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A Peculiar G-OFDM-IDMA Based Interference Mitigation in Cognitive for Femtocell Networks

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Abstract: **This manuscript intends to tell you about a downlink transmission scheme for femto cell networks grouping OFDM-IDMA. We assign macro users and femto users to a separate sub carrier groups for transmission to eliminate cross tier interferences. We use IDMA with deterministic interleaver, basically to mitigate the cotier interferences within the same group of users. The system model and deterministic interleaver is explained clearly, the performance of the proposed scheme in terms of spectral efficiency and bit error rate (BER) is explained elaborately. Having analyzed the theoretical aspects and simulations demonstrates that with the combination of femto cell and grouping ,the proposed schemes levels better performance compared with usual OFDM-IDMA system and at the same time a lower complexity is exhibited than the later.**

Keywords: **Deterministic Interleaver, femto cell, OFDM, IDMA, interference**

1. INTRODUCTION

The upcoming next generation (xG) wireless cellular network will provide very high data rate transmission. Due to high path loss, mobile users at the cell edge and indoor environment fail to maintain targeted quality of service (QoS), i.e., data rate and bit error rate. Thus the femtocell concept has been introduced by (Boudreau, 1999; Chandrasekhar, 2008). Femtocell are low powered, low cost, user deployed, self organizing base station that helps the users of macro cellular network to achieve high QoS at the indoor environment and cell edge. Interference is the main obstacle in heterogeneous, i.e., a mixture of macro and femto cells, multi-cell environment. A Macro cell Mobile Station (MMS) may receive interference from Femto Base Station (FBS) whereas a femtocell mobile station (FMS) may receive interference from macro and femtocell's. It can impair the spatial frequency reuse gain. Since FBSs are user deployed and installed without being planned, this increases the technical difficulties of interference management (Son, 2011). The combination terms OFDM and IDMA has drawn intensive research interest in OFDM-IDMA system[1] , the OFDM is utilized to avoid the inter signal interference (ISI) caused by frequency selective fading ,and user separation is realized by equipping users with different interleavers. The combination of OFDM-IDMA gives an advantage of finding out interactive multi user detection (MUD). This is very effective in mitigating the multiple access interference (MAI) it is affirmated that the complexity of such MUD is linear with the number of users. This grouping of OFDMIDMA system aims at reducing the detection complexity [2]. In such system, the available sub carriers are broken into several groups. Based on these group allocations, the total users are separated into subset and each one of them shares one group of sub carrier for their transmission. The users among different subset are separated by different sub carrier while the user within the same subset re distinguished by IDMA which bring out the number of users in each group is lesser than the traditional OFDMIDMA system hence leading to minimized complexity. However the complexity of MUD not only related to the number of interaction of MUD users but also relates to the number iteration of MUD. To achieve a sustained promising performance the MUD should work under sufficient number of iteration. The complexity would be still very high if the number of iteration is large. Considering a downlink scenario where the receiver is mobile used equipment. Such complexity may be a great load and hence prohibit IDMA from implementation in such an occasion. In this paper we focus on interference mitigation of OFDM IDMA based femtocells underlay in macro cellular networks. In OFDMIDMA systems, OFDM is employed to avoid the inter symbol interference (ISI) caused by frequency selective fading, while user separation is realized by equipping users with different interleavers. One advantage of OFDM-IDMA is its capability for iterative multi-user detection (MUD), which is proved to be effective in mitigating the multiple access interference (MAI) [3]. It is also reported that the complexity of such MUD is linear with the number of users [4].

2. FEMTOCELL NETWORK

The Femtocell network is a novelty emerging architecture which can enhance the performance of the macro cellular systems [5], [6]. One femtocell can be treated as a small cellular network consisted of one femto access point (FAP) with low transmit power and several femtousers (FUs) under its coverage. It provides high-quality transmission links thanks to the close transmission range between the FAP and FUs. In addition, the computing capability of FAP allows certain pre-processing operation such as decoding, before it forwards the information from the macro base station (MBS) to the FUs, which further improves the communication quality. Due to its

