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Development of an Interference Reduction Scheme for Femtocell Network

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ABSTRACT

The development of new multimedia applications has led to an increase in demand for broadband communications in recent years. To cater for this trend, it has been suggested to install cellular networks densely with extensive frequency reuse schemes. Densification of femtocells is a potential approach in this regard to meet the rising needs of mobile services and to sustain the Quality of Service (QoS) of users, especially for indoor users in situations such as homes and businesses. The primary issue with this type of setup is the co-tier (femtocell to femtocell) and cross-tier (femtocell to existing macrocell) interferences caused by many cells using the same spectrum at the same time. When femtocells are found in the macrocell's cell edge region, the issue becomes more complicated. This degrades the QoS. Therefore, reducing interferences is an important issue. Unfortunately, conventional methods of interference reduction have not been able to effectively tackle the interference problem in femtocell networks. To address this, a dynamic resource allocation method using the Breadth First Search (BFS) algorithm was developed in this study. In this study, femtocell was modeled considering low density and high density Femtocell Access Point (FAP) deployments to evaluate their impact of interference on the performance of the developed scheme. Modelling and simulations were carried out in MATLAB software environment. The results obtained showed that the developed scheme was able to reduce the interference level between femtocell users. Likewise, the developed scheme outperformed the conventional method of interference reduction in femtocell network. The study also reveals that more number of users can be accommodated with reduced interference level when the low density FAP deployments were used.

Keywords: Femtocell, Graph Coloring, Frequency Assignment, LTE Femtocell Access Point.

1. Introduction

Since the introduction of intriguing mobile devices and multimedia applications, user demands for wireless data communications in cellular networks have been rising quickly. Applications with high traffic volumes have a significant impact on increasing the data rate. As shown in Fig. 1, a study by Kovacs [1] indicates that over the previous five years, there has been a noticeable growth in the demand for mobile data traffic.

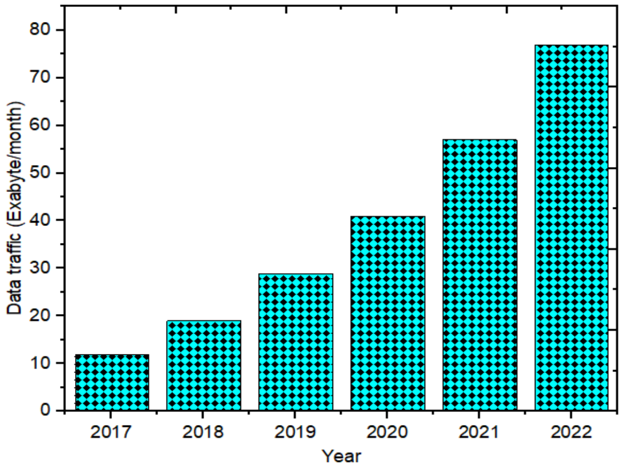

Fig. 1 Global mobile data traffic from 2017 to 2022.

Additionally, since consumers pay telecommunication firms more for data services than for voice-only services, they anticipate higher-quality services. Because of the numerous walls and obstructions found indoors, the channel quality from the mobile node and the cellular base station may be poor. Consequently, indoor wireless communication systems need to be built with the necessary service quality in mind for consumers. Even so, as 90% of data traffic and over 60% of voice traffic are anticipated to be generated indoors, the scarcity of wireless resources in cellular networks will worsen [2]. Unquestionably, more network infrastructure is needed to improve cellular network capacity. The application of femtocells, placed on top of the conventional macrocell-based based cellular networks is a crucial subject for the economical installation of new infrastructure [3]. Femtocell is an inexpensive, smaller cellular base station that uses low power. It can be implemented by service providers or customers anywhere wired IP access is available. Femtocells are low-cost, typically installed indoors and linked to the backhaul via a general IP connection. With cable modem and fiber-to-the-home, cellular networks could secure wireless resources more affordably while enabling customers to use high-speed, low-power wireless data communications. Conversely, exhibiting more channels per region (cell) typically results in increased capacity. This can be achieved by increasing channel reuse by decreasing the area of each cell. Cellular service demand can also come from indoor sources. Previous research in [4] has revealed that 18% of phone conversations and data sessions start indoors. The in-building wireless market is expected to grow rapidly by $18 billion by the year 2025 due to rising consumer data usage and the growing demand for smartphones [4]. Given that more sophisticated multimedia applications are anticipated to be deployed, it is in that the capacity demand for indoor communications will continue its horrifying upward trend. Therefore, to meet the multitude of data-traffic-intensive applications, more sophisticated indoor communication networks are needed. By nature, buildings are physical barriers to wireless communications, which may lead to penetration losses. Consequently, the quality of services may be compromised. The

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indoor customer requires sufficient power from the serving Base Station (BS) to compensate for penetration losses. To be able to meet the requirements of a high capacity network, large number BSs are installed outside which is quite costly. Also, having so many BSs would make network planning and optimization more difficult. Femtocells have been widely used in wireless communication systems as a solution to this issue because of their many benefits, which includes enhanced indoor coverage, low cost, and energy efficiency [5]. Femtocell was created to improve network coverage and capacity indoors. In order to achieve this, a large number of densely deployed femtocells, referred to as an ultra-dense network (UDN), are anticipated to underlay the current macro network. Large-scale femtocell deployments have the potential to increase wireless network interference. The effective deployment of femtocell networks is hampered by this interference, which reduces network performance, particularly when adjacent femtocell frequencies overlap [6]. Due to the potential of femtocells to improve indoor localization and coverage, reducing the interference level generated by the densely deployed cells has been a focus of many research studies [7]-[14].

