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Intercell Interference and Cross Tier Interference Mitigation in LTE based Femtocell Network using 'CASFR' Scheme

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Abstract: One of the effective techniques of improving the coverage and enhancing the capacity and data rate in cellular wireless networks is to reduce the cell size and transmission distances. Long Term Evolution (LTE) has developed small cellular base stations called femtocells that can dramatically improve voice and data coverage for the indoor subscribers. Therefore, the concept of deploying femtocells over macrocell has recently attracted growing interests in academia, industry, and standardization forums. Various technical challenges towards mass deployment of femtocells have been addressed in recent literature. However, the inter- and intra tier interferences in such systems can significantly reduce the capacity and cause an unacceptably high level of outage. In this paper we propose a scheme which mitigates co-tier as well as cross tier interference using cluster aware soft frequency reuse scheme. That assigns distinct set of Physical Resource Blocks (PRB)s to each interfering femtocells. The scheme first uses periodic messages from the femto-user (FUE) to identify the interfering femtocells. It then divides each femtocell area into cell-center and cell-edge. Finally, it uses the CASFR algorithm to assign un interfering sets of PRBs to the cell-center and cell-edge users of all the interfering femtocells Same process is followed by macrocells. The proposed interference mitigation scheme for femtocell networks offers significant performance improvement over the existing methods by substantially reducing the co-tier and cross-tier inferences in the system.

Keywords: Physical Resource Blocks (PRB), Femto-user (FUE), Inter-cell interference (ICI), PRB Swapping and Exchange (PSE).

I. INTRODUCTION

In the recent years, a rapid increase of data traffic in the cellular services point towards a data explosion in the near future. To cater to the increasing demands for transmission speed and low latency, the Universal Mobile Telecommunications System (UMTS) cellular technology has been upgraded and dubbed as Long Term Evolution (LTE). However, indoor coverage problem will continue to exist due to propagation path loss suffered by radio signals while travelling through walls from the outside macro base station (MBS). Since more and more people are ditching their landlines in favor of mobile phones, as well as because of the simple fact that people want to be able to talk on their cell phones wherever they are, it has become necessary to work on new technology that will facilitate calling coverage both indoor and outdoor. Femtocell technology could be the answer. In addition to facilitating better indoor call coverage, this emerging technology reduces the drain that advanced mobile services (such as mobile broadband) are placing on the capacity offered by phone companies. One of the solutions that people have started to use is femtocell technology. This technology may be better known to the user as an Access Point Base Station, a small device which is installed in the home or office in order to offer better support to mobile phones there. These base stations can accommodate up to five cell phones which means that you can get increased coverage for your whole household. Essentially, you set up the femtocell technology in your home and it serves to enhance the cell phone signal that you receive indoors so that your call quality isn't decreased when you're talking indoors. "Femtocell" is a wireless access point that improves cellular reception inside a home or office building.'' A femtocell is a miniature cell tower for homes or small businesses that extends a carrier's traditional network's range. Femtocells connect to a carrier's network over the customer's broadband internet connection and provide a strong local signal that cell phones in the building can use for any of the typical voice or data applications. Unlike macro networks, femtocells are usually deployed in an unplanned manner with overlapping coverage areas. In such a multicellular environment, ICI occurs when users from different cells are present on the same sub-carrier during data transmission. This is most seriously noticed in the cell edge terminals as a result of frequency collision with neighboring cells. For addressing this problem many solutions have been proposed.

In this paper we introduce a novel Cluster Aware Soft Frequency Reuse (CASFR) scheme and PRB Swapping and Exchange (PSE) scheme that effectively mitigates co tier as well as cross tier interference. Co-layer is the interference of the same network, i.e. a FAP interfere with the neighboring femtocell user.

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Cross-layer refers to the interference between the users of two different network layers as the FAP and the macrocell.

II. LITERATURE REVIEW

As femtocells are sometimes embedded inside a macrocell, both macro and femtocell should operate on a certain frequency. The operators need to specify the allotted frequency range for the macro and femtocells. This frequency allocation is a tedious job. A little mismanagement can lead to various levels of interference problems. For addressing this problem many solutions have been proposed. In the proposed scheme[1], macrocell coverage area is divided into two zones i.e. central zone and edge region. These two zones are further divided into three sectors. The frequency band is also divided into two parts, in which one part is further divided into three portions. The total frequency band is denoted by A, B, C and D in Figure .