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superior benefits, the concept of femtocell is widely adopted in various standards including Longterm evolution (LTE),where the OFDMA based femtocell is referred to as home evolved node base station (HeNB) [7]. However, despite of its envisioned benefits, additional interference is also caused by introducing femtocell into the existing macrocell. The interference can be classified into two categories, namely cross-tier interference and co-tier interference. The former is caused by simultaneous transmission between the femtocell and macrocell while the latter is due to the simultaneous transmission within/between femtocells [8]. Therefore, it is a challenge to design efficient transmission scheme for femtocell network in present of interference. Many interference mitigation techniques have been reported in the literature. The interference generated by the FBS cannot be handled by the macrocell network operator by means of centralized network planning (Boudreau,1999; Calin, 2010; Galindo, 2010). Thus the interference management in femtocells underlay in macro cellular networks is distributed. Giuliano et al. has proposed fractional frequency reuse (FFR) for wimax and 3GPP LTE in rural environment. In FFR the whole frequency bands were partitioned into sets of sub-channels and orthogonal sub-channels sets are assigned to adjacent users to mitigate interference. Boudreau et al. has discussed Static FFR and Adaptive FFR techniques. Two FFR with frequency hopping have been discussed in (Boudreau, 1999; Juang, 2010). The authors showed that in compared to the static FFR, the dynamic FFR reduced the downlink interference significantly. Performance of macro and co channel femto has been investigated in (Kim, 2010). Clausseu has also proposed that the transmit power control of FBS based on handoff statistics has reduced the interference considerably. The femto cell network is an emergency architecture which can enhance the performance of the macro cellular system. One femto cell can be treated as a small cellular network consisted of one femto access point (FAP) under its coverage. Due to close transmission range between FAP and FUS a high quality transmission linear to provide. In addition there is a tremendous improvement of communication quality because of certain pre processing operations, by the compiling capability of FAP ,such as decoding , before it forward information from the macro base station (MBS) of the FUS. Because of the highlighted benefits, the concept as femto cell is widely adopted in various standards including long term evolution (LTE), where OFDMA based femto cell is referred to as home evolved node base station (HENM). However an additional interface is also cause by introducing femtocell into the existing macro cell, despite of its envisioned benefits. The interference is identify in to two categories, one is cross tier and other one is co tier. The cross tier interference is caused by simultaneous transmission between the femtocell and macro cell while the co tier interferences causes between or within femtocells. Therefore its challenge to design efficient transmission scheme for femtocell network in the presence of interference. In this presentation its proposed to adopt G-OFDM-IDMA for the downlink transmission of femtocell network, aiming at combining the advantages of both. i such a practice cross tier interference could be totally avoided by assigning macro user and femtocell users in to different subcarrier groups. within the same group IDMA with deterministic interleaver namely modified circular shift interleaver could be employed to distinguish co-tier user. the numbers per group could be reduced in order to get lo complexity. Alternatively due to competing capability of FAP (femto cell Access Point), the transmitter signal from MBS (Macro Base Station) to FU (Femto User) can be decoded first by FAP with sufficient iterations, and then forwarded to FU's with relatively high power reception. The guaranteed performance the user is ensured with the small or insufficient number of iterations. The practical OFDMIDMA downlink is possible with a reduced decoding complexity as well as good performance. In this paper spectral efficiency followed by bit error rate (BER) is archived .An simulation result that with the help of femto cell grouping the proposed transmission scheme provides better performance compared with that of the macro cell scenario employing traditional OFDM-IDMA and further the decoding complexity at the user end is greatly reduced.

3. EVOLUTION OF WIRELESS AND CELLULAR COMMUNICATION

Wireless communication has involved relentless years of research and design and comprises cellular telephony, broadcast and satellite television, wireless networking to today's 3rd Generation Partnership Project's (3GPP) and Long Term Evolution (LTE) technology. However, cellular telephony networks surpass the others in terms of usage [1]. Although cellular networks were designed to provide mobile voice services and low rate mobile data services, data services have excelled voice and findings show that global data traffic has grown by 280% since 2008 and is expected to double annually in the next five years [2]. Importantly, it has already exceeded those expectations in 2010 by nearly tripling and it is further predicted that by 2015 nearly one billion people will access the internet using a wireless mobile device [3]. The limited and in some cases under-utilised spectrum cannot accommodate this continuous increase in traffic therefore network operators have to come up with ways of increasing spectrum efficiency.