2. Femtocell Concept

Femtocells are small, low-powered base stations used to give mobile users radio coverage in indoor environment. Similar to a Wi-Fi router, they are put indoor by the user and offer almost all cellular features to consumers [15]-[17]. The user's broadband internet connection is subsequently employed to link the Femtocell Access Point (FAP) to the operators' core network. In this case, the femtocell enables a variety of indoor User Equipment’s (UEs) to establish a connection with the FAP and utilize data and voice services. Femtocells deployed in WCDMA systems are also known as Home Node B (HNB).

Home e Node B (H(e)NB) in LTE systems is standardized since 3GPP release 8 and employs physical layer technology comparable to that of cellular networks. Every H(e)NB features an access mode that only permits connections from restricted and registered UEs; all other UEs cannot access it since their connection is denied. These H(e)NB are utilized in homes and small offices. Release 9 improves this control over access modes by offering hybrid and open access modes. Every user has the ability to ad hoc deploy femtocells within a macrocell and even relocate them from one place to another within their residence. As a result, operators find it difficult to dynamically manage radio resources [18]-[19]. To ensure that it is aware of its surroundings, it also needs effective self-organizing mechanisms. Distributed optimizing approaches should be used to reduce interference. Apart from potential spectrum shortages during dense co-channel femtocell deployment, opportunistic spectrum access is another feature that femtocells should have. This means that in order to be more intelligent, femtocells must possess cognitive functions. This is because of its additional features, which may offer effective answers to the problems that dense femtocell deployment may present in the future [20]. Cognitive femtocells can identify any empty spectrum areas by detecting spectrum in their immediate surroundings. The cognitive femtocells then make use of these spectrum gaps to give their users connectivity. Their ability to interact and synchronize with adjacent cognitive femtocells makes spectrum detection more accurate. When spectrum holes are unavailable, cognitive femtocells can function similarly to regular femtocells by using the licensed band [21]. The concept of femtocells emerged in 1999 when Bell Labs conducted its initial research on a home BS. A GSM-based home BS from Alcatel was announced to hit the market in 2000 [22]. Although their demonstration devices demonstrated functionality over a Plain Old Telephone System (POTS) line, the equipment's exorbitant cost prevented them from becoming commercially successful. Following this, Motorola unveiled their 3G home base station in 2002, although the idea was still somewhat novel [22]. The term "femtocell" was first used in 2006; however, this concept became widely recognized in 2005.

2.1 Topology of LTE Femtocells Network

The topology of the LTE femtocell network is shown in Fig. 2 [23] as defined by version 10 of the 3GPP. These networks installed in houses or offices can be linked to the core network via broadband networks (FTTH, ADSL, and Cable). By allowing fewer new base station deployments, the network operator and the user can reduce their respective expenses associated with the mobile communication network. The LTE femtocell network is composed of Home enhanced NodeB (HeNB) and enhanced NodeB (eNB), as illustrated in Fig. 2. To handle a large number of HeNBs, the HeNB gateway (GW) can be positioned between the HeNB and the mobility management entity/serving gateway (MME/SGW). The only connections that a single HeNB can make are to the HeNB GW or the MME; the S1 interface is used to connect to the HeNB GW directly or to the MME/S-GW. HeNBs have the benefit of being used anytime, anywhere, and depending on the situation. Which HeNB GW is linked to a given HeNB depends on its location. The Evolved Packet Core (EPC) receives control messages sent by the HeNB as well as traffic data between the HeNB and the MME/S-GW. The traffic from the EPC is subsequently sent back to the HeNB by the HeNB GW. From the standpoints of the MME and HeNB, respectively, the HeNB GW assumes the role of eNB and MME.The X2 interface between HeNBs is defined by 3GPP version 10, which allows for a handover process to occur between HeNBs via the X2 interface without the need for MME mediation [23].

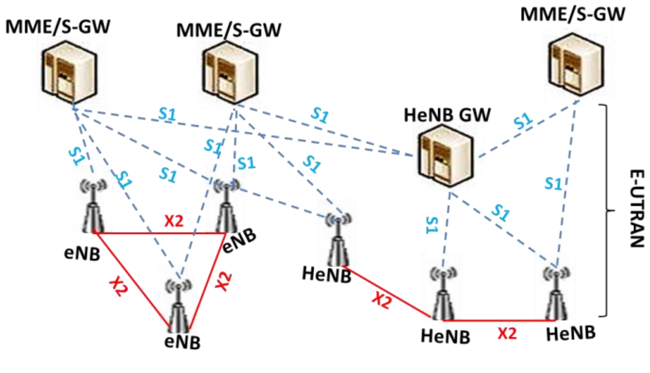

Fig. 2 A topology LTE femtocell.

