Spectrum Management, Power Optimization and Interference Cancellation in Ultra-Dense Heterogeneous Femtocell Networks

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Abstract*—With the imminent arrival of the next generation of mobile networks, extensive efforts have already been made to define and incorporate their key features. Among these advancements, ultra-dense heterogeneous networks have emerged as a primary catalyst in meeting the demand for enhanced device connectivity and higher data rates. To achieve these objectives, a multitude of Base Stations with diverse specifications will be deployed. Notably, Femtocells are expected to dominate this landscape due to their affordability, ease of deployment, and simplified maintenance. However, the utilization of multiple base stations operating within the same spectrum to improve spectral efficiency with femtocells poses a significant challenge in the form of severe interference. This issue can be effectively addressed through the implementation of spectrum sharing strategies and power control techniques. By employing these methods, the adverse effects of interference can be mitigated, leading to more robust and reliable network performance. Consequently, interference management becomes a critical concern for the successful operation of these networks. Therefore, a novel approach for femtocell management for heterogeneous networks is introduced where interference cancellation, power optimization and spectrum management to improve the overall performance. The performance of proposed approach is compared with existing priority delay scheduling and optimization schemes. The experimental results show that the proposed approach reported better performance in terms of delay, throughput, packet loss rate and energy consumption, etc.

***Keywords*—mobile communication, femtocell, spectrum management, energy optimization, interference cancellation**

I. Introduction

Since the last decade, there have a tremendous growth in demand of mobile communication. The widespread adoption of smartphones and the exponential increase in data usage have created a significant demand for higher data rates. Due to this increased demand, the traditional methods to improve the system capacity will fail to meet the substantial demand for higher data rates [1]. Recent research and studies indicate that the number of users is expected to increase by tenfold, accompanied by a hundredfold increase in the demand for traffic per user per day [2, 3]. Recently, the Fourth Generation (4G) cellular networks are being deployed worldwide. However, these industries have been facing several challenges in meeting telecom operators and user's expectations. To overcome these challenges, the telecom operators need to improve the network capacity to support the band width intensive traffic i.e. video or multimedia applications. Therefore, the current advanced transmission technologies such as Multiple-Input Multiple-Output (MIMO) systems have been considered as promising technique to address these challenges. Similarly, to accommodate the diverse heterogeneous devices, the network must have scalability and flexibility. Moreover, the network should be capable to incorporate efficient computing resources to handle the value-added services for numerous applications. therefore, research community has introduced the concept of Fifth Generation (5G) cellular networks. The 5G networks aim to deliver exceptionally high data rates, substantial enhancements in users' perceived Quality of Services (QoS), a significant increase in base station capacity, and ultra-low latency compared to existing 4G Long-Term Evolution (LTE) networks [1]. However, the rapid growth of mobile subscribers and their increasing service requirements has resulted in overwhelming demands on traditional Macro Base Stations (MBSs) [2].

However, achieving optimized energy and spectrum usage are the challenging issues in 5G wireless communication [4]. Recently, Heterogeneous Networks (HetNet) are considered as a promising technique to ensure the high-speed spectrum access and reduction of power consumption. HetNet, or Heterogeneous Network, employs diverse types of base stations based on their transmitted power levels. To enhance signal quality in indoor environments, low-power small cell base stations like femtocells [3] are utilized. MIMO base stations and femtocells are allocated different frequency bands to mitigate interference. The research focus in 5G HetNet lies in frequency reuse, an emerging area of study. 5G HetNet

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consists of multiple tiers. Tier-1 comprises high-capacity MIMO base stations that are connected to the core network via wired connections. Tier-2 encompasses femtocells [5], which generate low-power signals and are placed within the coverage area of MIMO base stations. A key aspect of small cell HetNet is the dynamic switching strategy [4], aimed at reducing energy consumption. The decision to switch off or on small cell base stations is influenced by various factors such as distance and user load. The combination of the heterogeneity concept with small cell base stations and the incorporation of multiple antennas represent an evolutionary stage towards achieving lesser densification in 5G HetNet.