The introduction of new or the upgrade of existing wireless standards such as the Institute of Electrical and Electronics Engineers (IEEE) Worldwide Interoperability for Microwave Access (WiMAX) and 3GPP's LTE have been developed to meet traffic and high data rates. Most of the methods to increase spectrum capacity in practice today are aligned towards, a) improving the macro layer by upgrading the radio access, b) densifying the macro layer by reducing the inter-site distances and c) the use of low power nodes to complement the macro layer [4]. The macro layer deployment is the typical approach of deploying Base Stations (BS) in proximity to each other covering large distances with reduced handover frequency. Although it is the backbone of most wireless networks, it has proven to be inefficient as it does not guarantee a high quality link in situations where the BS and Mobile Station (MS) are relatively far away. Moreover, a BS

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serving hundreds of contentious users all vying for resources is old fashioned [5]. Researchers indicate that 50% of all voice calls and most of the data traffic, more than 70%, originate indoors [6]. However, indoor users may suffer from a reduced Received Signal Strength (RSS) due to low signal penetration through the walls or attenuation leading to total loss of signal in situations where the distance between transmitter and receiver is large. There is a need to provide solutions for poor indoor coverage to satisfy consumers. According to [5] the solutions to poor indoor coverage can be classified into two types, Distributed Antenna Systems (DAS) and Distributed Radios. Distributed Antenna Systems comprise a group of Remote Antenna Units (RAU) spaced apart, providing not only enhanced indoor signal quality by significantly reducing transmission distance but also reducing transmit power (power of the reference signal) [7]. Some of the challenges involved in deploying DAS are the choice of antennas and selecting a suitable location [8], [9].

Distributed Radios involve the introduction of smaller cells to complement the deficiencies of the larger macrocell and the gains include an efficient spatial reuse of spectrum [10]. These small cells which include picocells and microcells are overlaid in the macrocell to provide voice and data service. Due to the two-tier nature of its architecture, it is prone to interference which may result to a low Signal to Interference plus Noise Ratio (SINR) and throughput and in some cases a total disruption of service. As a result, there is a need to provide interference avoidance and mitigation schemes. Recently, a new distributed radio known as femtocells has emerged that promises to be a viable solution to indoor cellular communication.

4. FEMTOCELLS: A SOLUTION TO INDOOR NETWORK COVERAGE

Femtocell provides the solution to poor indoor coverage in cellular communication which has hugely attracted network operators and stakeholders. Femtocells are low powered, low cost and subscriber controlled units which provide a dedicated BS to indoor subscribers. The concept of femtocells, also known as home base stations, Home NodeB (HNB) or Home eNodeB (HeNB) [11] and residential small cells [12] was first studied in 1999 by Bell Laboratory of AlcatelLucent but it was in 2002 that Motorola announced the first 3G based home base station product [13]. Femtocell units, known as Femtocell Access Points (FAPs), connect standard mobile devices also known as Femtocell User Equipment (FUE) to the network of a mobile operator through residential Digital Subscriber Line (DSL), optical fibres, cable broadband connections or wireless last-mile technologies as shown in Figure 1.1 [13]-[16]. By installing FAPs indoors, the cell sites are reduced thereby bringing the transmitter and receiver closer to each other. The use of the subscriber’s broadband network to backhaul data offer improved indoor mobile phone coverage for both voice and data because of improved connectivity compared to the Macrocell Base Station (MBS). Femtocells are similar to WiFi as both are connected to a wired backhaul but unlike WiFi, femtocells make use of an existing cellular standard for their operation [15], [17].

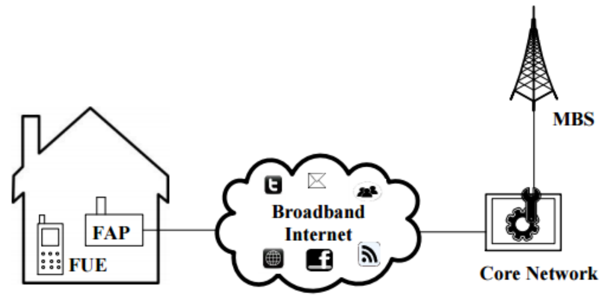

Figure 1. Femtocell deployment

The benefits of femtocells now and in the long term cannot be overemphasised as it has advantages for both network operators and subscribers. As far as network operators are concerned, the reduction in macrocells due to the deployment of femtocells will result in a huge saving in CAPEX (Capital Expenditure) of network operators and the reduction in traffic will also yield a saving in the OPEX (Operational Expenditure) through advanced self-management and optimisation techniques. The subscribers also benefit as the close proximity of the transmitter and receiver offered by femtocells enables subscribers to have high speed services such as voice, video and multimedia. The close proximity greatly lowers transmission power and increases the battery life of mobile devices. With a dedicated FAP in their homes, it offers subscribers a single billing address for mobile phone, broadband and land line as they are all channelled through the same backhaul [13], [18]. Femtocells also act as a solution towards convergence of landline and mobile [19].

