Efficient Data Offloading using Small Cell Wi-Fi

Vinila Nagaraj[#1], Shashiprabha K P[*2]
[#]Assistant Professor, Department of ECE, R.V College of Engineering
Mysore Road, Bengaluru, India
*MTech – Communication Systems, Department of ECE, R.V College of Engineering
Mysore Road, Bengaluru, India

Abstract:

User demands are so high these days that operators are compelled to think in alternate dimensions to increase the capacity with little modifications in the existing system. Small Cell Wi-Fi is one of the possible solutions which is used to offload the data access request from the macro cellular Base Station (BS) to Small Cell Base Station (SCBS). This work considers Access Point (AP) as the SCBS. Algorithms related to small cell formation and locating AP positions for the deployment are discussed. Results are taken in terms of the coverage for the clustering techniques and are used for comparison. Offloading process is modelled as Markov Chain by assigning weights to optimize the calculations.

Keywords—*Small Cell, Wi-Fi, SCBS, Access Point, Offload*

I. INTRODUCTION

Technologies in the communication field are expanding too fast in a way that the idea that has been put forth today may appear old in the next few days. All possible means of communication today have moved to wireless and now the innovations are made to explore different dimensions of the wireless technologies so as to increase the capacity and to increase the speed of the communication. There is a prediction that the global traffic might increase by 1000 fold in 2020 with respect to the global traffic levels of 2010 [1]. Increase in the number of users or the usage of smart phones have led to the increase in data traffic hits to the base stations which in turn have triggered the search for alternate solution that integrates with the existing system with the little changes to it and with the less hurdles of integration. Small cell (also referred as HetNets) is one of the possible solutions in this regard [2]. Integration of small cell base stations with the macro cellular base station leads to the concept called data offloading where the requests from the user to the macro cellular base station can be transferred to the small cell base station without the risk of dropping the request due to insufficient resources at the macro cellular base station to handle the request.

Some of the small cell deployment techniques like static, dynamic and mobile deployments have already been put forth as an idea [3] and offloading techniques over the licensed band and unlicensed band have also been put forth [4]. These techniques have been simulated with the real environment constraints and results show positive approach towards the deployment of small cell base stations. It has also been shown that Wi-Fi Access Points can be used as the small cell base stations and can be used to offload the data traffic from the macro cellular base station [5]. But the discussions on the techniques that could be applied for clustering the user elements to form the small cells is still in its infant stage and the clustering models like Greedy Approach [2] does not seem to be valid for the cell coverage where the users are uniformly distributed across the coverage of the macro cell.

In this work we first show how the greedy approach fails in the uniformly distributed users' scenario. We then show that another clustering algorithm called k-means algorithm that is widely used in the data mining application can be applied in the clustering of the users in the coverage of the macro cellular base station and form the small cells for the data offloading. We then put forth an idea called the weighted Markov chain that could be used for selecting the access points to offload the data request from the mobile user.

II. SMALL CELL AND WIFI

The Access Point is considered to be Small Cell Base Station (SCBS) if the Wi-Fi coverage is chosen to be the small cell as in [6] or AP can also be used to aid the SCBS if the SCBS is chosen to operate both in unlicensed and licensed band and the delay tolerant requests are offloaded to access point as in [7]. In this work access point is considered as the SCBS. The macro cellular BS is considered to have a pool of bands which is dedicated to answer the requests from UEs (user elements) in licensed band and the small set is reserved for control signal exchange for offloading purposes. If in case the macro cellular BS runs out of the licensed band to answer the requests, the requests are offloaded to access points with the aid of control signals that are exchanged between macro cellular BS and SCBS and the control signals are transmitted in the band chosen from the reserved pool of licensed bands that are used for dedicated purposes.

III. GREEDY APPROACH

The AP deployment locations have to coincide with the heavy traffic access requests locations. The problem for the deployment of AP locations is formulated as follows in the Greedy Approach. Consider,

$$R = \{(r_1, w_1), (r_2, w_2), \dots\dots\dots\dots, (r_m, w_m)\}$$

as the set of list of pairs representing user locations and the weights of the user requests. Consider $A_D = \{c_1, c_2, \dots\dots.c_K\}$ as the K number of APs that the operator wish to deploy inside a macro cellular BS. And let $P_D = \{\, p \in [1, m] | \exists k \in [1, K]: |r_p - c_k| \le R\}$ be the set denoting the indices of data requests to the macro cellular BS and is covered by the possible AP deployments A_D. The objective in this approach is to maximize the sum over the AP deployment locations:

$$\sum_{p \in P_D} w_i r_i$$

Hence the AP deployment locations are chosen such that this summation is maximized and there by maximizing the offload.