In these HetNets, numerus femtocells can be deployed in the traditional macrocell networks which is identified as a promising solution to offload the overburdened base stations and facilitate the increased network throughput with increased spectral efficiency. The deployment of femtocells in HetNets poses both advantages and challenges. On one hand, a higher network density can greatly enhance network capacity. However, when femtocells are densely deployed in co-channel mode, they can create significant interference, resulting in noticeable performance degradation for the macrocell network. This interference issue represents a key challenge that needs to be addressed for the successful deployment of femtocells in HetNets [6].The concept of Small Cells (SCs) holds great promise as a technology that aims to deliver energy-efficient 5G services to users [7–10]. SCs encompass femtocells, pico-cells, and relay nodes. By densely deploying these SCs in 5G HetNets (Heterogeneous Networks), notable improvements in coverage can be achieved, particularly in indoor and urban areas. Furthermore, SCs have the potential to significantly enhance network throughput. They are well-equipped to handle high data rate applications such as online games and video-supported applications. as discussed before, despite of several advancements the 5G HetNets still face several challenges such as efficient resource allocation, power consumption, and interference. Several methods have been developed to overcome these issues, e.g., Liu *et al.* [7] and Lin *et al.* [8] suggested toswitch SCs to sleep mode. Similarly, several works have been introduced to mitigate the interference related issues, e.g., Shen *et al.* [9] suggested cells on/off switching algorithm for 5G dense heterogeneous networks. Ebrahim *et al.* [10] introduced sleep mode selection approach for interference management and resource allocation. Therefore, 5G heterogeneous networks are considered as a promising technique to improve the communication performance of future cellular network. this work mainly focusses on several aspects of 5G HetNet and introduce a novel approach to improve the performance. This research mainly focusses on three main objectives of transmission optimization, resource allocation and spectrum management.

As discussed before, the ultra-dense networks with femtocell networks have gained huge attention in wireless communication systems however; these systems face several challenges such as spectrum scarcity, interference management and power optimization. In these networks, the femtocells are densely deployed along with the macro-cells and other cells which leads to increase the interference and inappropriate utilization of resources which can lead to downgrade the overall performance of the network. To overcome these issue, development of efficient spectrum management methods can be helpful to satisfy the user demands, and mitigate the interference. Similarly, efficient power control methods can improve the network performance by optimizing the power. This work has introduced a novel combined solution to overcome several issues in advanced communication networks such as efficient resource allocation, spectrum management and optimization of resources. the proposed approach focus on Signal to Interference & Noise Ratio (SINR) and Path loss estimation for the considered scenarios and uses these parameters to obtain the capacity of macro users. this capacity is used to obtian the overall throughput of the macrocell. In femtocell scenario, the subscribed users are assigned the resources of femtocells. however, the interference and resource allocation remains challenging issue in these cases therefore this work has introduced a power control mechanism which also handles the interference and QoS of the femtocells. furthermore, a hybrid access mechanism is also presented to reduce the power transmission of femto cells. Similarly, in resource allocation scenarios, the users are categorized into different classes to allocate the spectrum based on their allocation priorities. Thus, proposed model is able to handle the complete spectrum, resource and power management tasks and ensures better QoS.This research mainly focusses on three main objectives of transmission optimization, resource allocation and spectrum management.

Rest of the manuscript is organized in following sections: Section II presents a brief literature review about existing techniques of HetNets, and femtocell communication for 5G communication scenario, Section III presents the proposed solution to overcome the challenges, Section IV presents the comparative analysis and Section V presents the concluding remarks about this research.

II. Literature Review

This section presents a brief overview about existing schemes of 5G HetNet communication for resource allocation, interference management and transmission optimization.

Ghosh *et al.* [11] reported the issue of spectrum management and energy optimization for MIMO and femtocell based 5G mobile networks and introduced a game theoretic approach to overcome these issues. The MIMO systems help to transmit the signal with same time frequency to maximize the number of uses so that the user can communicate with less number of channels. Similarly, the cognitive radio networks help to increase the spectrum efficiency by sharing the primary user channels to transmit the data. Based on these concepts, this work considers a cognitive femtocell base station as secondary base station to occupy the channel by using auction game with utility function. Moreover, it uses opportunistic spectrum access by employing cognitive approach which helps to reduce the number of active antennas resulting in reduction in overall energy consumption.

