

Overview of Interference Management Techniques in Femtocell Networks: Challenges and Approach

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Abstract- *The most important use of techniques for the new technology network called femtocell, is to improve coverage and enhance capacity in mobile network. However, the deployment of femtocell over macrocell network has a new technology has attracted benefits in telecommunication industry. Several technical challenges toward the mass deployment of these new technology called femtocell have been addressed in industry. Interference mitigation between femtocell and macrocell, and among the neighboring femtocell user, is considered to be one of the major issues in femtocell networks due to sharing the same licensed frequency spectrum with macrocell. In this paper, we provide different techniques schemes for interference mitigation and general view for the efficiency of interference management techniques in femtocell network.*

Index Terms— Femtocell, Interference, Management, Techniques

I. INTRODUCTION

The deployments of femtocells connectivity to mobile operator's network using the cable broadband internet connection, through the access point to boost the network performance at the indoor setting, as gain the interest of the service provide. They are employed to work with the range of different cellular standards such as Coding Division Multiple Access (CMDA), Global System for Mobile Communication (GSM) and Universal Mobile Telecommunication System (UMTS) [1]. A study as show that more than 50% of calls are indoor environment and 70% of all data traffic originates from the indoor [2]. With the installation of femtocell, subscriber may use internet as a means to access cellular networks. More so, the engagement of femtocell facilitates the capacity requirement and quality of service to end users. It's provided good coverage and capacity performance in term of networking, as well as improves the cost effectiveness to both the mobile service and subscriber user.

There are technical challenges that associate with the deployment of femtocell. This challenge is the co-existence between the macrocell and femtocell using the same license band for their operation, and also among the neighboring femtocell users. These cause interference that brings about the poor reception in network at the indoor setting. In recent years, several types of femtocell have been designed and

developed based on various air-interface technologies, services standards and access control strategies. The table 1 show the interference scenario in two-tier architecture networks.

Table 1: show the interference scenarios in two tier architecture networks

Index	Aggressor	Victim	Interference types	Transmission mode
1	Macrocell Users Equipment	Femtocell Base Station	Cross-tier	Up link
2	Macrocell Base Station	Femtocell User Equipment	Cross-tier	Down link
3	Femtocell User Equipment	Macrocell Base Station	Cross-tier	Up link
4	Femtocell Base Station	Macrocell User Equipment	Cross-tier	Down link
5	Femtocell User Equipment	Femtocell Base Station	Co-tier	Up link
6	Femtocell Base Station	Femtocell User Equipment	Co-tier	Down link

However, interference mitigate techniques are required for a successful operation within the network, especially between the macrocell and femtocell, that uses the same license band for transmission and also among the neighboring user of femtocell, and more so to increase the system capacity of the network. Researcher is undergoing numerous activities on interference mitigation [3]. However, fractional frequency reuse is one of the interference mitigates technique, where the whole frequency band is divided into various sub-band and each sub-band is assigned differently frequency bands to each zone and edge region of the cell. This result bring a significant reduce in interference and the networks throughput is enhance.

Another mitigate technique is successive interference cancellation, it usually deployed signal power ranking to determine the cancellations .i.e. the strongest received signal is detect first, follow by other signal, and so on. These

technique has their merit in estimation that a received signal are not accurate [3] and power control such that each user received different power in order to track the same code time signal to interference plus noise ratio [4], [5].

The rest of the paper is organized as follow; in section II we described the technical challenges facing the deployment of femtocell networks. We present the interference techniques overview in section III. The general view for efficiency of interference management techniques is listed in section V. Finally the conclusion in IV.

II. TECHNICAL CHALLENGES IN DEPLOYMENT OF FEMTOCELL NETWORK

The deployment of femtocell have given rise to various challenges in the two tier architecture networks, among of which interference is the most important among other challenges, the interference management is cause due to sharing of spectrum of the existing macrocell networks with femtocell. This interference is between neighboring femtocells and, between macrocell and femtocell network. However, the two types of interference management in two tier architecture networks are:

- **Co-tier interference:** this interference is signal received at the femtocell, from other unwanted femtocells. This decreases the quality of communication. Co - tier interference occur at the same network layer and it mainly between the immediate neighbouring femtocell due to low isolation between houses and apartments. The figure 1 illustrate co tier interference.