4.1 Femtocells and the inherent interference problems

Due to the two-tier architecture of femtocells and macrocells, interference is imminent. The cell sites covered by a number of FAPs (in some cases overlapping each other) is overlaid in the larger cell site of the macro base stations as shown in Figure 1.2. Interference here denotes the transmitted signals from the FAPs or MBS and their serving User Equipments (UEs) that appear as unwanted signals to each other.

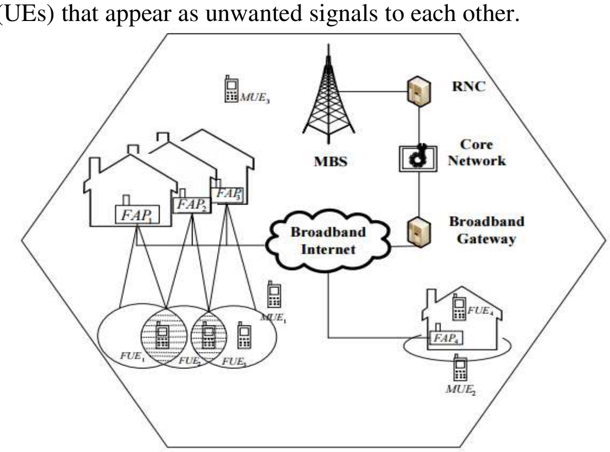

Figure 2. Femtocell scenario with co-tier and cross-tier interference

Interference could be between femtocell and macrocell which is known as cross-tier or between neighbouring femtocells known as co-tier [20]. Interference can be further classified as Uplink (UL) or Downlink (DL) based on the sources, which besides the FAP and MBS, also includes
the Femtocell User Equipments (FUEs - a UE served by a FAP) and Macrocell User Equipments (MUEs - a UE served by a MBS).

4.2 Femtocells - Interference versus Deployment

It is important to note that the scale at which interference affects a femtocell network is largely dependent on the deployment scenario. The 3GPP's technical specification of the scenarios for deployment of femtocells are summarised in [18] and described as follows; a) Spectrum Usage - Dedicated channel or Co-channel deployment. b) Access Methods - Open access or Close Subscriber Group (CSG). c) Transmit Power - Fixed Downlink (DL) transmit power or Adaptive DL transmit power.
Figure 3. summarises different femtocell deployment scenarios followed by explanation of interference versus deployment.

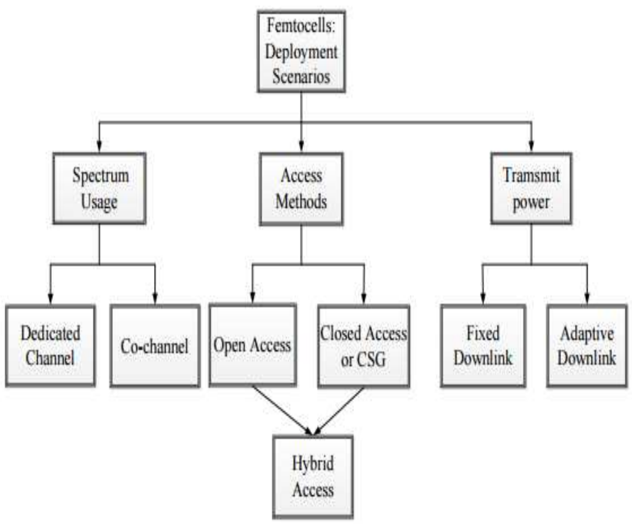

Figure 3. Femtocell deployment scenarios

In a dedicated channel deployment, the licensed spectrum is split into different portions for each tiered network to operate in a dedicated manner whereas both tiers share the same licensed spectrum in co-channel deployment [21]. The choice of deploying any of the two requires a trade-off between spectrum availability and interference. In dedicated channel, spectrum availability is limited as each portion is assigned a specific bandwidth to utilize. It still leads to a low cross tier interference. On the other hand, spectrum is available for all users in a cochannel deployment but this result to high cross tier interference. Network operators prefer a co-channel deployment due to the limited available bandwidth but will have to deal with the interference issues [22]-[25]. FAPs deployed in an open access allow connection for all users whereas in a CSG mode only the subscribed owners of the FAP have access. Cross tier interference in open access is reduced due to the fact that users can connect to the nearest FAP with the strongest signal. In CSG,

