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Traffic Normalization and Interference Management in Femtocell-Cellular Network: A Joint Strategy

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Abstract: ***The impact of large amounts of data traffic in a cellular network not only affects capacity requirements but also affects the quality of the services of the network. The usage of femtocells cost-effectively increases network connectivity and coverage. Based on the review analysis, it is found that the existing literature mainly focuses on the energy problem in the cellular network without much attention to interference-causing issues. Thus, the proposed work offers an analytical strategy for unitedly addressing traffic management and interference management issues to accomplish better power-efficiency in a femtocell-cellular network. The proposed study takes advantage of the simple concept of stochastic geometry and proposes an effective noise modeling scheme supported by algorithmic implementations. The effectiveness of the proposed system was verified by performance evaluation and comparative analysis, considering similar existing research work in terms of power consumption, interference control, and processing time.***

Keywords: Cellular network, Femtocell, Mobile Network, Stochastic Geometry, Energy Efficiency, Coverage

I. INTRODUCTION

In the past decades, the cellular network has grown tremendously. The number of users and cellular traffic demands are on the rise in astronomical figures. Demand for large-scale data traffic has increased in recent years with the launch of smartphones like Android and iPhone, social networking sites as an emerging trend in marketing, using Facebook, Instagram social connections, and the increasing digitization and digitalization process. As a result, user bit rate requirements continue to increase, and meeting these new demands in cellular communication networks with minimum cost becomes unavoidable for mobile operators [1]. Previously, cellular networks were primarily used to provide voice and text communication services. However, due to the continuous advancement in digital technology, data communication is growing quickly like the wind, which is currently accountable for most of the traffic in the cellular network communication.

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With the rapid growth in mobile traffic, the futuristic cellular networks face enormous challenges in meeting network capacity requirements [2]. Concurrently, the high data transmission rate and the speedily growing number of users also seriously affect the energy depletion and cost associated with cellular networks. Another major issue in cellular networks is call drop, which also does not meets user QoS requirements. In addition, the cellular network also suffers from loss of penetration in providing services to indoor users. In order to achieve high data rates and withstand the loss of propagation, the cellular network uses high-frequency signals that cannot penetrate the wall, leading to signal attenuation [3]. Due to this fact, indoor users often have to come out to get the desired signal. Thanks to the availability of Femtocells as a supportive device in cellular network. The Femtocell offers an interactive environment for the user with multiple base-stations and enables an effective way to increase system capacity and reduce the rate of energy depletion of cellular networks. Femtocells are small base stations, plug-n-play devices operating on low energy cost, having a fixed transmission range [4-5]. It offers multiple features to their users like spectrum reuse, quality-aware wireless links, and low transmission power. However, there are some challenges as well associated with the Femtocell like no control and management over usage of bandwidth, complicated and intricate hierarchical connections, highly dependent on internet connections and location information, etc [6]. Currently, there are several existing literatures focusing on various problems associated with the femtocell network [7-10]. However, a common is energy utilization in relation to base station transmission power. In addition, interference is another important problem that has not been studied in the existing literature. Therefore, this paper provides a simple design of an analytical framework for traffic normalization and interference management to achieve higher energy efficiency in the femtocell-cellular network. Considering the dynamic factors uncertainty and unpredictable pattern of traffic, a stochastic geometric concept is adopted to achieve energy savings in a cellular network. The proposed work also assumed a close relationship between interference and power and proposed an effective noise modeling that can utilize selective femtocells as needed based on traffic demand. Therefore, the transmission quality and power efficiency can be improved by regulating traffic and managing interference factors. The remnant portions of this paper are as follows: Section-II presents review of existing literatures. Section-III illustrates research problem.

Section IV discusses proposed system design. Section-V presents algorithm implementation. Section VI presents result and outcome analysis of the proposed methodology and finally the entire work is concluded in Section VII.

