Femtocell Networks Interference Management Approaches

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Summary
Small cells, particularly femtocells, are regarded a promising solution for limited resources required to handle the increasing data demand. They usually boost wireless network capacity. While widespread usage of femtocells increases network gain, it also raises several challenges. Interference is one of such concerns. Interference management is also seen as a main obstacle in the adoption of two-tier networks. For example, placing femtocells in a traditional macrocell's geographic area. Interference comes in two forms: cross-tier and co-tier. There have been previous studies conducted on the topic of interference management. This study investigates the principle of categorization of interference management systems. Many methods exist in the literature to reduce or eliminate the impacts of co-tier, cross-tier, or a combination of the two forms of interference. Following are some of the ways provided to manage interference: FFR, Cognitive Femtocell and Cooperative Resource Scheduling, Beamforming Strategy, Transmission Power Control, and Clustering/Graph-Based. Approaches, which were proposed to solve the interference problem, had been presented for each category in this work.

Keywords:
Interference, co-tier, cross-tier, femtocells.

1. Introduction

Although the ubiquitous use of femtocells and small cells boost the network's gain, it also introduces a set of challenges. Interference is one of those difficulties that has to be dealt as effectively as possible. In addition, interference control is seen as a critical obstacle for the effective deployment of two-tier networks [1] [2]. For example, installing femtocells networks within a certain traditional macrocell's geographic region. In general, there are two forms of interference: cross-tier interference and co-tier interference. It's common for two-tier networks to have this kind of interference. More details about interference in two-tier networks are summarized in the following descriptions.

1.1 Cross-Tier Interference

Typically, interference between two independent tiers of the network architecture will occur in this pattern of interfering signals. During the deployment of a macro-femtocell network, there is interference between the macrocell and the femtocell. This may be found in four distinct forms. The following are examples of cross-tier interference situations that might arise when femtocells are installed and layered over the coverage area of a macrocell.

(i) MUE-to-FBS Scenario: In this case, a macrocell UE is the aggressor, while a femtocell base station is the victim. This scenario is uplink transmission mode. Figure 1 shows an uplink cross-tier interference situation between a macrocell UE and a femtocell base station.
(ii) MBS-to-FUE Scenario: In this case, the aggressor is a macrocell base station, while the victim is a femtocell UE. This scenario is downlink transmission mode. Figure 2 shows a downlink cross-tier interference situation between a macrocell base station and a femtocell UE.
(iii) FUE-to-MBS Scenario: In this case, a femtocell UE is the aggressor and a macrocell base station is the victim. This scenario is uplink transmission mode. Figure 3 shows an uplink cross-tier interference situation between a femtocell UE and a macrocell base station.
(iv) FBS-to-MUE Scenario: In this case, the aggressor is a femtocell base station, while the victim is a macrocell UE. This scenario is downlink transmission mode. Figure 4 displays a downlink cross-tier interference situation between macrocell UE and femtocell base station.

1.2 Co-Tier Interference

The interference situations that occur between network components that are categorized in the same tier class are referred to as the co-tier interference scenarios. Femtocells are acknowledged as a distinct tier of technology. Any interference that happens between femtocells is referred to as co-tier interference, and it is defined as follows: It should be noted that with the massive implementation of femtocells, interference control becomes a more difficult challenge to solve. There are two scenarios in which this sort of interference happens. The following are examples of interference between co-tiers.

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(i) FBS-FUE Scenario: In this case, the aggressor is a femtocell base station, and the victim is a femtocell UE. This scenario is downlink transmission mode. Figure 5 displays a downlink co-tier interference situation between a femtocell base station and an adjacent femtocell UE.
(ii) FUE-to-FBS Scenario: In this case, the aggressor is a femtocell UE, while the victim is a neighboring femtocell base station. This scenario is uplink transmission mode. Figure 6 shows an uplink co-tier interference situation between a UE and a neighboring femtocell.

Also, Table 1 demonstrates all interference situations that can happen in two main types of interference: cross-tier interference and co-tier interference.

Table 1: Interference Scenarios

Scenario	***Interference source***	***Victim***	***Interference type***
MUE-to-FBS	MUE	FBS	Cross-tier
MBS-to-FUE	MBS	FUE	Cross-tier
FUE-to-MBS	FUE	MBS	Cross-tier
FBS-to-MUE	FBS	MUE	Cross-tier
FBS-to-FUE	FBS	FUE	Co-tier
FUE-to-FBS	FUE	FBS	Co-tier

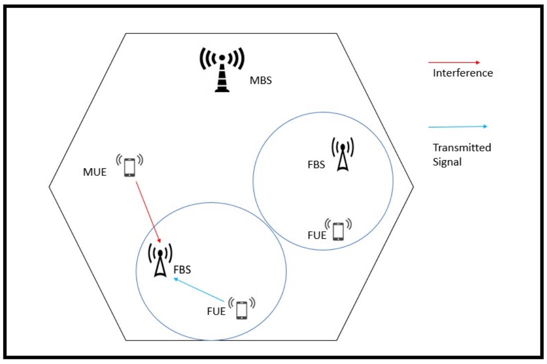

Fig. 1 MUE-to-FBS [3].

