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An Improved Modelling Of User Clustering for Small Cell Deployment In Heterogeneous Cellular Network

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Abstract: Users in practical cellular geographical areas are found to be non-uniformly distributed. Small cell (SC) deployments in heterogeneous user distribution in a cellular geographical area help to meet high data rate user demands for multimedia data communications in hot spots. SCs help to offload traffic burden from the macro cell (MC) base station, and also cater the data traffic need for the edge users where signal strength from the MC base station (BS) is very weak. For deployments of SCs along with the central MC BS (hence called *HetNet*) in such spatial heterogeneous user distribution, effective user grouping or clustering algorithm is required for appropriate and satisfactory service coverage. We call it service grouping or clustering of users to be put under a SC for data transmission and reception. It does not disturb the spatial positions of users in clustered non-uniform distribution. Efficient grouping or clustering of users and then deploying a SC at optimal location enhances the performance of the *HetNet*. It is found that the *K-means* algorithm used for such grouping of users to position SCs is not efficient. A novel and improved user grouping algorithm is proposed in this paper which performs much better compared to the *k-means* algorithm. The proposed algorithm of modelling of user clustering results in increase in the number of users under SCs, increase in more offloading of data traffic from MC BS thereby increasing data throughput of MC users. The algorithm also increases in the energy efficiencies of the SCs which is

considered as one important performance metric. A doubly stochastic poisson process (DSPP) also called Cox process is assumed here for simulation of non-uniform user distributions. We consider Rayleigh distributed small scale fading model, large scale fading factor representing shadow fading, and users' geographical distances from BSs to evaluate users' data rates.

Keywords - *Heterogeneous; Clustering; K-means Algorithm; Doubly Stochastic Poisson Process; Shadow Fading;*

I. INTRODUCTION

Presently, cellular mobile data communication has far grown than that expected in the last decade of the twenty first century [1]. The extensive growth of data volume generated due to ever increasing number of smart phone users has inspired the use of larger spectrum and more penetration of sophisticated mobile data communication systems in rural areas in addition to the urban usages. Also, the user distribution in a given geographical area is now more non-uniformly distributed than before, with number of hotspots of users where much activity is recorded and data volume generated significantly higher. Also, in areas near the edge of the geographical area, where signal strength from the center BS is very weak, cellular service coverage is needed [2-3]. Instead of a single BS at the center for coverage of all the users, SCs are also deployed at certain points like the centers of the hotspots or at the cell edge for enhanced throughput or data rate performance of the total cellular data communication system [4-7]. SCs not just

offload the traffic from a *MC BS* in the cell but also boost link quality by reducing the gap of communicating distance, and permit to utilize the spectrum in an efficient manner [6-7]. In [8], a novel *HetNet* planning model is proposed that involves deployment of *MC* and *SCs* considering least energy consumption and minimum total cost ownership (*TCO*) that fulfil the traffic demand. While deploying *SCs*, factors that are given importance are power and bandwidth allocation, traffic requirement, and spectral efficiency. Three heuristic procedures are adopted along with clustering approaches in [9] for joint deployment of *SCs* and point-to-point fibre links that meets the minimum level of *QoS* requirement as well as reducing cost of transport and *SCs* deployment. An observer-based system is used dividing a cell into a series of sectors and identifying the regions of mobile users' clusters for finding out the optimum location of deployment of *SCs* [10]. In order to cope with dense deployment scenario for heavy traffic requirements, *SCs* within a *MC* are clustered with grouping of 1, 4 or 10 based on 3GPP simulation methodology [11-12]. Hierarchical clustering algorithm with minimax linkage [13] is used to cluster *BSs* creating virtual cells based on best channel condition and user affiliation to a *BS* [14]. A Green Offloading scheme is proposed for offloading traffic from *MCs* based on Reverse Auction Model [15]. The first price sealed bid mechanism which matches with mobility based offloading process [16] is found to improve system energy efficiency of densely deployed *HetNet* under the constraints of user *QoS* requirements, bandwidth and transmission power limitations. Nowadays, a promising technology of 5G is hyper-dense *SC* deployed *HetNet*. However, with increased number of large *SC BSs* the level of power consumption also increases. Therefore, *SC BSs* are operated according to traffic load variations. During the day when user density is high *SC BSs* are activated gradually to serve offloaded traffic of *MC BS* and operated in off mode when traffic is low thus reducing total power consumption of the *HetNet* [17].

