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Interference Mitigation in LTE HetNet by Resource Allocation

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***Abstract*—** To provide high date rate for indoor services and communication, femtocells and microcells are planned in LTE-Advance system but main problem is how to reduce the interference between micro and femto cells and in the middle of the femtocells. In this paper we proposed regional Average channel state (RACS) to estimate the influence of interference and then we proposed hybrid clustering based on interference graph (HCIG) to reduce interference between femtocells and microcells. Based on the Results our scheme is given to reduce the interference and improve the spectrum efficiency.

***Keywords*—** Heterogeneous Network, Hybrid clustering interference graph, Regional average channel state, Micro User, Pico User etc.

I. INTRODUCTION

Reduction of cell sizes and transmission distances is one of the most effective methods to improve system capacity and cellular coverage, through which there has been 1600x gain in system capacity improvement since 1957 [1].

In categorize to provide high quality for those users at home and business center the Third Generation Partnership Project Long Term Evolution (3GPP LTE) has introduced low power nodes placed indoors, such as femtocells [2]. In case of the same bandwidth used by macro and femtocells, interference in the system is the key problem due to the randomness deployment of femtocell.

There are three types of frequency assignment schemes in the femtocell network [3]. The first approach is called shared frequency allocation (SFA) in this case same spectrum resource is used in macro and femto cells. This gives us results in high spectrum efficiency, while the co-channel interference may gravely humiliate the system performance. Another approach is called partitioned frequency allocation (PFA): femtocell uses partial spectrum while macrocell uses the remaining. While this scheme avoids interference between two tiers spectrum efficiency decreases critically. The last approach is called partial shared frequency allocation (PSFA): femtocell uses part of the bandwidth resources and macrocell uses all the available spectrum resources. It accomplishes cooperation between interference reduction and spectrum efficiency enhancement.

Numerous schemes have been proposed to reduce the interference in the LTE heterogeneous network (HetNet) mainly by means of resource allocation and power control. The cell is divided to inner and outer part in [4], and the femto user (FUE) in inner region uses the sub-band different from the Macro Base Station (MBS) to avoid interference. A resource management scheme based on fractional frequency reuse (FFR) is given in [6], in which orthogonal resources are used between FBS and MBS. Subject to the constraint on the minimum target SINR realized in macrocell, an iterative power selection algorithm is presented in [7] to maximize the system performance.

Recently graph theory is extensively used on the diminution of interference in LTE network. The vertex, which is generally Base Station (BS) in the traditional interference graph modeling schemes, expands to UE and femtocell BS (FBS) now. In OFDMA macrocell, Necker [8] introduces interference graph to resolve the interference coordination problem and presents graph coloring heuristic scheme to avoid interference, in which two graph nodes connected by an edge can't be assigned the same color. [9] Extends the graph vertex to UEs. However, the overhead of updating the graph is very high, because the MUE node is moving every time. For macro and femto heterogeneous system, graph-based adaptive frequency reuse (AFR) scheme is presented in [10] in which the FBS is taken as the vertex of graph to avoid interference among FBSs. However, the interference between MBS and FBS is not considered.

In order to reduce the interference between macrocell and femtocell, and that among femtocells, a weighted graph is proposed in this paper, in which the vertex of the graph is MUE or FBS. Based on the graph the resource allocation problem fundamentally differs from those traditional graph-based schemes. In our proposed scheme a fixed number of sub-bands are used and the hybrid clustering based on interference graph (HCIG) algorithm is proposed. After HCIG not only one sub-band is assigned to MUE and FBS, but also other available sub-bands are assigned to FBS under the interference constraint to improve the spectrum efficiency.

In what follow, the discussion of this study after the introduction is backgrouck, observation and methodlogy, HCIG method and then the results with discussion and lastly the conclusion.

