as the number of femtocells increases, the *SINR* performance of both conventional system and system models using the relay-based clustering method decreases. It means that the femtocells located in the cell edge area suffer much interferences. The interferences occur at observed HeNB coming from MUEs which is also located in the cell edge area of neighboring macrocells in addition to the others femtocells.

Fig. 4 shows the CDF of SINR. When we are targeting the *SINR* value of 20 dB, it can be seen from Fig. 4 that the probability of *SINR* not reaching the target, it means that the SINR value is below 20 dB (which is optimistic/excellent target), for conventional systems in sectors 1 and 2 are 86% and 87%, respectively. However, the probability of the SINR in a system using the relay-based clustering method that does not reach the target in both sectors 1 and 2 are 71% and 74% correspondingly. From these results, it can be said that the poor performance of femtocells located in the cell edge area can be improved by applying the relay-based clustering method. Group members in certain relays do not need to transmit larger power to the eNB as in the conventional system, so cross-tier interferences that occur at femtocells on the cell edge area can be minimized.

Fig. 5 depicts the simulation results for the CDF of throughput. In Fig. 5, the probability of femtocell throughput is less than 60 Mbps in conventional systems in both sectors 1 and 2 is 84% and 85%, respectively. Meanwhile, the probability of femtocell throughput is less than 60 Mbps in the system using the relay-based clustering method in both sectors 1 and 2 is 69% and 73%, respectively. These results are consistent with the SINR performance results.

The BER results are plotted in Fig. 6. In Fig. 6, the BER of observed femtocells in the conventional system of sector 1 in macrocell 3 which has a BER of more than 0.01 is 98% and similar result for the sector 2 of macrocell 3. Meanwhile, the BER from observed femtocell in the system using relay-based clustering method in sector 1 which has

TABEL I. SIMULATION PARAMETERS

No.	Parameter	Nilai
1.	The radius of macrocell [13]	1000 meters
2.	The radius of inner circle to border outer of macrocells [13]	750 meters
3.	The radius of femtocell [13]	30 meters
4.	The number of macrocells and eNB	3
5.	The number of femtocells per sector	33
6.	The number of MUE for each macrocells 2 and 3	50 users (100 users in total)
7.	Bandwidth [14]	10 MHz
8.	The transmit power of FUE and MUE [8]	23 dBm
9.	The number of relays on each macrocell	16
10.	Modulation type	16 QAM
11.	Simulation time	20 times

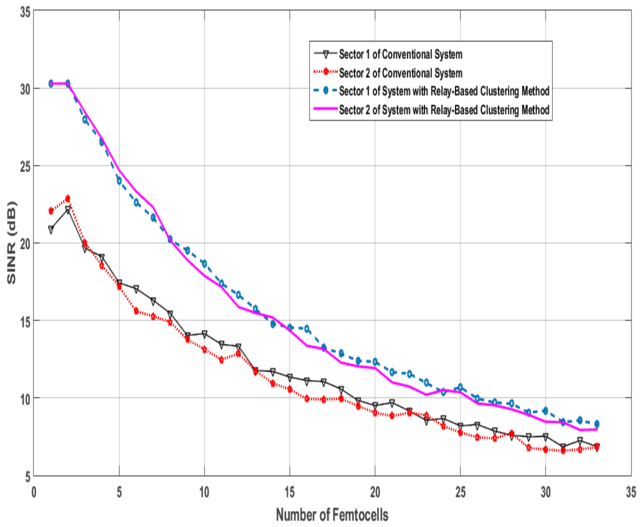

Fig. 3. Simulation results for *SINR* performance of conventional system and system using relay-based clustering method with increasing number of femtocells.

BER value of more than 0.01 is 86% and so for sector 2. From these results of this simulation analysis, it can be said that the relay-based clustering method can reduce data transmission errors better than conventional system.