The entire region is divided into sub regions as shown in the Fig 1 of NXN grids. The side of the square is taken as $\sqrt{2}R$ that is the biggest square that fits to the AP coverage of radius R. For each possible AP deployment locations user request densities is calculated and the K possible AP deployments corresponding to K higher density requests are chosen as the AP Deployment locations.

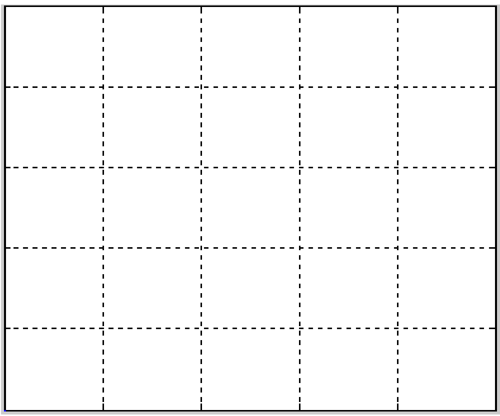

Fig 1: Nxn Subregions Formed Inside the Bs Coverage In Greedy Approach

Algorithm 1: Greedy Approach

1. K = Number of AP deployments
2. NXN subregions
3. For each subregion indexed with i and j calculate the user densities with:
UserDensity[i][j] = sum of the users in the subregion (i,j)
4. c=0
5. while c<=K
6. Obtain the maximum density from UserDensity [i][j] and make the centroid of the subregion as AP deployment location
7. Mask the user locations that are in the range of this sub region and update the UserDensity Matrix accordingly.
8. c= c+1

IV.K-MEANS APPROACH

K-Means is one of the data mining algorithms which is widely used for clustering the data. With slight modifications, this approach can be aptly applied to clustering of users in the small cell and to find the AP deployment locations. The approach tries locating the centroids which are very far apart initially to avoid the formation the clusters which are nearby. The centroids referred here is the AP deployment locations. Euclidean distance between each centroid and each UE locations are calculated and UE is assigned to the cluster of nearest centroid. Once the clusters are formed, the centroids are re-calculated. This process of centroids calculation and assignment of UEs to the cluster are iterated until the algorithm converges that is the centroids calculated in the previous iteration is same as the centroids calculated in the current iteration.

Algorithm 2: K-Means Approach

1. K= Number of AP deployments
2. Select K random centroids
3. For each user location calculate the Euclidian distance and assign the user to the cluster with the nearest centroid.
4. After the K clusters formation recalculate the centroid which is the mean of all the user locations of the particular cluster.
5. Repeat steps 4 and 5 until the convergence that is centroids obtained in the previous iteration is same as the current iteration.

V. OFFLOADING TECHNIQUES

UEs in macro cellular BS coverage are not static. They are mobile and hence the particular UE which sends the request to the macro cellular BS for data may not be in the same cluster as it was before while creating the clusters for calculating the AP deployment locations. Hence the distances have to be recalculated to select the AP to offload the data request. To optimize the calculation for the selection of AP Markov chain model is used. The user trace statics can be modelled as the semi Markov chain model. That is the current location of the UE is tracked based on the user trace statistics which has been acquired and modelled as Markov chain. Based on the user trace statics, weights are assigned to the next possible state (location in this case) of the UE. For simplicity, in this work distance is taken as metric rather than the user trace statics for assigning the weights in the Markov model. It is assumed that the probability of user sending the request from cluster where it was initially assigned is more than the probability of that particular user sending the request from the other clusters. Hence if there are three clusters the weights for the users belonging to the particular cluster sending the request to the BS from the other cluster can be modelled as below.

$$M = \begin{bmatrix} 0.5 & 0.375 & 0.125 \\ 0.25 & 0.5 & 0.25 \\ 0.125 & 0.375 & 0.5 \end{bmatrix}$$

The weights are assigned in the scale of 0 to 1. The calculation for each AP to offload the data to any one of the AP is done based on the weights. And this reduces offload delay that is the time required by the BS to transfer the request to the nearby AP.

