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APPROPRIATE BANDWIDTH SELECTION ACCORDING TO THE DETECTION SCHEME OF THE FEMTOCELL ACCESS MODE

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ABSTRACT

Nowadays, 5G and beyond mobile communication networks are deployed to accommodate higher dense traffic and different categories of applications. In 5G networks, the deployment of femtocells has increased, since femtocells are regarded as one of the main pillars for boosting network capacity and offering network users (UEs) high quality of service (QoS). Combining many different access nodes creates a heterogeneous network. But in a macro-femto heterogeneous network, specifically in areas of low signal power, macro-users (MUEs) like to access the closest femtocell. However, these accesses will have a negative impact on the serving femto-users (FUEs) because they will affect their demand for resources. Therefore, in our proposal, a femtocell access mode detection scheme (FAM-D) is proposed to find out the proper femtocell access mode (FAM) that will manage the distribution of resources between MUEs and FUEs that are inside the femtocell. After that, we select the proper bandwidth (BW) based on the FAM detection to achieve the resource demands of FUEs and MUEs. Presented numerical results show that the FAM-D is tested over various network densities. In each case, the FAM-D will detect the proper FAM to ensure high QoS for FUs while assisting MUEs who are in need of services without hurting FUEs' needs. After that, we select the proper bandwidth, which will minimize BW utilization. Finally, the number of users prohibited from service can be decreased from 10 UEs to 1 UE using our proposed model.

KEYWORDS: Femtocell, FAM-D Scheme, Bandwidth Selection, Prohibiting Users.

إختيار النطاق الترددي المناسب وفقا لنظام الكشف الخاص بوضع الوصول الى خلية الفيمتو

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الملخص

في هذه الأيام أصبحت شبكات الهاتف المحمول العاملة بتقنيات الجيل الخامس و ما بعدها تعتمد اعتمادا كبيراً على الخلايا الفيمتو (المتناهية الصغر) و ذلك كونها أحد أهم الركائز التي تستخدم لتنفيذ الشبكات ذات السعات الضخمة و التطبيقات الجديدة مما يعزز

قدرة الشبكة علي تقديم خدمات عالية الجودة في المناطق ذات الإشارة المنخفضة، حيث يفضل تقديم الخدمات للعملاء المسبق توصيلهم بالخلايا الكبيرة من خلال إعادة ربطهم بمحطات الفيمتو. ولكن، سيكون لهذه التوصلات تأثيراً سلبياً على خدمة المستخدمين المخصصين أولاً للمحطات الفيمتو لأنها ستؤثر على توزيع الموارد اللاسلكية المخصصة لهم مسبقاً. لذلك، يقترح هذا البحث، منهجية لاكتشاف وضعية الوصول (FAM-D) المناسبة للخلايا الفيمتو و ذلك لتحسين توزيع الموارد اللاسلكية بين عملاء الخلايا الكبيرة المنقولين حديثا و العملاء المسبق تسكينهم في خلاليا الفيمتو. كما يقدم هذا البحث تصوراً عن أسلوب تخصيص النطاق الترددي المناسب (BW) بناء على متطلبات الموارد اللاسلكية من جميع العملاء داخل نفس الخلايا الفيمتو. ويتضح ذلك من خلال استعراض للنتائج العددية المستنبطة من البحث، حيث يتم تطبيق منهجية الاكتشاف FAM-D بناء على نسبة إشغال الشبكات المختلفة مع ضمان الحفاظ علي مستوي الخدمة لعملاء الفيمتو و مساعدة عملاء الخلايا الكبيرة و تقديم خدمه لهم بدون الإضرار باحتياجات العملاء السابق تسكينهم في خلايا الفيمتو. بعد ذلك، يتم اختيار النطاق الترددي المناسب، مما يقلل من تعظيم التفع من الموارد اللاسلكية المستخدمة كما يمكن تقليل عدد المستخدمين المحظورين من الخدمة من عشر الى واحد من خلال المقترح المقدم بالبحث.