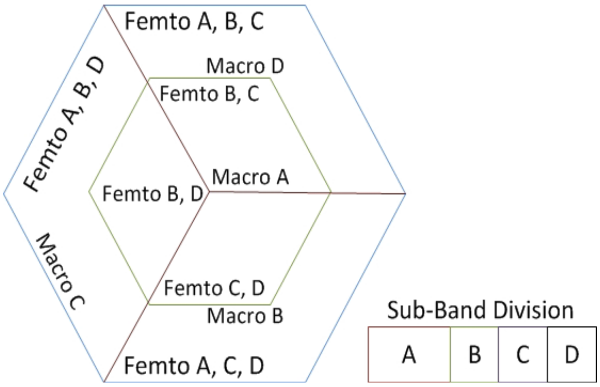

Fig 1: Sab-Band Division Model

The macrocell's center zone uses the frequency band A while the edge users uses the B, C and D sub-bands. The femtocell chooses the bands which are not used in the particular macrocell sub-area e.g. as shown in Figure 1. The center zone femtocells uses the B, C and D frequency bands while the edge region femtocells chooses the sub-bands which are not used by particular edge region macrocell. Due to small coverage of femtocell the sub-bands are reused as much as possible. The proposed scheme enhances the overall throughput, especially throughput of the edge users. It also reduces the interference problem. In [2][3], fractional frequency reuse (FFR) strategy adopted by macrocell in two tier macrofemto network is presented. The macrocell located at the origin transmits its signals in a circular disc shape as shown in Figure 2. This coverage zone is divided into two sub-regions i.e. inner circle and outer circle. This coverage zone is divided into two sub-regions i.e. inner circle and outer circle. By using FFR strategy, the allocated set of channels within the bandwidth is divided into two sub-bands i.e. one band for inner circle and other for outer circle. The femtocells are randomly distributed over the entire area. The macrocell and the femtocell schedule one sub-channel to one Mobile Station (MS) at a time. This scheduling is performed in a round robin fashion. The proposed strategy achieves a substantial gain in transmission capacity.

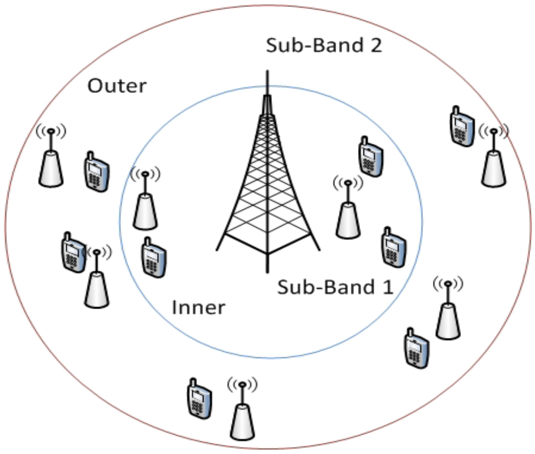

Fig 2: Network Model Based on Two Sub-Bands

However a drawback in the proposed approach is that in practical environment, the cell shape is hexagonal not circular shaped. In [4][5], FFR scheme is presented. The proposed scheme adjusts the frequency reuse according to the working environment. This technique helps in mitigation of inter femtocell interference. Based on the mutual interference information, the femtocell gateway classifies femtocells into number of groups. It then allocates minimum number of orthogonal sub channels for each group of femtocell. After allocation, the transmit power of each femtocell is adjusted to provide target performance. This scheme does not work properly in dense femtocell environment when each femtocell has different load. In [6], frequency planning scheme for femtocells in the existing macrocell environment is presented. The scheme presented is based on soft frequency reuse. In the proposed scheme, macro and femtocells are divided into two regions i.e. inner and outer region The inner macrocell and the outer femtocell use the same frequency band while the outer macrocell and inner femtocells uses the same frequency band. In this scheme the femtocells do not cause co-channel interference to nearby macrocell users and there is no use of signaling between the MS and femtocell for resource allocation. However, the inner femtocell throughput increases while the outer femtocell throughput decreases as power ratio and transmission power of femtocells increases. In [7] Adaptive Soft Frequency Reuse (ASFR) scheme was proposed which allows the cell-edge users to borrow Physical Resource Blocks (PRBs) from the neighbouring cell that has the highest numbers of free cell edge PRBs. Only those PRBs that are reserved but not in use by cell edge users in the neighbouring cell can be borrowed. However, ASFR cannot guarantee low ICI, as borrowable PRBs in one neighboring cell may be in frequent use by cell edge users in another neighboring cell. In [8] Cluster Aware Soft Frequency Reuse (CASFR) scheme and PRB Swapping and Exchange (PSE) scheme was proposed that effectively mitigates the downlink and uplink interference within the femtocells. The main contributions of our scheme are: 1) In contrast to other SFR scheme, CASFR divides the bandwidth in each cell based on the number of interfering FBSs. This flexible resource allocation guarantees complete obliteration of ICI