VI. SIMULATION RESULTS

Simulations are done in MATLAB. The coverage of the clustering based on the two approaches that is Greedy and K-Means are compared for varying number of users in the coverage of single BS. Fig 2 shows the cluster formation and coverage of Greedy Approach for number of clusters equal to 3 with BS coverage to be considered as 100 units and the radius of AP coverage as 10 units. The subregions created for the simulation is 5X5. The scenario considered is the uniform distribution of users that is there are equal number of users in each subregion. The figure clearly shows the Greedy approach fails when the users are very much uniformly distributed in the BS coverage since this approach chooses the K (number of clusters that the operator is willing to form or the number APs to be deployed) subregions with the maximum densities. Since most of the subregions have uniform density, adjacent clusters are formed and this approach fails to cover vast BS coverage. But from Fig 3 one can conclude that K-Means approach tries to create the cluster which are very separated from each other and tries to cover the users as much as possible.

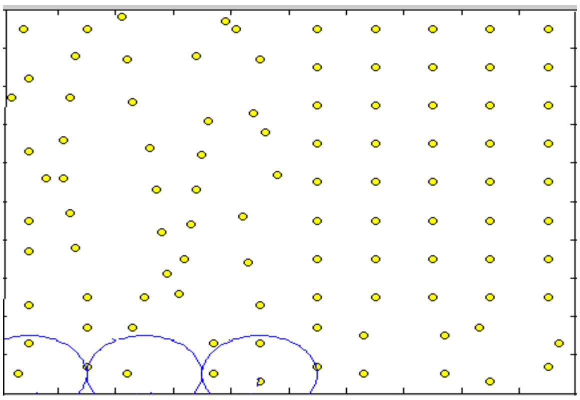

Fig 2: Cluster Formation with the Radius of AP Coverage = 10 for 5X5 Subregions Using Greedy Approach

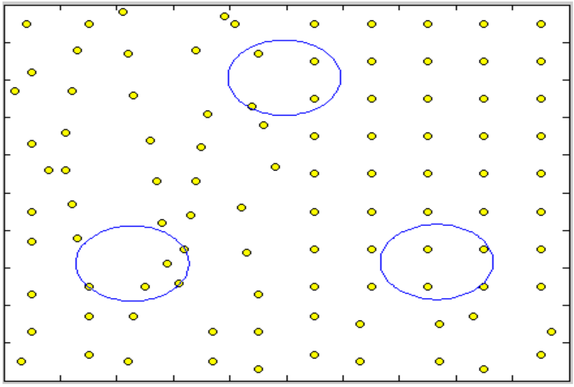

Fig 3: Cluster Formation with the Radius of AP Coverage = 10 Using K-Means Approach

Fig 4 shows the plot for 100 users with varying number of AP deployments that try to cover the users based on Greedy and K-Means Approach. It can be clearly concluded from the results that K-Means performs well both in crowded region as well as uniform region where as Greedy approach performs well only in the crowded region.

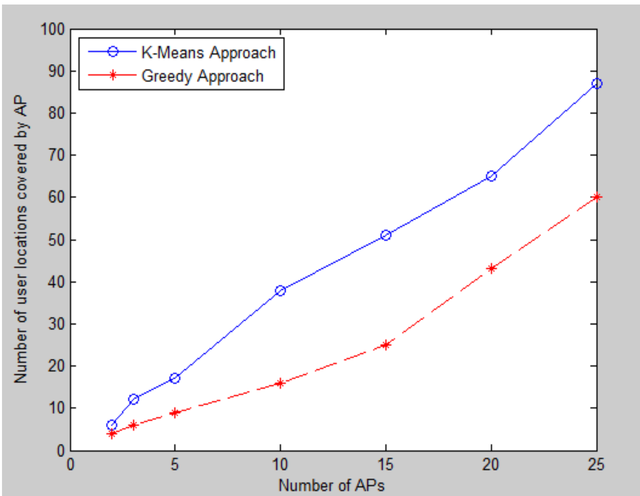

Fig 4: Plot For The AP Coverage For The Varying Number of Aps For 100users in a Single BS Coverage Based on K-Means and Greedy Approach

VII. CONCLUSION

In this work, the comparison between two approaches that is Greedy and K-Means for the cluster formation and AP deployment is done and it is shown that K-Mean approach can be applied well for both crowded and uniform distribution of users in the BS coverage. It is also been proposed that modelling the offloading technique as semi Markov chain simplifies the computations and minimizes the delay for offloading the request.

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