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# Inter-cell Interference Mitigation Reduction in LTE Using Frequency Reuse Scheme

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***Abstract-*** For satisfying the need of increasing number of users, their demands for the services and to provide enhanced indoor coverage, Long Term Evolution (LTE) has developed small cellular base stations called Femtocells. However, limited spectrum Availability in the cellular networks causes severe interference Issues in the neighboring femtocell users transmitting in the same radio band. In densely deployed environments, interference problem in co-channel femtocell networks causes significant degradation in performance. In this paper, we propose a Cluster-Aware Soft Frequency Reuse (CASFR) scheme that assigns distinct set of Physical Resource Blocks (PRB) s to each interfering femtocells. At first this scheme checks interference level of the Femtocell User Equipment (FUE) to identify the interfering femtocells. It then form a cluster of all interfering femtocells and apply Cluster Aware Soft Frequency Reuse (CASFR) algorithm to partition area of each femtocell into cell-center and cell-edge regions then assign non-interfering unique sets of RBs to the cell-center and cell-edge users of all the interfering femtocells. This method achieves improvement in the performance for the overall femtocell network by efficiently alleviating the uplink and downlink interference.

***Index Terms*: LTE, Femtocell, CASFR, PRB**

## 1. INTRODUCTION

Femtocells are low-power base stations that can be installed inside buildings as a single stand-alone device or in clusters, and provide improved indoor coverage at low-cost . The femtocells are linked to the main core network using the mobile backhaul scheme that uses the user's Digital Subscriber Line (DSL) or other internet connections. In addition to high performance and better coverage, femtocells can also help to reduce load from MBS by channelling a fraction of its traffic through the internet service provider of the user. This freed-up capacity can be used to accommodate more users entering the network.

A broadband internet connection is a prerequisite for connecting a femtocell. The femtocell encrypted all voice calls and data sent or received by the mobile phone. This makes it impossible for an external user to break into a user's home network. For a standard 3G cellular phone, the femtocell appears as another cell site or macrocell, hence communicating with it as it would with a macrocell, when the mobile phone is used outdoors. Since femtocells operate at very low radio power levels, battery life is high. Also call quality is excellent, when the distance between the femtocell and the mobile handset is short. The mobile operator's data switch and telephone switch communicate with the femtocell gateway in the same way as for other mobile calls. Therefore, all services including call diversion, phone numbers, and voicemail etc. all operate in exactly the same way and appear the same to the end user. The connection between the femtocell gateway and the femtocell is encrypted using IPSec, which prevents interception. There is also authentication when the femtocell is installed for the first time to ensure that the access point is a valid one. Inside the femtocell there are the complete workings of a mobile phone base station. Some additional functions are also included, such as the RNC (Radio Network Controller) processing, which would normally reside at the mobile switching center. Some femtocells also include core network element so that data sessions can be managed locally without needing to flow back through the operator's switching centers.

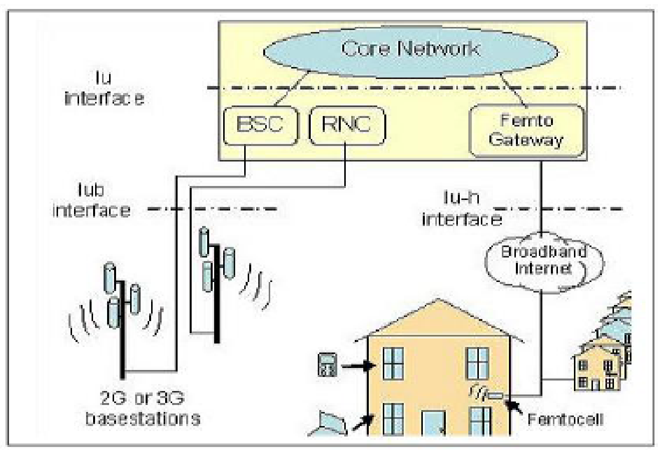


Fig 1 Femtocell using a Core Network

Interference mitigation between neighboring femtocells and between the femtocell and macrocell is considered to be one of the major challenges in femtocell networks because femtocells share the same licensed frequency spectrum with macrocell. Further, overly concerned with convention radio resource management techniques for hierarchical cellular system is not suitable for femtocell networks since the position of the femtocells is random depending on the users' service requirement. In this, we provide a survey on the different state-of-the-art approaches for interference and resource management in orthogonal frequency-division multiple access (OFDMA) based femtocell networks.

