Interference Management with Handover Performance in Heterogeneous Mobile Network

Aya Allah A. Elserwe *, Adly S. Tag El Dein, and Reham S. Saad

Department of Electrical Engineering, Faculty of Engineering at Shoubra, Benha University, Cairo, Egypt;
Email: adlymerg@feng.bu.edu.eg (A.S.T.E.D.), reham.naseer@feng.bu.edu.eg (R.S.S.)
*Correspondence: eng.aya.ahmed2012@gmail.com (A.A.A.E.)

***Abstract*—The next generation of a cellular mobile network requires a higher bandwidth in order to achieve a greater data rate and capacity. The small cell is one of the best solutions to get a high data rate with low signal delay; however, it also suffers from various issues, such as interference. The interference occurs when the femtocells are overlaid on macrocell at the same spectrum, as well as when the user moves across a macrocell overlaid with femtocells. The ongoing call or data session is transferred from one base station to another while maintaining the services. This process is called Handover. In our paper, we explain the interference management techniques, including power control, fractional frequency reuse, and we explain the handover procedures. Finally, we propose an algorithm for interference management that combines the fractional frequency reuse technique with the fixed power control technique then we apply the handover technique in the heterogeneous mobile network to mitigate the interference and dropped calls. Simulation results show that the average throughput, and the spectral efficiency are improved, and the packet loss ratio and the number of handovers is reduced for different velocity by using Matlab program.**

***Keywords*—interference management, handover, heterogeneous network**

I. Introduction

Nowadays, the next generation of cellular mobile networks improves mobile services and industries by introducing new technologies such as small cells. Interference management is one of the remarkable areas in the 5G research field.

The next generation of cellular mobile network will enhance small cell technology as the number of users will exponentially increase, which makes small cells an attractive solution to achieve high data rate. There are several types of small cells, including pico, micro, and femtocells. However, it suffers from various problems, such as interference.

Interference occurs when the propagation of femtocells over macro cells is on the same spectrum.

There are many techniques for interference management, such as cognitive [1], Femto aware management, clustering of Femtocells [2], power control [3], and frequency allocation (FFR) [4].

There are several published related works that concern techniques for interference mitigation in femtocell/macrocell deployments. In [5], the power control algorithm is combined with beamforming to enhance and increase the beam power in the required direction. In [6], the FFR in the cellular network leads to improve the coverage and rate for the user. In [7], the power control algorithm and the radio resource management algorithm combination can improve capacity, and reduce interference in the heterogeneous mobile network. Also, in [8], the transportation process from one base station to another during the ongoing call or data session while the user moves across a macro cell overlaid with a femtocell is called Handover. In [8], vertical handover in the cellular network improves in major parameters such as unnecessary handovers and packet loss ratio.

In our paper, we propose an algorithm for interference management that combines between the fractional frequency reuse techniques, the fixed power control technique to reduce interference and then we apply the handover technique for all types of cells (femtocell or macrocell) in the cellular network to minimize dropped calls. In our proposed algorithm, the spectral efficiency and average throughput are enhanced, as are the number of handovers and the packet loss ratio.

The organization of the paper is as follows. In Section II, interference management techniques and handover technique have been discussed. In Section III, the system model has been discussed. Simulation results are demonstrated in Section IV. Finally, Section V concludes the paper.

II. Literature Review

There are many challenges in many types of research for fifth generation (5G) like small cells, Millimeter waves, Massive Multiple-input Multiple-output (MIMO), Beam forming, Full Duplex, and Interference management. Femtocell is a cellular network access point used to enhance indoor connectivity. Interference management is one of the striking regions in the 5G research field. The propagative of femtocell over full scale cell can cause interference between them as they utilize a similar range.

Manuscript received June 19, 2023; revised July 25, 2023; accepted August 29, 2023.

There are many algorithms for interference management such as: cognitive, clustering of Femtocells, power control [7], Femto-aware management [8], and Frequency allocation algorithm [9].

We will give an overview on interference management techniques such as power control algorithm and frequency allocation algorithm. Also, we will discuss the handover technique.

Interference Management Techniques:

A. Power Control Algorithm

The Power control approach can be linked with beamforming to preempt power collapse in space or alternately we could raise the power of beam in the required direction [7]. It can increase the femtocell range and number of macro-femtouser to increase signal to interference noise ratio (SINR), and throughput.