Pourkabirian *et al.* [12] reported that employing spectrum sharing scheme in femtocells introduces interference in the network which degrades the network performance. Therefore, authors introduced an interference control mechanism for 5G femtocell networks. The first phase presents a problem statement based on non-cooperative game mechanism to analyze the competition among users for accessing the shared spectrum. Later, a pricing mechanism is included in utility function to ensure the QoS for macro users. This helps users to experience the lower interference and achieves the minimum required data rate. Thus, the QoS of macro and femto users is satisfied by using non-cooperative mechanism. Moreover, a minimax decision rule is also employed to achieve the optimal performance for worst-case performance.

Abiri *et al.* [13] 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 where MU denotes the maximum number of users availing the video services, MQ denotes the maximizing the mean QoE and MP represents the minimizing the power consumption, respectively. The first optimal solution is obtained by employing genetic algorithm-based optimization. Later, greedy algorithm is incorporated to present a maximum resource-efficient solution with lower computational complexity.

Ahmad *et al.* [14] reported the issue of excessive co-channel interference which degrades the network performance. To overcome this issue, authors introduced game theoretical based approach for optimal uplink power allocation for small cells. According to this mechanism, the femtocell users operate as non-cooperative game theoretical model to maximize the sum rate.

Recently machine learning based methods also have gained huge attention in this domain of wireless communication. In this context of 5G communication, Tejasvi *et al.* [15] introduced deep learning-based approach for energy and spectral efficient resource allocation for 5G HetNets. In this work, authors have reported that the deployment of femtocells increases the network coverage and capacity for 5G communication systems. However, increased data traffic leads to excessive energy consumption. Therefore, authors developed a novel approach where energy efficiency and spectral efficiency constraints are considered to formulate the multi-objective optimization problem. The issue of resource allocation was addressed by introducing the hybrid Deep Bidirectional Battle Royale Long Short-Term Memory (Deep Bi-BRLSTM) model. Further, a Fuzzy based energy efficient adaptive atom search optimizer is also included to optimize the trade-off between EE and SE.

Sharma *et al.* [16] developed secrecy aware energy efficient approach for HetNets, which consists sub-6 GHz macrocell and mmWave pico-cells. The proposed approach focuses on maximizing the energy efficiency by using optimization problem of power control, channel allocation and beamforming by considering secrecy rate and signal–to-interference ratio. However, the formulated optimization problem is non-convex in nature therefore transformed into Reinforcement Learning (RL) problem using Markov Decision Process. The RL model is based on the reward mechanism therefore authors proposed a multi-agent reinforcement learning approach to achieve the maximum rewards. Moreover, it uses a multi-agent cooperative deep reinforcement learning approach to solve the MDP problem and double Q architecture to optimize the power control, channel allocation and beamforming.

Nie *et al.* [17] addressed the heterogeneous resource allocation as NP hard problem in 5G Networks therefore traditional optimization algorithms fail to solve the resource allocation problem therefore authors introduced distributed multi-agent deep reinforcement learning approach for resource allocation to maximize the spectral efficiency and energy efficiency. The distributed learning process is employed in a stochastic geometry based realistic HetNet scenario.

Eslami *et al.* [18] 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.* [19] 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 issue. 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.*[20] 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. Mohite *et al.* [21]reported that the dense deployment of femtocells leads to excessive interference and also impacts on resource allocation performance. To overcome these issues, authors introduced a hybrid optimization scheme based solution by combining Hybrid Whale and Rain Optimization (HW-RO) approach which helps to obtain the optimal solution for given resource allocation problem.

III. Proposed Model

This section presents the proposed model to overcome the aforementioned issues of heterogeneous networks. Fig. 1 shows the overall architecture of the proposed model. The complete work is divided into three phases: the first phase present solution to optimize the transmission capacity for ultra-dense HetNets, next phase focuses on combined resource allocation and spectrum management.

