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Energy Efficient Base Station Deployment in Cellular Network.

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Abstract

In the last two decades, the need for a fast and ubiquitous wireless network has increased to unexpected levels. So we develop an energy-efficient base station deployment framework for cellular networks. Micro base station deployment increases the total capacity of the network. However, increasing the number of micro base stations excessively may reduce the energy efficiency of the network. Therefore, we examine the energy efficiency aspect of the micro base station deployment problem. This problem can be divided into two subproblems: choosing feasible candidate micro base station locations and selecting the optimum set of micro base stations among the candidate locations. The proposed approach first chooses the subset of the feasible locations as candidate locations, and then selects the micro base stations which maximize the energy efficiency of the network iteratively. It is hoped that the proposed algorithm is a constant-factor approximation of the optimal solution.

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Chapter 1

Introduction

1.1 Background

Now-a-days the number of user of wireless network is increasing in an unexpected level.To cope up with the increasing traffic demands mobile operators have to find some better solution.One solution can be deploying more Base Stations.The problem of more BSs deployment is to determine where (locations),how many and which type (macro/micro)of BSs need to be deployed in an energy-efficient manner.

Deploying more Macro BSs can not be a better solution as deploying more Macro BSs reduces the gain because of intercell interference.One of the technologies that can provide better data rates while creating intercell interference is Heterogeneous Networks(HetNets), e.g.,[1],[2],[3]. HetNets seek attention because of its improvement of overall capacity.Another problem of deploying more BSs is although deploying more BSs increases the power consumption but it can be the cause of the emission of Green house gas in serious levels.To cope up with this problem Green Cellular Communication has got our attention , e.g., [4],[5],[6],[7].

As there is problem of deploying more Macro BSs,deploying Micro BSs can be better than deploying more Macro BSs.Each additional Micro BS increases both the capital expenditures (CAPEX) and operational expenditures(OPEX) of the system in Heterogeneous Network[8].Additional Micro BSs also comsume lower power than the Macro BSs .So , the solution of deploying more BSs can be resolved by deploying additional Micro BSs in an optimal way that meets the criteria.Our proposed algorithm can find the optimum solution while satisfying the increasing traffic demands of the network.

1.2 About Cellular Network

A cellular network is a radio network distributed over land through cells.Here each cell includes a fixed location transceiver known as base station. These cells together provide radio coverage over larger geographical areas.

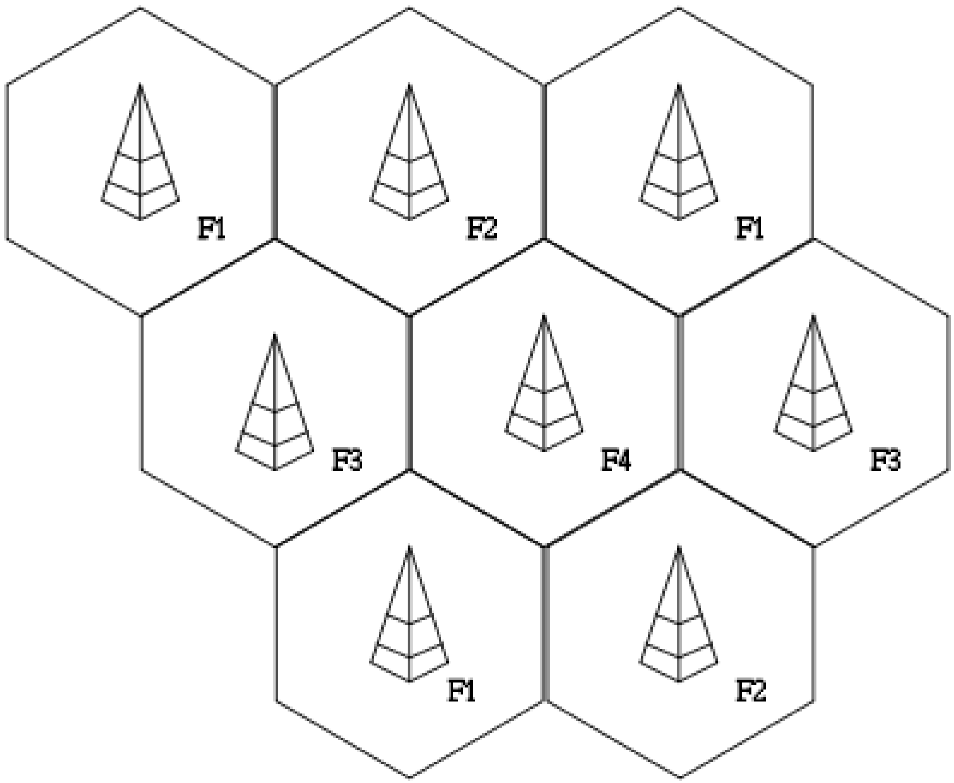


Figure 1.1: Cellular Network.