There are three different types of power configurations: the fixed power method, the constant radius method, and the target SINR method.

B. Frequency Allocation Algorithms

Different network scenarios will be selected based on Inter-Cell Interference Coordination (ICIC):

Co-channel operation (No-ICIC): This operation [8] purposes the worst case of interference between femtocell and macrocell where no partition for frequency is enforced.

Integer frequency reuse (IFR**):** In this scenario, macrocell is employed, and the sub-bands that are assigned to its neighbor can be consumed by femtocells at the cell edge [8].

Soft frequency reuse (SFR): In this scenario [9], the cell area is divided into two regions; an inner region where almost of the frequency band is available, and an outer region where only a small part of the frequency band is available.

Fractional Frequency Reuse (FFR): the frequency band dedicated to the cell centre users is commonly of reuse factor 1. Then, Femtocell can use sub-bands that are allocated to neighboring macro cell based on factor of 3 since only macro cell is employed [9].

C. Handover Technique

Handover [10, 11] occurs when a user moves from the cell coverage serving it towards another; a process where the user established session must not be interrupted due to this cell change. The handover algorithm depends on some parameter to make successful transportation between the source cell and the target cell such as the hysteresis margin (HOM). A hysteresis margin (HOM) is a constant value that represents the threshold for the difference in the reference signal received power (RSRP) between the serving and the target cell, it can reduce unnecessary handovers. The successful handover occurs when the reference signal received power (RSRP) of the target station must be greater than that of the serving station plus a certain hysteresis margin (HOM).

$$RSRP_T \geq RSRP_S + HOM \quad (1)$$

III. System Model

A. The System Model of the Proposed Alogrithm

In our proposed algorithm, we combine fixed power control and fractional frequency reuse to increase the SINR and throughput as well as decrease the packet loss ratio and the number of handovers.

Fig. 1 shows the system model of the proposed algorithm.

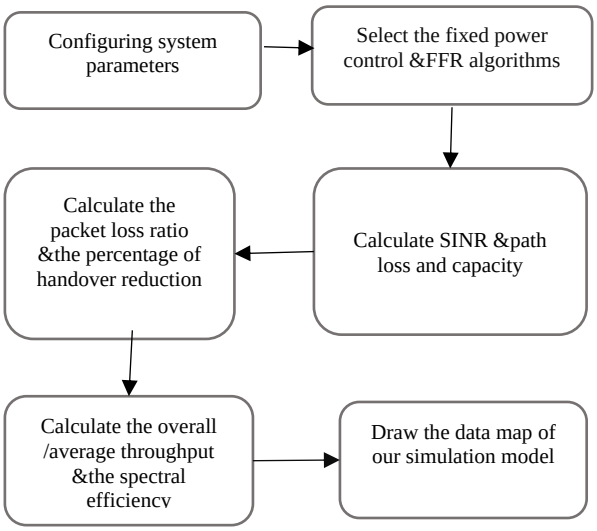

Figure 1. System model.

B. The Implementation Steps of Our Proposed Alogrithm

After configuring the system parameters (number of Macro users, Number of Femto users, Number of Femtocells, Number of Buildings, Bandwidth/Modulation type), the power control technique (Fixed technique) [12, 13] is selected. The main parameter of handover is selected [14, 15] then femto base station (FBS) transmission power is calculated, which determines whether the user can be attached to the femto or macro base station. Next, we apply the FFR technique [16, 17]. We then calculate throughput, path loss, and SINR for all users [18]. Next, we calculate the packet loss ratio [19, 20], the percentage of handover for all types of cells in our heterogenous network, the spectral efficiency [21, 22], then we calculate the overall throughput, the average throughput, and we can draw the throughput's data map for each user within the macrocell range. Finally, we analyse the results of the system.

According to Fig. 2, we draw the data map of our proposed simulation model.

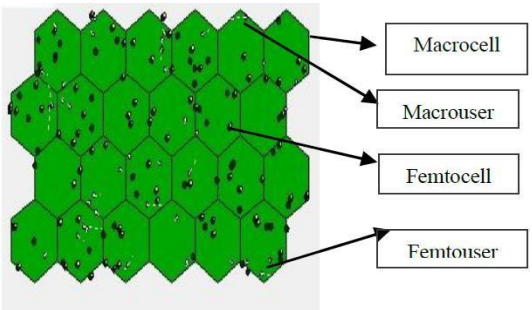

Figure 2. The data map of our proposed algorithm.