Stochastic Modelling of the user distribution and deployments of *SCs* for network performance evaluation are now prevalent.

Cox process or cluster model is used to model the non-uniform distribution in a cellular area [18-23]. To divide the cellular area in a number of clusters, *k-means* clustering technique with Voronoi cells may be used [6]. *SC BSs* may now be placed at the centroids of the cells, and the *BS* caters the data service required by the users with a specific circular area of the *SCs*. Similarly, *SC BSs* may be located judiciously near the edge of the *MC*. However, the *k-means* clustering technique has certain defects such as within the circular area of some *SC BSs*, there may be no user at all or the numbers of users are very small. The authors in [24] discuss the impact of *SCs* on the throughput enhancement in *HetNets* and have shown the limitation of *k-means* user clustering approach. It is obvious that the *SC BSs* should be located in such locations where the users' density is maximum within its *SC* area. This results in offloading of data traffic from the *MC BS* maximum possible which is a requirement in cellular communication design of *HetNets*. Also, by bringing more and more users to the coverage of *SCs* enhances the data throughput of those users [25-26].

In this paper, we assume a *HetNet* with a *MC BS* serving the macro users and a few *SCs* deployed in the macro geographical area serving users in cluster locations. *SCs* are placed at the centroid of the clusters of users obtained applying *k-means* algorithm and the proposed algorithm obtained by improving upon the *k-means* algorithm. We obtain the total data throughputs of users under the *MC BS* and under all the *SCs* separately, for both the algorithms. The proposed algorithm increases data throughput of macro users, and also increases total number of users under the *SCs*, which are considered as metrics to show the efficiency of the proposed algorithm. The effective throughput offloading, *OFFLOAD* and energy efficiency of *SC BSs*, *BS_SC_W* are two other metrics used for performance evaluation. We consider different cluster scenarios for evaluation of the proposed algorithm. The user spatial heterogeneity is simulated using *Cox* process and the *MC BS* is assumed to be in the center of a circular geographical area.

The rest of the paper is organized as follows: We describe in Section 2 the system model and modelling of users resulting in the improved user grouping and obtaining optimum location to deploy *SCs*. In Section 3, the metrics are formulated for evaluation of the new improved modelling of user clustering. Section 4 describes the simulation studies and discussions. Section 5 concludes the findings of this paper.

II. SYSTEM MODEL

We consider a circular geographical area of radius 1500 meters which is filled by a non-uniform Cox process that generates users as clusters spatially. A *MC BS* is positioned at the center and a few *SCs* of radius 100 meters are located in the clusters of users of the geographical area. The users are taken in different numbers in clusters, the *Centroid* or *Centre* of which is obtained with *k-means* clustering algorithm. An example *HetNet* is shown in Fig. 1, wherein the red outer circular area is the *MC* and the red pyramid is the *MC BS*. The small red circular areas are serviced by *SC BS* which are shown as green pyramids, the solid small circles represent the *SC* locations obtained by *k-means* algorithm, and the dashed red circles are the new locations of *SCs* obtained by applying the proposed algorithm. The black arrow shows the shifting in the location of a *SC*, and the black dots are the non-uniformly distributed users

Fig. 1 An Example *HetNet*

The data traffic of the users under the *SCs* is serviced by the *SC BSs* and the data traffic of the remaining users is serviced by the *MC BS*. The interference model assumed in this paper considers interference between *MC BS* to different *SC BSs*, between *SC BSs*, and *SC BSs* to *MC BS*. We propose an improved algorithm for modelling user clustering which performs better than the *k-means* algorithm. The improvement is shown by metrics that quantifies the increase in the number of *SC* users and the increase in the data throughput of the remaining macro users. We also quantify the offloading of data traffic from the *MC BS*, and also the energy efficiency of the *SCs* to be used as performance metrics.