2.2 Conventional Femtocell Network

Fig. 3 shows a conventional network of LTE femtocell. In this network, a Scheduling Block (SB) should be sent to the UE by the femtocell when it comes into contact with it. Keep in mind that the SB is the key component utilized in resource management, the femtocell notifies the resource management system (RMS) so as to increase the number of SBs allotted to it in the event that no resources are available. The UE arriving in the cell is subsequently presented with the granted SB. To control the SBs' availability, the RMS replies to request messages that the femtocells send.

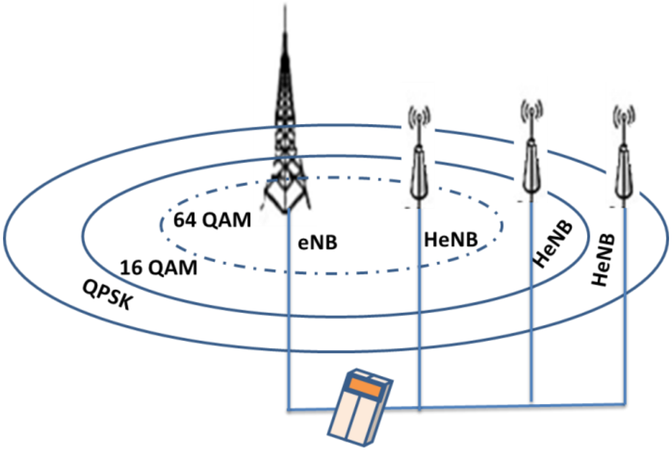

Fig. 3 Conventional femtocell network architecture.

2.3 Interference Categories in Femtocell Network

ii) Co-tier interference

This is related to two different kinds of interference between femtocells that are next to each other. Uplink and downlink co-tier interferences are the two types [24]. Network components that are part of the same network layer are the cause of this kind of interference. As indicated by indicator 1 in Fig. 4, uplink co-tier interference occurs when femtocell users (aggressors) interact with the surrounding femtocell BS (victims). As seen in indicator 2 of Fig. 4, downlink co-tier interference occurs when a nearby femto-user (victim) experiences interference from a femtocell base station (aggressor). Since they are next to one another, the femtocells that interfere with one another are typically immediate neighbours. Femtocell placement is random, and they can be placed in close proximity to one another, perhaps with insufficient wall separation to prevent interference. When there is a dense deployment and multiple nearby interferers, the total interference detected at a certain femtocell is probably more than the sum of the individual interfering femtocells.

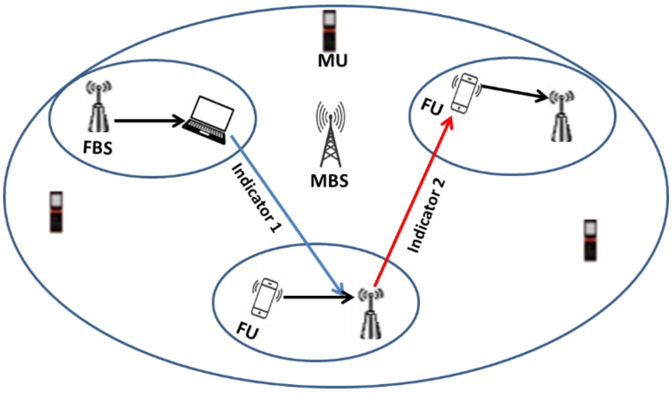

Fig. 4 A typical co-tier interference scenario from neighboring FBSs.

ii) Cross-tier Interference

Interference from the femtocell and macrocell layers, as well as vice versa, is the cause of this. Uplink cross-tier interference happens when femtocell users (aggressors) interfere with the operations of a nearby macro-cell BS (victims) or when macro-cell users interfere with the operations of a nearby femtocell base station (aggressors), as displayed in indicator 3 of Fig. 5 [24]. Using the same indicator, downlink cross-tier interference happens when an aggressor macro-cell BS interferes with a nearby victim femto-user or when an attacker femtocell base station interferes with a nearby victim femto-user**.**

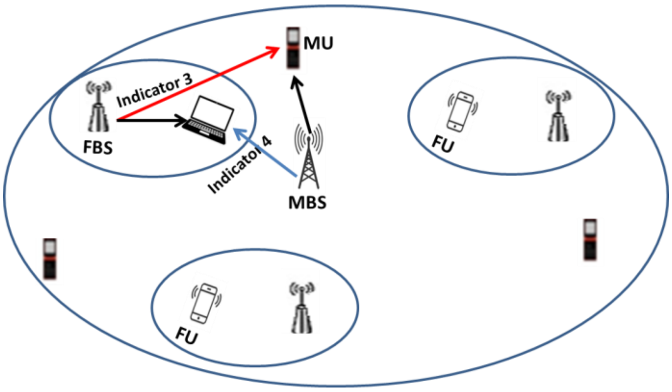

Fig. 5 A typical cross-tier interference scenario between FBSs.