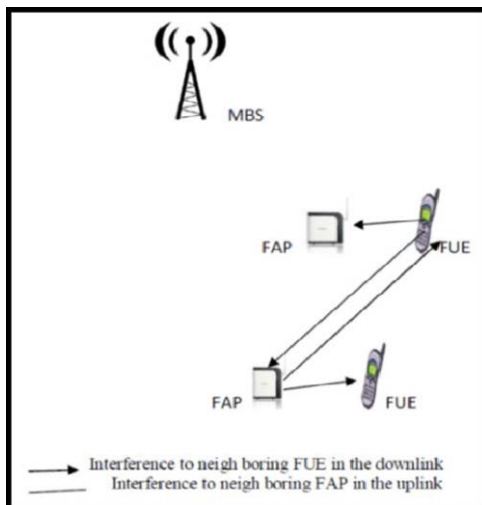


Figure 1: co tier interference between neighboring femtocells

- **Cross-tier interference:** Interference in cross-tier occurs between different network elements. For example, the unwanted signals by FAP cause interference to downlink of macrocell users and likewise the unwanted signal by macrocell user at the uplink cause interference to FAP user. The cross-tier interference is more sever in CDMA co-channel deployment due to the reason that both femtocell and macrocell make use the same frequency band. The figure 2 below illustrate cross tier interference.

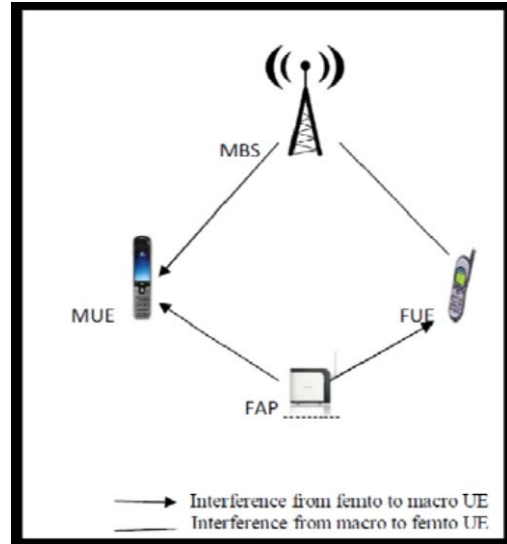


Figure 2: Typical cross tier interference between femtocell and macrocell.

In order to guarantee the required quality of service to macrocell users, femtocells should occupy a little bandwidth as possible which will leads to co-tier interference, and the throughput of the network would significantly decline due to co-tier and cross-tier interference. As the outcome of interference, it is crucial to embrace an effective and healthy interference management techniques that would mitigate both co-tier and cross-tier interference, and enhance the throughput of overall networks. Other challenges of femtocell deployments are such as: handover and mobility management, timing and synchronization, auto-configuration and security.

III. INTERFERENCE MANAGEMENT TECHNIQUES OVERVIEW IN FEMTOCELL NETWORK

In this section, different classes of techniques are described, in order to mitigated interference among femtocell uses in the network such as macrocell BSs and femtocell BSs, and exchanges of information (such as path loss, geographical location), among the neigh boring femtocell and sharing of spectrum logically with them self, which can be consider to decrease both co-tier and cross-tier interference in the network. Here, we provide an overview of different approach for interference management techniques in femtocell networks. These approaches consider both co-tier and cross-tier interference such as;

❖ Femto aware spectrum approach

This approach is proposed by Yi Wu et al [6] to avoid cross-tier interference between macrocell and femtocell. In this approach, the frequency spectrum for macrocell coverage is divided into two portion; such that the macrocell is assign one portion of spectrum and macrocell-femtocell shared the other portion of spectrum. However, the configuration is done by the mobile operator which shared spectrum for both femtocell UEs and macrocell UEs, the macrocell base station has the adequate knowledge of the shared frequency spectrum. Though, the setback of this approach is that it does not consider inter-femtocell interference and may be

ineffective if the number of macrocell UEs near the femtocell increase.