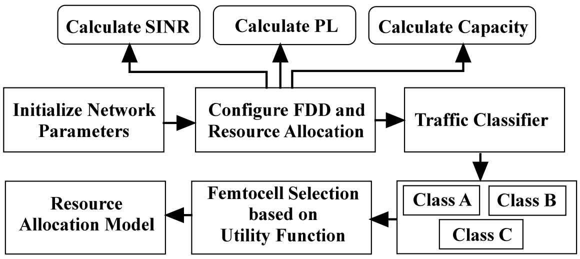

Fig. 1. Overall architecture of proposed model.

In ordertoestimate the overall SINR of the system, the proposed model considers the interference caused due to the rest of the cells that are present within their range. For a macro user scenario on subcarrier, the proposed model considers impact of macro and femtocell. Eq. (1) demonstrates SINR computation for any given signal can be expressed as:

$$SINR_{m,k} = \frac{P_{M,k} G_{m,M,k}}{N_0 \Delta f + \sum_{M',k} G_{m,M',k} + \sum_F P_{F,k} G_{m,F,k}} \tag{1}$$

Where represents the transmit power of macro-cell BS denoted byon subcarrier, represents the neighbouring macrocells and denotes the nearby femtocells, denotes the channel gain betweenuserand cell, is the white noise and denotes the subcarrier spacing. Eq. (2) demonstrates the received SINR for any user on subcarrier which is given as

$$SINR_{f,k} = \frac{P_{F,k} G_{f,F,k}}{N_0 \Delta f + \sum_{M',k} P_{M,k} G_{f,M,k} + \sum_{F'} P_{F',k} G_{m,F',k}} \tag{2}$$

However, estimating the channel gain requires path loss computation which is characterized in Eq. (3) and expressed as:

$$G = 10^{-PL/10} \tag{3}$$

The path loss depends on the network conditions which can be seen from Eq. (4). For example, for an urban environment, the path loss can be expressed as:

$$PL\,(db) = 15.3 + 37.6 \log_{10} R + L_{ow} \tag{4}$$

Whererepresents the penetration loss for indoor users. Similarly, the femtocell user in indoor scenario can be estimated by taking the path loss in consideration which is characterised in Eq. (5):

$$PL(db) = 38.46 + 20 \log_{10} R + L_{ow} \tag{5}$$

Based on these parameters, the practical capacity of macro user m on any given subcarrier k can be obtained which is presented in Eq. (6) as follows:

$$C_{m,k} = \Delta f \cdot \log_2\left(1 + \alpha \cdot SINR_{m,k}\right) \tag{6}$$

Furthermore, the overall throughput of macrocell$M$ can be expressed as in Eq. (7):

$$T_M = \sum_m \sum_k \beta_{m,k} C_{m,k} \tag{7}$$

where $\beta_{m,k}$ represents the subcarrier assignment for macrocell users

In hybrid access, when a user who is not subscribed to the network connects to a femtocell, a portion of the femtocell's resources will be assigned to that user. The allocation of spectrum to the external user depends on various parameters. The proposed approach revolves around the key concept that the deployment of a femtocell should have minimal impact on the overall network. Therefore, the femtocell will allocate resources to the non-subscribed user in order to compensate for any potential performance degradation caused by its presence. This mechanism takes into consideration the user's throughput prior to the femtocell deployment and aims to replicate it as closely as possible.

However, this allocation of resources to non-subscribed users will inevitably reduce the capacity available for subscribed users. In order to address this issue, a power control mechanism is introduced in this work that takes into account the presence of other femtocells in the vicinity. It is highly likely that inadequate services in a particular area will attract multiple individuals to adopt the femtocell solution, resulting in the emergence of multiple femtocells in close proximity to each other. In such scenarios, a non-subscribed user located near a cluster of femtocells will experience significant interference caused by the neighbouring femtocells. Nevertheless, when connected via hybrid access, the interference will primarily affect the users of the hybrid femtocell itself. To mitigate this, the power control mechanism aims to distribute the burden of providing services to closed access users among all the femtocells within the cluster. By adjusting the power levels of these femtocells, the interference and its impact on the hybrid femtocell users can be minimized while ensuring that the non-subscribed users receive satisfactory service quality. The traditional methods face two main challenges first; only one femto base station may operate in given hybrid access. Therefore, it is required to consider more number of femto cell members to allow non-subscribed users. Second, the hybrid access-based mechanism can lead to reduce the overall capacity. This cause due to decrease in femtocells power transmission. The power transmission of femtocells is impacted by neighbouring femtocells. This relation can be characterized according to Eq. (8) which is given as:

$$Imp_{j,i} = \frac{P_{j,k} G_{x,j,k}}{N_0 \Delta f + \sum_M P_{M,k} G_{x,M,k} + \sum_F P_{f,k} G_{x,f,k}}, f \neq i \tag{8}$$