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in the downlink of LTE femtocell networks; 2) The PSE scheme takes care of the uplink interference by avoiding PRB reuse and swapping the interfering PRBs with the PRBs from the non interference zones. This scheme mitigates only co tier interference.

III. IMPLEMENTED MODEL

Femtocells are not only a good solution to overcome the indoor coverage problem but they can also deal with the growth of traffic within the network to some extent. However with the deployment of new femtocells, the performance of macrocell layer can be undesirably impacted. The challenges that can arise are the allocation of spectrum resources and avoidance of electromagnetic interferences.

Co-layer is the interference of the same network, i.e. a FAP interfere with the neighboring femtocell user. Above schemes are useful to mitigate co tier interference.

Cross-layer refers to the interference between the users of two different network layers as the FAP and the macrocell. This type of interference results in poor signal quality. To mitigate cross tier interference along with co tier interference we proposed new scheme "co tier and cross tier mitigation in LTE based femtocell network using cluster aware soft frequency reuse scheme".

A. Project Algorithm Steps

Project solves both Co-tier Interference and Cross-tier Interference in femtocell network based LTE.

1] Simulation parameters are defined 2] LTE network comprising of macrocell and femtocell are defined. 3] Number of Femtocells interference is placed in the network scenario. 4] The Coverage Probability for the LTE network is calculated. 5] Dynamically allocate Resource Blocks (RBs) to the User Equipment (UE).

B. Mitigating Co-tier Interference in the network

i) FBS Continuously receives periodic information from its FUE & all FBS should synchronize with each other. ii) Threshold is defined iii) Calculate SINR(interference) for the network iv) Condition check as if Interference > Threshold v) If condition is true then make group of interfering FBS & perform cell partitioning: - cell center as well as cell edge area. vi) Allocating RBs which is not in used by any interfering FBS & serving FBS. vii) Then again check above condition. viii) If condition is true then exchange RBs with neighboring cell edge. ix) If condition is false then END process.

C. Mitigating Cross-tier Interference in the network

i) MBS Continuously receives periodic information from its MUE & all MBS should synchronize with each other. ii) Condition check as if Interference > Threshold iii) Perform cell partitioning: - cell center as well as cell edge area. iv) RBs which is free i.e. not in used by any interfering FBS/MBS & serving MBS/FBS that can be Reuse. v) Then perform adaptation process for above & check Interference is below threshold level then END process.

Downlink interference mitigation.

First all the PRBs are allocated randomly by FBS and MBS to all FUEs and MUEs. This is done by mapping process. A specific message is sent to all the users periodically and according to that their reports are collected periodically by the MBs and FBs. If the message is not sent in the expected time then there is the chance of interference. From these results throughput is compared with the Intercell interference and cross tier interference. If throughput is greater than interference then there is no problem. If it not so then we have perform CASFR. If throughput is less then FBs and MBs creates the list of the interfering cells. Then it Divides the PRBs into a set ‘N’, Allocates distinct set of PRBs to interfering cells so that they can use the frequency from the al-located PRB’s and then no two FUEs or MUEs will use the same frequency. Ultimately the interference will get reduced. Also the FBs and MBs makes the cluster of Two or Three interfering cells so that one set of PRB can be allocate to cluster and not to individual cell. It preserves the set of PRBs. This procedure is continued till the throughput becomes more than the interference and interference is mitigated dramatically. At the end cell center radius is decreased till the cell edge radius becomes equal to the entire cell.

Uplink interference mitigation.