There are different types of base stations. They are -

- Macro
- Micro
- Pico and
- Femto

1.2.1 Macro Base Station

- Cell radius 1-30 km.
- High power consumption.
- Cover larger area.

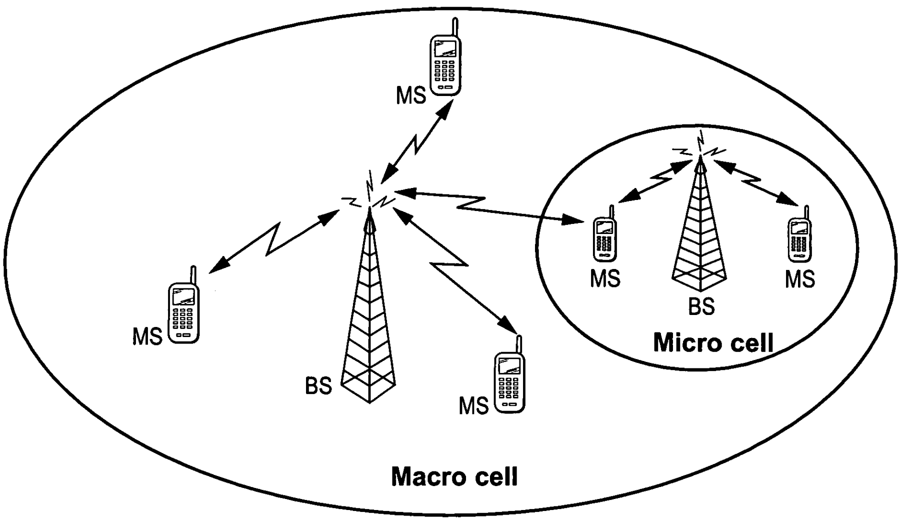


Figure 1.2: Macro and Micro base stations.

1.2.2 Micro Base Station

- Cell radius 200-2000m.
- Low power consumption.

- Cover Small area.
- Can re-use same frequency.

1.3 Motivation

- The demand for fast and ubiquitous wireless network has increased to unexpected level .
- User distribution or density based approach can improve the system capacity.
- There are scopes to improve published base station deployment algorithm in cellular network.

1.4 Challenges in deployment

Deploying base stations has two challenges-

- Choosing feasible locations for base stations to deploy .
- Selecting optimal set of micro base stations.

1.5 Limitations of base station deployment

- Addition of more macro base stations increases inter cell interference.
- Addition of more micro base stations increases total capacity but reduces energy efficiency .
- Deployment of more base stations increases energy consumption of the network as well as causing the growth of emission of green house gases to very high level .

1.6 Problem Statement

- Developing energy efficient base station deployment framework.
- Maintaining the capital expenditure(CAPEX) and operational expenditure(OPEX).
- Increasing energy efficiency and total capacity of the network .
- Therefore, the final objective is to achieve a balance among
  - Energy efficiency ,
  - Total capacity and
  - CAPEX and OPEX.

1.7 System Model

In this System Model section, the System Model, power consumption of the Base stations and the energy efficiency problem formulation are represented.

Considering a wireless network in which all users are treated by sets of macro base stations denoted by B_M and micro Base stations denoted by B_m. Here M indicates macro BSs, m Indicates micro BSs and B inicates all BSs in the network area throughout the rest of the paper. are denoted by i.e.,$B = B_M \cup B_m$. The mobile users are linked with the base station which provides the maximum signal strength at the location of that particular user. If more than one base stations provide same signal strength at the user location, the user selects one of the BSs randomly.For transmitting data users require a bandwidth allocation.The signal-to-interference-plus-noise ratio (SINR) of a macrocell associated to user k on subcarrier n can be written as

$$\gamma_c^{(n)} = \frac{P_M^{(n)} g_{k,b}}{\sum_{b' \in B_M, b' \neq b} P_M^{(n)} g_{k,b'} + P_m^{(n)} g_{k,b'} + \delta^2} \qquad (1.1)$$

where $P_M^{(n)}$ and $P_m^{(n)}$ are the transmit power of a macro cell M and a micro cell m on sub carrier n, respectively.In this paper we mainly focus on the down-link communication.So the same ideas can be applied for the up-link as well.The channel gain from Base station b to user k is denoted by$g_{k,b}$.The channel gain includes the path loss attenuation, shadow fading, and multi-path fading components. The effective thermal noise over a sub carrier is denoted by δ^2. Similarly,the SINR for micro cell user k on sub carrier n can be written as

$$\gamma_k^{(n)} = \frac{P_m^{(n)} g_{k,b}}{\sum_{b' \in B_M} P_M^{(n)} g_{k,b'} + P_m^{(n)} g_{k,b'} + \delta^2} \tag{1.2}$$