A qualitative comparison among their different approaches is provided. To this end, an open challenges in designing interference management schemes for OFDMA femtocell networks.

Initially the CASFR algorithm gets knowledge about the current interference level of the Femtocell User Equipment (FUE) and then proceeds to reduce it. Hence it improves the Signal-to-Interference-and-Noise Ratio (SINR) values, for the users also increases spectrum efficiency of the network. The proposed methodology not only increases the resource efficiency but also reduced interference between Co-channel cells.

**Orthogonal Frequency Division Multiplex (OFDM)**

One of the key features of LTE is the use of Orthogonal Frequency Division Multiplex (OFDM) as the signal bearer Due to its resilience to interference and robustness to multipath fading. The actual implementation of the technology, although, will be different in the uplink and the downlink. It has been decided that Single-Carrier Frequency Division Multiple Access (SC-FDMA) will be implemented in the uplink and Orthogonal Frequency Division Multiple Access (OFDMA) in the downlink. Both SC-FDMA and OFDMA encodes digital data over multiple orthogonal sub-carrier frequencies which are then transmitted over several orthogonal sub-bands, thus mitigating intra-cell interference. Thus, the major portion of the interference management problem in LTE based femtocell networks narrows down to mitigation of interference among neighboring cells, also termed as Inter-cell Interference (ICI).

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 and soft frequency reuse (SFR) is considered as the most representative approach due to its effectiveness of Inter-Cell Interference Coordination (ICIC) without compromising spectrum efficiency.

***Inter-Cell Interference Mitigation*** It is known that effective reuse of resources in a cellular system can highly enhance the system capacity. With a smaller frequency reuse factor (FRF), more available bandwidth can be obtained by each cell. So, in this sense the classical FRF deployment is desirable.

**1.1Problem Definition**

ICI mitigation is a big challenge issue in cellular systems. Excessive ICI may lead to severe performance degradation or connection loss especially in the border area of cells. In order to efficiently reduce the ICI whilst not drastically reduce the utilization of the scarce frequency spectrum, suitable radio resource management (RRM) is desirable.

In densely deployed environments, interference problems in co-channel femtocell networks cause significant degradation in performance.

**1.2 Proposed Scheme**

The main objetive of this proposal is to mitigate Co-channel interference between the femtocells present in the cell edge areas. Interference occurs when two or more closely located FBSs with overlapped regions transmit using the same RB. This has severe degrading affects to the SINR values of both the FBSs and the FUEs; thereby reducing their throughput to a great extent. One way to solve this issue is by allocating distinct set of sub-carriers to the users at the cell edge of each cell.

Uplink Interference

As seen in figure 2, MUEs in the transmission range of FBS cause interference in the uplink. FUEs of the neighboring cell also cause uplink interference if transmitting on the same PRB.