2.4 Reviews of Related Studies

Hassan and Gao [25] proposed an adaptive power control technology for downlink interference management. The study shows that when femtocell access points and their users are placed inside the same building, there is no need for an external wall, and optimal throughput is reached. When an FAP is installed in a separate structure than its user, more throughput is attained than in the previous scenario. Additionally, it was claimed that network performance improved with access points located closer to users. Furthermore, for seamless and continuous QoS delivery, the access points must be in close proximity to the individual users. Over time, extra costs are reduced to a manageable level. The authors [26] employed a cluster-aware soft frequency reuse strategy for LTE femtocell networks third generation collaboration project. The model is used to reduce circumstances where nearby femtocells interfere. This was accomplished by using simulations to assign distinct resource blocks to the cell edge users, greatly enhancing system performance and raising base station throughput overall. The impact of femtocell deployment using dedicated, co-channel, and cognitive co-channel techniques on subscribers' performance evaluation was discussed in [27]. The cognitive co-channel approach used channel capacity measures. The findings showed a similar pattern to the application of cognitive co-channel in larger interior spaces where service quality is preserved. The femtocell backhaul link can also be used by the macrocell base station to offload excess traffic. Power regulation is a useful technique for reducing inter-cell interference in ultra-dense tiny cell networks. For example, a power control methodology as discussed in [28] employs Newton's method to improve both the energy efficiency and the network utility for millimeter-wave-based ultra-dense small cell networks. An adaptive on-off power control method that can stop interference in a dispersed pattern is suggested in [29]. A distributed target-SINR tracking-based power control technique is described in [30] to improve system throughput. The opportunistic power control technique and tracking power control are applied selectively by this algorithm. An interference control algorithm as developed in [31] optimizes the power control to minimize cross-tier interference.

Abiri *et al.* [32] developed a novel approach for femtocell development for scalable video traffic in 5G HetNets. The number of required femto base stations is determined by solving a Multiple Fractional Knapsack Problem (MFKP) with three objectives called MU, MQ, and MP. In this study, MU denotes the maximum number of users availing the video services; MQ is used when maximizing the mean QoE and MP represents the minimized power consumption. The first optimal solution is obtained by employing genetic algorithm-based optimization. Later, a greedy algorithm is incorporated to present a maximum resource-efficient solution with lower computational complexity.

Eslami *et al.* [33] focused on facilitating the spectrum reuse mechanism for D2D and femtocell users in three-tier dense networks by addressing the issue of joint model selection and resource allocation. The main aim of this model is to maximize the sum rate and minimize the interference. The spectrum can be reused but co-tier and cross-tier interferences impact the overall communication performance therefore authors reported this as the mixed integer non-linear, non-convex problem and introduced a joint convex relaxation method which uses Lagrange dual decomposition method is introduced and a low-complexity (primal) decomposition-based method is also incorporated to reduce the computational complexity of the system.

Pak *et al.* [34] focused on indoor areas with poor cell phone reception and suggested that it can be improved by deploying femtocells inside the building however, the performance of these cells is limited due to co-channel interference and introduced a novel approach to handle these issues. According to this approach the cells are divided into three different cells such as the Cell Center Area (CCA), Cell Middle Area (CMA), and Cell Edge Area (CEA) and different allocation policies are assigned to each cell resulting in minimal interference. Jon *et al.* [35] reported that femtocell based ultra-dense networks are the promising solutions to satisfy the demand of increased data traffic but it leads to frequent handovers which increases the power consumption and reduces QoS. To address this, issue authors introduced a novel uplink handover approach which determines the target cell based on bandwidth and direction of UEs.

3. Methodology

As shown in Fig. 6, the cell was modelled as one circular cell with a separate uniform distribution for the position of each user and FAP.

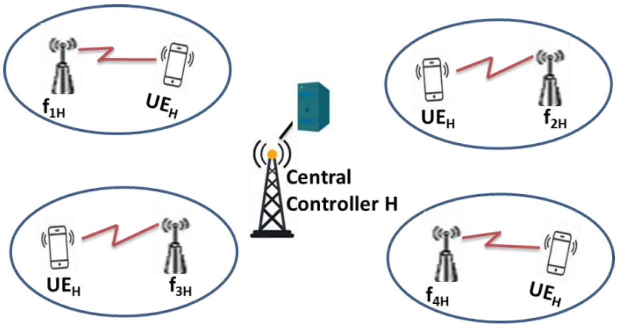

Fig. 6 Femtocell model.

Only one FAP is connected to by a user. The cell model only takes into account users who are using FAPs (also known as small cells) for their wireless communication and doesn't consider users who might be connected to other types of network or access points. At the middle of each femtocell access point, the coverage area is located. The FAP transmit power and environmental factors both affect the radius (*d*) of the coverage region. Given that femtocells are dispersed randomly across space, some of them may interfere. In another way, there's a chance that some users are in an area that is served by multiple FAPs.