The SINR of a macro-user (x) at sub-carrier (k) (taking into account the impact of both the adjacent macro cells and overlaid femtocells) can be calculated as [22, 23]:

$$SINR_{x,k} = \frac{P_{M,k}G_{M,x,k}}{N_0 f_s + \sum_F P_{F,k}G_{F,x,k} + \sum_{M'} P_{M',k}G_{M',x,k}} \quad (2)$$

where,

$P_{M,k}$ is the power transmission of Macro serving station (M) at subcarrier (k).

$G_{M,x,k}$ is the gain between the Macro serving station (M) and user (x) at subcarrier (k).

$P_{M',k}$ is the power transmission of neighboring Macro station (M') at subcarrier (k).

$G_{M',x,k}$ is the gain between the neighboring Macro station (M') and user (x) at subcarrier (k).

N_0 is the power density of white noise.

f_s is the sub-carrier frequency.

$P_{F,k}$ is the power transmission of Femto serving station (F) and subcarrier (k).

GM, y, kGF, x, k$G_{F,x,k}$ is the gain of the Femto serving station (F) and user (x) at subcarrier (k).

The SINR of a Femto user (y) at sub-carrier k can be calculated as [15, 23]:

$$SINR_{y,k} = \frac{P_{F,k}G_{F,y,k}}{N_0 f_s + \sum_M P_{M,k}G_{M,y,k} + \sum_{F'} P_{F',k}G_{F',y,k}} \quad (3)$$

where

$P_{F,k}$ is the power transmission at subcarrier (k) of Femto serving station (F). $G_{F,y,k}$ is the gain at subcarrier (k) between user (y) and the Femto serving station (F).

$P_{F',k}$ is the power transmission of neighboring Femto station (F') at subcarrier (k).

$G_{F',y,k}$ is the gain at subcarrier (k) of neighboring Femto station (F') and user (y).

$G_{M,y,k}$ is the gain at subcarrier (k) of Macro serving station (M) and user (y).

The average SINR can be calculated as [12, 15],:

$$SINR_{avg} = \frac{\sum_{i=1}^{n} SINR_i}{n} \quad (4)$$

where

$SINR_i$ is the overall SINR for i^{th} user.

n is the number of users.

Path loss heavily [11] relies on the environment and the technology of the network. Regarding this paper, an urban environment is considered, thus the path loss for a macro-user at distance *R* from the transmitter and frequency of 2GHz is given by:

$$PL\ (dB) = 15.3 + 37.6 \log R + L_{OW} \quad (5)$$

where the term L_{ow} is added for an indoor macro user to denote the penetration loss of the external wall. Similarly, the suggested model according to [15, 25] for the case of an indoor and outdoor Femto-user is estimated, taking into account the penetration loss due to exterior and interior walls. Values For internal and external walls, respectively, penetration loss values of 7 and 15 dB are a good estimate.

The capacity for a macro-user (x) at subcarrier (k) can be calculated as [10, 23]:

$$C_{x,k} = \Delta f \log_2(1 + \propto SINR_{x,k}) \quad (6)$$

The capacity for a femto-user (y) at subcarrier (k) can be calculated as [10, 23]:

$$C_{y,k} = \Delta f \log_2(1 + \propto SINR_{y,k}) \quad (7)$$

Where, α is a constant for a target bit error rate (BER) can be calculated as:

$$\propto = -1.5/\ln(5\ BER) \quad (8)$$

The formula for calculating the total throughput of a macro cell (M) for a macro-user (x) at a subcarrier (k) is [15]:

$$T_x = \sum_y \sum_k \beta_{x,k} C_{x,k} \quad (9)$$

Where, $\beta_{x,k}$ is the sub-carrier assignment for macro-user (x) at sub-carrier (k).

where,

T_i is the overall throughput for i^{th} user.

n is the total no of users.

The Packet Loss Ratio can be calculated as [26]:

$$PLR = \frac{\text{the number of packet not received}}{\text{the total number of packets sent}} \quad (10)$$

The percentage reduction of Packet Loss Ratio can be calculated as [26, 27]:

$$PLR_{reduction} = (\sum_i^n PLR_T - \sum_i^n PLR_P) / \sum_i^n PLR_T \quad (11)$$

where

PLR_T is the packet loss ratio of the traditional algorithm "without interference management technique" from i=10 to n=100 users.