It may be noted that the users are spatially clustered because of their non-uniform distribution in the coverage area. In this paper, our grouping or clustering algorithm by modelling of user spatial clustering is to find optimal locations of the *SCs* for deployment for efficient service coverage in the *HetNet*. The grouping or clustering of users, while explaining the proposed algorithm is merely to collect users in groups or clusters for downlink data transmission and reception from respective *SCs*, users' spatial geographical locations remain unaltered. Hence, the proposed algorithm may be taken to perform service clustering only. Further we considered a static case of user distribution with no mobility of users in the simulation experiment.

We state below the *k-means* clustering algorithm and the proposed improvement in the modelling of users' clustering from the *k-means* algorithm.

The basic *k-means* algorithm is stated as below [6]:

- a. From the non-uniform user points, select *k* random points as initial centroids.
- b. Repeat
  - i. Construct *k* clusters by assigning users closest to its centroid
  - ii. Recompute the centroid of each cluster.
- c. Repeat until centroids do not change.

The improvement of the above algorithm is obtained as stated below.

- d. Start with the centroids from the step *c* above.

- e. Draw circles of radius 300 meters around each centroid. Size of the radius is chosen to have no-overlapping or minimal overlapping between the nearby circles around the centroids. It may be a design parameter.
- f. Find which user point within 300 meters of radius of each cluster has highest number of neighbors within its 100 meters of radius.
- g. The user point having highest number of neighbors around it in 100 meters of radius is taken as the new cluster centroid.
- h. Repeat for every cluster from basic k-means algorithm.

The benefits of the proposed algorithm are as follows:

- i. The SCs which centers are the centroids from the basic k-means algorithm may not contain any user within its 100-meter cell radius which centers are the centroids from the basic k-means algorithm may not contain any user within its 100-meter cell radius. Also, the centroids may be located in zones where users are sparsely spread.
- The SC centers as obtained from the proposed algorithm contain the maximum number of user points within its 100-meter radius. Hence, the SC centers are located in the densest sites of each cluster in proposed improved algorithm obtained from basic k-means algorithm.
- ii. The offloading of traffic from the MC BS is much less as the SCs obtained by k-means algorithm contain no or much less number of user points. Since, the SCs as obtained from the proposed algorithm have the maximum possible number of user points in each SC, the offloading of traffic from the MC BS is highest possible.
  - iii. As offloading of data traffic from MC BS is highest possible, it enhances the data throughput and data rate obtained by each macro users from its MC BS.

To obtain the x number of SC locations (*centroids*) in the MC BS coverage area, we proceed in two different methods. In the

first method, we obtain x number of groups or clusters of users and their *centroids* applying *k-means* and the proposed algorithm. We then evaluate the performance of the *HetNet* designed under the two algorithms. In the second method, applying the two algorithms, we start with y number of SCs in the MC BS coverage area and then switch off some SCs by z numbers, where $z = 1, 2, 3, 4$ and keeping $y-z$ SCs in their original positions as per the algorithm. We then evaluate the performance of the *HetNet* designed under the two algorithms.

For simulation studies, we consider four different cellular *HetNets* with total user points in the range of 1000-1400, each one with one MC BS and 4-8 SC BSs. The SCs are distanced from the MC BS by 400 meters so that interference from the MC BS to users under the SCs are low. In Fig.2(a) and 2(b) we show such a cellular *HetNet* with 4 SCs and 7 SCs respectively, after applying the proposed algorithm. In Fig.2(c) we show the network of Fig.1(b) with 3 SCs switched off randomly. In Fig.3(a), 3(b) and 3(c), show another network with same number of SCs

Fig.2(a) : Hetnet1, 4 SCs

Fig.2(b) : Hetnet1, 7 SCs.

Fig.2(c) : Hetnet1, 4 SCs. 3 SCs removed randomly from a total of 7 SCs.

Fig3 (a) : Hetnet2, 4 SCs

Fig.3 (b) : Hetnet2, 7 SCs.

Fig.3 (c) : Hetnet2, 4 SCs. 3 SCs removed randomly from a total of 7 SCs.