Physical resource blocks (PRBs) in the frequency domain are routinely allotted to HeNBs. Put differently, when a PRB is assigned to a HeNB, it also assigns other PRBs that share the same sub-channel frequency to the HeNB. Let $K = \{1, 2, 3\ldots |K|\}$ represents the set of PRBs in the frequency domain that the femtocell network can access. A HeNB resource demand is determined by the total of its associated UEs resource demand, and each HeNB has a unique resource demand to meet the throughput demands of its UEs. This means that the resource demand of HeNB *f*, or *Df*, can be estimated as

$$D_{f}{=}\textstyle\sum_{U\,\epsilon U_f} D_u \tag{1}$$

where D_u is the resource demand of UE *u* and *Uf* is the set of UEs connected to HeNB *f*. Actually, multiple data flows with distinct bit rates required for each UE may exist. Consequently, the bit rates needed by the UE's data flows add up to the overall bit rate that the UE needs as

$$R_u^{req} = \sum\nolimits_c \epsilon\, C_{u\, R_c^{req}} \tag{2}$$

where R_u^{req} and R_c^{req} denote the bit rates needed by u^{th} UE and data flow c, while C_u is the collection of data flows connected to UE *u*. Eq. (3) can be used to estimate the amount of PRBs needed by UE *u*. In Eq. (1), D_u is expressed as

$$D_u = \left\lceil \frac{R_u^{req}}{fPRBS_E} \right\rceil \tag{3}$$

where f_{PRB} is the frequency of the PRB. A PRB has a bandwidth of 180 KHz, the modulation and coding scheme that is selected for transmission determines the attainable spectral efficiency. The Adaptive Modulation and Coding (AMC) module in the Medium Access Control (MAC) layer of LTE networks gives the received SINR, which can be used to estimate S_E. Under the Breadth First Search scheme, every UE communicates with its serving HeNB on a regular basis to deliver a measurement report that includes the received signal strength (RSS) of the reference signals provided by all HeNBs. This determines whether an interference event has happened based on this measurement report. When the following inequality is true, interference occurs between i^{th} HeNB and its nearby j^{th} HeNB:

$$P_{ui}^{ref} = (db) < P_{uj}^{ref}(db) + T_h(db) \tag{4}$$

where T_h is a protection margin that accounts for the cumulative interference from nearby macrocells and fading effects, while P_{ui}^{ref} and P_{ij}^{ref} denote the RSSs received at UE *u* from the serving i^{th} HeNB and the nearby j^{th} HeNB, respectively. When the i^{th} HeNB receives a measurement report that is pertinent to j^{th} HeNB, it then modifies the quantity of measurement reports N_{IJ}^{MR}. The amount of interference occurrence N_{ij}^{IE} is also modified once an interference occurrence is identified. Eq. (5) can be used to estimate the amount of time that HeNB *j* interferes with HeNB *i* based on the facts provided.

$$W_{ij} = \frac{N_{ij}^{IE}}{N_{IJ}^{MR}} \tag{5}$$

Thus, the interference correlations among HeNBs can be described by an $|F|\times|F|$ restriction matrix with interference restriction elements w_{ij}.

3.1 Channel Model

The 3GPP TR 36.814 and TR 36.922 version 10.2.0 served as the foundation for the channel model utilized for femtocells in metropolitan areas. For macrocells, it is expressed using Eq. (6).

$$PL_{macroocell} = 15.3 + 37.6 log r + L_{oth} \qquad (6)$$

where $PL_{macrocell}$ is the pathloss due to macrocell channel, d is the distance between the HeNB and the FUE while L_{oth} is the penetration loss caused by the wall between the HeNB and FUE. For femtocell, the channel model used is expressed using Eq. (7).

$$PL_{femtocell} = 127 + 30 log\left(\frac{d}{1000}\right) \qquad (7)$$

Taking the path loss between the FAP and the user for indoor and outdoor propagation into consideration,

$$PL = 38.46 + 20\, log(d_{in}) + 15.3 + 37.6 \times log\left(\frac{d_{in}}{10}\right) + L + L_s \qquad (8)$$

where L is the penetration loss, set to 10 dB and 3 dB (with equal probability) for an external wall and windows, respectively, d_{in} is the distance, measured in a uniform distribution between 1 and 5 meters between the FAP and the wall or window, L_s is a log-normal random variable with a standard deviation of 10 dB that takes shadowing into consideration.

3.2 Breadth First Search Algorithm

The BFS is a traversal algorithm that investigates each node in the network level by level. Notably, optimal coloring of networks can be obtained with minimal complexity if the interference graph is sparse, that is., each node is connected to at most N nodes, where N is the total number of channels. A modified version of the BFS algorithm can be used to color such graphs optimally. Its complexity is O (|V|+|E|), where |E| = α|V| = O (|V|). In this case, |E| and |V| represent the cardinality of the edges and vertices, respectively, and α is a scalar quantity. Algorithm 1 illustrates how the BFS algorithm works.