There is interference pre-sent in uplink which causes due to the MUEs pre-sent in the FBs region of coverage and FUEs of other cells. To mitigate this interference we pro-pose the concept of PRBs exchange and swap-ping. As we know interference is experience in only that area of the cell where the user is present in other area there may not be the same quantity of interference. Thus when some user experiences the interference in some area of the cell then that user can exchange its set of PRBs with the other user which is present in the same cell but in the other area where interference may be less. Thus we can use this concept of swapping and ex-change of PRBs to mitigate uplink interference.

Calculation of parameters

As stated the objective of this system is to mitigate the interference. For these purpose we have to calculate all the parameters related to interference.

Sources in time and frequency domain the interference should be consider in both. So the interference is given as,

$$I_n^r = \sum_{i \in M'} P_n^m G_n^{r,i} + \sum_{j \in F'} P_n^f G_n^{r,j}.$$

Where n denotes the total number of users. P^m denotes the transmit power of the MUEs in the uplink and MBS in downlink. $G^{r,i}$ is the gain between interfacing MUEs and FBS. P^f denotes transmit power of FUEs in the uplink and FBS in the downlink. $G^{r,j}$ is the gain between interfacing FUEs and MBS.

From the above equation we can calculate the SINR, Signal to Interference and Noise Ratio.

$$SINR_n^r = \frac{P_n^t G_n^{r,t}}{\sum_{i \in M'} P_n^m G_n^{r,i} + \sum_{j \in F'} P_n^f G_n^{r,j} + \eta}.$$

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Where P^t is the transmit power per PRB and $G^{r,t}$ is the gain between receiver and transmitter. η is the thermal noise. Now we can calculate the throughput of the system from the SINR.

To calculate throughput we will use Shanon's theorem. By this theorem the channel data rate is given as, Where LS is the path loss. Now we have to calculate all the path losses described in [5].We will con-sider indoor, outdoor and indoor-to-outdoor path losses.

First we will calculate the path loss of the distance between femtocell user and macrocell user and the FBS. It is given by,

$$LS = 15.3 + 37.6\log_{10}\left(\frac{d}{1000}\right) \quad dBm$$

D is the distance between transmitter and receiver .Second path loss is between the MUE and MBS. It is given by,

$$LS = 15.3 + 37.6\log_{10}(d) \quad dBm$$

Last path loss is indoor user to MBS. It is given by,

$$LS = 15.3 + 37.6\log_{10}(d) + L_W \quad dBm$$

Where Lw is the penetration loss. From above three equations overall path loss is calculated. Average of all losses is calculated and used in the calculation of gain between the transmitter and receiver. Gain is calculated in db.

IV. EXPERIMENTAL RESULT

Using experimental result we show co-tier cross -tier interference as well as throughput for both. First the simulation parameters for the network are loaded. after that power and SINR calculation is done. Then CASFR algorithm is applied to both femtocell and macrocell network. The simulation environment has been designed in MATLAB and consists of M = 5 MBS each having ʎ FBS in their coverage area. The value of ʎ varies between 1 and 5. The MUEs are uniformly dropped in the MBS cells. The FBSs are dropped within a predetermined area of the MBS to ensure femtocell overlap. Each FBS can serve upto 4 FUEs while each MBS can serve multiple MUEs at a time. We consider a closed-access FBS system where only registered users have access to a FBS

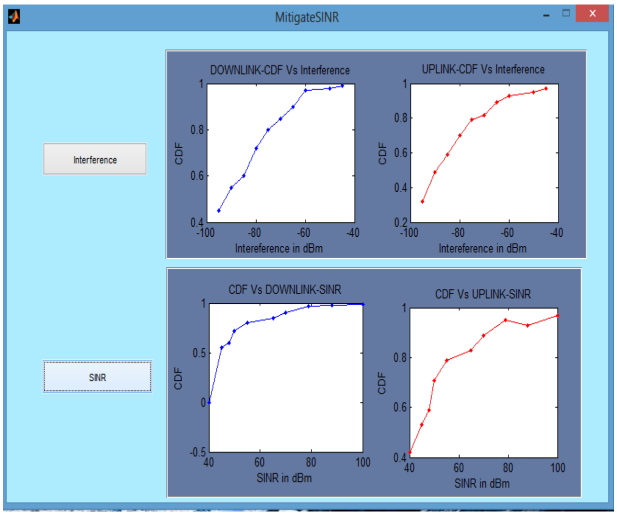

Fig1: Interference for downlink and uplink for co -tier.