الكلمات المفتاحية : خلايا الفيمتو، منهجية FAM-D، اختيار النطاق الترددي، المستخدمين المحظورين.

1. INTRODUCTION

Future wireless cellular network deployments will need to evolve with the increasing amount of mobile data traffic [1]. Aiming to lower network costs and increase the efficiency of the current macrocell [2]. According to [3], over 80% of mobile traffic (including voice and data) originates from interior spaces such as homes, offices, malls, and other indoor areas. One of the prompt solutions to deal with this indoor traffic is femtocell technology.

Femtocells enable the extension of the macro-cellular network's radio characteristics, thereby improving coverage, especially indoors, and offering mobile wireless services to users. In 5G and beyond, the deployment of femtocells increased, growing at a CAGR of 23.44% from 2021 to 2028 [4]. Because by using femtocells, which are often known as home base stations, the overall network performance will be enhanced at a lower cost [5].

A heterogeneous network is a type of wireless network in which different access nodes are combined to achieve high-quality mobile broadband services [6]. However, in a two-tier macro-femto heterogeneous network, MUEs prefer to connect to the closest femtocell because they sometimes receive weak signals, especially at cell borders. Therefore, these accesses will negatively impact FUEs. The goal for femtocell deployment should be to take into account MUE's demands without compromising FUE's demands.

The user's ability to connect the femtocell can be determined by one of three different access control modes. It is possible to use closed, open, or hybrid access control modes [2].

- In the case of closed access, only femtocell customers are allowed access. It is mostly utilized at home to deliver high-quality service for FUEs. However, this mode cannot support outside users, which often results in a reduction in the total network throughput.
- In the case of open access, users who choose open access have equal access to femtocells, whether they are customers or not. Users who are unable to connect to nearby macrocells can use this mode. In this mode, the capacity of the entire network is increased. On the other side, femto-users may see a decline in service quality.
- In the case of hybrid Access, a portion of the femtocell resources will be allocated to non-customers, while the remaining resources will be allocated to femto-customers.

Unfortunately, if this mode assigns some resources to FUEs and others to MUEs, it might not balance out the demands for femto-users' and macro-users' resources.

As a result, each method offers some advantages but also a variety of disadvantages. To enhance overall network performance, choosing the proper mode should be according to the network users' demands. Therefore, our contributions in this paper can be summarized as follows:

1. We will detect the proper access mode for each femtocell according to the network constraints.
2. Help the suffering MUEs get femtocell's access as well as provide high QoS for FUEs.
3. Minimize bandwidth utilization to reduce network costs.

2. RELATED WORKS

Resource allocation between users was managed by the Round Robin (RR) algorithm, which is based on first come, first served. It is an easy and simple way to allocate resources, but for network throughput, it is not efficient [7]. The maximum channel quality indicator (CQI) scheduling algorithm was used to manage the radio resources where the highest value of CQI is served [8]. This algorithm provides good throughput, but faraway users cannot allocate it. Also, the proportional fair (PF) Algorithm is used, where High CQI has priority and the allocation is continuing until all radio blocks are allocated [9]. However, all of the above models don't distinguish between users, whether they are customers or not.

Several publications focus solely on the hybrid femtocell access mode improvement [10, 11], where, the authors proposed a dynamic resource allocation management algorithm in a hybrid femtocell access using shared spectrum frequency [10]. This proposed algorithm allows non-subscribers to access the femtocell without compromising subscriber requirements. Also, the authors proposed a handover strategy between the hybrid femtocell and the macrocell. The handover strategy takes into consideration interference, velocity, received signal strength, and quality of service level [11]. A scheme to allocate resources for FUEs has been proposed without exposure to co-tier interference between femtocells [12]. In this scheme, a transmission power management system was introduced, allowing co-tier interference to be regulated. Thus, to increase the overall network capability, an individual femtocell's transmission power management should be autonomously changed to take interference into account. Also, a mode selection mechanism has been proposed that allows femtocells to automatically configure their modes to address interference issues and fulfill the minimum quality-of-service requirements for their registered users because the interference problem increased when deploying closed access mode compared to open access mode [13]. The proposed mechanism select between the different modes based only on the location of macro users from the femtocell to avoid interference [13]. Other authors focused on the closed access mode of the femtocell and proposed a spectrum pricing strategy to rent the spectrum resource to the suffering macro users so femtocell holders could make a profit [14].