II. LITERATURE SURVEY

Various research efforts have been made in the last few years in the field of cellular communication systems towards meeting user quality of service demands and energy conservation. This section provides a brief review of the existing techniques for energy efficacy, interference control, and traffic management. The work carried out by Zhong et al. [11] presented a scheme to investigate the delay factor cellular networks-(CN) considering the Spatio-temporal traffic pattern where the authors have carried different scheduling performance assessment. The study towards enhancing power efficiency in CN Zhang et al. [12] uses a cell zooming approach that includes a scheme of load balancing and modified load concentrated technique to narrow down the unwanted power utilization and to improve Power Efficiency-(PE). Wei et al. [13] constructed a power supply control model for multi-hop rely-CN and utilizes combined formulation of ant colony algorithm-(ACA) and convex optimization principle-(COP) technique to reduce the power consumption and maximize coverage for seamless communication. Xiang et al. [14], focuses on the problem of poor convergence factors in cellular networks. The study introduces a cell neighbor graph-based predictive scheme to improve the power efficiency and quality of the network. Wang et al. [15] have introduced BS sleeping methodology using the concept of the coalitional game for effective and quality efficient communication in the solar-powered IoT-cellular. Fan et al. [16] suggested a technique using a sleep scheduling algorithm for improving multiple factors such as user capacity, energy efficiency, and coverage probability in a large cellular network. Jiang et al. [17] have presented a topology-aware algorithm to attain the most favorable power usage mechanisms in cellular networks. The main intention of this work is to lower the rate of BS switching frequency for LTE networks. Cao et al. [18] focused on the quality feature aspects of the communication and introduced an entropy oriented weighting mechanism to determine the hotspot in the CN. Zhang et al. [19] use a machine learning-based approach to investigate complicated patterns presented in cellular data. The authors then develop a deep learning architecture to analyses such complex data and find better strategies towards identifying the cause of traffic burden and its management. Budhiraja et al. [20] presented a hybrid channel scheduling mechanism and energy management technique based on non-orthogonal multiple access for enhancing PE and quality features of the communication process in the femtocell-cellular network. Shifat et al. [21] have used game theory concepts with adaptive channel scheduling mechanisms for communication quality improvement and interference management in heterogeneous CN. The work of Liu et al. [22] designed a channel assignment mechanism to determine an optimal number of subchannels allocation policies. In this, the authors have also build a non-cooperative game model considering all quality feature requirements for the communication in the femtocells. The work of peng et al. [23] introduced the data-driven mechanism and load-aware scheme to control unwanted energy consumption due to the Interference factor in the Dense Networks. Haider et al. [24] investigated the energy efficiency factor in Femtocell-networks, considering spectral efficiency under opportunistic scheduling approaches. Wang et al. [25] carried an analysis of coverage and throughput factor for a dual-layer Femtocell network and macro BS under uniformly deployment scenario. The critical features of the Femtocell were briefly summarized in the study of Zaheer et al. [26] and the challenges and issues presented in the wide-scale deployment. Also, issues related to intervention management are discussed in detail here, and analysis is made on existing solutions for managing the intervention. Sharif et al. [27] tried to control interference issues in the dual-layer-femtocell network where the user performs a communication process under the same frequency shared by the existing macrocell users. The authors have constructed a transmission control mechanism to mitigate the interference factor and to increase connectivity in the deployment area. A scheme based on the Q-Learning approach is used in the work of Gao et al. [28], to build hybrid strategies for controlling and managing the energy depletion factor for enterprise LTE-femtocell network.

III. RESEARCH PROBLEM

Based on the review and analysis, the proposed study highlights the following research problem associated with the existing system in the area for a cellular communication network.

- It has been found that the traditional cellular network power model does not consider the standard radio energy model in most studies.
- Another problem that was discovered was that in most studies, existing cellular network power models did not consider standard radio energy models.
- Most existing research has followed a similar approach to addressing energy issues in cellular networks. In the case of dynamic networks, global factors for optimizing energy consumption and improving energy efficiency are rarely considered.
- Also, the existing studies subjected to robust network modelling for interference management and energy control mechanism generally suffers from computational complexity problem.