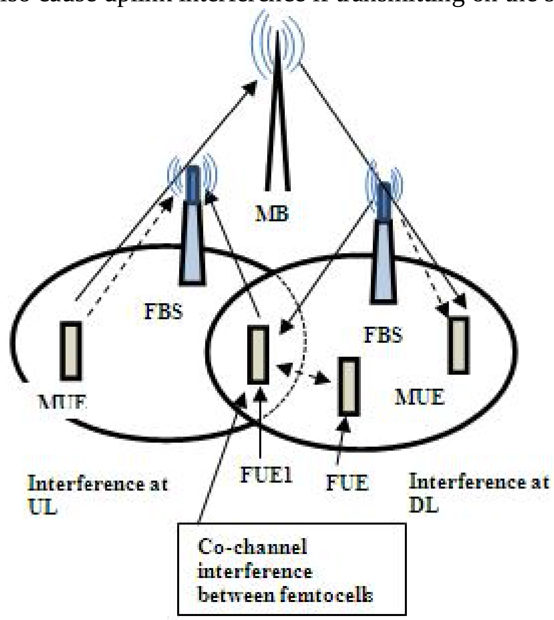


**Fig 2:** Interference Scenarios.

**2. CLUSTER-AWARE SOFT FREQUENCY REUSE SCHEME**

A Cluster-Aware Soft Frequency Reuse (CASFR) scheme 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.

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. The algorithm is shown below.

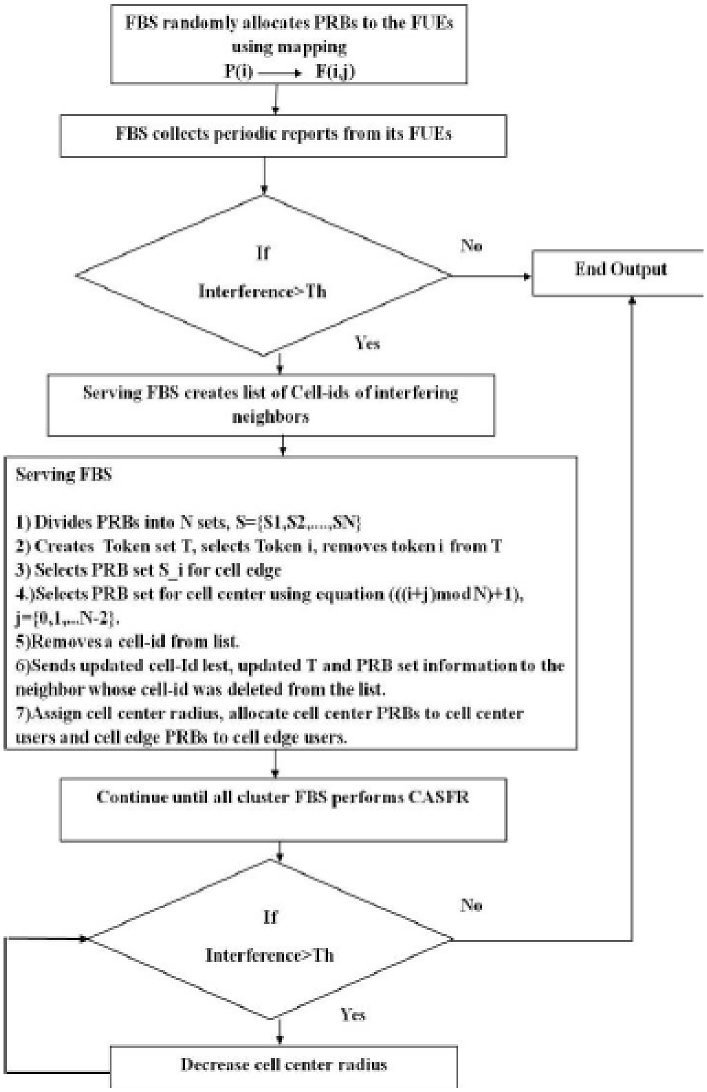


**Fig 3: CASFR Algorithm**

SYSTEM MODEL

### 2.1 Mathematical Equations

As stated, the main objective of this paper is to mitigate co-channel interference between the femtocells present in the cell edge areas. We consider a system with bandwidth B that is divided into N PRBs. The signal power observed by receiver r from transmitter t on PRB n is given by,

$$Y_n^r = P_n^t G_n^{r,t} \qquad (1)$$

where $P^t_n$ is the transmit power per PRB n and $G^{r;t}_n$ is the channel gain between r and t.