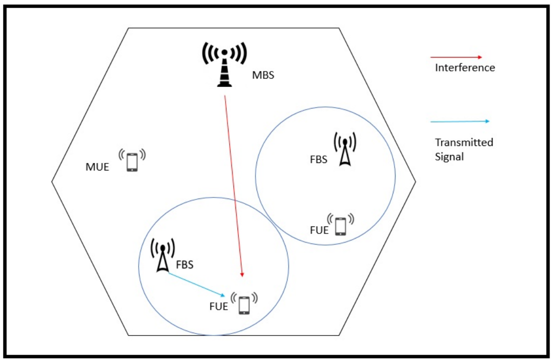

Fig. 2 MBS-to-FUE [3].

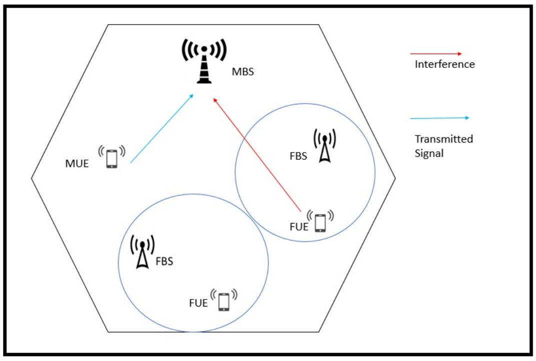

Fig. 3 FUE-to-MBS [3].

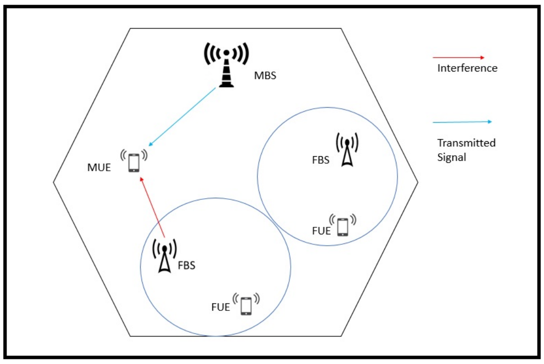

Fig. 4 FBS-to-MUE [3].

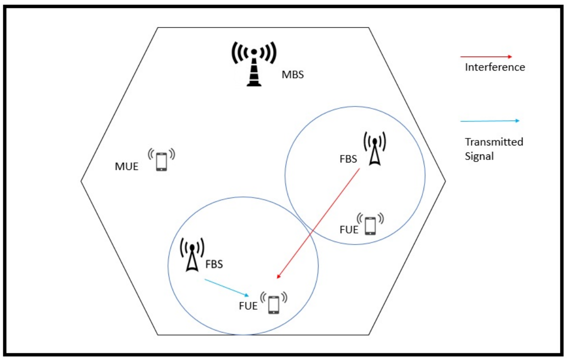

Fig. 5 FBS-to-FUE [3].

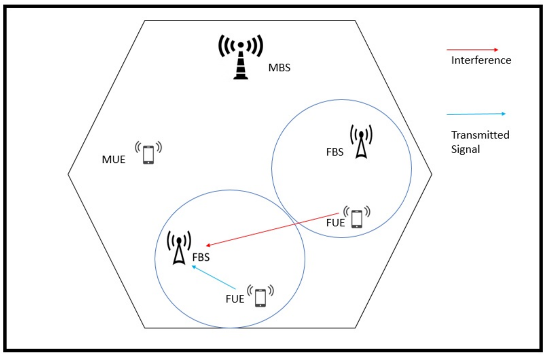

Fig. 6 FUE-to-FBS [3].

There have been prior works on the subject of interference management. The concept of categorization of interference management systems is discussed in this work. Many techniques were developed in the literature with the goal of reducing the effect of co-tier interference, cross-tier interference, or a combination of the two forms of interference. Approaches to interference management that have been proposed may fall into one of the categories listed below:

- Fractional Frequency Reuse FFR
- Cognitive Femtocell and Cooperative Resource Scheduling
- Beamforming Strategy
- Transmission Power Control
- Clustering and Graph-Based

2. FFR Approaches

The first usage of the FFR idea was to coordinate inter-cell interference between macrocells, which was the initial use of the FFR concept. In an effort to increase cell edge throughput of macrocells, inter-cell interference coordination (ICIC) systems reused the frequency band. Co-channel interference was implemented with the help of this. Based on a predetermined distance, the frequency band would be divided into several parts. Using this principle can improve network throughput compared to conventional approaches [4][5]. In order to secure exclusive spectrum allocation between the inner and outer zones, the allocation of bands to each area must not overlap. Additionally, inter-cell interference should be minimized. According to this theory, resources that aren't used by macrocells in a certain region are instead distributed to femtocells in the same area. Thus, interference between femtocells and the UEs of other macrocells may need to be controlled. Many strategies have been suggested to better divide the outside regions of a macrocell, particularly for neighboring macrocells [7][7][8].