The available bandwidth was taken into account as a dynamic element to select the best suitable network in a heterogeneous environment; in other words, a node would have to select the best network to send/receive traffic [15, 16]. A QoS admission control scheme was proposed to guarantee high QoS for FUEs and determine whether to accept or reject the MUEs that are transferred to the femtocell [17]. The cell load capacity has been estimated for resource assignment to create a load balance between the macrocell and the small cells [18]. The authors in [19] realized some environmental network constraints, and for each network constraint, there were two views of femtocell access mode selection, one from the network operator view and the other from the femto-owner view.

Therefore, in this paper, we will propose the FAM-D Scheme to detect the proper access mode for a femtocell based on operational network constraints such as resource availability and cell capacity. Therefore, it will allow the chance to choose the best access mode among open, closed, and hybrid access modes, taking into account the demands of both FUEs and MUEs and providing QoS for suffering MUEs that are placed within femtocell range without compromising FUEs's QoS. The suggested detection model will therefore be a strategy that based on user demands and operational network limitations. Also, a proper bandwidth will be selected based on the corresponding FAM-D to serve more MUEs. Thus, the overall network capacity will be improved without wasting bandwidth.

The proposed paper is organized as follows: Section 3 describes the FAM-D scheme and the BW-selection scheme. Section 4 provides the simulation parameters, discussion, and results. Finally, conclusion is summarized in Section 5.

3. PROPOSED SYSTEM MODEL

3.1 FAM-D Scheme

We consider a two-tier macro-femto network as shown in **Fig. 1**, where a macro base station (MBS) is located at the center and a number of femto base stations (FBSs) are deployed which are indexed by FBS_i = 1, 2, 3, ..,N. As shown in **Fig .2**, inside the femtocell range, a number of interfered MUEs are located in the FBS_i range, which can be indexed by m = 1, 2, 3, .., N_m^{FBSi} and number of FUEs are located in the FBS_i range, which are indexed by f = 1, 2, 3, .., N_f^{FBSi} . In order to provide quality of service (QoS) for interfered MUEs that are placed in femtocell coverge area without decreasing FUEs's QoS, each femtocell will have to choose whether an open, closed, or hybrid access mode is appropriate for it.

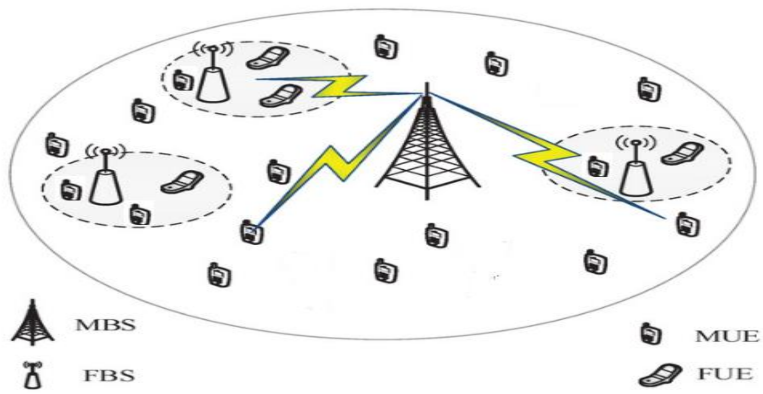

Fig. 1. Macro-Femto Network Architecture [14].

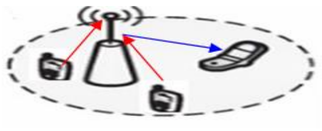

Fig. 2. MUEs Interference on Femtocell [14].