## Interference:

Since the macro and femtocells share the same available resources in both time and frequency domain, the interference received at any receiver r is the aggregated interference from both. Thus $I^r_n$ is given by:

$$I_n^r = \sum_{i\in M'} P_n^m G_n^{r,i} + \sum_{j\in F'} P_n^f G_n^{r,j} \qquad (2)$$

Where $P^m_n$ denotes the Macro User Equipment (MUE) Transmit power in the uplink and MBS transmit power in the Downlink. Likewise, $P^f_n$ denotes uplink Femto User Equipment (FUE) and downlink Femto Base Station (FBS) transmit power respectively. The sets of interfering macro and femtobase stations are denoted by M0 and F0 respectively. $G^{r;I}_n$ is the channel gain between the FBS and interfering MUE in the uplink and FUE/MUE and interfering MBS in the downlink. Similarly, $G^{r;j}_n$ is the channel gain between the FBS and interfering FUE in the uplink and FUE/MUE and interfering FBS in the downlink.

## Signal-to-Interference-and-Noise-Ratio

The Signal-to-Interference-and-Noise-Ratio (SINR) can be determined from Equation (1) and (2) as follows:

$$SINR = \frac{P_n^t G_n^{r,t}}{\sum_{i\in M'} P_n^m G_n^{r,i} + \sum_{j\in F'} P_n^f G_n^{r,j} + \eta} \qquad (3)$$

where η is the thermal noise per PRB n.

### 3. SIMULATION RESULTS

The simulation parameters are summarized in Table 1.

TABLE I: Simulation Parameters

| Parameters | Values |
|---|---|
| Macro cell layout | 3 sectors per MBS |
| Femto cell layout | 1 sector per FBS |
| Bandwidth | 15 MHz |
| Max. FUE per femto cell | 4 |
| Macro cell radius | 500 m |
| Femto cell radius | 10 m |
| Thermal noise, $\eta$ | -174 dBm/Hz |
| Operating Frequency | 2 GHz |
| Wall penetration loss, $L_W$ | 20 dBm |
| Interference Threshold | -60 |
| MBS TX power | 38 dBm |
| FBS TX power | 20 dBm |
| Max. MUE TX power | 24 dBm |
| Max. FUE TX power | 20 dBm |
| Min. MUE/FUE TX power | -30 dBm |
| cluster size | 2,3,4 |
| r-percentile path loss value, $\alpha$ | 124 dB |
| Balancing factor, $\xi$ | 1 |

We generate a dense Femto cell environment where multiple FBSs are randomly deployed in an apartment complex. Each apartment can have only one Femto cell. However, due to a higher number, the coverage areas of the Femto cells overlap with each other. Some FUEs of this femto cell will fall in these overlapped zones. Since a FBS only serves it's registered users, any unregistered user located in its coverage area will suffer from interference. The MUEs that lie close to a FBS will also suffer from interference. On the other hand, the FBSs will also suffer uplink interference from the nearby MUEs. Finally, if a FBS is located at the edge of a macro cell, it will suffer interference from the neighboring macro cells. This paper only aims to mitigate interference between the Femto cells, thereby maximizing the throughput of the FUEs.

The rest of this section analyzes the downlink interference and user throughput of the FUEs and uplink interference and throughput of FBS. We consider femtocell cluster of sizes 2, 3 and 4. The femtocells that do not participate in a cluster are not considered. The graphs represent the performance of CASFR in all types of FUEs. That is, we consider all the FUEs irrespective of whether they lie in or out of the interference zones. The CASFR algorithm is compared against an Adaptive Soft Frequency Reuse (ASFR) scheme that allocates one-third of the cell bandwidth to the cell-edge users. The cell center users can share the cell edge bandwidth without causing intra-cell interference. Figure 4 compares the cumulative distribution function (CDF) of downlink interference of CASFR against ASFR. The figure clearly demonstrates the significance of CASFR in mitigating ICI in closely located Femto cells. When CASFR is utilized, the average interference of the FUEs is reduced by 14%. This is due to the fact that the cluster FBSs keep shrinking their cell-center radii until the FUE interference level goes below the threshold. As the cell edge of each Femto cell in the cluster operates on distinct PRB sets, the only interfering entity is the overlaying MBS. The same effect can be seen in the SINR values, as shown in Figure 5. As a result of reduction in interference, the SINR values produced by CASFR are 15% more than that of the ASFR algorithm. As seen from Figure 7, PSE further reduces the uplink interference by controlling PRB reuse.