Control information should be shared sparingly within network tiers because excessive coordination signals need to be discarded. This design also made it easier to manage interference between tiers.

The authors of [9] investigated the use of an FFR-based strategy to solve the issue of interference in heterogeneous networks. Using FFR-aided OFDMA two-tier networks as the focus, an analytical framework was then presented. Co-channel deployment of macrocells and femtocells was considered in this case. This deployment was also tested under the worst-case scenario when there was no coordination between macrocells and femtocells. This framework would be used to assess the impact of interference occurring at the cross- and co-tier levels. The number of UEs per cell or sub-area, the number of femtocells per area, and power attenuation are all examples of parameters, which are used in designing resource scheduling mechanism. In this proposed FFR- based optimization technique, the aim was to establish an optimum division of the spectrum among all sectors. In order to preserve and meet the constraint on frequency reuse, this partitioning approach should increase the macrocell's mean throughput at the same time. Thus, three developments of optimization FFR-aided two-tier OFDMA networks have been presented.

For two-tier OFDMA networks supported by FFR, the authors proposed a fixed-spectrum-allocation-factor design (FxD). Spectrum partitioning between cell centers and edge regions was established in this architecture. With this design, a high degree of spectral efficacy might be achieved. In other situations, it may, however, be inimical to fairness. In addition, an idea known as the area-proportional design (ApD) was proposed (ApD). Spectrum is evenly divided between cell centers and cell edges in this configuration. Fairness level among macrocell's UEs, which are distributed between center and edge of the cell, can be achieved. Mean macrocell throughput may be influenced by this design and be reduced as a result. In addition, Quality-constrained design (QoScD) was the third design examined in this context. All of the cell centers and edges were to be evenly divided across the macrocell's UEs to ensure fairness. Cell edge area throughput might be guaranteed to be less than half of the cell center area throughput using a constraint in an optimization problem. QoS would be significantly improved for the macrocell's UE, which is located on the cell edge area, and the spectral efficiency of the macrocell would be increase distance threshold ratio. Two factors are taken into consideration for constructing the optimization problem: distance threshold ratio and spectrum allocation ratio. Analytical findings were validated by the Monte Carlo simulation. The MSINR scheduling approach was used for resource scheduling in this simulation. Therefore, macrocell throughput improved. When the number of femtocells is substantially expanded, the effect of interference is amplified. The appropriate threshold radius for FFR design might be defined by factors such as the density of UEs in femtocells and macrocells. Different architectures and resource allocation strategies were used in the simulation to compare the outcomes. These ideas should, however, be included into the ICIC techniques that have been created. The distribution of resources between femtocells and macrocells should also be taken into account.

In [10], authors suggested a resource assigning scheme, which operated based on FFR approach. The region of macrocell would be divided into multiple regions. Also, a portion of spectrum would be allocated for each divided area according to FFR concept. There are three divisions for each frequency part in this design. These included a dedicated macrocell segment, a dedicated femtocell segment, and a shared segment. The objective of this work was to define suitable ratio for all three parts in certain sub-area. UEs connected to macro- and femtocells were constrained in terms of their throughput, therefore the overall system capacity was maximized by calculating an appropriate ratio between the three aforementioned sections. The quantity of UEs that may be used was limited. This technique had a unique process where macrocell’s UE can be secured from the interference caused by neighboring femtocells. In this scenario, a macrocell’s UE can report destructive interference knowledge to serving macrocell. According to and. assembled table, which contain both Shared dedicated group (SHG) and availability indicator (SAI). This information reveals whether radio resources were allocated or not. The base station allocates the resources and implements the shared dedicated fraction based on that choice. As predicted by the simulation findings, the femtocell UE throughput was significantly improved by the proposed approach. Protecting macro-cells from severe interference caused by nearby femtocells has also helped improve system throughput.

In [11], authors proposed a tridimentional frequency reuse based mechanism to solve the corss-tier interference problem. To make use of this unique concept, the whole area would be split into several areas. Based on this partition of space, the frequency band would be assigned. The tridimentional cell had been designed according to the characteristics of antenna radiation. The functional form was a cylinder space. S1, S2, and S3 comprise the top and bottom layers, respectively, of the cylinder space. Then, the whole frequency band would be divided into five sequential bands. The third, fourth, and fifth bands were allocated for cell edges. Also, the first band would be allocated for the central region of all cells, which was also the S1 region in a formulated cylinder. The second band would be allocated for the S2 area of the cylinder. Additional restrictions on cross-tier interference were made by prohibiting femtocells from operating in the second band. For femtocells, the fourth and fifth bands were reserved for those located in the S1 and S3 zones. Cross-interference is reduced in certain areas. Second, third, and fourth-band femtocells couldn't work since they were located in the S2 area. The implementation of the developed tridimentional TFR was examined by a conducted simulation. It was compared to the standard FFR mechanism. Therefore, the suggested TFR could achieve a significant advantage over the existing FFR in simulation results. The interference was also well-managed by the TFR in this case. However, tridimentinal space may not even be viable in all interference circumstances. Also, limited resources would be allocated when greater spectrum division is assumed.