PLR_P is the packet loss ratio of the proposed algorithm "with interference management technique" from i=10 to n=100 users.

The spectral efficiency can be calculated as [13], [18]:

$$\text{spectral efficiency} = \frac{\text{data rate in bit/s}}{\text{channel bandwith in hz}} \quad (12)$$

The percentage reduction of the handover can be calculated as [28]:

$$HO_{reduction} = (\sum_{i}^{n} H_T - \sum_{i}^{n} H_P)/\sum_{i}^{n} H_T \quad (13)$$

Where,

H_T is the handover of the traditional algorithm "without interference management technique" from i=10 to n=100 users.

H_P is the handover of the proposed algorithm "with interference management technique" from i=10 to n=100 users.

IV. Simulation Parameters and Results

Our simulation results show that the average throughput, and the spectral efficiency are improved, and the packet loss ratio and the number of handovers is reduced for different velocity

A. Simulation Parameters

We simulate our technique by use the simulation parameters which shown in Table I.

TABLE I. Simulation Parameters

Simulation Parameters	Value / Range
Macrocell Transmission Power	46 dBm
Femtocell Transmission Power	15 dBm
Macro cell Radius	250 m
Femto cell Radius	8 m
Bandwidth	20 MHz
Subcarrier spacing	15 KHz
Resource Block	180 KHz
Modulation	64 QAM
Fading channel type	Rayleigh fading
No. of Femto cells	120
No. of Macro cells	15
No. of Macro Users	40
No. of Femto Users	100
No.of neighboring Macro cells	14
No of subcarriers	30 subcarriers
The thermal power density of white noise	–174 dBm/hz
Hysteresis margin	6 dB
User velocity	30 km/h
Simulation Time	5000 ms

B. Simulation Results

According to Fig. 3, the number of handovers with interference management (our proposed algorithm) at velocity 30 km/h, 120 km/h gives better performance than the number of handovers without interference management (traditional algorithm) for the heterogeneous network. After calculation, we found the percentage reduction of handover is 34% at velocity 30 km/h, we found the percentage reduction of handover is 59% at velocity 120 km/h.

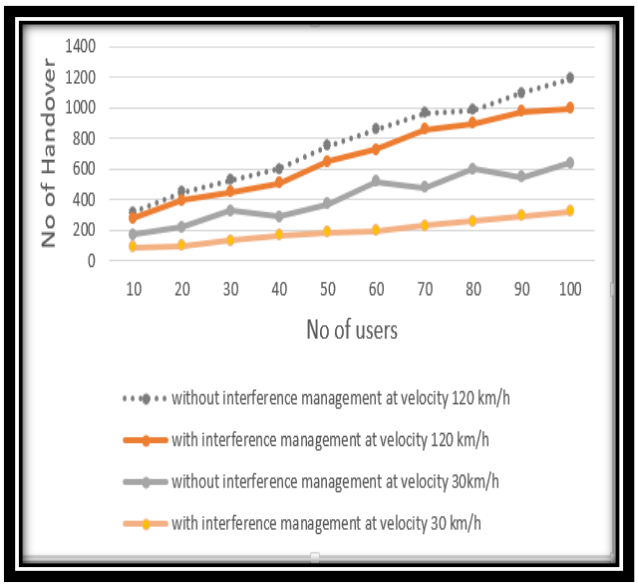

Figure 3. The relation between the number of Handovers and the number of users.

According to Fig. 4, the percentage reduction of packet loss ratio with interference management (our proposed algorithm) at velocity 30 km/h and 120 km/h gives better performance than the packet loss without interference management (traditional algorithm) for the heterogeneous network. After calculation, we found the percentage reduction of packet loss ratio is 64 % at velocity 30 km/h and the percentage reduction of packet loss ratio is 25% at velocity 120 km/h.