For simplicity, we use the same symbol $\gamma_k^{(n)}$ for SINR of both macro and micro cell users. In the sequel, the capacity of user k can be written as

$$C(k, B) = \sum_{n=1}^{N_k} W_k^{(n)} \log_2(1 + \gamma_k^{(n)}) \qquad [bits/sec] \tag{1.3}$$

where $W_k^{(n)}$ denotes the bandwidth of sub carrier n of user k and Nk is the number of subcarriers assigned to user k.In this paper,we consider equal bandwidth scheduling [16]. In this scheduling, each and every BS shares its resources equally among its users. In LTE systems, the smallest coarseness which can be assigned to a user is a resource block with 12 subcarriers. Therefore, if K users are associated with the base station b with N_{RB} RBs, $K_h = \text{mod}\ (N_{RB}, K)$ of the users get12$(\lfloor N_{RB}/K \rfloor + 1)$ subcarriers, whereas the rest of the users receive $12\lfloor N_{RB}/K \rfloor$ subcarriers. In this paper, we assume that a BS allocates equal power on its subcarriers.

The energy efficiency of the network can be improved in two ways.The ways are either increasing the total capacity of the network and providing the same power or decreasing the consumed power of the network and providing the same capacity.Though macro BSs provide better coverage and data rate, macro BSs consume higher power than the micro BSs. On the other hand, the transmission power of micro BSs is less than the macro BSs but they cover less area. However, micro BSs consume less power and do not interfere with the other transmissions as demanding as macro BS transmissions. So, micro BSs are more energy efficient than the macro BSs especially in densely deployed networks. For this reason we have proposed to deploy micro BSs to the network as a basic for macro BSs to maximize the energy efficiency of the network and for satisfying the traffic demand.

The power consumption of a BS consists of two parts. The first part is the static power consumed by the BS with no transmission and the second part depends on the load and the transmission power of the BS. There are many power consumption models proposed in the paper, see,e.g., [17],[18], [19]. In our paper, we use the power consumption model proposed in the paper [17]. It is given by

$$\begin{aligned} P_M &= P_{0,M} + \triangle_M P_t x \\ P_m &= P_{0,m} + \triangle_m P_t x \end{aligned} \tag{1.4}$$

where P_M , P_m and $P_t x$ are the average consumed power per macro BSs, micro BSs, and transmission power respectively. $\triangle_M$ and $\triangle_m$ scale the transmission power depending on the load. $P_{0,M}$ and$P_{0,m}$ denote the static part of the power consumption of the macro and micro BSs respectively.Earlier in this paper we assume that users always have data to transmit with full buffer. In addition, no power control algorithm is used. Therefore, BSs are fully utilized and $\triangle_M$ and $\triangle_m$ are constant for all BSs. Then, the energy efficiency ($\eta_{EE}(B)$) of the network can be written as

$$\eta_{EE}(B) = \frac{\sum_{k \in K} C(k,B)}{N_B P_M + N_b P_m} \qquad [bits/Joule] \tag{1.5}$$

where N_B and N_b are the number of macro and micro BSs in the network, respectively.

Chapter 2

Related Works

There are several number of works done previously on the Energy-Efficient base station deployment in HetNets.The authors of [9],[10],[11],[12] have mostly concentrated on power control and resource allocation problems.However, the deployment of micro BSs and the energy efficiency aspects of the problem have not been fully investigated.A related topic described in [13] make inquiries about the ASE(Area Spectral Efficiency).The authors of [13] deploy micro BSs to an area which is covered by macro BSs to increase the ASE of the network.The authors observe that if the cell boundaries are selected as candidate locations then the ASE environment increases the coverage of the Base Station.A greedy based algorithm is proposed in this aspect.The proposed algorithm runs until the requirement is fulfilled.The authors of [13] consider the cell edges as candidate locations.But if energy efficiency of the network is considered ,the fact is cell edges may not be good candidates always.The proposed algorithm in [13] also works poorly for the clustered user distribution scenarios.The algorithm that we will propose is designed to overcome the problem.