IV. PROPOSED SYSTEM

The primary objective of the proposed study is to come up with a framework that ensures an effective traffic management policy and a superior energy conservation mechanism in cellular networks. The secondary goal of this research is to address the interference problem and energy issues allied with femtocells. The entire strategy for implementing the proposed system design is executed into multiple phases: i) strategies to alleviate traffic burdens through modeling;

ii) using stochastic geometry to ensure better energy efficiency in cellular network iii) strategy towards noise modeling considering uplink transmission to address interference factor in Femtocell iv) strategy for scheduling transmissions in Femtocell-cellular network. The design components of the proposed framework are shown in Fig.1.

The significance of the proposed system is that it collaboratively solves the problem of both traffic management and interference issues to enhance energy efficiency. The proposed system employs a stochastic geometry that takes into account the randomness of user-(mobile station) the base station-(BS) in the cellular region. Analytical modeling of traffic management is performed based on the estimation of accumulated interference from the interloping BS and the MS-(mobile station). The proposed system also considers some other unwanted factors like scattering effect, fading effect, and path loss impact on the wireless cellular signals. Eventually, the introduced system presents an algorithmic approach that effectively identifies dynamic and unpredictable traffic occurrence, and delivers superior resiliency against undesired interference and cuts the cost of BS power depletion, thereby extending energy conservation and efficient coverage factor.

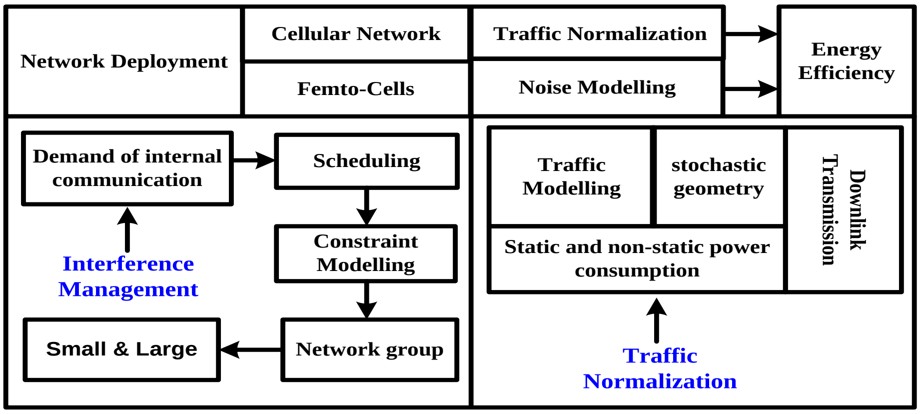

Fig.1 Proposed System Architecture

V. IMPLEMENTATION STRATEGY

The first phase of implementation is subjected to cellular-network construction under the simulation area with localization of the MS and BS accomplished by adopting the principle of the Poisson process. The study then assumes that the traffic comes from MS and calculates the accumulated traffic load on each network cell. In addition, the system estimates accumulated BS transmission power, too, which in turn relies on multiple factors like interference, noises, traffic-rate, and channel status. The study at this stage also introduces consideration of the weighting factor to recognize the degree of density in the deployment or in the simulation region and employed a power-law concept to manage traffic density measured in the proposed system. As a final point in traffic management policy, the system approximates the traffic probability distribution and attains a traffic-aware link after executing a power-law factor. A research strategy towards preserving energy is instigated by assessing the energy needed to carry out downlink transmissions, which is being performed between random MS in the particular cell. Here, the system considers that the degree of interference between two identical wireless links is not greater than one. In order to analyze the interference effect effectively, the study estimates the power needed for both intervening MS and BS. The description of the algorithm for traffic management and energy conservation is as follows:

Algorithm for traffic management

Input: Cell region-(C_r), nodes-(N), interference (I)

Output: Traffic with less density and Energy Efficiency-(E_E)