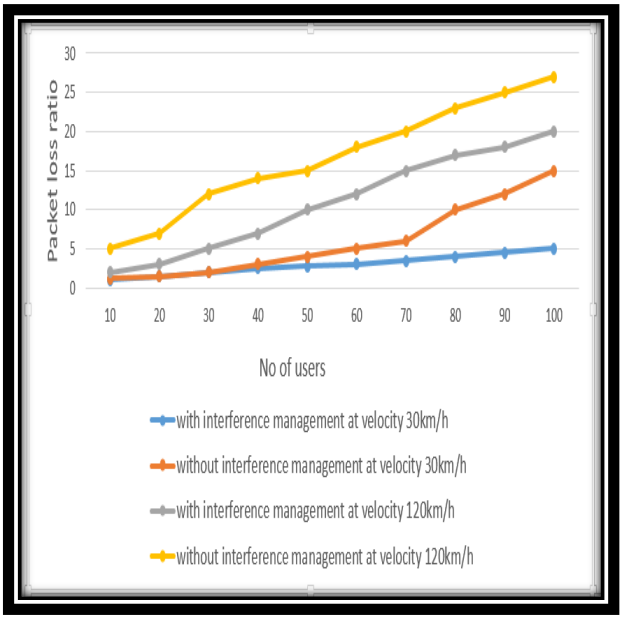

Figure 4. The relation between the Packet loss Ratio and the number of users.

According to Fig. 5, the average throughput with interference management (our proposed algorithm) at

velocity 30 km/h gives better performance than the average throughput without interference management (traditional algorithm) for the heterogeneous network.

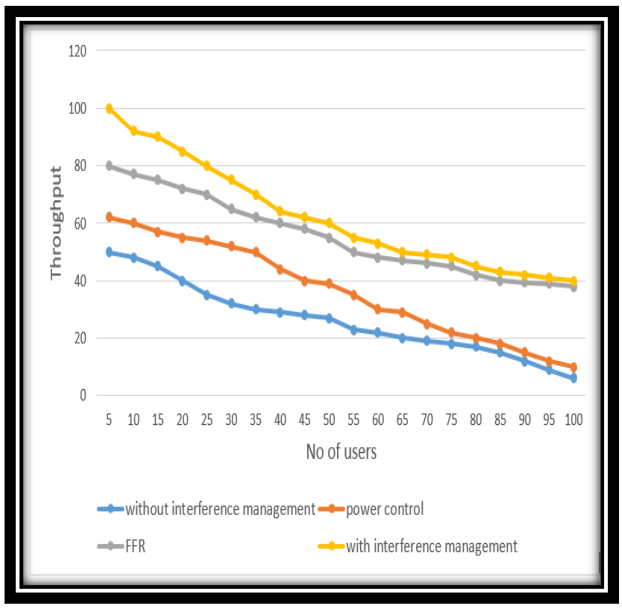

Figure 5. The relation between average throughput and the number of users.

According to Fig. 6, the total cell throughput with interference management (our proposed algorithm) at velocity 30 km/h gives better performance than any other type of algorithms such as power control or fractional frequency reuse algorithm and the total cell throughput without interference management (traditional algorithm) for the heterogeneous network.

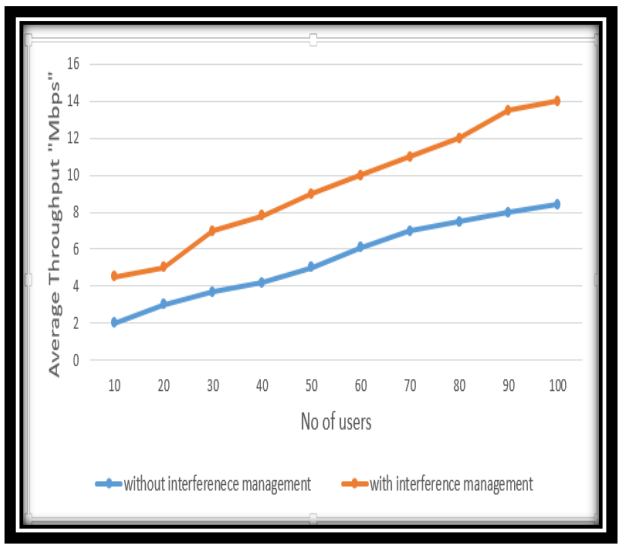

Figure 6. The relation between the total cell throughput and the number of users.

According to Fig. 7, The spectral efficiency with interference management (our proposed algorithm) at velocity 30 km/h gives better performance than the spectral efficiency without interference management (traditional algorithm) for the heterogeneous network.