In [12], authors adopted frequency reuse principle to alleviate unfavorable influence of interference. In this study, a novel adaptive frequency reuse (AFR) system was presented. All sub-channels were divided into two main categories: primary sub-channels (PSCs) and Secondary sub-channel (SSCs). The framework contained two main algorithms: primary sub-channel self-configuration (PSC-SC) algorithm and interference-aware resource allocation (IARA) algorithm. All of the femtocells in the system were taken into account while formulating this issue, which aimed to minimize the received interference power. This problem was formulated with the aid of game theory. To define the existence of interference between femtocells, a created interference graph is employed. In order to reduce the amount of disagreement in the PSC assignment process, this was a cost-effective measure. Accordingly, exhaustive search strategy is utilized to solve the problem. T he algorithm was developed based on PSC-SC. Then, an IARA algorithm was developed to independently operate in every femtocell in the network. Its goal is to achieve optimal assignment of every femtocell. The major characteristic of IARA algorithm was to mitigate the interference influence on femtocell's UEs, which were located in cell edge of femtocells.

3. Cognitive Femtocell and Cooperative Resource Scheduling Approaches

To prevent interference, a resource scheduling awareness method might be implemented. For instance, femtocells may avoid using resources reserved for macrocell' UEs. Mcrocells may communicate with nearby femtocells to coordinate the allocation of their available resources. Consequently, collaborative strategies for avoiding the use of resources that resulted in interference could be developed.

Article [13] introduced an innovative approach for resolving the interference issue. Scheduling the resources process was a critical component of this approach. This scheme's foundational knowledge would be an understanding of how current and future resources are being scheduled. All of this might be accomplished by channelizing the LTE's dependent scheduling mechanism. In this approach, femtocells were needed to listen for, detect, and monitor the UE of macrocells in order to forecast future subcarrier allocations and avoid utilizing them to mitigate interference. The femtocell should listen to the macrocell's UEs through downlink macrocell transmission in this arrangement. The listening module of the femtocell was used to receive reference symbols. This listening mechanism required that the femtocell and macrocell being synchronized [14]. After the femtocell receives synchronization signals, it may be simple to frame the timing. However, the femtocell must first receive the primary synchronization signal (PSS) and the secondary synchronization signal (SSS). Additionally, femtocell should recognize macrocell physical ID (PCI). Furthermore, the master information block (MIB) gave information about macrocell bandwidth. All of these aided the femtocell in identifying resources that overlap with those of the macrocell. Once overlap resources were identified, the femtocell would detect the UE of the macrocell inside its coverage. The received signal strength (RSS) of a femtocell might be used to discriminate between closed and further remote macrocell UEs [15]. Each UE in an LTE system is recognized by a unique identification. Each associated UE should be issued a unique cell radio network temporary identification (C-RNTI). This identification included critical data about the femtocell. A macrocell downlink map would show which macrocell UEs had resources that were of interest, so they could be found there. This aided the femtocell in forecasting the UE's resource allocation. Channel-dependent scheduling was decided by the SINR value, with the channel quality indicator (CQI) determining the appropriate modulation and coding scheme (MCS) for specific downlink transmissions. Femtocells utilized the CQI value to determine whether to use or avoid certain subbands. Additionally, femtocells may specify preferred subbands for macrocell UEs. Using computer simulation, the authors were able to assess the suggested algorithm's performance. However, this technique necessitated extra processing at the femtocell's RLC sublayer.

Additionally, the authors in [16] presented a strategy for controlling interference and distributing resource allocation. This paper investigated a heterogeneous network in which numerous femtocells were installed and overlapped in a macrocell area. In addition, this work made more efficient use of the spectrum. Interference management is employed in the present study via resource scheduling. The primary objective of this study was to solve the issue of cross-interference in co-channel deployment environments. Additionally, this effort aimed to improve the QoS of femtocell UEs. Allocating resources and managing transmission power both contributed to the formation of the problem. The authors began by analyzing the QoS requirements for the UEs of femtocells. On this basis, a joint problem of transmission power regulation and resource allocation was defined. This article provides two distributed methods for solving the defined issue. Two distributed algorithms for resource allocation and power management were incorporated in the proposed scheme. The first algorithm was developed specifically for the issue of resource allocation. The challenge was subdivided into subproblems according on the number of femtocells introduced into the system. The proposed algorithm optimally solve the problem. The gradient-based standard approach was utilized to demonstrate the proposed problem's convergence [17]. The second sub-problem was concerned with transmission power. This issue, as phrased, cannot be solved using traditional methods. As a consequence, the problem was converted to a convex problem. As a result, the suggested distributed method may be used to achieve local optimum transmit power. The authors of this paper used simulation to assess suggested methods. The simulation results suggested that with a fast convergence rate, the local optimum transmission power could be attained. However, the simulation took into account just three femtocells with their associated UEs. It was not apparent that whether the interference threshold would be updated with dense deployment of large number of femtocells or would be guaranteed. Intensive deployment of a large number of femtocells should be investigated in order to assess the proposed scheme's stability. Intensive deployment of a large number of femtocells should be investigated in order to assess the proposed scheme's stability.