Algorithm 1: BFS Resource allocation for Femtocells

```
Require: femtocells, adjacency, list, resource
    Ensure: resource allocation

Initialize a queue queue
Initialize a set visit
Initialize a dictionary resource_allocation
Define resources: resource = [Resource_Macrocell_2, Resource_Macrocell_3]
Assign the initial resource to the first femtocell:
first_femtocell←femtocell (0)
resource allocation [first femtocell←resource [0]
queue.enqueue (first_ femtocell)
visited. Add (first_ femtocell)
while queue is not empty do
current_femtocell← queue.dequeue()
for neighbor in adjacency_list [current-femtocell] do
    if neighbor is not in visit then do
        for resource in resources do
            if resource = resource_allocation [current_femtocell] then
                resource_allocation [neighbor] ←resource
Break
            end if
            end for
            queue.enqueue {neighbor}
            Visited. Add (neighbor)
        end if
    end for
    End
return resource_allocation
```

3.3 Performance Evaluation

The performance of the developed scheme was evaluated using the SINR, outage probability and the BER.

SINR: Eq. (9) was used to calculate the SINR, a metric that is used to assess a femtocell network's connection performance.

$$SINR = \frac{P_s^f}{\sum_{s=1}^{n} I_{s} + \sum_{k=1}^{m} I_{k+N}} \qquad (9)$$

Where P_s^f *is* the transmit power at FUE to HeNB (in mWatt or Watt), I_s is co-tier interference caused by another femtocell (in mWatt or Watt), I_k is the cross-tier interference from MUE to HeNB (in mWatt), and N is the noise power (in mW or W). Eq. (10) was used to calculate the power transmitted from the FUE to the HeNB (the power for the desired signal) or the transmitted power from another FUE to the HeNB (co-tier interference).

$$P_s^f(dBm) = P_{FUE}(dBm) - PL_{femtocell}(dB) \qquad (10)$$

where P_{FUE} is the transmit power of the desired FUE or other interfering FUEs.

Bit Error Rate: The performance of BER is dependent on the used modulation technique. 16-QAM, or 16-quadrature amplitude modulation, was employed in this study. The BER performance was estimated using Eq. (11).

$$BER = \frac{3}{4} Q\left(\sqrt{\frac{4}{5} E_b/N_o}\right) \qquad (11)$$

where Q(.) denote the Q-function of the argument in the brackets and E_b/N_o is a normalized measure for *SINR* per bit.

Outage Probability: An outage probability is the likelihood that the received data rate will drop below a specific data threshold. These days, systems work tirelessly to minimize this likelihood in order to enhance network performance, particularly with regard to UE connection Table 1 shows the parameters used for the simulation.

4. Result and Discussion

4.1 Overview

The simulation's results are shown in this section. The FAP density λ is one per 100 m^2, or one per radius of 5.5 m, with the cell radius set to 100 m. The results also illustrate the same metric in a low FAP density network, where λ is 1 per 1000 m^2, or 1 FAP every 18 m radius. The user density in both scenarios is set at 4 λ, or an average of 4 people per FAP. Every user has an equal need. The results are computed using ten channel realizations per set of locations and an average of more than 100 unique user and FAP locations.

Table 1 Simulation parameters.

Parameters	Values
Carrier frequency	12 GHz
Channel bandwidth	20 MHz
Carrier spacing	15 kHz
Resource block	180 kHz
Total number of PRBs	100
N	50
Transmit power	20 dB
Noise figure in UE	10 dB
Maximum distance	1 m from FAP

4.2 Outage Probability

Fig. 7 shows the result of the outage probability obtained for high density FAPs using the developed scheme. This result is compared to the conventional method for interference reduction in femtocell networks.

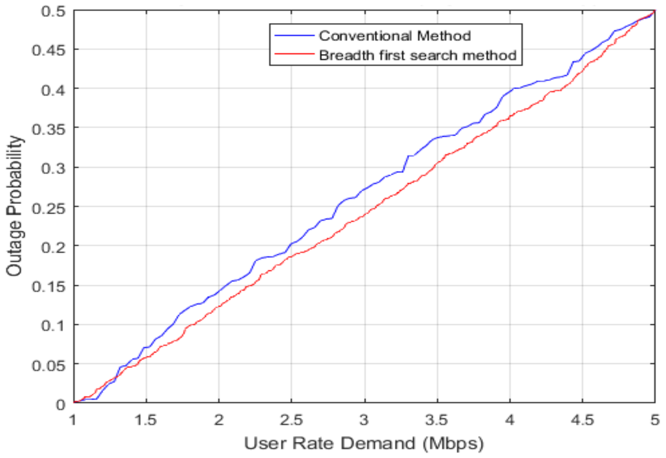

Fig. 7 The outage probability vs user rate demand for the developed scheme and the conventional method considering high density FAP deployment.