Therefore, in our proposal, the FAM-D scheme will be divided into two cascaded parts: FAM-D1 and FAM-D2 to find out the proper femtocell access mode. In FAM-D1, Equ. (1) will be implemented. This equation can decide if a macro user can access a femtocell or if they should be denied access [17] where, Equ. (1) combines the required BW demands of FUEs and MUEs located in the femtocell's range with respect to the available BW. Therefore, it is a fractional equation to compare the required BW of users with the available BW of femtocell [17, 18]. Then when Equ. (1) is true, it means that the required BW of users is smaller than the available BW of the femtocell, then it will guarantee the availability of radio resources for both FUEs and MUEs that are located in the femtocell's range. So, the optimal detected access mode will be open access mode. But when Equ. (1) is false, it means that the required BW of users is greater than the available BW of femtocell, and then the operational mode will be either hybrid access or closed access. Therefore, we will go through FAM-D2. In FAM-D2, we will take apart of Equ. (1) that relates to the required demands of FUEs with respect to the available bandwidth that is shown in Equ. (2). So, when Equ. (2) is true, it means that there is still an available radio resource for femtocell after FUEs required demands are fulfilled. Hence, the optimal detected access mode is hybrid access mode. However, if Equ. (2) is false, then the operational mode will be closed access mode. **Fig. 3** shows the proposed FAM-D block diagram.

$$\frac{\varpi_f \cdot N_f^{\mathrm{FBS_i}}}{BW_{FBS_i}} + \frac{\varpi_m \cdot N_m^{\mathrm{FBS_i}}}{BW_{FBS_i}} \le 1 \tag{1}$$

$$\frac{\varpi_f \cdot N_f^{\mathrm{FBS_i}}}{BW_{FBS_i}} \le 1 \tag{2}$$

$$\varpi_f = \frac{\Re_f}{\log_2\left(1 + SINR_f\right)} \tag{3}$$

$$\varpi_m = \frac{\Re_m}{\log_2\left(1 + SINR_m\right)} \tag{4}$$

Where ϖ_f, ϖ_m : are the demanded BW for a FUE and a MUE respectively. $N_f^{\mathrm{FBS_i}}$, $N_m^{\mathrm{FBS_i}}$ are number of FUEs and MUES inside the FBS_i. BW_{FBS_i} is the bandwidth available at FBS_i. $\Re_f$, $\Re_m$ are the data rate demanded for a FUE and a MUE respectively. $SINR_f$, $SINR_m$ are the received signal power at a FUE and a MUE respectively which are the ratio of the received power from serving cell (femtocell or macrocell) to the total interference power of the rest of the cells plus the thermal noise power (σ^2). Hint: We use the Shannon formula for channel capacity to express Equ. (3) and Equ. (4) as in [17, 20].