5. STRUCTURE OF THE SIMULATOR

In SLS, the performance of a whole network can be analyzed. It supports the network implementation of a multitude of MBSs in a defined region of interest while supporting static or mobile UEs. Individual physical layer links can be simulated with the investigation of AMC feedback, MIMO gains, modelling of the channel code as well as retransmissions

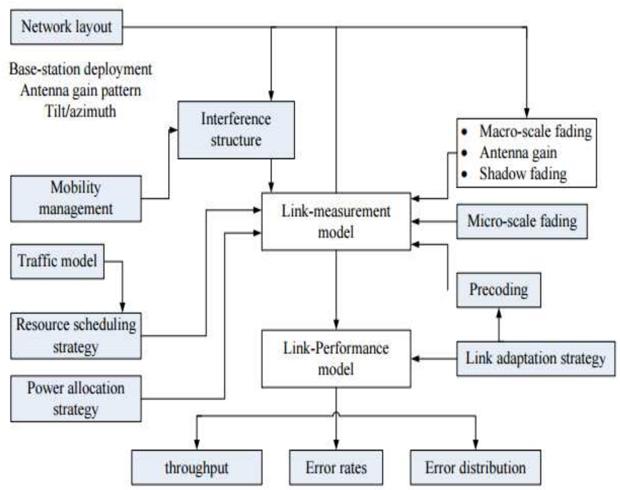

Figure 4. Schematic block diagram of the LTE Vienna system level simulator

From Figure 4. the simulator consists of two parts:

Link measurement model: This reflects the quality of the link which is determined by UE measurement reports. This model is also responsible for link adaptation and resource allocation in the network. The quality of a link is largely measured by evaluating each SC. The UE computes the feedback based on the SINR, which is used for link adaptation at the MBS. SINR is evaluated based on the network layout based on macroscopic fading, pathloss, shadow fading [130], and microscopic fading [131].

Link performance model: The link performance model builds upon the link measurement model and it is responsible for predicting the Block Error Ratio (BLER) of the link, which is based on transmission parameters such as modulation and coding and received SINR

5.1. Reduced complexity

One of the high points of the simulator is the ability to pre-calculate as many of the simulation parameters as possible. This offers repeatability by loading a pre-calculated scenario which is very useful when same scenarios have to be employed to compare different algorithms. This reduces computer overhead. Scenarios that can be pre-calculated include but are not limited to the generation of path loss maps and small-scale fading traces.

5.2. Validation of the simulator

The results of link level throughput from the simulator was compared with the minimum performance requirements stated by 3GPP in the technical specification TS 36.101 [65] with results showing up to 99% confidence intervals. Also the link and the system level simulators were cross validated by comparing their results against each other [124].

In the next chapter an adaptive power control algorithm in presented for blindly placed femtocells. It is presented as a solution to the power control problem discussed in section 3.3.4 (see Figure 3.5).

6. POWER CONTROL SCHEME FOR INTERFERENCE MITIGATION IN BLINDLY PLACED FEMTOCELLS

Since FAPs are usually user deployed, blind placement of FAPs is inevitable leading to problems of power spillage causing severe co-tier and cross-tier interference and subsequent performance degradation. This chapter presents performance analysis of a coverage radius based power control scheme to circumvent the problems caused by blind placement of FAPs. The coverage radius based power control scheme does not require FAPs to be relocated to optimal positions for interference mitigation; rather a self-update algorithm is implemented by cognitive FAPs to reduce their cell radius by adaptive adjustment of power values for interference management. Using system level simulations, the performance of the scheme has been analysed for different scenarios and compared to existing schemes. The scheme provides improved interference mitigation and throughput results.

A FAP is user deployed and is usually blindly placed in an indoor environment such as near the walls and windows. In the absence of any antennas' beam directivity (Section 2.1.3) the FAP power could spill out in the surrounding regions thereby causing considerable co-tier and cross-tier interference figure 4.1). Research work carried out in [132]-[134] investigates optimal positions to place a FAP in an indoor environment to improve the throughput and mean capacity. However, it might not always be possible and necessary to find the optimal positions and move a FAP to effectively mitigate the interference caused. Thus there is a serious need for the development of interference mitigation schemes for blindly placed LTE femtocells. Coverage radius based power control scheme, which adaptively varies the pilot power of FAP based on its distance from the farthest served FUEs, is presented as a potential solution to this problem.