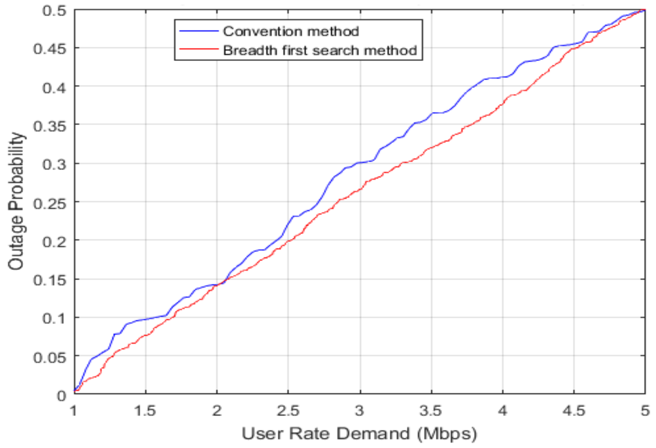

Fig. 8 The outage probability vs user rate demand for the developed scheme and the conventional method considering low density FAP deployment.

From the Fig. 7, it is observed that the developed scheme has a superior outage probability for almost all the user rate demand. A lower outage probability signifies a good interference reduction. It means that the SINR of the link between femotcell UE and its serving base station is strong enough to maintain a successful connection. Thus, the QoS is not degraded. In comparison to a conventional method as shown in the figure, the outage probability produced by this method is higher than that of the developed scheme. This means that the FUEs will experience higher interference, which will degrade the quality of service.

A similar result was obtained for the outage probability when the low FAP density was considered as shown in Fig. 8. However, for the conventional system, it is observed that for user rate demand ranging from 2.5 Mbps to 4.5 Mbps, the outage probability is greater than that obtained when high density FAPs was considered. It can be deduced that the interference level produced by the developed scheme is not affected by either of the two scenarios, as there are no significant variations.

4.2.1 Effect of number of users

In Fig. 9 and Fig. 10, various numbers of users (100, 500, and 1000) were selected to ascertain their respective interference levels in both low-density and high-density FAP deployments to evaluate their impact of interference on network performance

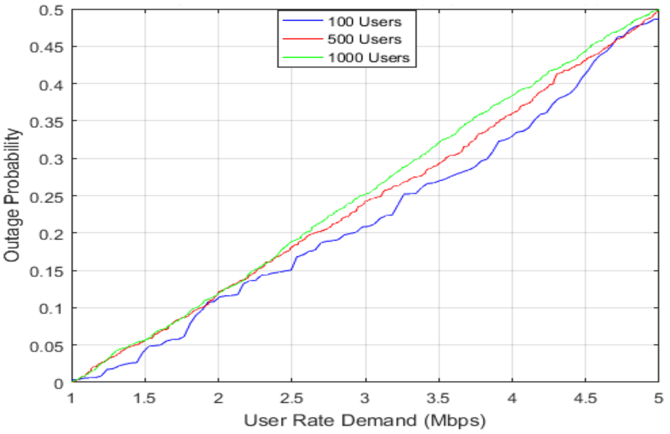

Fig. 9 Outage probability against the user rate demand in high FAP density network of 1 per circle.

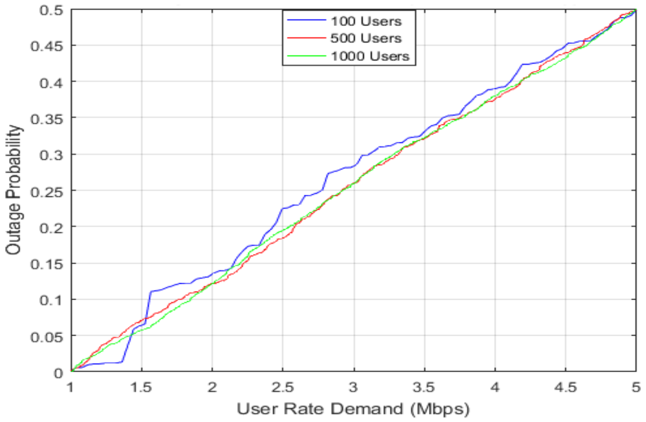

Fig. 10 Outage probability against the user rate demand in low FAP density network of 1 per circle.

In Fig. 9, for the high-density FAP deployment, 100 femtocell users experienced the least interference level with more outage probability. With more than 100 users, interference levels may increase due to the high outage probability produced, which will impact the network performance. Thus, managing a large number of users under the high-density FAP deployment is difficult. However, when the low density FAP deployment is considered (Fig. 10), a large number of users can be accommodated with a reduced interference level. From Fig. 10, at more than 1.4 Mbps user data rate, both 500 and 1000 users can be accommodated with reduced interference level compared to the high density deployment.

4.3 SNIR Result

Fig. 11 illustrates the SINR against the number of femtocells for the developed method in comparison to a conventional system. It is observed that, generally, the SINR value decreases as the number of femtocells rises. This trend is the same for the developed scheme and the conventional system. However, the SINR value for the developed scheme is higher than that of the conventional method. The SINR value for the developed scheme when the number of femtocells equals 5 is 15.91 dB; meanwhile, for the conventional method, the SINR value at the same number of femtocell is 7.93 dB This means that there is an improvement in the SINR value by 7.98 dB. It is important to note that this improvement is observed to reduce slightly as the number of femtocells increases. In fact, almost the same value is observed for the developed and conventional methods when the number of femtocells ranges between 90 and 100. Between these ranges (90 to 100), the reduction in the value of the SINR becomes almost linear; thus, the interference from the neighbouring femtocells will become significant due to the reduced SINR value at these points. This trend was noticed for both methods.