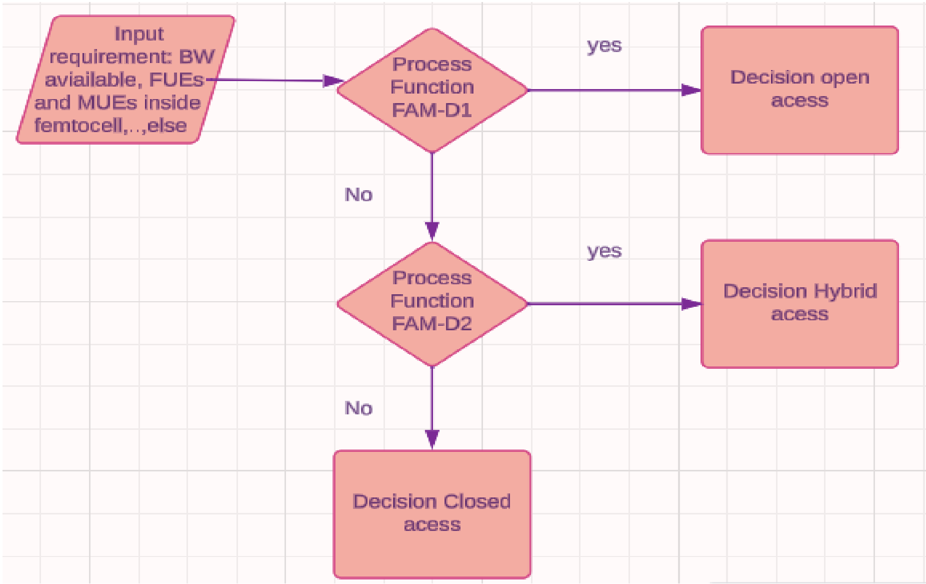

Fig. 3. Proposed FDM-D Block Diagram.

3.2 Bandwidth Selection Scheme

To help the operator to select the most proper BW for the femtocell that guarantees the availability of radio resources for both FUEs and MUEs located in the femtocell range. The selection of BW should be based on the result of detecting access mode to avoid the use of a higher BW, which will be a waste in BW utilization. Therefore, decreasing the utilization of BW will consume network costs [21]. **Fig. 4** represents the proposed BW selection based on the FAM-D block diagram, where, for open access detection, the operator should use the femtocell's current BW. However, for hybrid or closed access detection, the operator should increase the BW until the access mode shifts towards the open access mode. Thus, the operator will ensure the availability of resources for all users located in the femtocell with lower BW consumption.

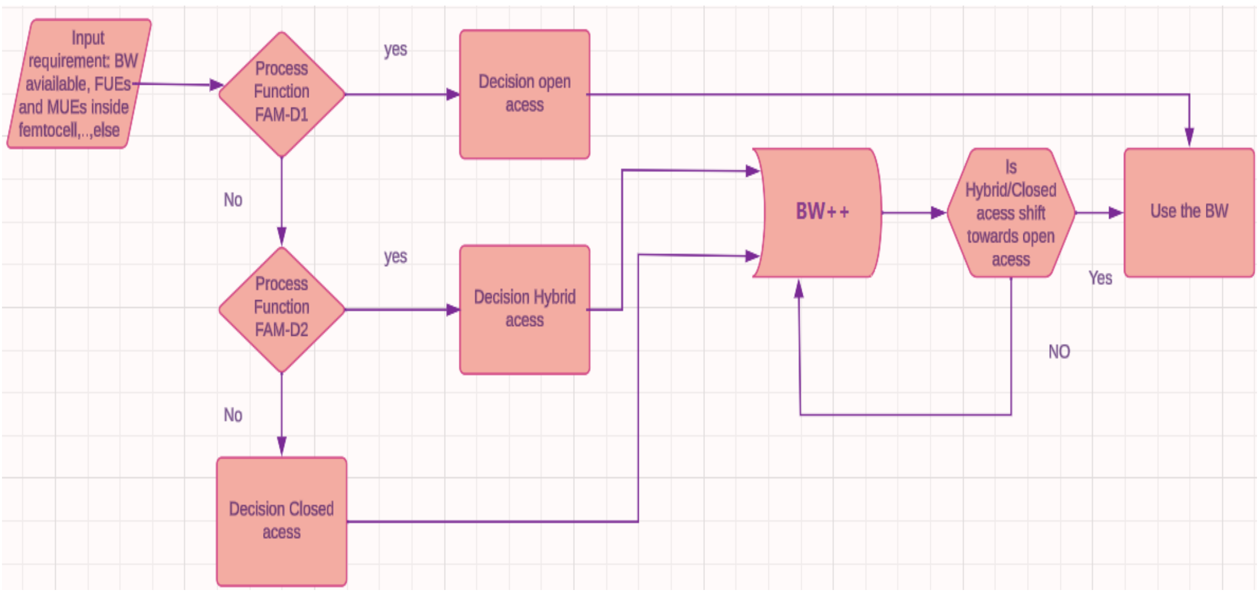

Fig. 4. Proposed BW Selection Based on FAM-D Block Diagram.