The other two networks, considered for our study have been shown in the result and discussion in Fig. 4 and in Fig. 5. For throughput and data rate calculations, we consider Rayleigh distributed small scale fading model, large scale fading factor representing shadow fading, and user distances are considered as user points are at different distances from their servicing BSs.

III. THEORETICAL FORMULATION OF METRICS

In this Section, we develop four metrics, $PI\_MU\text{DR}$, PI_SC , $OFFLOAD$, PG , and BS_SC_W for evaluating the performance of the proposed modelling of user clustering.

The downlink signal to interference and noise ratio (SINR) for the j^{th} user under the service of the MC BS (only one MC BS), and the k^{th} user under the service of the i^{th} SC BS is as follows.

A. Downlink SINR for the j^{th} macro user, interferences from all SCs:

$$SINR_j = \frac{\left(P_j |h_j|^2 g_{pl,j} \right)}{\left(\sum_{i=1}^{N_s} P_s^i |h_{s,j}^i|^2 g_{pl,j}^i + N_0 \right)} \quad (1)$$

The numerator in Eq. 1 stands for j^{th} MC user signal from its serving MC, the first term in the denominator stands for the total interference from all N_s SCs to the j^{th} MC user. P_j is

received power, h_j is the small scale fading gain, and $g_{pl,j}$ is the path loss at distance d from the MC BS. P_s^i is the power received, $h_{s,j}^i$ is small scale fading gain, and $g_{pl,j}^i$ is the path loss from the i^{th} SC BS to the j^{th} macro user. N_0 stands for Gaussian noise power in W Hertz, N_s is total number of SCs. The path loss model is defined as:

$$g_{pl,j} = cd_j^{-\alpha} \text{ and } g_{pl,i,j}^i = cd_{i,j}^{-\alpha} \quad (2)$$

Where, α is the path loss exponent, c represents large scale fading factor representing shadow fading, d_j and $d_{i,j}$ are the distances of the j^{th} user from the MC BS and the i^{th} SC respectively.

The data rate of the j^{th} MC user with bandwidth W Hertz is given by

$$\gamma_j = W \log_2(1 + SINR_j) \quad (3)$$

The sum data rate of a total n_m users under the MC BS is given by:

$$SR_m = \sum_{j=1}^{n_m} \gamma_j \quad (4)$$

B. Downlink SINR for the k^{th} user in the i^{th} SC, interference from MC BS and other SCs :

$$SINR_k^i = \frac{\left(P_{s,k}^i |h_{s,k}^i|^2 g_{pl,k}^i \right)}{\left(P_k |h_k^i|^2 g_{pl,k}^i + \sum_{l=1}^{N_s-1} P_{s,k}^l |h_{s,k}^l|^2 g_{pl,k}^l + N_0 \right)} \quad (5)$$

The numerator of Eq. (5) stands for user received signal from its serving SC. In the denominator, the first term stands for the interference signal from the MC BS, and the second term stands for the interference signals from the rest $N_s - 1$ SCs. P_k is received power, and h_k^i is the small scale fading gain and $g_{pl,k}^i$ is the path loss, of the k^{th} user in the i^{th} SC with respect to the MC BS. $P_{s,k}^i$ is the power received, $h_{s,k}^i$ is small scale fading gain, and $g_{pl,k}^i$ is the path loss, of the k^{th} user in the i^{th} SC. And $P_{s,k}^l$ is the received power, $h_{s,k}^l$ is small scale fading gain, and $g_{pl,k}^l$ is the path loss, of the k^{th} user in the i^{th} SC with respect to the l^{th} SC. ($N_s - 1$) is the number of interfering SCs, $g_{pl,k}$, $g_{pl,k}^i$ and $g_{pl,k}^l$ follow the definition in Eq. 2