This represents the fraction of SINR reduction caused by femtocell j of any user which is connected to femtocell i. Thus, the power transmission adjustment is based on the difference of performance reduction between femtocells caused due to hybrid access. The power transmission change can be expressed as:

$$PC(i) = \sum(SINR_{d,i} - SINR_{d,j}) \cdot a \cdot Imp_{j,i} \tag{9}$$

where a is the parameter which is used to ensure that the power reduction will be performed in certain femtocells that have faced greater reduction in SINR due to hybrid access. This can be expressed as:

$$a = \begin{cases} 1, if \ \ SINR_{d,j} - SINR_{d,i} > 0 \\ 0, otherwise \end{cases} \tag{10}$$

Given that the majority of interference is likely to emanate from neighbouring femtocells, therefore it can be readily derived the necessary reduction in power transmission as follows:

$$P_{new} = (1 + PC(i)) \cdot P_{curr}(i) \tag{11}$$

where P_{new} and P_{curr} represents the new and current power levels of femto BS. Once the power control process reaches its conclusion, it reinitiates whenever any changes are detected, such as the presence of additional users. Furthermore, it considers the resource allocation task and presents a novel approach where the proposed model categorizes available users based on the resource availability. The first category is represented as class-A which consists subscribed users list. Femtocells pay more attention towards these users during spectrum allocation and power levels.

Similarly, the second class of users also consist of subscriber groups but belong to the neighbouring femtocells. This group helps to facilitate the redistribution of users among base stations. However, users from this class can be transformed into Class A if they are admitted in the femtocell of Class A. finally; a new class is introduced in which the users don't belong to any previous classes. Moreover, these users are assigned least priority when compared with Class A and Class B user. Based on Eqs. (1)–(4) the minimum and maximum boundaries of spectrum can be expressed according to Eq. (12):

$$\begin{gathered} min: SP_{B,B} \frac{\log(1 + SINR_{B,B})}{\log(1 + SINR_{B,A})} \\ max: \min\left(\frac{SP_F}{\#users}, SP_{ToT} - \frac{SP_{A,M} \cdot \log(1+SINR_{A,M})}{\log(1+SINR_{A,F})}\right) \end{gathered} \tag{12}$$

SP_F represents the availability of femtocell spectrum.

After determining the user allocation on the base stations and their respective classes, as well as establishing the power and spectrum resources per base station, the next step involves the allocation of spectrum to each class of femtocell users. This allocation ensures equal division of spectrum among the users within a particular class who are being served by a given base station. However, the change in topology may lead to reevaluate the entire process.

IV. Result and Discussion

This section presents the complete experimental analysis of proposed approach and compares the obtained performance with state-of-art mechanism for 5G HetNets.

First of all, simulation parameters are described in this section and later the performance of proposed approach is compared with existing methods. Table I demonstrates the various simulation parameters and their corresponding value to simulate the proposed model.

TABLE I. Parameters with Corresponding Value

Parameter	Considered Value
Macro Base Stations (MBS)	12
Macrocell Radius	250 m
Number of Femto BS	250
Number of subscribers per femtocell	1–3
Carrier Frequency	2GHz
Macro BS Power (Transmitter)	46dBm
Femto BS Power (Transmitter)	20 dBm
Macrocell Path Loss	$PL(db) = 15.3 + 37.6 \ log_{10}R + L_{ow}$
Femtocell Path Loss	$PL(db) = 38.46 + 20 \ log_{10}R + L_{ow}$
AWGN power density	−174 dBm/Hz

The experimental analysis considered a network consisting of 12 macrocells and analysed its performance. the macro cells have several advantages and it plays crucial role in providing the increased coverage and capacity of communication network. These cells have several advantages such as increased coverage in large geographic areas, these cells are capable to handle large number of users to satisfy the high data traffic volumes. Moreover, it is considered as a cost effective solution rather than deploying the large number of smaller cells to achieve the similar coverage. These cells also provide the effective solution to high-speed mobility scenarios to ensure the seamless handover.