4. RESULTS & DISCUSSIONS

In this section, our proposed algorithm model is investigated based on simulations of different network densities using the MATLAB© 2021a software, where the FAM-D model is implemented to determine the appropriate access mode for the femtocell. After that, the BW selection algorithm is implemented to select the proper BW. The simulation parameters are illustrated in **Table 1** based on [17, 22]. Finally, we will compare the proposed model with the traditional closed access model, which is preferred by femto-owners [19].

Table 1: Simulation Parameters.

Transmitted power of femtocell	20 dBm
Transmitted power of macrocell	46 dBm
BW_{FBS_i}	20 MHz
$\Re_f$	512Kbps
$\Re_m$	128Kbps
σ^2	-104 dBm
$N_f^{FBS_i}$	Variable (4-16)
$N_m^{FBS_i}$	Variable (2-10)

Fig. 5 shows the outputs of FAM-D. As we first used the FAM-D1, the outputs that are under the threshold value (i.e., under 1) will be considered the proper femtocell access mode to be open access mode, while those over the threshold value will go to the FAM-D2 to find that above the threshold will be closed access mode. Therefore, from **Fig. 5**, we can notice that when FUEs increase to 12 FUEs, open access mode will change to closed access mode because the FAM-D (i.e., FAM-D1 and FAM-D2) output is above the threshold value.

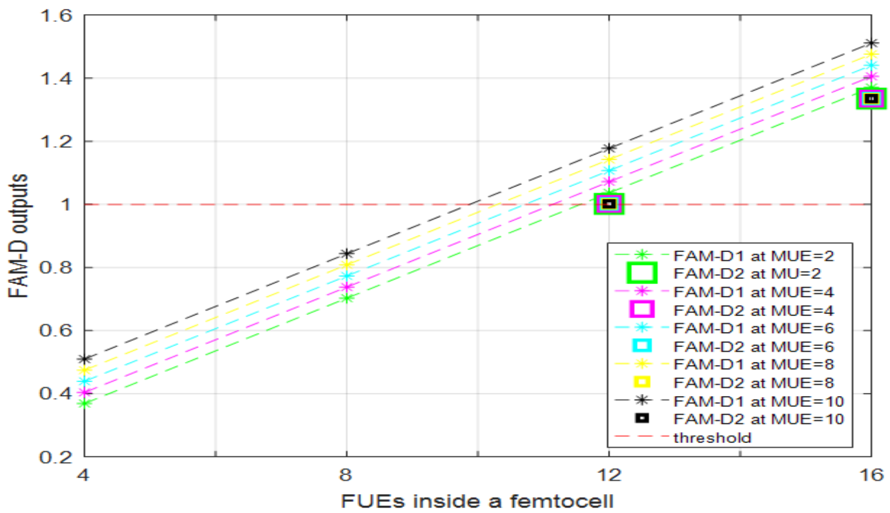

Fig. 5. FAM-D Outputs for Different Network Densities**.**

In order to investigate the BW selection, **Fig. 6** shows the FAM-D outputs using different BW selections when 16 FUE are located inside the femtocell. From **Fig. 6**, we can realize that 30 MHz is the proper BW selection for the existing 8 MUEs in the femtocell.