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II. Background

Long Term Evolution (LTE) has many features considered for future fourth generation (4G) systems [11], but the performance of LTE does not meet IMT-Advanced requirements introduced by the International Telecommunications Union (ITU) [12] which leaded to a need for other releases. The evolved versions (LTE Release 10 and beyond), named LTE Advanced, satisfy the requirements defined by IMT-Advanced. Since data traffic demand in cellular networks is exponentially growing, further increasing of the node density is required to enhance the system spectral efficiency. However, site acquisition costs can get prohibitively expensive particularly in a space limited dense in urban areas [13]. Therefore, several technologies have been suggested to improve the performance of LTE-A networks. One of the advanced technologies is to deploy heterogeneous networks (HetNets).

A Heterogeneous Network consists of macrocells and low power nodes including picocells and femtocells. They are categorized in terms of transmit powers, antenna heights, the access types, and the backhaul connection to other cells. The goal of using low power nodes is to offload traffic from macrocells, improve indoor coverage, and increase the spectral efficiency through spectrum reuse. By this means, the larger numbers of cells have access to more efficient spectrum reuse and higher data rates [14].

III. Observations and Methodology

1. *IMBS,FUE* is the Co-Channel Interference (CCI) caused by MBS to FUE, e.g. the interference from MBS to FUE3.2) *IFBS,FUE* is the CCI between femtocells, the interference from femtocell2 to FUE1.3) *IFBS,MUE* is the CCI caused by FBS to MUE, e.g. the interference from femtocell1 to MUE1.

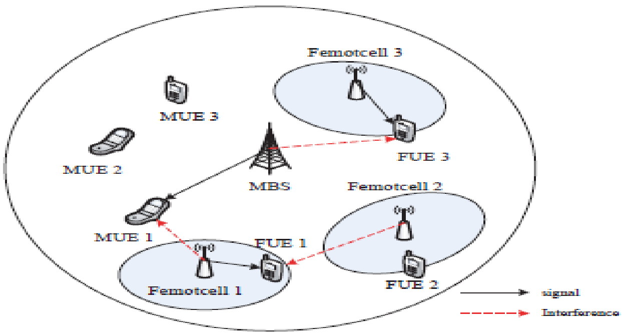

Fig.1 Downlink Interference scenarios in LTE-Heterogeneous Network

In order to terminate all the three types of interference shown in Fig.1, an active interference graph construction scheme in which the vertex of graph is a femto base station FBS and the MUE which is suffering interference from FBS. As the location of FBS is fixed and only partial MUEs are considered in the graph, the overhead of updating the graph is low.

Our current problem is how to determine whether two nodes can be connected by an edge in the graph and how to estimate the interference influence. Note that the effect of interference depends on the ratio of interference power to signal power, so the Regional Average Channel State (RACS) metric is proposed to evaluate the influence of interference. The RACS of region m which is served by BS_i and interfered by BS_j represents the average SINR, and can be calculated as:

$$RACS(i,j,A_m) = \iint_{A_m} SINR_{i,j}(x,y)dxdy / S(A_m) \quad (1)$$

Where $SINR_{I,J}(X,Y) = P_{r,i}(x,y) / p_{r,j}(x,y) + N_0$; $p_{r,i}(p_{r,j})$, is the received power from $BS_i(BS_J)$; N_0 is the noise power; $S(A_m)$ is the area of region m. Let A_i be the coverage region of BS_i and when $RACS(i,j,A_i) < SINR_{th}$ orthogonal sub-bands should be assigned to BS_i and BS_j to avoid interference. For the three Scenarios shown in Fig.1, the interference threshold based on RACS is given in the following argument.

A. A Interfernce between FBS's

We consider the situation in which FBS_k and FBS_j are located at (0, 0) and (d,0), with circular coverage radius R_k and . When a FUE is located at (x, y) the received power from FBS_k and FBS_j are as follows.

$$P_{r,k} = P_k d_k^{-\alpha} = P_k(x^2+y^2)^{-\alpha/2} \quad (2)$$

$$P_{r,j} = P_j d_j^{-\alpha} = P_j((x-d)^2+y^2)^{-\alpha/2} \quad (3)$$

Where α is the path loss exponent, $P_k(P_j)$ is the transmit power of $FBS_k(FBS_j)$; $d_k(d_j)$ is the distance from the FUE to $FBS_k(FBS_j)$. Let α = 2 and ignore the noise power, the $SINR$ of the FUE which is served by FBS_k is:

$$SINR_{k,j}(x,y) = \frac{P_{r,k}}{p_{r,j}+N0} \approx \frac{P_k}{p_j} \bullet \frac{(x-d)^2+y^2}{x^2+y^2} \quad (4)$$