Each macrocell had a centrally located Base Station (BS) that transmitted signals at a constant power of 46 dBm. Among these cells, 250 femtocells were deployed in a random distribution throughout the network. For each femtocell, the number of subscribers was randomly determined, ranging from 1 to 3 users. The positions and distances of these subscribers from their respective femtocells were also randomly assigned, ranging from 1 to 15 m away from the BS. Additionally, there are 250 non-subscribed users are also deployed in the given area, representing potential users for hybrid access. These users were distributed throughout the network in a randomized manner.

The user of 5G networks follow several characteristic related to QoS and security which are as follows: requirement of high speed data: several Mbps to Gbps, low latency requirement such as below 1 ms for Ultra-Reliable

Low-Latency Communication (URLLC) applications and 1–10 ms for real-time applications such as gaming and remote control with an end-to–end delay of 5 ms. Similarly, these devices support high mobility communication upto 300km/h or more. To incorporate the security aspects, it considers AES-256 or higher for data in transit as encryption strength.

The further section demonstratesthe performance of proposed model and compared the obtained performance with existing mechanisms. The performance of this model is evaluated for video and VoIP in terms of throughput, delay, packet loss, spectral efficiency, and energy consumption. Figs. 2 and 3 below shows throughput performance for number of users taking Video and VoIP respectively.

Table II demonstrates the obtained throughput performance for each set of Users for Video and VoIP data

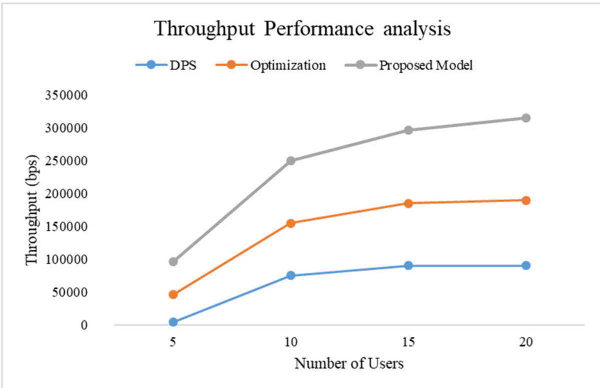

Fig. 2. Throughput performance for varied number of users (Video).

TABLE I. THROUGHPUT PERFORMANCE FOR VARIED NUMBER OF USERS

	Number of Users	DPS	Optimization	Proposed Model
Throughput Performance for Video	5	400,000	4,200,000	5,000,000
	10	7,500,000	8,000,000	9,500,000
	15	9,000,000	9,500,000	11,200,000
	20	9,000,000	10,000,000	12,500,000
Throughput Performance for VoIP	5	14,000	15,000	20,000
	10	30,000	35,000	42,000
	15	44,000	50,000	56,000
	20	60,000	65,000	70,000

The throughput performance analysis shows that the average throughput performance is obtained as 6,475,000 bps, 7,925,000 bps, and 9,550,000 bps by using DPS, Optimization, and Proposed Model, respectively. The experimental study shows that the increased number of users increases the overall throughput of the network.

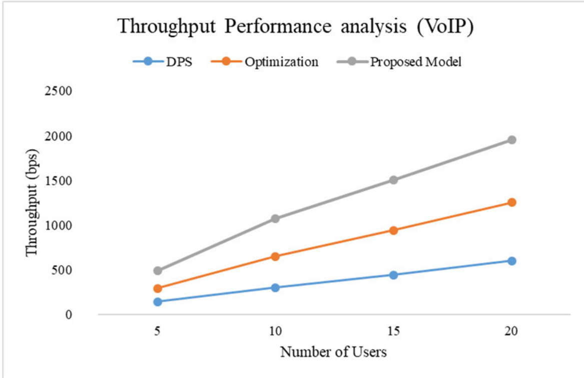

Fig. 3. Throughput performance for varied number of users (VoIP).