Start

1. *Init* N, C_r
2. *Assign* $\rightarrow M_N, BS$
3. $(M_N)_{x/y} \leftarrow C_r * \phi_{rand}(M_N, 1)$
4. $(BS)_{x/y} \leftarrow C_r * \psi\,(BS, 1)$
5. *Network* $\rightarrow \pi\,(x, y)$
6. *Compute:* $P_R \rightarrow (p)^q / E_u(z).z^{q-1} * \exp(-pz)$
7. *Compute:* $P_\Omega \rightarrow w_I \Omega_{\min}^{w} * 1/z^{w+1}$
8. *Execute:* $P_{PD} \rightarrow T_R = \arg_{\min}\left(w_{i\Omega_{\min}} / w_i - 1\right)$
9. *Compute:* $(M_N)_{SIR} \leftarrow R_p / I_A$
10. *Evaluate* Ω_{SIR} *relationship:* $\Omega(z) \rightarrow B.\log_2(1+SIR/\beta)$
11. *Compute* $(E_C)_{cell} \rightarrow \sum\left(\left(\| px_i - py_j \|^{\alpha}\right) / BS_N\right) * R_p$
12. *Compute* $(E_C)_{BS} \rightarrow \left(R_p / C_G\left(\| px_i - py_j \|\right)\right) * BS_N$
13. $E_E \rightarrow (T_R)_{real}(1 - E_{out}) / AVG_{Etot}$

End

The above algorithm is responsible for addressing dynamic and inconsistent traffic patterns in cellular networks, thereby achieving a control over unwanted energy dissipation in cellular networks. Initially, the presented algorithm takes inputs of cell area- (CR), mobile nodes- (MN), and interferences- (I). The proposed algorithm first constructs a cellular network considering real-time deployment scenario with asymmetric cell region-(Cr) with two core components i.e. MN and BS. Here, the distribution of MN in Cr is performed using the random function -(ϕrand), and the placement of the BS is performed using the function ψ subjected to Poisson Point process based network deployment-(steps 3 and 4).

The next step is associated with network formation based on another function on π refers to (Voronoi-structure) where MN-(MS or user) and BS are placed in multiple cells (step 6).

In addition, connectivity is established using the computation of Euclidean-distance of MN and the associated BS.

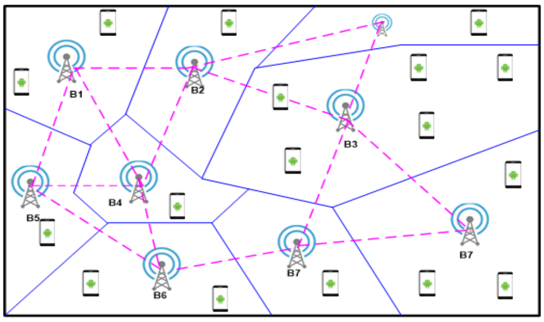

Fig.2 Network deployment scenarios

The system then calls the Euler function-(Eu) to be implemented to get all the information about the random traffic pattern. The procedure mentioned in step-6 calculates the relative probability of the randomness for traffic analysis considering the traffic density-Ω, where the variable p (inverse characteristic Eu), q refers to the shape attributes, Ω to refers to traffic density, and w1 indicates the weighting factor considered in the proposed system (step-6 and step 7). The proposed research work also suggests that the fewer the weighting factors, the more likely the probability of downlink traffic will be sudden. Using probability approach, traffic patterns are considered to be very dense if the value of the weighting factor lies in the range of 0.7-1. In addition, the system calls the power-law probability distribution-(PPD) function to establish an efficient strategy to manage and control the traffic density in the simulated region (step-8). In the next process, the presented algorithm estimates the SIR value for the MN downlink transmission (step 9), after which the relationship between Ω and SIR is calculated, taking into account the presence of interference (steps) 10). Afterward, the algorithm begins the computation of the energy consumption of each cell with the location of the MN and the BS (step 10). In this, the variable Rp as the received power of the total number of BS-(BSN) users (step 11) is also primarily computed to assist in attaining an energy-saving mechanism. Considering CG (link gain), the transmission energy of all the respective BSs is estimated (step 12). Finally, the energy efficiency of the entire traffic is calculated considering the output energy Eout, where the variable (TR) real represents the real-time traffic conditions computed from step 8. The efficiency of the proposed algorithm is that it explores the optimal link with low interference levels and, thereby reducing the traffic load from the BS in uplink and downlink transmissions. The second phase of implementation is executed by modeling the noise model for balancing the interference factor and boosting the energy efficiency by prolonging the coverage. The initial operation of this phase is to construct the cellular network with Femtocells.