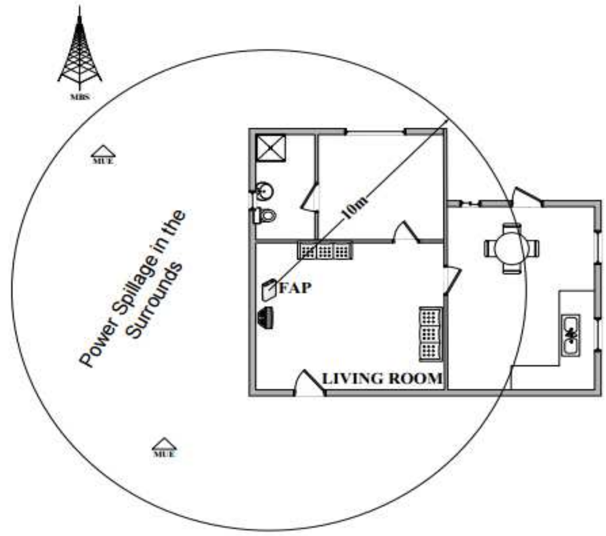

Figure 5. Blind placement of a FAP & Power Spillage

7. A HYBRID UE ADMITTANCE AND CONTENTION FREE RESOURCE ALLOCATION FOR FEMTOCELLS

Femtocells are designed to co-exist alongside macrocells providing spatial frequency reuse, higher spectrum efficiency and cover areas where macrocells cannot. This chapter proposes a joint threshold power based admittance and contention free resource allocation scheme for interference mitigation in cognitive femtocells. In the proposed scheme, a CF sets a threshold value on the mutual interference between itself and a close-by MUE. To mitigate cross-tier interference, a CF classifies MUEs which fall above this threshold value (high interference value) as Undesired MUEs (UMUEs). MUEs which fall below this threshold are classified as Desired MUEs (DMUEs). To mitigate co-tier interference, proposed scheme introduces a scheduling engine which employs matching policy attributes and assigns RBs of unique DMUEs to CFs to avoid any possible contention problems, thus providing improved co-tier interference. System level simulations have been performed to demonstrate working and effectiveness of proposed scheme.

When it comes to frequency/spectrum allocation schemes, CFs perform the task of sensing spectrum holes of PUs, analyzing, deciding, and taking an action by assigning resources to secondary users (SUs) (see Section 1.4.1). However, the availability of a spectrum is not restricted to white spaces but the possibility of reusing the resources of PUs that have an insignificant interference to a SU. In this concept, a FAP is able to assign resources of less interfering MUEs (PUs) to its FUEs (SUs). This concept has been investigated in [104] where a FAP obtains the scheduling information in the uplink (UL) of far-away MUEs from the MBS through a backhaul or over the air. A scheme which combines channel sensing and resource scheduling is proposed in [90, 104, 137, 138]. Femtocells in this scheme sense channel occupation, capitalizing on the strong uplink (UL) transmit power of a MUE as it tries to reach its serving MBS, to find available

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frequency channels. This is achieved by analyzing the energy in the sub-channels and subsequently assigning those with the lowest interference signature to its users. In [89] an algorithm is proposed to orthogonally assign MUE channels to FUEs. A channel is deemed available for communication if a FAP detects no busy tone at the expiration of the timer, otherwise it abandons and waits for the expiration of the next back off timer until each FAP is able to communicate on an available channel. In the scheme, the utility of each channel is calculated by each FAP and subsequently a back-off timer is set for each channel. However, the aforementioned schemes largely target either co-tier or cross-tier interference mitigation, thereby failing to provide a complete solution. Thus in this section, a joint threshold power based admittance and matching policy based spectrum allocation scheme is proposed for co-tier and cross-tier interference mitigation in cognitive femtocells. The proposed scheme calculates the mutual interference between itself and a close-by MUE and admits the closest MUEs (UMUEs) as one of its UEs to mitigate cross tier interference. Furthermore, this scheme employs a scheduling engine which engages a matching policy that orthogonally assigns the RBs of DMUEs resulting into significantly reduced co-tier interference. In other words, a CF interweaves into the transmission of the primary user (transmission is concurrent but interference is limited) and CFs can assign these RBs to their UEs due to frequency reuse with spatial separation policy.

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