Also, a new method described in [18] took into account resource management techniques using sleep model selection approach, which were employed as fundamental principles. In this way, not only could interference be reduced, but the whole system's throughput could also be increased. Small cells have two distinct modes of operation: ready mode (RE) and sleep mode (SL). All hardware components were turned on. On the other hand, hardware components in sleep mode may work in a low-power mode or may be completely turned off. This could be accomplished via the use of an energy-saving algorithm [2]. This kind of approach might be used to determine which components should be partly or completely disabled. Additionally, mode transitions between ready and sleep modes may be initiated by the core network, the small cell owner, or the small cell itself. Additionally, to the power savings, the authors in this study applied a sleep mode-based method to maximize capacity increase while minimizing interference. The authors developed a cell selection technique to give the resource partitioning mechanism with the essential information for deactivation decision-making. The system may decide to disable the small cell based on incoming information whenever this decision had greater capability. The main goal of the proposed scheme was to figure out when deactivating a device would be good for the whole system. Thus, an algorithm was developed to assess all associated femtocells and identify a subset of them that might be disabled. The choice would be made through a centralized method for resource allocation. Once a femtocell is designated for shutdown, its attached UEs are offloaded to the nearest femtocells. Accordingly, goal of this framework was to maximize network's capacity. Based on that, a problem with this goal was formed. Integer linear programming (ILP) techniques, which were often employed to tackle this kind of formulated problem, have an unpredictable running time. As a result, the authors proposed a solution that partitioned the problem into two sub-problems. Additionally, they developed a set of deactivation criteria for femtocells. This criterion aided the centralized controller in making a deactivation decision. Conflict zones with significant intervention would be notified. Also, the proportion of UEs that were associated with the femtocells to the number of UEs, which were located in handover zones. Additionally, the total number of UEs linked to all femtocells would be evaluated. Additionally, the degree of aggregation of all received signal power was examined, as was the total amount of interference power received by each femtocell. All of them were needed for the deactivation algorithm to be able to work. The authors conducted a simulation in which heterogeneous network deployment was considered. When unused femtocells were deactivated, the network's capacity was boosted and power was efficiently preserved. This technique, however, would be inefficient for femtocells that operate in restricted access or hybrid access modes.

Also, in [19], paper developed joint resource allocation and power control scheme. The proposed scheme was a distribution solution with lower complexity. It used resource allocation and power management methods to overcome the interference issue. This technique was developed for networks of femtocells operating in hybrid access mode. Additionally, this technique aimed to encourage femtocells to accept serving macrocell's UEs in order to take use of certain femtocells' spare resources. In this technique, phases of problem decomposition and problem reduction were considered. The problem was decomposed into two sub-problems. Then, techniques like dynamic programming and the Hungarian algorithm were used to make the problem easier to solve. Also, mathematical formulation was designed for SINR based on CQI measurements. In this paper, solutions were examined through simulation and shown an increase in network capacity.

4. Beamforming Strategy Approaches

Because omnidirectional antennas emit interference in all directions, directed beamforming is another way to reduce undesirable interfernce. However, this includes multiple antennas. Directional beamforming transmission causes just LOS interference. Therefore, femtocells that are not positioned in this direction will be unaffected. To choose the beamforming vector, there are several options. Choosing UEs with higher SINR is one.

The authors of [20] developed a unique approach that combined clustering and selective beamforming. This technique was designed to reduce severe interference for a certain femtocell. This approach uses clustering to identify the main interference region in HetNet. A location-aware method would then aggregate nearby femtocells into a cluster. The associated UEs of femtocells and macrocells in particular cluster regions would therefore be viewed as outputs of this clustering approach. This study investigated uplink transmission. A macrocell is divided into clusters to surround an interference source. This approach was designed to reduce severe interference produced by macrocell UEs or other femtocell UEs after separating a macrocell's region and determining sensitive sub-areas. Sensitive sub-areas were discovered using the location-aware clustering approach. To guide uplink transmission, a beamforming approach was developed. Each cluster had a weak femtocell that received increased uplink interference from the neighboring UEs. According to the clustering, each femtocell and macrocell UE would be able to distinguish femtocells that would be significantly interfered. The CSI value indicates sensitive femtocells in each cluster. The beamforming approach in this work was recognized as Minimize Generated Interference (MinGI). Three steps were taken to decrease the interference. The preliminary stage had three phases. The femtocell would form static reference spaces (SRS). These references were developed to be sent to all femtocells and macrocells in their cluster. Then, each femtocell disclosed the number of associated UEs to all femtocells and macrocells in its cluster. So an SRS for each fmetocell would be evaluated. The second step was to construct a macrocell UE beamforming. Finally, appropriate beamforming would be configured for femtocells' UEs. This method could minimize uplink interference. This technique may not work well when the number of femtocell UEs grows.