The data rate of the k^{th} user in the i^{th} SC with bandwidth W Hertz is given by:

$$\gamma_k^i = W \log_2(1 + SINR_k^i) \quad (6)$$

The sum data rate of n_i users under the i^{th} SCs is given by:

$$SR_s^i = \sum_{k=1}^{n_i} \gamma_k^i$$

The sum data rate of all users under total N_s number of SCs is given by:

$$SR_s = \sum_{i=1}^{N_s} SR_s^i \quad (7)$$

We can define the percentage increase of total SC users under all SCs, PI_SCU as defined below. Let, $n_m^!$, n_m^* be the total number of macro users when clusters are constructed by k-means clustering algorithm and the proposed algorithm, respectively. Let, $\sum_{i=1}^{N_s} n_s^!$ and $\sum_{i=1}^{N_s} n_s^*$ be the total number of SC users under a total N_s number of SCs, following basic (k-means) and proposed clustering algorithms.

$$PI\_SCU = \left(\frac{\sum_{l=1}^{N_s} n_s^* - \sum_{l=1}^{N_s} n_s^!}{\sum_{l=1}^{N_s} n_s^!} \right) \times 100 \quad (8)$$

Similarly, the percentage increase of data rates of the macro users, PI_MUDR due to the proposed clustering algorithm is defined as:

$$PI\_MUDR = \left[\frac{\left(\sum_{j=1}^{n_m^*} \gamma_j / n_m^* \right) - \left(\sum_{j=1}^{n_m^!} \gamma_j / n_m^! \right)}{\left(\sum_{j=1}^{n_m^!} \gamma_j / n_m^! \right)} \right] \times 100 \quad (9)$$

Both the parameters PI_MUDR and PI_SCU are used in this paper to evaluate the performance of the proposed clustering algorithm.

The amount of data traffic difference caused by N_s SCs from the MC BS is defined as:

$$OFLD = (SM\_DR\_B) - (SM\_DR\_A) \quad (10)$$

where, $OFLD$ is the data traffic difference, SM_DR_B is sum data rate of total macro users before SCs are deployed,

and SM_DR_A is sum data rate of total macro users after SCs are added. The total number of users under N_s SCs in the new proposed and basic (k-means) algorithms contribute to $OFLD$, and are multiplied with corresponding $OFLD$ to define a new metric called $OFFLOAD$. Thus, $OFFLOAD$ in the proposed algorithm and in basic (k-means) algorithm is defined as below. The parameter $OFFLOAD$ is used as a metric in this paper to evaluate the performance of the proposed algorithm

$$\begin{aligned} OFFLOAD_{NEW} &= (SR_{n_m} - SR_{n_m^*}) \times \sum_{i=1}^{N_s} n_s^* \\ OFFLOAD_{OLD} &= (SR_{n_m} - SR_{n_m^!}) \times \sum_{i=1}^{N_s} n_s^! \end{aligned} \quad (11)$$

We also define the gain in the system data rate because of adding SCs. As is intuitively understood, there would be increase in the sum data rate of the system when service is provided by the MC and the SCs together compared to the sum data rate when service is provided by the MC only. The percentage gain PG in the proposed algorithm, and in the basic (k-means) algorithm are defined as below:

$$\begin{aligned} PG_{New} &= \frac{Sys\_Thp_{New} - Thp\_mc}{Thp\_mc} \times 100 \\ PG_{Old} &= \frac{Sys\_Thp_{Old} - Thp\_mc}{Thp\_mc} \times 100 \end{aligned} \quad (12)$$

where, Sys_Thp_{New} and Sys_Thp_{Old} are the total throughput or sum data rate of the system with macro and SCs as per new proposed algorithm and basic (k-means) algorithm. Thp_mc is the sum data rate of the system due to MC only and before addition of SCs.

Observation: Although we defined *percentage gain*, PG in Eq.12, it cannot be used as a metric for evaluating the system performance. This is because the combined data throughput of all SCs in the basic (k-means) clustering algorithm may happen to be several times higher, compared to the case in the improved proposed algorithm, as the number of users under a SC may be very small. The greatest disadvantage of the k-means clustering algorithm is that the centroid of the cluster may be quite separated from its members. Also, the SC which is placed at the centroid has small coverage area. The observed

effect on the data throughput of all users under a *SC* and hence of all *SCs* is the outcome of round robin user scheduling assumed here for data transmission by a *BS*. Hence, as shown in Eq. 12, PG_{New} is expected to be smaller than PG_{Old} , as $Sys\_Thp_{New} < Sys\_Thp_{Old}$. This is further explained in the next section.