The authors in [14] deploy low power base stations to minimizes the outage of the network.They firstly deploy inexorable number of micro BSs and then iteratively shift the locations of these BSs noted that the system characteristics, the path loss and shadowing are strictly dependent on the location of the BSs.Though the proposed algorithm in [14] performs well for the test cases, obtaining these parameters in every iteration may not be practical in real BS topologies.

The authors in [15] investigate the energy efficiency of micro BSs on the hexagonal grids.In this paper [15] , micro BSs are located to the cell edges as candidate locations to minimize the inter cell interference in HetNets but the fact is larger gain can be acquired depending on the user distribution in the network.

Among all these related works some works are described below :

2.1 Optimal new site deployment algorithm for heterogeneous cellular networks

In this work authors propose a set of Scalable Multi-radio deployment AlgoRiThms (SMART) - a class of fast-convergent meta-heuristic algorithms. SMART has direct coupling with network KPI that needs to be optimized and is based on traditional meta-heuristic algorithm. In order to accelerate the convergence speed, the proposed SMART starts with an initial solution preselected by a non-iterative algorithm using the traffic characteristics in the analyzed network.

2.2 Energy efficiency aspects of base station deployment strategies for cellular networks

In this work authors investigate on the impact of deployment strategies on the power consumption of mobile radio networks. They consider layouts featuring varying numbers of micro sites per cell in addition to conventional macro sites. They introduce the concept of area power consumption as a system performance metric and employ simulations to evaluate potential improvements of this metric through the use of micro base stations. The investigations show that for the studied propagation scenarios and under the employed power consumption models, the power savings from deployment of micro base stations are moderate in full load scenarios and strongly depend on the offset power consumption of both macro and micro sites. Furthermore, the feasible offset power consumption of micro sites increases inversely proportional with the average traffic load.