Also, in [21], authors developed a beamforming approach for reducing interference. They integrated beamforming and power consumption to reduce interference. The main problem in this effort was energy efficient beamforming. The authors also considered Multiple Input Single Output (MISO) femtocell networks. MISO clearly indicates multi-antennas femtocells base stations, and a single antenna of fmetocell's UE. The authors were driven by rising energy costs and also strict environmental criteria requirements. So they combined beamforming direction and power management to solve the problem. This problem's goal was to optimize the energy efficiency of all femtocells in the system. This problem's essential factor and goal function for each femtocell is the data rate's relation to power consumption. The formulated problem in this paper was a non-convex problem. According to [22], an approximate solution may be used to address the problem. Instead, they used a fractional method from [23]. This fractional method was used to convert a non-convex problem to a convex one. As a consequence, convex theory might find the optimum solution. After transformations, the Lagrange duality approach [17] was utilized to solve convex problems. A simulation setup was also used to assess the suggested strategy. The proposed algorithm was compared against zero force ZF method. The proposed technique, according to simulation findings, saves a lot of energy. Various antenna configurations were also used in the simulation. In the simulation, however, the transmission power of all femtocells decreases as the number of installed femtocells increases. This approach is used to control high transmission power level interference. A drop in capacity was a result of this effort to lower the transmission power of all femtocells.

In [24], authors presented a beamforming-based interference control approach. It was used in a two-tier femtocell network. Unlike earlier methods, this femtocell network design included MIMO. This approach addressed the beamforming strategy's coordination mechanism. Coordination is an important step in beamforming. Oversignaling between femtocells and macrocells was essential for coordination. Controlling interference becomes a more difficult task in this scenario. So, the authors tried to design a system that didn't consider the signaling between femtocells and macrocells. As a consequence, the suggested approach sought to employ the least amount of information feasible to complete the beamforming coordination process. Only a small amount of angle data and chosen beam information could be shared. To reduce unnecessary signaling, the system focused on just two forms of information.The new method is called angle-interference control random beamforming (AIC- RB). This strategy is a low-complexity beamforming strategy coordinating mechanism. The system assumed a macrocell would pick beam subsets for its UEs. It also assessed channels that may interfere with femtocells. Then a femtocell selects a beam for its UEs using SINR to enhance femtocell capacity. This effort covered both macrocell and femtocell UE throughput analysis. This paper also included numerical examples based on Monte Carlo simulation. Also, numerous situations of this technique were investigated to compare outcomes. As a result, it is possible to attain satisfactory results. In this case, the macrocell and femtocells exchanged less information. This study focused on cross-tier interference. More attention should be paid to both cross-tier and co-tier interference. Also, simulation only explored variations of a single system. It should be compared with other strategies.

5. Transmission Power Control Approaches

Managing transmission power is an effective approach, which can be recognized to alleviate interference. This method allows femtocells to utilize more resources and reuse frequency more efficiently. This allows femtocells to adjust their transmission power to boost capacity or prevent interference. Increased transmission power increases femtocell capacity. When excessive transmission power causes interference, it may be reduced until the interference is minimized. Power may be controlled in a centralized or decentralized fashion. For example, distributed power adjustment solutions are provided via reinforcement learning and game theory [25][26][27].

In [28], the authors explored the possibility of co-channel deployment of femtocells overlay on a macrocell region. Both femtocell and macrocells would utilize the same channels. The auto-configuration functionality of femtocells is required for such co-channel deployment. The authors proposed a technique to assure a femtocell's transmission power. This system was designed to manage transmission power and prevent excessive transmission power. Reducing unnecessary transmission power may help reduce interference. Local parameters were utilized to facilitate auto-configuration for a specific femtocell. Based on its radius, the femtocell could decide its transmission power level. The pilot power of a cell, which defines its radius, and the maximum transmission power where inter-cell interference should be handled are two essential keys mentioned in this paper. The coverage of the cell is determined by transmission power. The coverage would expand dynamically as transmission power grew. However, high transmission power may create cell interference. Configuring suitable transmission power is thus desirable, particularly for co-channel deployment. A technique for configuring maximum transmission power by radius was proposed by the authors. This transmission power arrangement also relied on the received transmitted power, which was communicated by serving macrocell, to limit the effect of any co-channel deployment style interference.