As more users are included under a *SC* in the proposed clustering algorithm compared to the basic (k-means), we define energy efficiency for *SCs* considering together as below:

$$\begin{aligned} BS\_SC\_W_{New} &= SC\_STHP_{New} / TP_s \\ BS\_SC\_W_{Old} &= SC\_STHP_{Old} / TP_s \end{aligned} \quad (13)$$

Where, $BS\_SC\_W_{New}$ and $BS\_SC\_W_{Old}$ are the sum data rate of the *SCs* per watt as per the proposed and basic (k-means) clustering algorithms, respectively. SC_STHP_{New} and SC_STHP_{Old} are the sum data rate of the *SCs* together as per the proposed and basic (k-means) clustering algorithm, respectively, TP_s is the total transmission power of the whole *SC BSs* together. The performance of the proposed clustering algorithm is evaluated using energy efficiency for *SCs* as defined in Eq.13.

IV. SIMULATION RESULTS AND DISCUSSIONS

We consider that the *MC BS* and all *SC BSs* service data traffic to their users independent of each other, and the users under a *BS* are scheduled using round robin algorithm. As the users under the macro cell are large in numbers, the round robin time frame length is much longer and results in smaller individual user data throughputs. This is opposite in *SCs* where the round robin time frame length is much smaller resulting in much higher individual user data throughputs. Further, for simulation studies, we consider the positions of the users and hence their distributions shown in various networks remain static. We consider Rayleigh distributed small scale fading model, large scale fading factor representing shadow fading, and users' geographical distances from *BSs* to evaluate users' data rates

We consider 4 different *HetNets*, each in a 1500-meter circular geographical area and each with 1 *MC BS* and 4-8 *SC BSs*. The *MC BS* is located at center and *SC BSs* are located at the centroids of the clusters. We first apply the k-means algorithm, thereby obtaining the locations for the *SC BSs*. We then apply the proposed algorithm to the cluster points from *k-means* algorithm, thereby obtaining the new locations of the *SC BSs*

Table 1

Parameters	Values
Path loss exponent (α)	2.5
Large scale fading factor (c)	$10^{-3.53}$
Bandwidth (W)	180 KHz
Time slot for service	0.5×10^{-3} seconds
Noise power spectral density	-174 dBm/Hz
Transmit power of MC BS	46 dBm
Transmit power of SC BSs	23 dBm
Radius of MC	1500 m
Radius of a SC	100 m

In each case, the users within an area of 100 meter of the locations of the *SC BSs* are taken to be the users for service by the *SCs*. The remaining users in the circular geographical area are serviced by *MC BS*. Parameters for the *HetNets* considered in this paper are shown in Table 1.

Of the 4 different *HetNets*, two are shown in Fig.2, and Fig.3 in the section of System Model above. The other two networks are shown in Fig.4, and Fig.5 below. Fig. 4 (c) and Fig. 5 (c) shows remaining 4 *SCs* after 3 *SCs* are switched off randomly from Fig. 4 (b) and Fig. 5 (b), respectively.

Fig.4 (a): *HetNet* 3, 4 *SCs*

Fig.4 (b): *HetNet* 3, 7 *SCs*

Fig.4 (c): *HetNet* 3, 4 *SCs*. 3 *SCs* removed randomly from a total of 7 *SCs*.

Fig.5 (a): *HetNet* 4, 4 *SCs*

Fig.5 (b): *HetNet* 4, 7 *SCs*

Fig.5 (c): *HetNet* 4, 4 *SCs*. 3 *SCs* removed randomly from a total of 7 *SCs*

The experimental simulation results of PI_MUDR and PI_SCU for the four *HetNets* are shown in Fig.6 and Fig.7, using Eq. 8 and Eq. 9 respectively. It is observed that there are considerable increase in the *MC* user data rates, and in the number of users in different *SCs*. The increasing trend is shown in case of all *HetNets*.

Fig. 6: Percentage increase in throughput of macro users applying proposed algorithm for *HetNet*1, 2, 3, and 4.

Fig. 7: Percentage increase in *SC* users applying proposed algorithm for *HetNet*1, 2, 3, and 4.