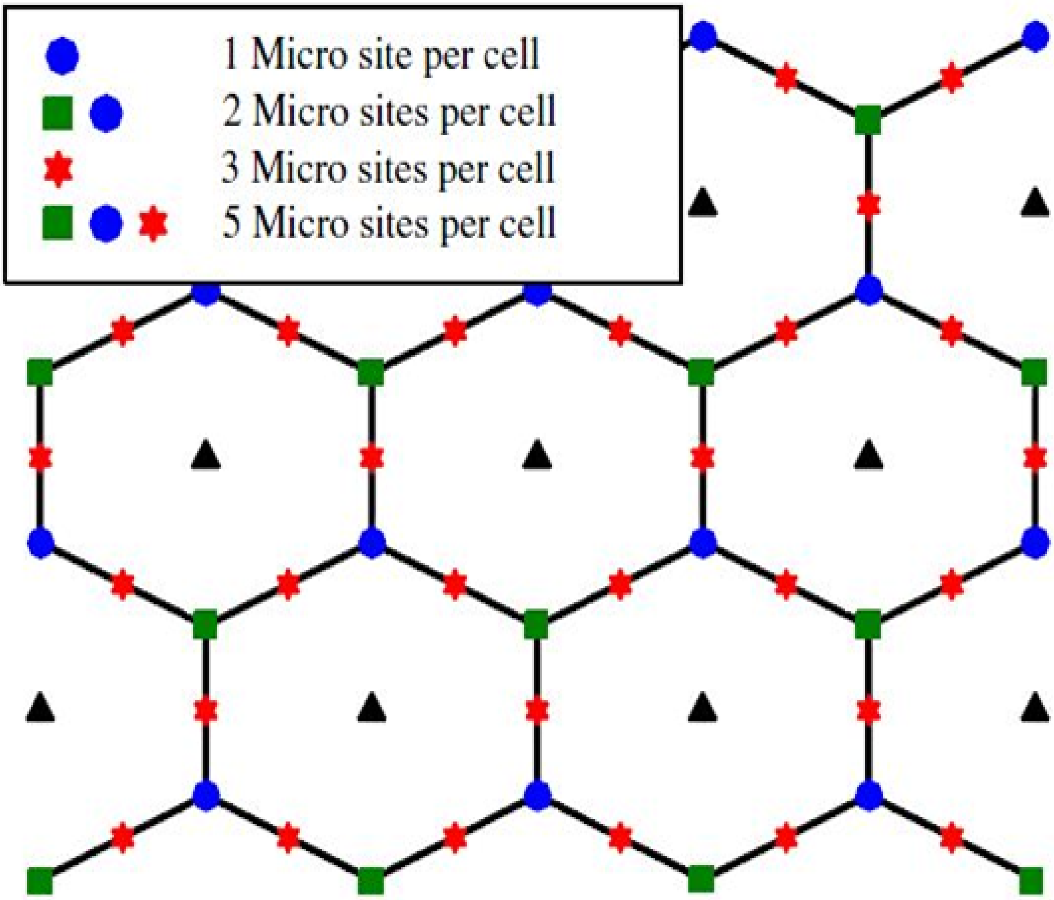


Figure 2.1: Positioning of micro sites within the macro grid

2.3 Energy-aware hierarchical cell configuration from deployment to operation

In this approach, an energy-aware hierarchical cell configuration framework is proposed that provides both theoretical and practical guidelines on how wireless network operators manage their BSs.In this work authors specifically focused on a problem pertaining to total energy consumption minimization while satisfying the requirement of ASE, and decomposed it into deployment problem at peak time and operation problem at off-peak time. For the deployment problem, authors proposed a constant-factor approximation greedy algorithm to find the maximum efficiency.

2.4 A greedy algorithm for energy efficient base station deployment in heterogeneous networks

A greedy BS deployment algorithm is proposed to improve the energy efficiency of the network. Imprudent increase of the number of micro BSs may harm the energy efficiency of the network. In this approach there are two steps :

- First step is to select a set of feasible micro BS locations.
- Then greedily deploys a subset of them until the required capacity of the network is satisfied.

2.4.1 Candidate Selection

we divide the network area into equal grids and select a candidate location in each grid.

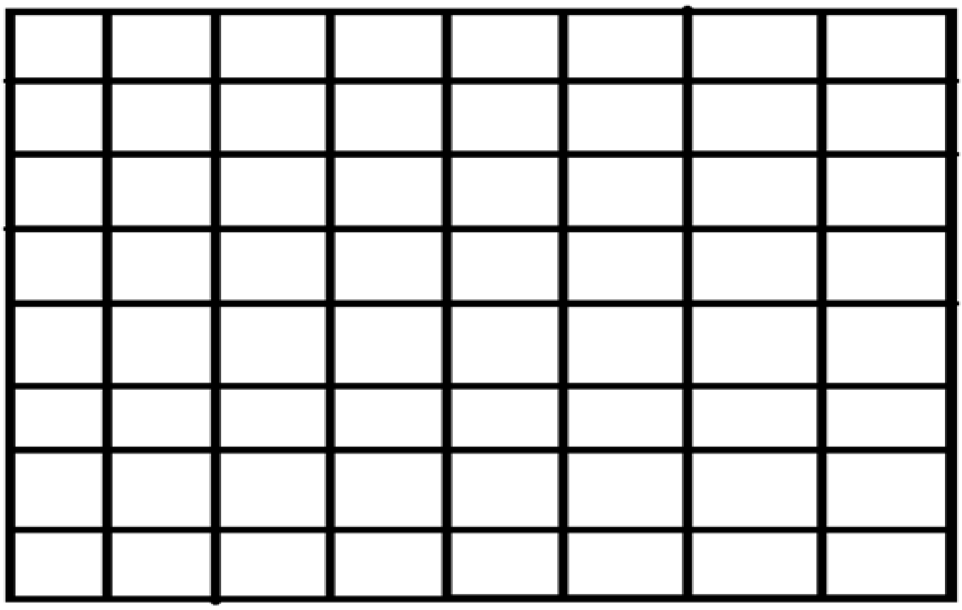


Figure 2.2: Square Grids

This approach performs well for both clustered and dispersed networks. However, it does not guarantee that a feasible location exists in every grid. In addition, if more than one feasible location exists in a grid, selection of the candidate location is another problem to solve. Therefore, the following approach is proposed. If all the neighboring grids of the center grid have at least one feasible location, the candidate location which is closest to the center of the grid is selected as a candidate. In cases where some of the neighboring grids do not have any feasible location, the closest feasible location to the centroid of the center grid and neighboring grids with no feasible location is selected as a candidate.