Algorithm for Femtocell-Cellular Network Deployment
Input: T_{range} (transmission range)
Output: Nodes distribution and Interference control
Start
1. *init* T_{range}
2. ***For*** $i=1$: T_{range}
3. *deploy nodes*
4. ***End***
5. ***If*** $\eta \geq 0$
6. *re-position* $\rightarrow N(x,y)$
7. ***End***
8. *deploy* $\rightarrow \phi_{rand}(N, 1) < C_R$
9. *compute: Ed of nodes*
10. ***If*** $\arg_{max}(Ed) \geq T_{range}$
11. *Allow link establishment among all nodes*
12. $f(q) \rightarrow 1-e^{p}$
13 $\upsilon(a,b) = \int_{\mu_c}^{\mu_{c+1}} df_b(q) = \kappa p$
14 $e_n \rightarrow \arg_{max}(\text{rand}, g)$
End

The initial step of the proposed algorithm is to consider the Femtocell node and deploys it randomly in the cellular deployment region (step 2-3). The node localization parameter-(η) is evaluated to determine that if any femtocells are outside the cellular area-(Cr) (step 5). In this case, a modification mechanism is applied to make sure the localization of Femtocell under the cellular transmission range-(*Trange*) (step-6 and step-8). The system then executes computation of the Euclidean distances of all active nodes in the cellular area to the Femtocell (Step-9 10) considering the sensing range of Femtocell. Once the optimal distance is computed, a communication link is established between the nodes and Femtocells (step-11). Further, the study constructs a noise modeling-(step 12), which helps to assess the definite noise distribution for the deployed Femtocell node, for this the proposed system formulates a numerical expression where variable d refers to a function subjected to noise distribution, q is element of natural number and exponent p numerically expressed as -f / mean SNR. Based on the probability factor, the proposed system constructs another numerical expression considering that mobile node-(user) under a range of Femtocell node transmits encoded data to its target node (step 13), where the variables a holds to noise value, and the variable b holds the value of the particular user. The introduced system also defines threshold factor θ, with an attribute kp that stands for the indicating difference of two exponential attributes considering the power factor of threshold µ and mean SNR. This is a fundamental consideration made in this approach to determine the existence of noise and balances it via using a threshold value, which is laid down on the basis of the probabilistic approach. However, the study mainly focuses on choosing the optimal number of Femtocells nodes to eliminate noisy signals and interference factors. Therefore, only one Femtocell node is elected based on the efficient coverage that is also accountable for controlling overhead and turns out in the energy-saving factor for the other Femtocell nodes in the network.

Moreover, this entire operation of optimal user selection is managed and performed by BS, which is also authorized to schedule communication for the mobile nodes with corresponding Femtocell node. A numerical expression is formulated in step-14 for performing this operation, where the variable Φn refers to interference factor linked to the n number of users, rand indicates the random variable, and j refers to the next node. This representation actually means that the proposed system provides an optimization mechanism over network variables without involving any external parameters to ensure seamless and quality-aware communication. In addition, the introduced system determines a significant extent of compensation count that allows communication to sustain an efficient communication process even there is a presence of any forms of noise and interference factor. The next operation performed by the proposed system is associated with maximizing energy efficiency by taking signal-to-interference-noiserate-SINR factor into consideration. In order to execute this operation, the presented study divides the femtocells network into two parts of deployment i.e., small Femtocell coverage area and larger Femtocell coverage area. Even for smaller and larger Femtocell coverage areas, the same expression mentioned in the algorithm (step12-step-14)- is applied for managing interference problems, controlling overhead issues, and enhancing the power saving factor. However, the value of the threshold factor is set to be according to both types of Femtocell, coverage area. Therefore, by adopting efficient strategies, the proposed system manages interferences factor and resists the impact caused by the traffic overhead and traffic burden, thereby offering energy-saving mechanisms. The next section presents the outcomes for justifying the effectiveness of the proposed methodology.