❖ Clustering of femtocell

The authors in [7], present a framework to limit interference between cross-tier and co-tier interference, in order to improve the spectral efficiency of the network. This framework is designed by using femtocell system controller (FSC) for each macrocell obtains through all the information from femtocell system configuration, and all the necessary performs compute by the femtocell. However, interference is minimized due to the combination of dynamic frequency band sharing among femtocell and macrocell, and the clustering of femtocell centered on their geographical location. In this approach, a portion of the whole frequency band is assigned to macrocell users and other portion of the frequency band is reused by both macrocell and femtocell. The merit of this approach is that it solve the problem of dead zone of macrocell UE at downlink and guarantee quality performance of service required. More so, the frequency band shared, is determined by the total number of femtocell clusters that it obtained through a clustering algorithm. The cluster algorithm allocate different frequency for femtocell UEs. This approach has improve in regarding to the problem of dead zone around femtocell and to the minimized co-tier interference among the neighboring.

❖ Beam subset selection strategy

In [8], the authors propose an orthogonal random beam forming based cross-tier interference reduction approach in a closed-access network. For the purpose of multiuser, researchers have investigate the use of beam forming which satisfies the quality performance of the system [9]. The macrocell beam subset selection strategy is structure on the number of macrocell UEs and the strength of femtocell in the network. The macrocell base station selects the beam subset and users for each channel centered on the SINR information for all the channel which is feedback by macrocell UEs. The main objective is to enhance the throughput of the network. The use of beam forming techniques mainly used to suppress interference between macro and femto, enhance data rate, and improve the SINR of wireless systems and the quality of service in the network.

❖ Collaborative frequency scheduling

Co-channel interference can be avoided, if only femtocell did not use the same resource that belong to macrocell UEs in the same network system. However, the spectrum sensing result for femtocell may be damaged. In [10], Sahin et al proposed a framework for OFDMA-based to deal with this problem where the information for macrocell UEs is accepted from the macrocell through air interface. This information accepted are used to increase the spectrum sensing result for femtocell. The major purpose of this approach proposed are as follows:

- To receive information from macrocell UEs.
- To enable femtocell find the occupied parts of the spectrum, which is not be used by macrocell through the energy detection.

- To compares the spectrum results with the information obtained in order to decide about the spectrum opportunities.

❖ Cognitive approach

This approach is centered on distributed spectrum sensing used to alleviate interference in femtocell networks. In [11], a well-organized approach was proposed for co-tier interference management for an OFDMA-based system where all the path-loss information is shared among femtocell neighbors, more so the adjacent femtocell, share information allied to component carriers, in order to achieve the technique in a distributed manner.

Whenever femtocell is on, it recognizes the adjacent neighbors and acknowledge the Component Carriers (CCs) used by the neighbors'. The main idea of this approach, is that each femtocell estimates the co-tier interference built on the information received, and then acknowledge the usage of CCs by the neighbor's and also accesses the spectrum in order to reduce interference.

❖ Power control

Power control approach is another technique that has been used to addresses the issue of interference management where the transmitting power in each mobile base station is adjusted so as to minimize power consumption. The application of power control is widely practiced and applied to network management with a view of mitigating interference and increasing network capacity. The work of Claussen et al. [12], considers the reduction of interference in an indoor environment by altering the power points according to the mobility of events passing indoor users. Since the main relationship between femtocells and macrocells does not consider the full indoor coverage and load balance of multi base station. It is, within such limits, to reduce the impact of interference that affects performance of cellular network.

Other proposed by Vikram et al. [13], presented a coordinated uplink power-control architecture for both macro-femtocells networks by allowing macrocell to use their power control algorithm. Jo et al. [46] proposed a simple uplink power for femtocell, that adjusts the transmit power of femtocell user in proposition to the feedback interference level of macrocell.