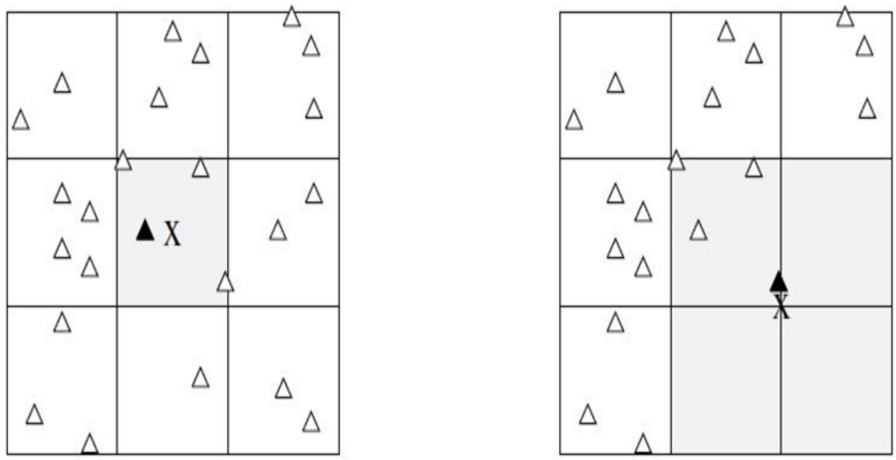


Figure 2.3: Candidate selection

2.4.2 Deployment Algorithm

In this approach a greedy algorithm is proposed that selects one micro BS to deploy in each iteration. The algorithm selects the candidate micro BS which maximizes the weighted sum of the energy efficiency of all scenarios as next micro BS. This process continues until the required capacity of all scenarios are satisfied. In each iteration, the proposed algorithm assumes the previously selected micro BSs are deployed, and then calculates the energy efficiency over the updated set of BSs.

Chapter 3

Proposed Approach

3.1 Proposed Approach

Analyzing all those related works, we propose a user distribution or density based approach for selecting the candidate location and then apply the local search to find the solution from those candidate locations.

3.1.1 User density Based Method

- It might fit for both clustered and dispersed scenarios.
- Less inter cell interference.
- Dynamic on/off process.
- Capital and operational expenditure control.
- Energy efficiency and capacity increase.

3.1.2 Selecting Candidate Locations

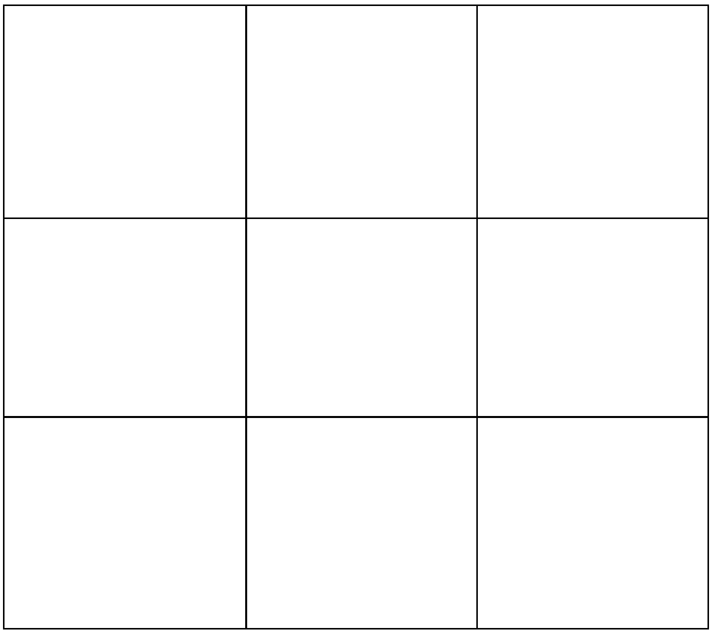


Figure 3.1: Selecting Candidate locations

In the above figure we divide the whole area into some square grids. There are users and feasible locations in the grids. Among all the feasible locations we have to select candidate locations to deploy the micro base stations. The process of selecting Candidate locations among all the feasible locations is to find the distance between the base station to the user. The base station that has a lesser distance is our candidate location. The process of selecting candidate locations is described in below figures .