As the FUE is moving in the coverage area of FBS_k which is, the RACS of the coverage region of FBS_k is calculated as follows.

$$RACS(k,j,A_k) = \int_{R_{min}}^{R_k} \int_0^{2\pi} SINR_{k,j} r dr d\theta / S(A_k) = \frac{P_k}{P_j}\left(1+\frac{2d^2}{R_K^2-R_{min}^2}\ln\frac{R_k}{R_{min}}\right) \quad (5)$$

Where $R_{\min}$ is the minimum distance between FUE and FBS.

When the power of FBS is fixed, the value of $RACS(k, j, A_k)$ is only related to the distance between two FBSs. therefore, the SINR condition $RACS(k, j, A_k) < c_{th}$ can be rewritten as the distance function:

$$d < d_{\min} = \sqrt{(R_k^2 - R_{\min}^2)(\frac{c_{th} P_j}{P_k} - 1) / (2\ln\frac{R_k}{R_{\min}})} \quad (6)$$

B. Interfernce from MBS toFBS

Consider the same situation complete in subsection A, when there is a MBS_M located at (*D*, 0) with transmit power P_M, the FUE served by FBS_k will suffer interference from the MBS. Similar to the analysis in subsection A, the RACS of FBS_k caused by the interference from the MBS is:

$$RACS(k, \mathrm{M}, A_k) = \frac{P_K}{P_M}(1 + \frac{2D^2}{R_k^2 - R_{\min}^2}\ln\frac{R_k}{R_{\min}}) \quad (7)$$

When $RACS(k, M, A_k) < c_{th}$ $RACS(k, M, A_k) < c_{th}$ we can get:

$$D < D_{\min} = \sqrt{(R_k^2 - R_{\min}^2)(\frac{c_{th} P_M}{P_k} - 1) / (2\ln\frac{R_k}{R_{\min}})} \quad (8)$$

To make simpler the expression, the FBS is called inner FBS when the location of FBS satisfies inequality.

C. Interfernce from FBS to MUE

In this situation that a MBS located at (0, 0) with transmit power *PM* and FBS_k located at (x_f, y_f) with transmit power *PF*. When the MUE_i served by the MBS is located at (*x*, *y*), the SINR of the UE is:

$$SINR_i(x, y) = \frac{P_{r,\mathrm{M}}}{P_{r,F} + N0} \approx \frac{P_M}{p_F} \bullet \left[\frac{(x - x_f)^2 + (y - y_f)^2}{x^2 + y^2}\right]^{\alpha/2} \quad (9)$$

Where noise power is ignored; α is the path loss exponent. In organize to estimate the interference from FBS to MUE, the MUE interference region of FBS is calculated, in which the SINR of the UE is below a predefined threshold.

IV. HCIG CONSTRUCTION METHOD

In our proposed hybrid clustering interference graph (HCIG) scheme, the interference graph $G(V, E)$ is constructed by MBS, where the vertex set V stands for all FBSs and the MUEs which are in the interference region of FBS, and W is the influence matrix to characterize the prospective interference between two vertexes in which $(i, j) = w(j, i)$. When $w(i, j) = 0$, node*i* and node*j* is not connected in the graph.

To judge whether two nodes are connected by an edge, the distance threshold in subsection A and B as well as the interference region in subsection C are utilized. in the meantime, as MBS is not the graph vertex, inner FBS node and MUE node are connected in the graph to avoid the interference. As two MUEs can't be assigned the same resources in LTE network, we let the weight between them be *w*0 which is a very large value. As MUE has higher priority than FUE, W_0 is assigned to denote the interference from FBS to MUE in order to guarantee the performance of MUE. For other types of interference, 1/RACS is used to express the sum of interference.