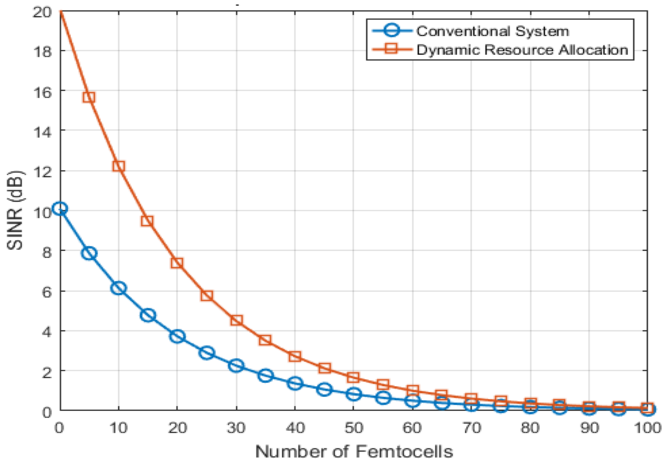

Fig. 11 The SINR result for the developed algorithm with the conventional system.

4.4 Bit Error Rate

Fig. 12 shows the comparison of the Complementary Cumulative Distribution Function (CCDF) of BER for the developed scheme and a conventional method. In this figure, the probability of BER in the conventional system above a target of 0.45 is 71%, while the developed method that has a BER above 0.45 is 54%. This indicates that the developed scheme has a superior BER performance than a conventional method. A reduced BER is obtained with the developed method. At BER above 0.45, the performance of the developed method is better than the conventional one by 18%. It shows that the probability of errors in data transmission that the greater BER value would have introduced in the conventional method has been reduced using the developed method.

4.5 Comparison of the Current Study with other Related Studies

In Table 2, the result obtained from the developed scheme was compared to other related studies. Adebayo *et al.* [36] use the Open Channel Allocation (OCA) scheme to ascertain the most optimal result; the downlink interference experienced is 1.3 dBm, while for BFS, 0.01591 dBm was recorded, which shows that the BFS has a better SINR compared to OCA. Also, Alisha *et al.* [37] use the clustering method for interference reduction in femtocell networks. The BER was 77% in the BFS scheme developed in this study, and the BER was 54%, which shows that the BFS has superior advantages over the clustering method. In Susanto *et al.* [38], Radio Resource Allocation (RRA) was used in minimizing the interference level, and the value of BER was 75%. And BER recorded in BFS was 54%, respectively. This shows that the BFS scheme has a better performance than the (RRA) in this scenario.

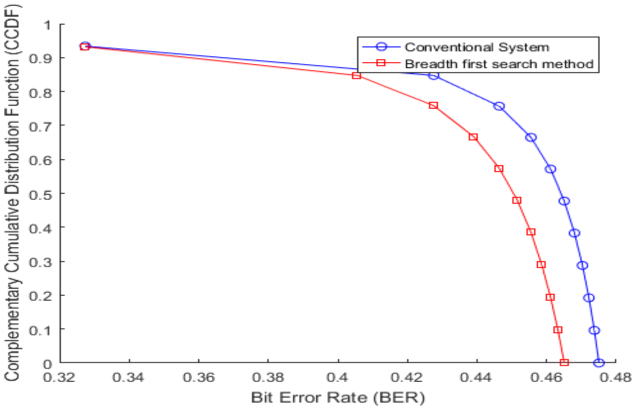

Fig. 12 The CCDF of BER for the conventional system and system with a breadth first search.

Table 2 Comparison of the current study with other research studies.

Author	Methodology	Result
Adebayo et al. [36]	Use OCA schemes to ascertain the most optimal solution.	Downlink interference of 1.3 dBm for OCA was recorded.
Alisha et al. [37]	Clustering method	When no of femtocell equal to 5, SINR for OCA was found to be 33.1dB and BER was 77%
Susanto et al. [38]	Radio resources allocation (RRA)	SINR was 40 dB with a BER of 75%.
This study	BFS algorithm for interference reduction.	SINR of 0.001591 dBm and BER of 54%, were recorded.

5. Conclusion

Femtocells are typically used in highly populated areas to increase wireless network capacity and lessen signal attenuation that indoor customers encounter. However, because of the radio resource sharing with other femtocells and its accompanying macrocells, this technology may lead to an increase in co-tier and cross-tier interference.

To reduce the interference level, this study developed a dynamic allocation resource method using the BFS algorithm for interference reduction in a femtocell network. The efficacy of the developed scheme was analyzed using the outage probability, the SINR, and BER and compared to the conventional method. The simulation results for the parameter used for the evaluation have depicted a good improvement in the interference level between the femtocell users. The result shows that the developed scheme has a better performance than the conventional system.

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