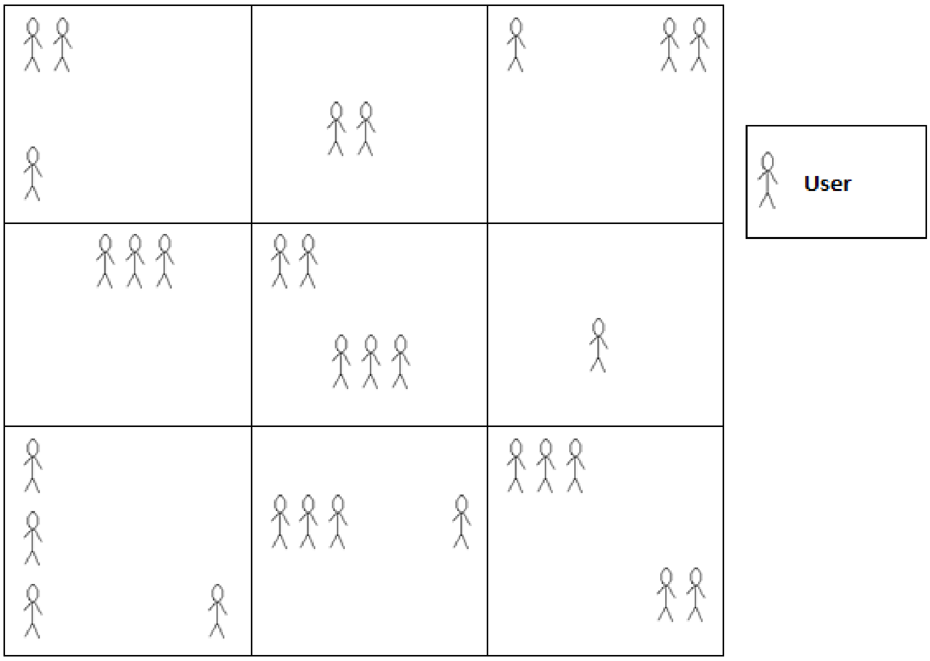


Figure 3.2: Selecting Candidate locations

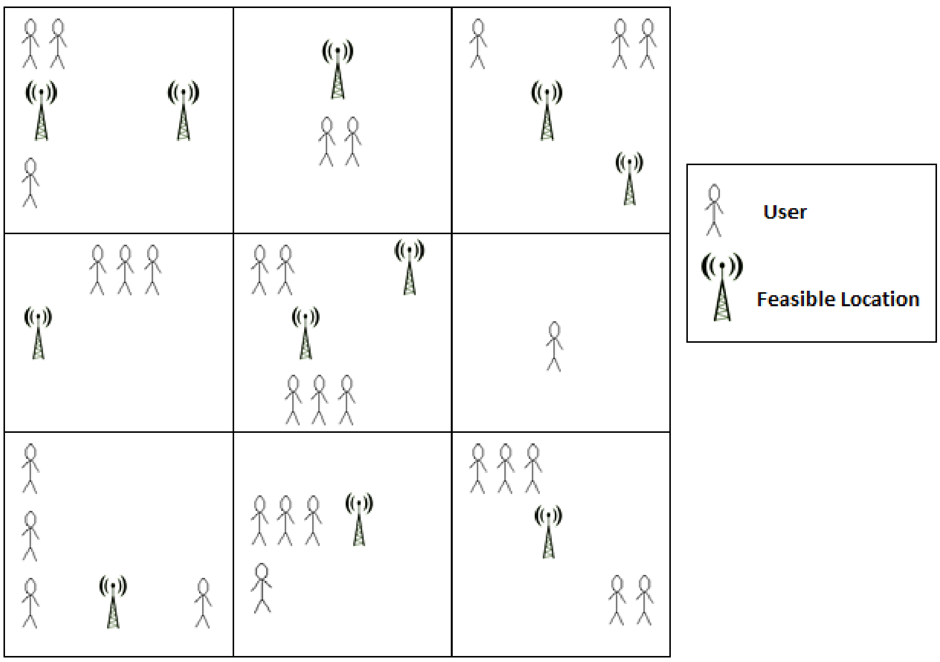


Figure 3.3: Selecting Candidate locations

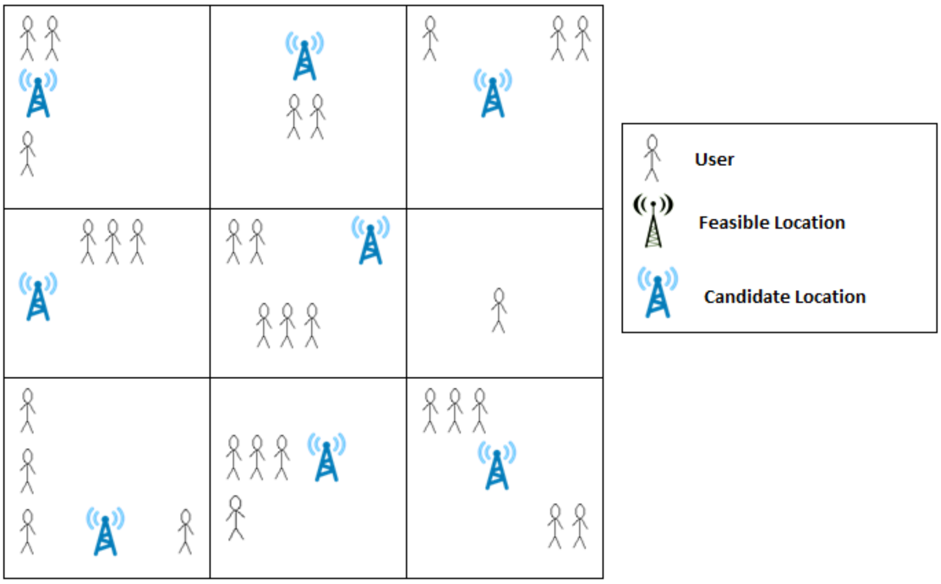