The results of using the proposed algorithm in all 4 *HetNets* are shown below by simulation in the MATLAB. To evaluate the proposed algorithm, the parameter *OFFLOAD*, using the proposed and basic (*k-means*) clustering algorithms as in Eq.11, experimental simulation results for the four *HetNets* are shown in Fig. 8 (i-iv) as bar diagrams. The metric shows clear advantage in using the proposed algorithm. The increasing trend is shown in case of all *HetNets*.

Fig. 8 (i): Data offloaded by *SCs* in *HetNet*1 applying proposed algorithm and *k-means* algorithm

Fig. 8 (ii): Data offloaded by *SCs* in *HetNet*2 applying proposed algorithm and *k-means* algorithm

Fig. 8 (iii): Data offloaded by *SCs* in *HetNet*3 applying proposed algorithm and *k-means* algorithm

Fig.8 (iv): Data offloaded by *SCs* in *HetNet*4 applying proposed algorithm and *k-means* algorithm

As is observed in the discussion of Eq.12, the percentage gain, PG in the sum data rate of the system when service is provided by the MC and the SCs together compared to the sum data rate when service is provided by the MC only is worse while using the proposed algorithm. The reason is explained in the observation. The experimental simulation results for the four *HetNets* are shown in Fig. 9 (i-iv).

Fig.9 (i): Percentage gain in system data rate for *HetNet1* applying proposed Algorithm and k-means Algorithm.

Fig.9(ii): Percentage gain in system data rate for *HetNet2* applying proposed Algorithm and k-means Algorithm.

Fig.9 (iii): Percentage gain in system data rate for *HetNet3* applying proposed Algorithm and k-means Algorithm

Fig.9 (iv): Percentage gain in system data rate for *HetNet4* applying proposed Algorithm and k-means Algorithm

The performance metrics $BS\_SC\_W_{Old}$ and $BS\_SC\_W_{New}$, the sum data rate of the SCs per watt using the basic (k -means) and new proposed algorithm, respectively are evaluated for the four *HetNets*. The experimental simulation results are shown in Fig. 10 (i-iv) using Eq.13. As is observed from the bar diagrams, there is increase in the energy efficiency of the combined SCs in all the four *HetNets*.

Fig. 10 (i): Energy Efficiency in *HetNet1* applying proposed algorithm and k-means algorithm

Fig. 10 (ii): Energy Efficiency in *HetNet2* applying proposed algorithm and k-means algorithm

Fig.10 (iii): Energy Efficiency in *HetNet3* applying proposed algorithm and k-means algorithm

Fig. 10 (iv): Energy Efficiency in *HetNet4* applying proposed algorithm and k-means algorithm

As stated in Section 2, for the second method of *HetNet* design, following the k -means and the proposed algorithm, we start with y number of SCs where $y = 8$ and switch off z number of SCs where $z = 1, 2, 3, 4$ in steps. The remaining SCs $y-z = x$, where $x=7, 6, 5, 4$ in the *HetNet* are the results of randomly switching off SCs from the initial scenario of total 8 SCs . The simulation results of switching off z number of SCs are shown in Table 2 and Table 3. All four metrics are dependent on SCs that are switched off from initial 8 SCs . We are of the opinion that the decision of which SCs may be switched off depends on certain factors which may be technical, financial as well as administrative. Here we switched off SCs randomly with no obvious reason.

The simulation results of PI_MUDR , PI_SCU , as shown in Table 2 are expected to be different from the results shown in Fig. 6 and Fig. 7. Similarly, the simulation results of $BS\_SC\_W_{New}$, and $BS\_SC\_W_{Old}$ as shown in Table 3 are expected to be different from the results shown in Fig. 10. Hence, the values of all four metrics are also dependent on the user distributions in the *HetNets*. However, the proposed algorithm always provides positive values of the metrics studied in this paper. As there are a greater number of users in SCs , the centers of which are obtained by using the proposed algorithm, the data traffic offloading from the macro BS by the SCs is always larger than the case of using k -means algorithm. The way how we retain or design *HetNet* for a particular number of SC BSs/SCs may decide the performance of *HetNets*. The design objectives should satisfy the required

service coverage or total transmit power available for the SC BSs.