The transmission power of each femtocell, which is overlapped with a specific macrocell's region, is determined and computed as follows:

$$P_F = min(P_M + G\, PL_M(D) + PL_F(r), P_{max}) \quad (1)$$

where P_M is the received transmitted power from the macrocell. The antenna gain G. The macrocell path loss at distance D is $PL_M(D)$ and the femtocells path loss at radius r is $PL_F(r)$. According to the results of the simulation technique that was carried out, this mechanism demonstrated satisfactory coexistence between femtocells and the macrocell when co-channel deployment was used. However, there was a modest negative influence on macrocell throughput as a result of the experiment.

The authors in [29] developed a framework for managing the transmission power. Utility-Based Power Control (UBPC) is the name of the strategy (UBPC). This scheme is a decentralized manner scheme, which enables each cell to modify its transmission power occasionally according to some received parameters. This strategy is essentially presented by reformulating the control power problem utilizing concepts from game theory as well as microeconomics and applying them to the control power problem [30] [31]. Both utility and cost are critical considerations on which the scheme's success was predicated. The scheme's usefulness was shown by the relaxation of the SINR criterion. The cost defined the penalty that would be applied as a cost function. The suggested strategy was designed to enhance net utility to the greatest extent possible. A cost penalty, on the other hand, would be considered. Due to the fact that this technique was deemed non-cooperative, the nature of this strategy was disseminated. Despite the fact that it was seen as non-cooperative, there was indirect cooperation among the participants. When congestion occurs, the target SINR for each user would be dynamically reduced to account for the reduction. According to this scheme the base station could be able to adjust its transmission power occasionally. Therefore, the predetermined target of SINR would be targeted as an accomplishment in each period. The transmission power is adjusted according to the following formula:

$$P_{(k+1)} = \frac{SINR_t}{SINR_c}\, \mathrm{p(k)} \quad (2)$$

Where the target SINR is $SINR_t$. $SINR_c$ represented the current SINR value. The transmission power level amount for a certain iteration kth is denoted by P_k. This technique is suitable for heterogeneous networks, according to this work's simulation. It demonstrated user fairness and adaptability. It may also meet certain heterogeneous network needs. Especially in terms of latency and bit error rate. However, maximum transmission power is restricted to the predefined target SINR. The transmission power was estimated each step, causing excessive computation. The concept of game theory was also discussed. Many game theory models have been developed to handle the interference issue in heterogeneous networks. Generally game theoretic models support distributed power control techniques. In fact, non-cooperative and cooperative game theory models were examined by two primary groups.

Authors hypothesized a method based on game theory in [32]. Power control for co-channel deployment was proposed. This study evaluated massive femtocell deployment across a macrocell area. All network layers used OFDMA for downlink transmission. The goal of each was to maximize cell throughput. In this method, power control was a constraint parameter that defined the maximum attainable capacity. This study employed the Stackelberg game theory model. Correspondingly, it was a non-cooperative framework. It also needs leaders and followers. Macrocells were the game's leaders. Femtocells symbolized the followers of this game. Leaders of the game presumed to have all vital information about the followers. Leaders required this data to formulate their strategy. Stackelberg equilibrium was nurtured to guarantee appropriate leader-follower interaction. The competition would take place not only between players from different groups, but also amongst players from the same group. The game was also split into two parts. The upper sub-game represented the leaders group. The lowest sub-game incorporated and depicted the followers. To reach the Nash equilibrium, all players would compete. The potential players' competitiveness was uncooperative. That was the work's solution to the problem. The developed method relies on Lagrangian theory [33]. Despite the low complexity of the proposed approach, the result was suboptimal.

6. Clustering and Graph-Based Approaches

One strategy explored in the literature is to cluster femtocells into numerous clusters to reduce co-tier interference. Femtocells are grouped into clusters depending on parameters. When assigning femtocells to distinct clusters, distance between femtocells might be considered. Graph-based solutions have been suggested.

In [34], authors presented a unique distributed approach to minimize cross-tier and co-tier interference. The idea was to optimize clustering. A hybrid clustering optimization and radio resource assignment issue was defined. It was hard to resolve the problem. Therefore, the problem has been divided into two sub-problems for easier understanding. The first was called clustering optimization and the second resource allocation. This technique utilizes Femtocell Gateway. Its job was to collect data about distributed femtocells. Distributed femtocells were clustered and assigned to distinct clusters using a clustering optimization technique, which was developed. Then each cluster would choose a leader femtocell. A prospective femtocell manages radio resource allocation in its small cluster. To construct a mathematical model for the optimization problem, the LINGO strategy was employed in conjunction with other techniques. To get the best solution, LINGO mainly employed Simplex and Branch-and-Bound algorithms. The authors theorized that the ideal solution may be obtained. A radio resource assignment method was also presented. Their suggested algorithm could reduce interference. It could also have excellent capacity and throughput. This mechanism's ideal clustering approach allows femtocells to freely allocate resources, reducing interference. Also, LINGO technique efficiently supported joint clustering optimization problem. A simulation was used to compare the suggested strategy to alternative methods. These algorithms outperformed others in terms of interference reduction and resource allocation. This mechanism's excellence came from its excellent solution search strategy. However, only 16 femtocells were included in the simulation, indicating that a greater number of femtocells was required. The femtocell model should encompass additional femtocells and macrocells.