A. Resource Allocation in HCIG

HCIG is proposed to reduce the system interference and improve the spectral efficiency, which is shown as follows.

Step 1: one sub-band is randomly allocated to a cluster and the nodes in the cluster reuse the same resource.

Step 2: In HCIG, orthogonal resources are allocated to MUE and inner FBS in order to cancel the high interference from MBS. Though, when there are not enough orthogonal resources after the resource allocation of MUE in the graph and inner FBS, the remaining MUE should reuse the sub band which is used by inner FBS. To minimize the system interference, the sub-band used by the inner FBS which is farthest from the MBS is reused by the remaining MUE.

Step 3: After that, each FBS is assigned a sub-band. In order to get better the spectrum efficiency of FBS, this step will search more sub-bands which can be assigned to FBS on the condition that the sub-bands are not used by the interfering nodes. Through the graph connection information, a FBS could know the resource set used by connected FBSs in the graph. Therefore, the sub-bands which are unused by neighbor FBSs are assigned to the FBS to improve the spectrum efficiency.

V. RESULTS AND CLASSIFICATION

The system simulation parameters are configured according to 3GPP LTE condition [10], as presented in Table where Inter-Station Distance (ISD) indicates the distance between two neighbor MeNBs. In our simulation, 19 microcells are considered, in each of which the same number of femto cells are placed. Due to the interference from neighbor cells can't be ignored, only the results of central 7 cells are collected. The

MUEs are uniformly distributed over the macrocell area and the FUEs are distributed in the coverage area of femtocells. The SINR threshold for construction the interference graph is set to 10 dB.

TABLE 1

Modal Parameters

Parameters	***Femtocell***	***Microcell***
System Bandwidth	20MHz	20MHz
Cell Layout	Circular Cell	Hexagonal Network
Cell Cize	Radius=18m	ISD=400m
Transmit Power	18dbm	41 dBm
Antenna Gain	0dBi	14dBi
Path Loss	126+30*log10(d)	126+36.5*log10(d)
Fast Fading	SCME	SCME
Daviation	4dB	4Db
Noise Level	-176dBm/Hz	-176dBm/Hz
UE Allotment	2 per cell	60 per cell

A. MUE and FUE SINR Results

The Cumulative Distribution Function (CDF) of femto user equipment FUEs' SINR of all edge users. As the interference from FBS to MUE is dynamically canceled by HCIG proposed scheme remarkably improves the SINR performance of FUE, especially reduces the number of FUEs with low SINR. In addition, as only the interference among FBSs is considered in adaptive frequency reuse (AFR), the FUEs' SINR in AFR is similar to that in SFA as shows in Fig.2.

The Cumulative Distribution Function (CDF) of Micro user equipment MUEs' SINR of all edge users. As the interference from MBS to FUE is dynamically canceled by HCIG, the proposed scheme remarkably improves the SINR performance of FUE, especially reduces the number of MUEs with low SINR. In addition, as only the interference among MBSs is considered in AFR, the MUEs' SINR in AFR is similar to that in SFA as shows in Fig.3.

The Cumulative Distribution Function (CDF) of inner MUEs' SINR. The interference to MUE can be divided into two types: from neighbor FBSs; from the MBS. In addition, the interference from MBS to FUE is getting more seriously when FUE is closer to the MBS. In AFR, only the interference from neighbor FBSs is canceled; while in HCIG, the interference from MBS is also canceled by assigning orthogonal resources to MUEs and inner FBSs. So for inner FUEs, the SINR performance insignificantly improved by HCIG compared to SFA and AFFR; for outer FUEs, the SINR of FUEs is improved similarly by AFR as shows innFig.4.

The Cumulative Distribution Function (CDF) of inner FUEs' SINR. The interference to FUE can be divided into two types: from neighbor MBSs. In addition, the interference from FBS to MUE is getting more seriously when MUE is closer to the FBS. In AFR, only the interference from neighbor MBSs is canceled; while in HCIG, the interference from MBS is also canceled by assigning orthogonal resources to MUEs and inner FBSs. So for inner FUEs, the SINR performance insignificantly improved by HCIG compared to SFA and AFFR; for outer FUEs, the SINR of FUEs is improved similarly by AFR as shows in Fig.5.