Fig. 4 depicts the average delay performance for video transmission scenario for varied number of users. The proposed approach has hybrid access model where multiple femtocells are deployed and increased number of users facilitate efficient data transmission because the subscribed users (Class B) can be transformed into Class A and vice-versa. The experimental analysis shows that the average delay for video data is obtained as 0.06 ms, 0.053 ms, and 0.035 ms by using DPS approach, Optimization scheme and Proposed Model, respectively. Similarly, Fig. 4 depicts the delay performance for VoIP scenario. The experimental study shows that the average delay is obtained as 0.0016725 ms, 0.001655 ms, and 0.00125 ms, by using DPS approach, Optimization scheme and Proposed Model, respectively.

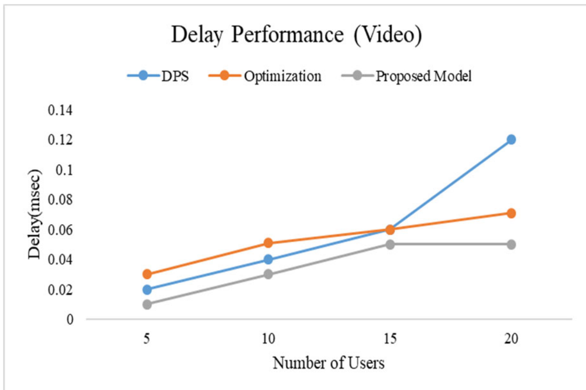

Fig. 4. Delay performance (Video).

Fig. 4 depicts the delay performance where Proposed Model has reported the significant reduction in overall delay when compared with other models

According to outcome presented in Fig. 5, the packet loss ratio performance is obtained as 0.033, 0.03, and 0.0235 by using DPS approach, Optimization scheme and Proposed Model, respectively. The experimental analysis reported that the increased number of users ensures the efficient transmission of packets by switching the users from one femtocell to another femtocell.

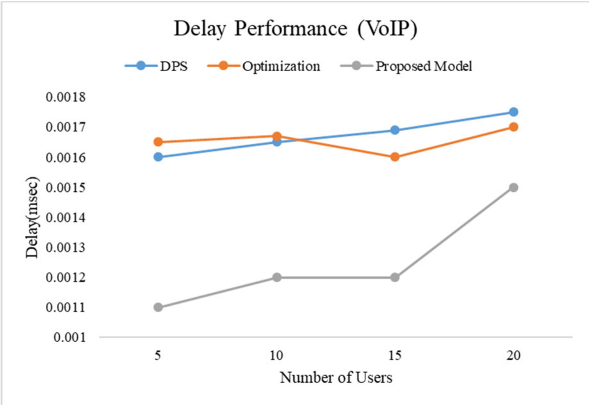

Fig. 5. Delay performance for VoIP.

Based on these experiments on delay analysis, the obtained performance for varied users for video and VoIP is presented in Table III.

TABLE III THROUGHPUT PERFORMANCE FOR VARIED NUMBER OF USERS

	Number of Users	DPS	Optimization	Proposed Model
Delay Performance for Video	5	0.02	0.03	0.01
	10	0.04	0.051	0.03
	15	0.06	0.06	0.05
	20	0.12	0.071	0.05
Delay Performance for VoIP	5	0.0016	0.00165	0.0011
	10	0.00165	0.00167	0.0012
	15	0.00169	0.0016	0.0012
	20	0.00175	0.0017	0.0015

Finally, the energy consumption performance for varied number of user test case is measured and described below. Figs. 6 and 7 depictsthe obtained performance in terms of packet loss rate and energy consumption for varied number of users. The proposed approach also focusses on optimizing the transmission power by dynamically adjusting the power levels and cancelling the interference effect. However, the increased user count lead to increase the energy consumption but the average performance of proposed approach outperforms the traditional methods.