❖ Fractional frequency reuse

The basic mechanism of this scheme is partitioning the entire frequency band of the network into several sub-bands, in which each sub-band is separately allocated to sub-area of the macrocell. The entire frequency band is divided into two parts; one is assigned to the center and the other part to edge region, containing three sectors each. However, the resources are not overlapped, so interference between macrocell and femtocell can be mitigated. This approach make use of reuse factor of one for the center zone and reuse factors of three for the edge region. Figure 3.1 depicts interference management approach using FFR method within the serving macrocell sub-area. The sub-band A is used in the center zone and sub-bands B, C, and D are used in

region E1, E2 and E3 respectively. For instance, when a femtocell is sited in region E1, it uses sub-band A, C and D while the macrocell uses sub-band B, but if is positioned in center zone, sub-band C and D is applied. Femtocell evades sub-band A which is used by macrocell in center zone. Also it avoids B which is used by macrocell in region E1 due to the received signal power of sub-band is high for femtocell. Under this approach, cross-tier interference is minimized significantly and the overall network performance increases.



as; (i) improves/significantly reduces both co-tier and cross-tier interferences; (ii) it must be applicable for both uplink and downlink transmissions; (iii) it must ensure cooperation and organization between femtocell base station, macrocell base station and other neighbors using femtocells, or capitalizes on minimal amount of information, i.e., path-loss, geographical location, or usage of the spectrum or; (iv) handles ICI (e.g., by using any method); (v) accepts an adaptive power control scheme; (vi) corresponds to opportunistic access of the spectrum by the femtocell base stations centered on RSSI value from macrocell base stations signals; (vii) it must be scalable and robust, i.e., implementable for mass deployment of femtocell; and (viii) it must be applicable for all three types of access modes (i.e., closed, open, and hybrid

Table 2: show the overview techniques of interference management in femtocell network

Figure 3: shows interference management approach using FFR

❖ Game theory with the concept of price policy

In [14], Akinlabi et al proposed a scheme to mitigate interference management in femtocell network using the concepts of game theory which allow for self-governing decision making. There has been growing interest in accepting game theoretic method to wireless systems. The problem of interference management in femtocell network is approached from the prospective of game theory with the concept of price policy. Whereby price is used to control the power transmission of each femto users in the cell coverage. In this approach, a price policy introduce to reduce the effect of interference between the femto users at both center and edge regions of cell network. The performance of our proposed algorithm is demonstrated by simulation results. The main objective of this model is to monitors and fulfills the following aims;

- ❖ The usage patterns of users that administer the necessary requirement for the quality of performance in the network.
- ❖ The policy enhances the use of the common resources for reliable transmission.
- ❖ The policy promotes fairness and quality of service among the network users.

The formulation of interference management in femtocell network with game-theoretic setting and using the Nash equilibrium as the balance solutions of the formulated problem.

IV. GENERAL VIEW FOR EFFICIENCY OF INTERFERENCE MANAGEMENT TECHNIQUES IN FEMTOCELL NETWORK

In table 2, provides an overview approach of interference management techniques in femtocell network in order to maximum interference, (which is the major challenges for the mobile operators and subscribers in the system) and enhance quality performance of service for mobile uses. For the “efficiency” of a techniques use by the mobile operator, which is determined by this factors for each techniques such

No	Scheme	Transmission Mode	Cooperation between femtocell and macrocell	Efficiency	Type of Interference
1	Femto-aware spectrum	Uplink	Required	Low	Cross-tier
2	Clustering of Femtocells	Downlink	Required	Moderate	Cross-tier and co-tier
3	Beam subset selection strategy	Downlink	Not required	Moderate	Cross-tier
4	Collaborative frequency approach	Up and down link	Not required	High	Cross-tier and inter-carrier interference
5	Power control	Downlink	Not required	High	Cross-tier
6	Cognitive	Downlink	Required	Moderate	Cross-tier
7	Fractional Frequency reuse	Downlink	Not required	High	Co-tier and Cross-tier
8	Game theory	Uplink	Required	High	Co-tier and Cross-tier

V. CONCLUSION

In order to allow mass deployment of femtocells network in the existing macrocell base stations, it is important to develop interference management techniques to handle

interference and primarily satisfy for quality performance of service and fairness resource required by femtocell UEs and macrocell UEs and at the same time improves the capacity coverage of the network. However, such a techniques must acquire low overhead cost to the end users of femtocell and coordination among femtocell BSs and macrocell BSs, and also should be able to integrate various access mode and synchronization issues.

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