TABLE-2

No. of SCs.	<i>HetNet 1</i> <i>PI_MUDR</i> <i>PI_SCU</i>		<i>HetNet 2</i> <i>PI_MUDR</i> <i>PI_SCU</i>		<i>HetNet 3</i> <i>PI_MUDR</i> <i>PI_SCU</i>		<i>HetNet 4</i> <i>PI_MUDR</i> <i>PI_SCU</i>	
8	19.85	75.71	12.16	20.2	13.07	29.95	14.43	39.18
7	18.75	70.59	9.56	16.41	9.15	22.95	13.83	37.58
6	15.14	82.08	7.17	13.19	8.31	20.79	8.94	39.23
5	9.49	70.1	4.84	14.84	3.37	6.85	6.72	35
4	7.21	60.49	2.77	12.93	1.13	3.48	5.31	34.34

TABLE-3: Energy Efficiency (EE)

Number of SCs.	<i>HetNet1</i>		<i>HetNet2</i>		<i>HetNet3</i>		<i>HetNet4</i>	
	Proposed Algorithm	<i>k-means</i> Algorithm	Proposed Algorithm	<i>k-means</i> Algorithm	Proposed Algorithm	<i>k-means</i> Algorithm	Proposed Algorithm	<i>k-means</i> Algorithm
4	1.2×10^8	1.1×10^8	2.09×10^8	1.77×10^8	1.28×10^8	1.27×10^8	1.09×10^8	1.42×10^8
5	1.32×10^8	0.94×10^8	1.97×10^8	1.74×10^8	1.49×10^8	1.48×10^8	1.17×10^8	1.33×10^8
6	1.24×10^8	0.93×10^8	1.89×10^8	1.76×10^8	1.62×10^8	1.61×10^8	1.26×10^8	1.42×10^8
7	1.31×10^8	0.94×10^8	1.85×10^8	1.68×10^8	1.76×10^8	1.71×10^8	1.28×10^8	1.37×10^8
8	1.35×10^8	0.99×10^8	1.89×10^8	1.69×10^8	1.92×10^8	1.92×10^8	1.22×10^8	1.31×10^8

V. CONCLUSION

We proposed an improved grouping or clustering algorithm of user points, non-uniformly distributed (*Cox* process model) in a circular area, over the *k-means* algorithm. We use the algorithm to obtain the location centers of SCs which overlays the *MC BS* area. In the given circular service area of the SC, maximum possible number of user points are obtained. The improved cluster centers (*centroids*) are obtained from the initial spatial clusters. We first construct users' groups using the *k-means* algorithm, then an area of radius 300 meter is considered around the initial *k-means* centroids. As the SCs are deployed to service the hot spots, edge users, or in general to offload the data traffic from the *MC BS*, location of SCs should cover maximum possible users within its service area. By doing so the offloading is maximum possible, and hence increase in the data rate per macro user happens to be maximum possible. We define in this paper two metrics like *PI_MUDR*, *PI_SCU*, where the first one quantifies the

percentage increase in per macro user data rates and the second one quantifies the percentage increase in the total number of users under all SCs. We also define two more metrics *OFFLOAD*, and *BS_SC_W*, where the first one characterizes the advantages in deploying the SCs and the second one characterizes the energy efficiencies of the SCs, resulting from application of the proposed algorithm. The simulation results are shown for 4 different *HetNets* with 4-8 number of SCs, with 1000-1400 user points constructed using *Cox* process. The results show the validity of the claim that the proposed algorithm is an improved one over the basic *k-means* clustering algorithm. We also experimented with random switching off some SCs observing that the performances of *HetNets* remain similar. We intend to explore this further in our future report. We also intend to consider spatial mobility of users within the *MC* service area.

DECLARATION

I. Funding – Not Applicable

- II. Conflicts of Interest/Competing Interest – No conflicts of Interest.
- III. Availability of data and material – Standard parameters are used and algorithm developed is of our own.
- IV. Code availability – For simulation Matlab is used.

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Figures

Figure 1

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Figure 2

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