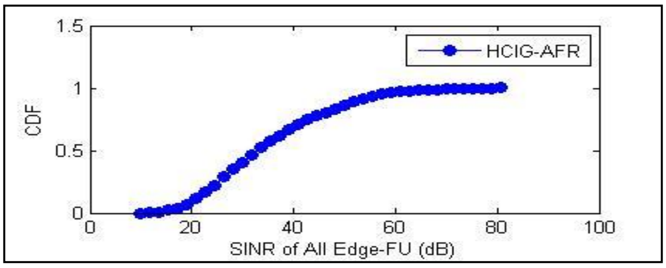

Fig.2 All edge FU SINR CDF

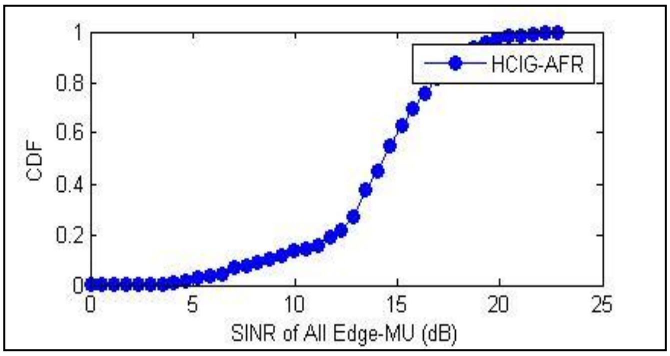

Fig.3 All edge MU SINR CDF

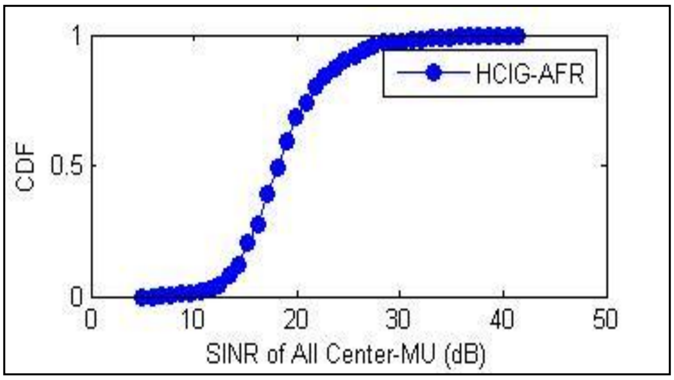

Fig.4 All Center MU SINR CDF

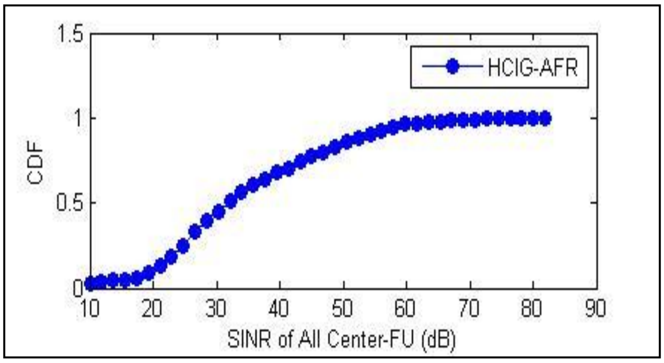

Fig.5 All Center FU SINR CDF

VI. CONCLUSION

Our proposed hybrid clustering interference graph (HCIG) in which three types of interference is reduced. Also the best clustering algorithm is formulated. After HCIG, not only the minimum sub-bands are allocated to FBS, but also other sub bands which are not interring with neighbor FBSs are assigned to FBS to enhance the spectral efficiency. Furthermore, as the location of FBS is fixed and only interfered MUEs are taken as graph node, the overhead of updating the interference graphing HCIG is very low. The system level simulation shows that both the SINR of MUE and FUE are significantly improved by HCIG.

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