Fig1. shows the cumulative distribution function (CDF) of downlink interference and uplink interference of CASFR as well as SINR for downlink and uplink for co-tier

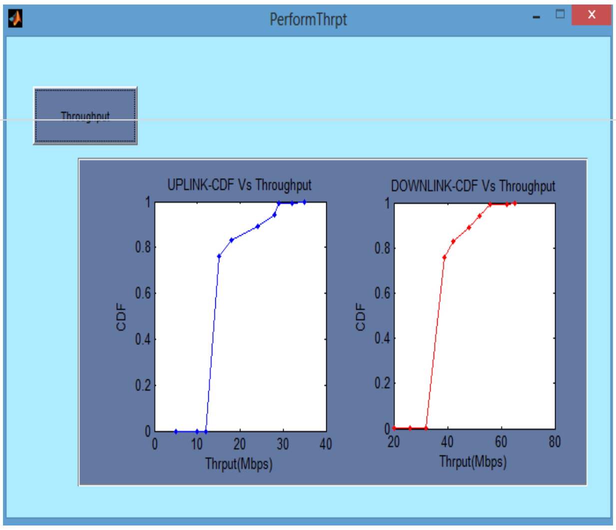

Fig 2: Output for co-tier .

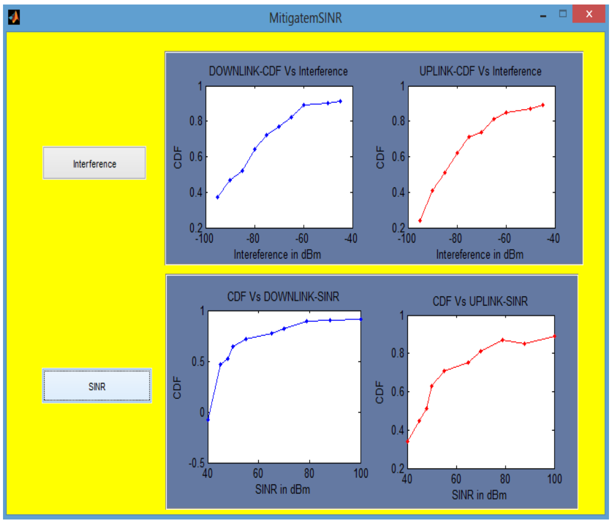

Fig 3: Interference downlink and uplink for cross-tier.

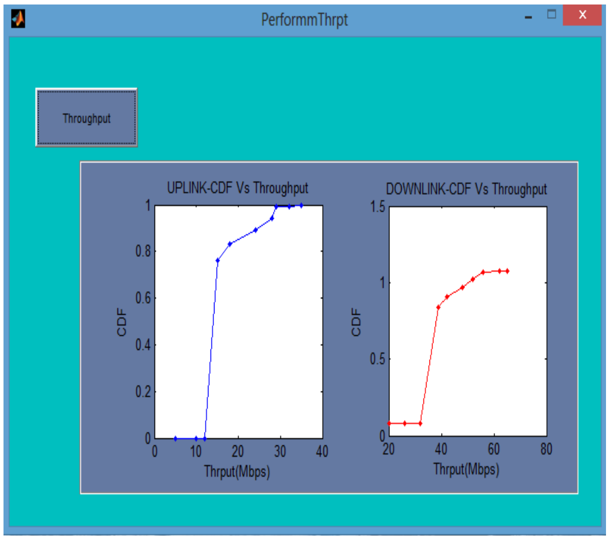

Fig 4: Output for cross-tier.

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As seen fig shows the cumulative distribution function (CDF) of downlink interference and uplink interference of CASFR as well as SINR for downlink and uplink for cross-tier

V.CONCLUSION

In this paper we propose a soft frequency reuse scheme for the 3GPP LTE femtocell networks. The scheme is triggered every time a FUE experiences strong interference from its neighboring femtocells. By allocating distinct set of PRBs to the cell edge users, our scheme considerable reduces the interference, which, automatically increases the throughput of the cells. As future enhancement the performance of this scheme can be improved by increasing numbers PRB's.

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