In [35], the researchers proposed cluster strategy to resolve elevated interference because of overlaid co-channel deployment of femtocells and macrocell. It was named the Joint Frequency Bandwidth Dynamic Division Clustering and (JFCPA). This approach relied on the clustering principle. First, the authors looked at a co-channel deployment scenario that featured femtocells layered over macrocells. This model was constructed using specified assumptions to mimic femtocell and macrocell overlaid systems (FMOS). The outcome was three forms of interference. The macrocell's interference with femtocell-attached UE was examined. They also studied femtocell-to-macrocell and femtocell-to-femtocell interference. The authors then applied their suggested strategy to the aforesaid deployment model. The suggested design divides the macrocell into two sub-regions. This division was made rationally based on interference intensity. The interference intensity followed the femtocell intensity. The femtocells' location and distribution determine the interference intensity. The basic distinctions were interference sensitive area (ISA) and non-ISA (NISA). The usable frequency bandwidth is split into three portions based on macrocell area segmentation. All FMOS entities would reuse one part. One of the two remaining parts would be reserved for macrocells. The last part would be devoted to femtocells. The frequency bandwidth segmentation depends on the femtocell clustering outputs. JFCPA guaranteed the geographical and bandwidth divisions. JFCPA also verified the distance-based grouping. The main goal of clustering femtocells in this study was to cancel inter-femtocell interference and minimize inter-femtocell interference inside a cluster. Furthermore, SMA-based power control was employed to alleviate cross-interference. Essentially, clustering problem was decided to apply to MAX k-CUT problem with the above targets. A simulation was performed for assessing this scheme. The findings revealed a significant decrease in interfering. In this simulation, just one macrocell was evaluated. The ICIC problem would be exacerbated with multi macrocell deployment. The ICIC problem would be exacerbated with multi macrocell deployment.

The authors in [36] introduced a graph-based strategy for minimizing co-channel OFDMA interference. This scheme used graph coloring. Goal of this method was downlink link system performance. This scheme's main goals were to reduce downlink interference and improve system performance. The method proposed included two essential phases. The first approach assigned femtocells to groups. The graph coloring method was utilized. To group femtocells, an interference matrix should be built. The matrix would be a binary matrix, which indicates the interference. Each femtocell's interference effect would be measured using a predetermined threshold. Thus, the produced matrix is utilized to build a graph for the graph coloring procedure. The DSATUR method was used to color the graph's vertices. Then the femtocell gateway took place, using the fewest colors possible. The second stage was to allocate dynamic channels. The channel is allocated based on the graph coloring algorithm's output. Increasing capacity would be a crucial component in this step's allocation procedure. Strong and gentle interference both influenced femtocell channel allocation. The interference matrix and coloring graph would reveal both scenarios. Author performed a simulation for different indoor environments. The suggested scheme was also compared to others. In terms of capacity, the proposed design outperformed others. The capacity of UEs coupled to various femtocells increased noticeably. Thus, the system's performance increased. However, increasing the number of femtocells may reduce the capacity of the system as a whole.

7. Conclusion

Deployment of small cells especially femtocells are considered as a promising solution for the limited resources that are necessary for meeting the massive demand for data. Also, they tend to increase wireless networks' capacity. However, although the extensive use of femtocells boosts network gain, it also poses a number of difficulties. Interference is one of those issues that must be dealt with. Furthermore, interference control is regarded as a critical obstacle for the effective deployment of two-tier networks. For example, installing femtocell networks within a certain classical macrocell's geographic zone. In general, there are two forms of interference: cross-tier interference and co-tier interference. Cross-tier interference is the most common type of interference. In two-tier networks, such sorts of interference are almost always present in some form. The interference can be in terms of downlink transmission. Also, it can be in terms of uplink transmission. There have been previous studies conducted on the topic of interference management. An investigation of the notion of classification of interference management systems is presented in this paper. An abundance of approaches have been created in the literature with the purpose of lessening or eliminating the effects of cot-ier interference, cross-tier interference, or a mixture between the two types of interference. Some of the approaches to interference management that have been presented may be classified into one of the following categories: Fractional Frequency Reuse FFR, Cognitive Femtocell and Cooperative Resource Scheduling, Beamforming Strategy, Transmission Power Control, and Clustering/Graph-Based. Approaches, which were proposed to solve the interference problem, had been presented for each category in this work.

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