IV. CONCLUSION AND FUTURE WORK

In this paper, we discuss and propose interference management on UDN networks in femtocell-macrocell networks and mitigate the interference by relay-based clustering method. We focused the analysis on femtocells located in the cell edge area in both sectors 1 and 2 of a sectored macrocell having 6 sectors. Then, the proposed relay-based clustering scheme was examined through a simulation experiment. The simulation results compared between the conventional system, i.e., the system without relay-based clustering and system using the relay-based clustering method. The simulation results show that the proposed method (relay-based clustering) can improve *SINR*

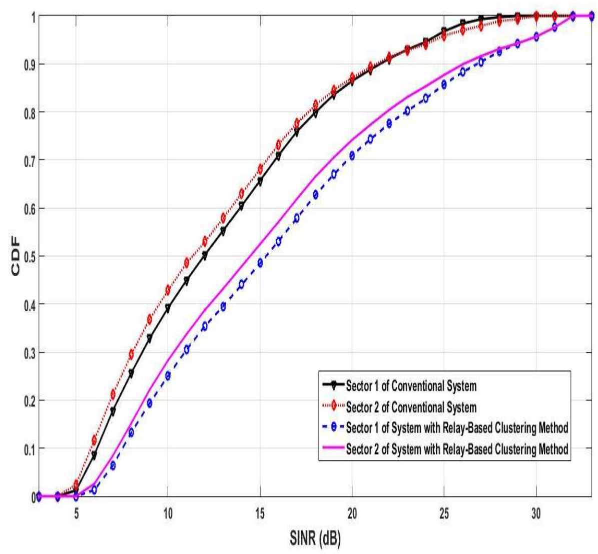

Fig. 4. The comparison of Cumulative Distribution Function (CDF) of *SINR* for Conventional System and the system with Relay-Based Clustering Method.

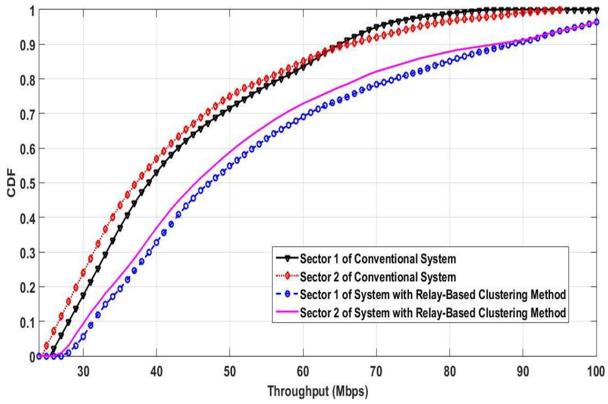

Fig. 5. The comparison of Cumulative Distribution Function (CDF) of Throughput for Conventional System and the system with Relay-Based Clustering Method.

and system throughput compared to the conventional system. When we are targeting the SINR value of 20 dB, the *SINR* values which is below 20 dB for conventional systems in sectors 1 and 2 are 86% and 87 %, respectively. Meanwhile, the probability of the *SINR* in the system using the relay-based clustering method that does not reach the target in both sectors 1 and 2 are 71% and 74%, correspondingly. These results are in line with the expectation that the relay-based clustering method can improve the performance of femtocells in the cell edge area. As the future works suggested, it can be considered to apply other methods to mitigate the interference on the cell edge area as both users and femtocells can likely suffer more interferences than others.

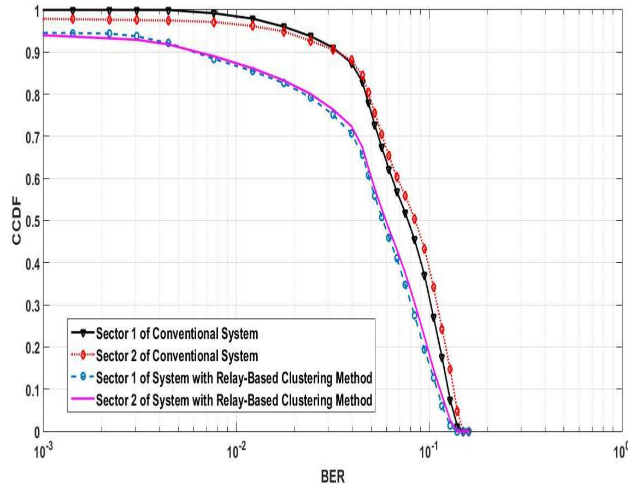

Fig. 6. The comparison of Complementary Cumulative Distribution Function (CCDF) of Bit Error Rate (BER) for Conventional System and the system with Relay-Based Clustering method.

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