VI. RESULT DISCUSSION

The proposed methodology designed on numerical computing tools, and the performance of the proposed system is evaluated by similar existing research work [28] and [29]. In the simulation parameters, the study considers the traffic load extent with a probability of 0-1 and considers that the femtocell network is functioning on 30 MHz, channel capacity with average data packet size of 2500 bytes, and with a transmission rate of 27 MBPS. Also, the results are assessed with different performance indicators such as energy consumption, interference control, and processing time at varying channel capacity.

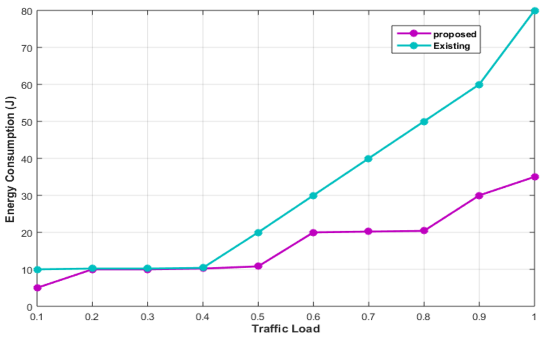

Fig.3 Analysis of Energy Consumption

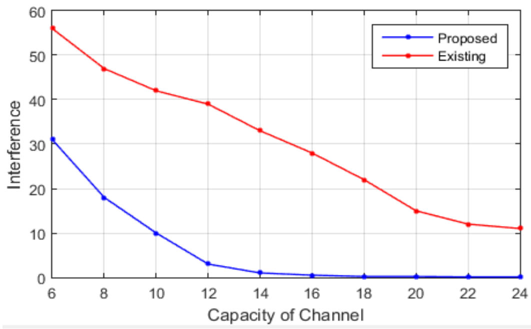

Fig.4 Analysis of Interference

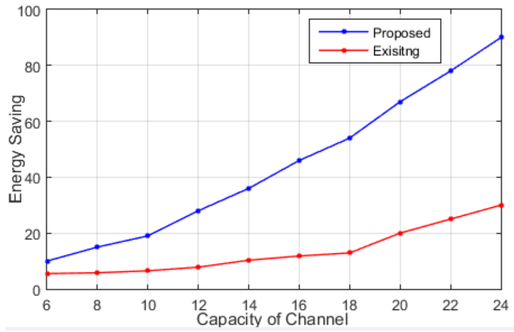

Fig.5 Analysis of Energy Saving

The above fig 3 indicates that the proposed system tries to maintain a better uniformity of energy consumption with increasing load as compared to the existing system. However, with a slight difference in energy consumption over the traffic load system maintains efficient energy utilization as it is likely to occur in any real-time cellular network scenario due to dynamic traffic situations. Fig 4 shows the contribution of the proposed system that it is better in controlling interference over increasing channel capacity because it focuses on communication requirements and selects optimal Femtocell node with a higher coverage rate for seamless connectivity. Though the existing system is more inclined to network modeling where the degree of interruption is high, and therefore it can manage the interference factor if the traffic goes beyond its peak range. Fig 5 exhibits the efficiency of the proposed system that it holds a better power-conservation mechanism because no additional energy is used when increasing the channel capacity, thereby delivers better energy-saving performance compared to existing systems. During performance analysis regarding processing time, it has also been analyzed that the proposed mechanism does not involve complex factors and takes less processing time compared to the existing system.

VII. CONCLUSION

The introduced framework has constructed a simple strategy to handle the impact caused by massive traffic load, interference issues, and thereby enhancing energy conservation mechanisms in femtocell-cellular networks. A stochastic geometry mechanism is adopted to construct traffic modeling where the system considers dynamicity and volatile traffic nature and constructs a simple algorithm to perform normalization operation with less density. The proposed system introduces a novel interference modeling, where an empirical expression is constructed to estimate the probability of transmission at any level of SINR. A threshold factor is used to perform the communication process based on the decision that Femtocell with higher coverage rate is only preferred to perform communication processes associated with the user in respective deployment regions without involving other Femtocell nodes in a similar cellular region. The simulated result confirms the effectiveness of the proposed system as it has an effective algorithmic strategy suitable for maintaining traffic conditions, controlling interference factors, and hence better energy efficiency can be claimed with a lower cost of resource usage.

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