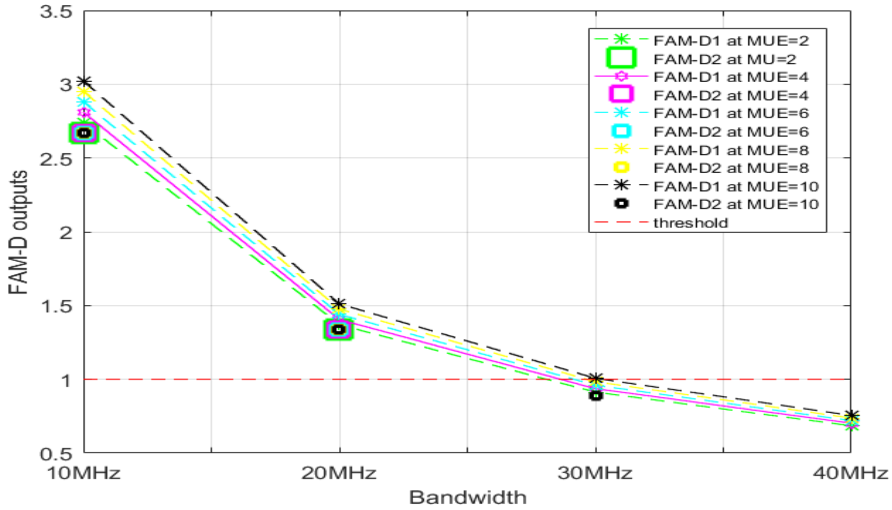

Fig. 6. FAM-D Outputs vs. Different Bandwidth Selections**.**

While at 10 MUEs, the FAM-D2 was below the threshold so, it determined as hybrid access mode thus, the proper BW selection will be 40 MHz to shift the access mode to open access mode to serve all of the 10 MUEs. In [19], there is a gap between the selective access mode needed by the network operators and the femto-owners. Because as user density increases, network operators prefer femtocell to be open access mode to serve the MUEs, while femto-owners prefer closed access mode to guarantee high QoS. So our proposal will avoid this gap, as it will serve MUEs and guarantee high QoS for FUEs. Therefore, in **Fig. 7**, we can compare the number of prohibited UEs in the presence of closed access mode, where owners of femtocells typically wanted to guarantee the demanded FUE resources [19], and in the presence of our proposed FAM-D mode detection using 30 MHz selective BW. So, from **Fig. 7**, we can infer that our proposed mode detection will minimize the prohibited UEs from 10 UEs to 1 UE while considering all demand's needs for FUEs and providing resources for suffering MUEs.

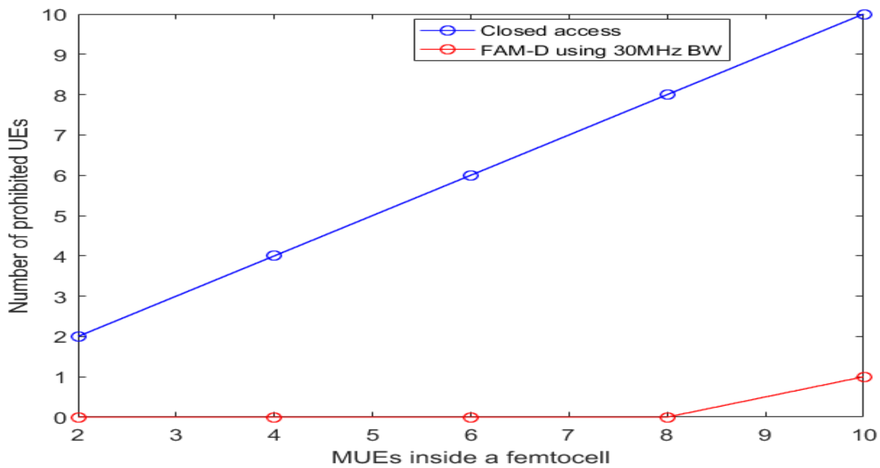

Fig. 7. Number of Prohibited UEs Using Closed Access Mode and Using the Proposed Model.

5. CONCLUSION

A femtocell access mode detection (FAM-D) scheme is proposed to determine the proper access mode for femtocells based on the network density. The MUE will be accepted or denied based on the determined access mode. Therefore, the output access mode of FAM-D will allow MUEs to access the femtocell without compressing the FUEs needs. In addition, we propose a BW selection scheme based on the FAM-D outputs to find out the proper BW that should be used to serve the suffering MUEs that are located in the femtocell range without causing a waste in BW utilization. Hence, the prohibited users of services will be minimized, which will minimize the interference that is generated from MUEs on FUEs and, furthermore, enhance the overall network performance.

CONFLICT OF INTEREST

The authors have no financial interest to declare in relation to the content of this article.

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