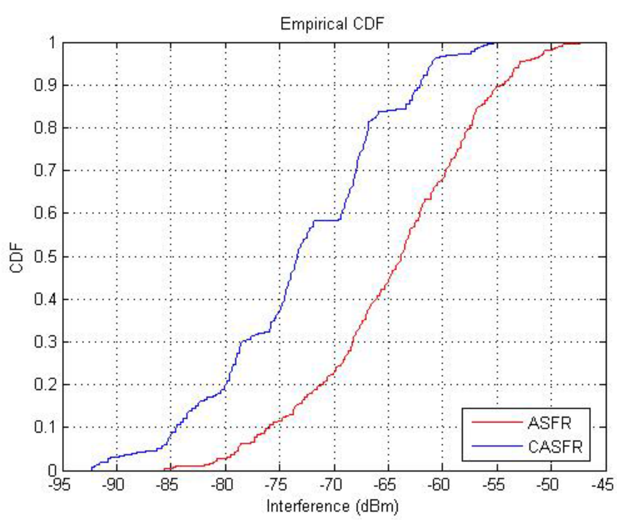


Fig. 4: Downlink user Interference

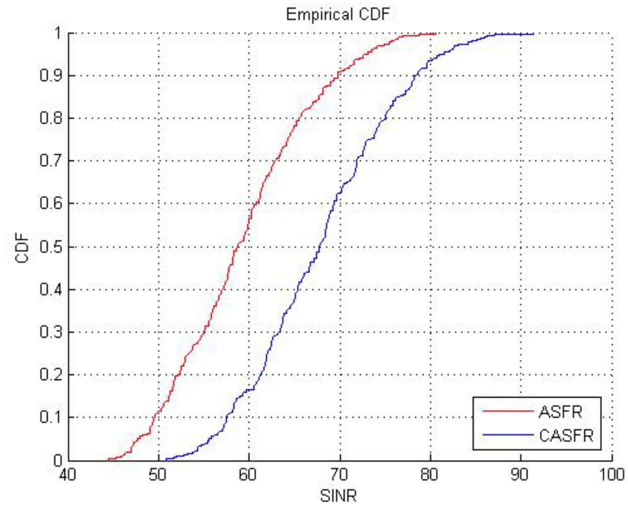


Fig. 5: Downlink user SINR

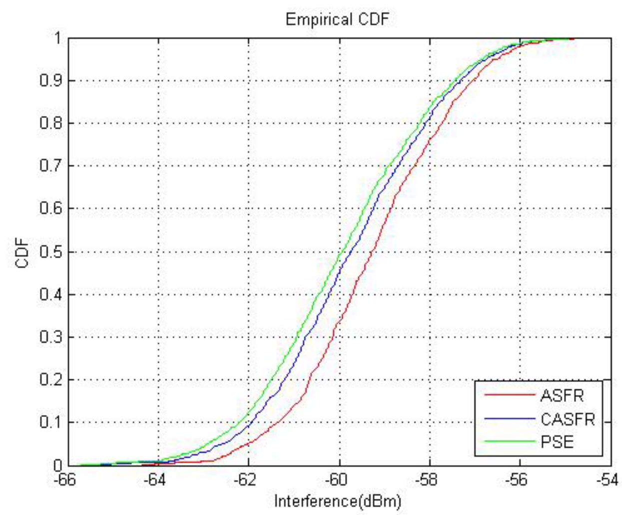


Fig. 6: Uplink interference of FBS

4. CONCLUSION

In this paper a Cluster Aware Soft Frequency Reuse scheme is proposed 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 this scheme considerably reduces the interference which automatically increases the SINR of the cell.

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