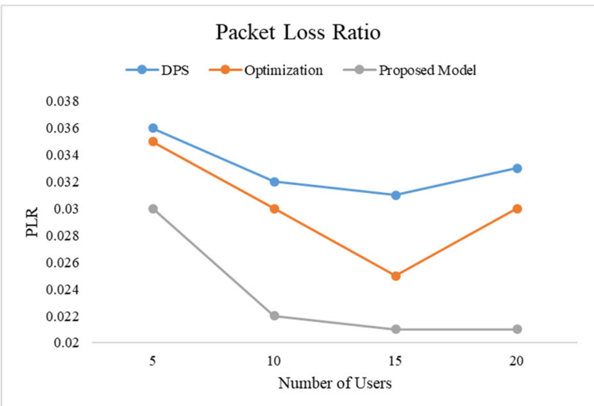

Fig. 6. Packet loss performance for varied number of users.

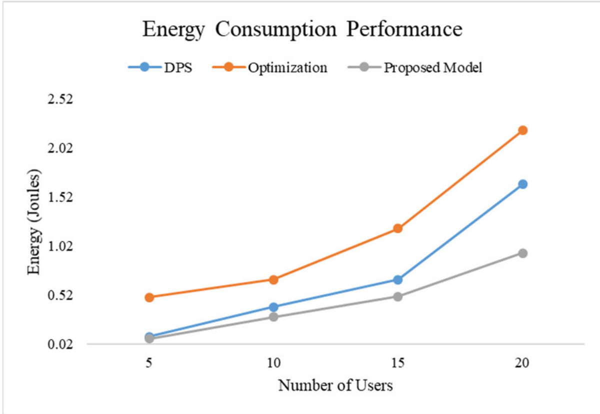

Fig. 7. Energy consumption performance for varied number of users.

According to a recent study presented in the paper [22], it is reported that the optimization methods also can be useful in power optimization of heterogeneous networks. However, the experimental analysis have reported that increased number of users inflates the power consumption ratio due to increased interference therefore more transmission is required to obtain the signal-to-interference ratio threshold. The proposed model is also employed for varied SIR threshold and compared the power consumption performance. Fig. 8 depicts the obtained power consumption performance.

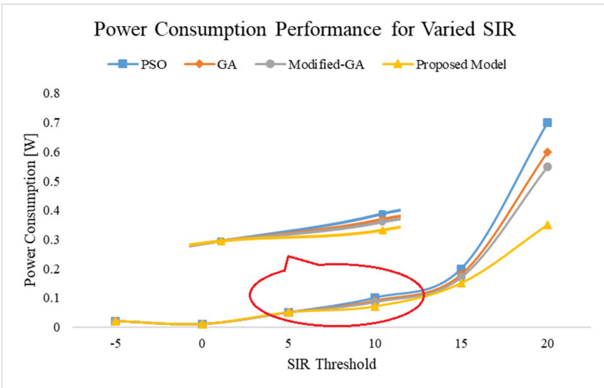

Fig. 8. Power consumption performance for varied SIR levels.

The average power consumption is reported as 0.18 W, 0.158 W, 0.14 W, and 0.10 by using PSO, GA, Modified-GA, and Proposed Model, respectively.

V. CONCLUSION

Deployment of ultra-dense heterogeneous femtocell networks represents a promising solution to meet the increasing demand for device connectivity and data rates in the next generation of mobile networks. However, several key challenges need to be addressed to optimize the performance of these networks such as power optimization, interference and spectrum management. Power optimization plays a crucial role in femtocell networks to achieve efficient resource allocation and mitigate interference. By carefully managing the transmit power levels of individual femtocells, interference can be minimized, resulting in improved spectral efficiency and overall network performance. Interference cancellation techniques are essential to combat the interference caused by the deployment of multiple base stations sharing the same spectrum. Spectrum allocation is another critical aspect in optimizing the performance of heterogeneous ultra-dense femtocell networks. To overcome of these issue, a new combined approach is presented where subscribed and unsubscribed users are grouped into different classes and modelled the power optimization and resource allocation to improve the performance of system. The experimental analysis shows that the proposed approach achieves better performance when compared with traditional schemes.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Shilpa Bhairanatti conducted the research, analyzed the data and wrote the paper; Rubini P had verified and approved the final version. All authors had approved the final version.

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