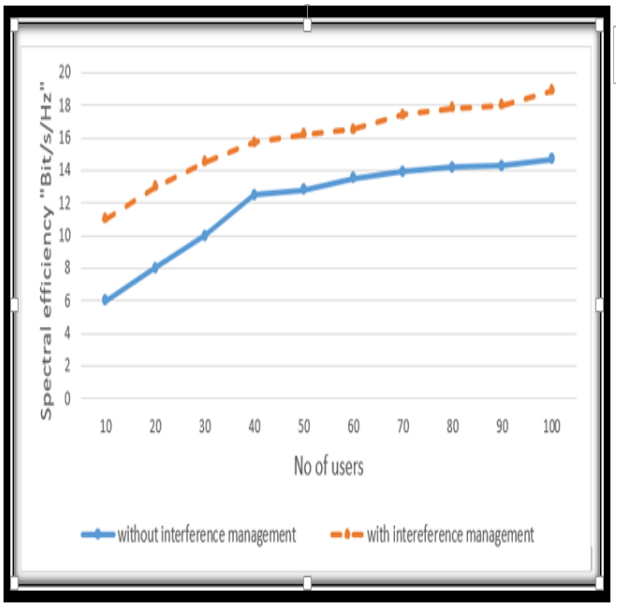

Figure 7. The relation between spectral efficiency with the number of users.

V. Conclusion

We optimize an algorithm that combines handover with the fixed power control technique, FFR algorithm. Our Proposed algorithm improves the SINR & throughput and reduces the interference from neighbor cells. It enhances the spectral efficiency, also it can reduce the packet loss ratio and number of handovers.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Aya Allah A. Elserwe designed the interference management technics, simulation results and wrote the paper; All authors had approved and analyzed the final results and the final version.

References

[1] H. Fourati, R. Maaloul, and L. Chaari, "A survey of 5G network systems: Challenges and machine learning approaches," *International Journal of Machine Learning and Cybernetics*, vol. 12, pp. 385–431, 2015.

[2] M. Ree *et al.*, "Key management for beyond 5G mobile small cells: A survey," *IEEE Access*, vol. 7, pp. 59200–59236, May 2019.

[3] K. S. Mohamed, M. Y. Alias, and M. Roslee, "Review on femto-cell networks interference management techniques," *International Journal of Engineering and Technology*, vol.10, pp. 1248–1262, 2018.

[4] Y. Ni *et al.*, "Research on key technology in 5G mobile communication network," in *Proc. International Conference on Intelligent Transportation, Big Data and Smart City (ICITBS)*, Changsha, China, pp. 199–201, 2019.

[5] M. Osama, S. E. Ramly, and B. Abdelhamid, "Interference mitigation and power minimization in 5G heterogeneous networks," *Electronics*, vol.10, pp. 1–21, 2021.

[6] K. Revathy, K. Thenmozhi, and P. Praveenkumar, "Hybrid spectrum management using integrated fuzzy and femtocells in cognitive domain," *Journal of Intelligent and Fuzzy Systems*, pp. 1–10, 2021.

[7] Q. Zhang *et al*., "Dynamic load adjustments for small cells in heterogeneous ultradense networks," in *Proc. IEEE Wireless Communications and Networking Conference (WCNC)*, pp. 1–6, 2020.
[8] Y. A. Abohamra and M. R. Soleymani, "Using beamforming for dense frequency reuse in 5G," *IEEE Access*, vol. 7, pp. 9181–9188, 2019.
[9] W. Li and J. Zhang, "Cluster-based resource allocation scheme with QoS guarantee in ultra-dense networks," *IET Communications*., vol. 12, pp. 861–867, Apr 2018.
[10] N. K. Madi, Z. B. M. Hanapi, M. Othman, and S. Subramaniam, "Link adaptive power control and allocation for energy–efficient downlink transmissions in LTE systems," *IEEE Access*, vol. 6, pp.18469–18483, 2018.
[11] S. A. Khan, A. Kavak, S. A Çolak and K. Küçük, "A novel fractional frequency reuse scheme for interference management in LTE-A HetNets," *IEEE Access*, vol. 7, pp. 109662–109672, August 2019.
[12] G. Kumar and G. Saini, "Implementation of fractional frequency reuse schemes in lte-a network," in *Proc. 2nd International Conference on Communication Computing and Networking*, vol.4 6, pp. 313–321, 2019
[13] E. S. Attia, S. A. El-Dolil, and M. Abd-Elnaby, "Performance enhancement-based resource allocation scheme using soft frequency reuse for LTE femtocell networks," in *Proc. 34th National Radio Science Conference (NRSC)*, pp. 246–255, 2017.
[14] X. Huang *et al.*, "Fairness-based distributed resource allocation in two-tier heterogeneous networks," *IEEE Access*, vol.7, pp. 40000–40012, 2019.
[15] M. Ghanbarisabagh *et al.*, "Capacity improvement in 5G networks using femtocell," *Wireless Personal Communicatio*ns, vol.105, pp. 1027–1038, 2019.
[16] S. Alotaibi and H. Sinky, "Power and radio resource management in femtocell networks for interference mitigation," *Sensors*, vol. 21, no.14, pp.1–19, July 2021.
[17] Z. E. Khaled and W. Ajib, "An accurate empirical path loss model for heterogeneous fixed wireless networks below 5.8 GHz frequencies," *IEEE Access*, vol.8, no. 6, pp. 182755–182775, 2020.
[18] B. Shen *et al*., "An interference contribution rate based small cells on/off switching algorithm for 5G dense heterogeneous networks," *IEEE Access*, vol. 4, no. 6, pp. 29757–29769, 2018.
[19] L. Lei, Y. Yuan, T. X. Vu, S. Chatzinotas, and B. Ottersten, ''Learning based resource allocation: Efficient content delivery enabled by convolutional neural network,'' in *Proc. IEEE 20th International. Workshop Signal Process. Adv. Wireless Communication*, pp. 1–5, 2019.
[20] Y. Teng, M. Liu, F. R. Yu, V. C. M. Leung, M. Song, and Y. Zhang, "Resource allocation for ultra-dense networks: A survey, some research issues and challenges," *IEEE Communication. Surveys and Tutorials*, vol. 21, no. 3, pp. 2134–2168, 2019.
[21] L. Huo *et al*., "Soft frequency reuse-based optimization algorithm for energy efficiency of multi-cell networks," Computers and Electrical Engineering Journal, vol. 66, 2018.
[22] R. Akl and U. Sawant, "A novel metric to study the performance of sectorized fractional frequency reuse techniques in LTE," *IEEE Wireless Telecommunications Symposium (WTS*), pp. 1–7, 2017.
[23] M. Hina and S. Sohaib, "Centralized dynamic frequency allocation for cell-edge demand satisfaction in fractional frequency reuse networks," *Telecommunication Systems*, vol. 65, pp. 795–808, 2017.
[24] M. S. Hossain *et al*., "Multi-layer soft frequency reuse scheme for 5G heterogeneous cellular networks," in *Proc. IEEE Globecom Workshops (GC Wkshps)*, pp. 1–6, 2017.
[25] S. N. Hasim and M. M. Susanto, "Performance evaluation of cell-edge femtocell densely deployed in OFDMA-based macrocellular network," in *Proc. 3rd International Seminar Research of Information Technology and Intelligent Systems (ISRITI)*, pp. 262–266, 2020.
[26] S. Sonmez, I. Shayea, S. A. Khan, and A. Alhammadi, ''Handover management for next-generation wireless networks: A brief overview,'' in *Proc. IEEE Microwave Theory Technology in Wireless Communication (MTTW*), vol. 1, pp. 35–40, 2020.
[27] Y. Liu, F. R. Yu, X. Li, H. Ji, H. Zhang, and V. C. M. Leung, "Self-optimizing interference management for nonorthogonal multiple access in ultra-dense networks," *IEEE Wireless Communications and Networking Conference (WCNC)*, pp. 15–18, 2018.
[28] A. B. Shams, S. R. Abied, and M. A. Hoque, "Impact of user mobility on the performance of downlink resource scheduling in heterogeneous LTE cellular networks," in *Proc. 3rd International Conference on Electrical Engineering and Information Communication Technology (ICEEICT)*, vol. 66, pp. 316–331, 2018.

Copyright © 2023 by the authors. This is an open access article distributed under the Creative Commons Attribution License (CC BY-NC-ND 4.0), which permits use, distribution and reproduction in any medium, provided that the article is properly cited, the use is non-commercial and no modifications or adaptations are made.