Figure 3.4: Selecting Candidate locations

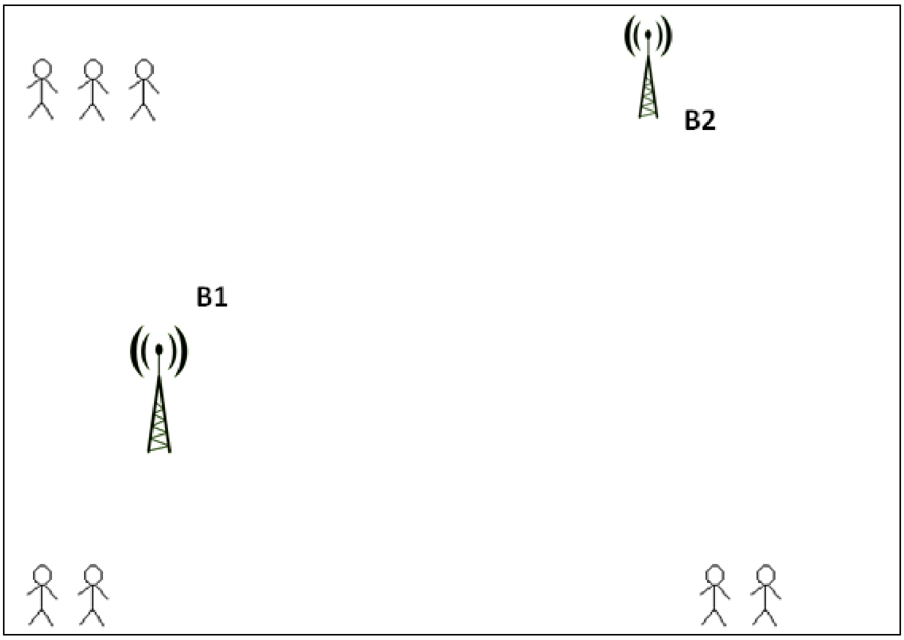


Figure 3.5: Selecting Candidate locations

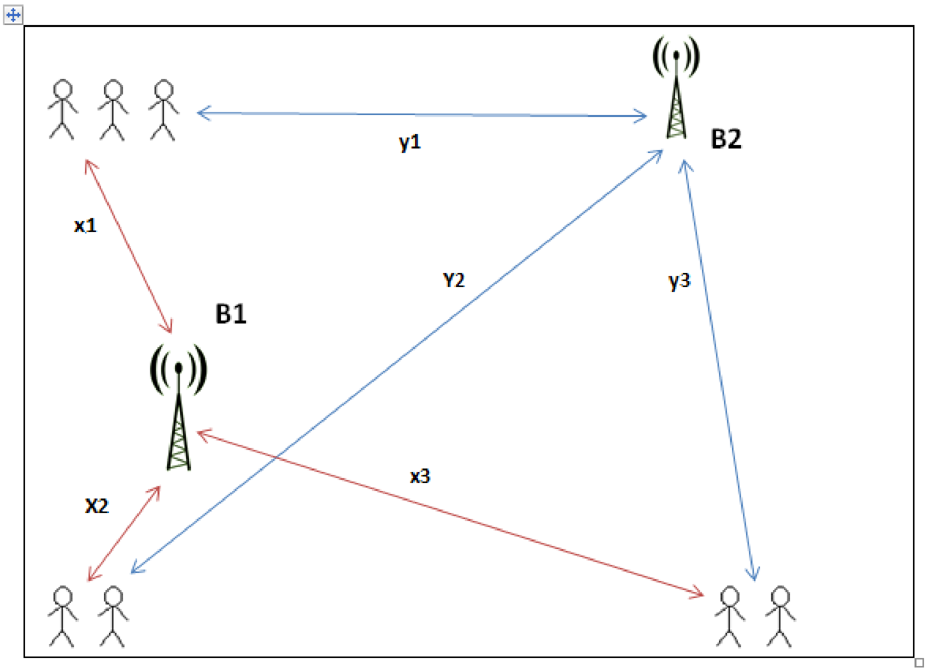


Figure 3.6: Selecting Candidate locations

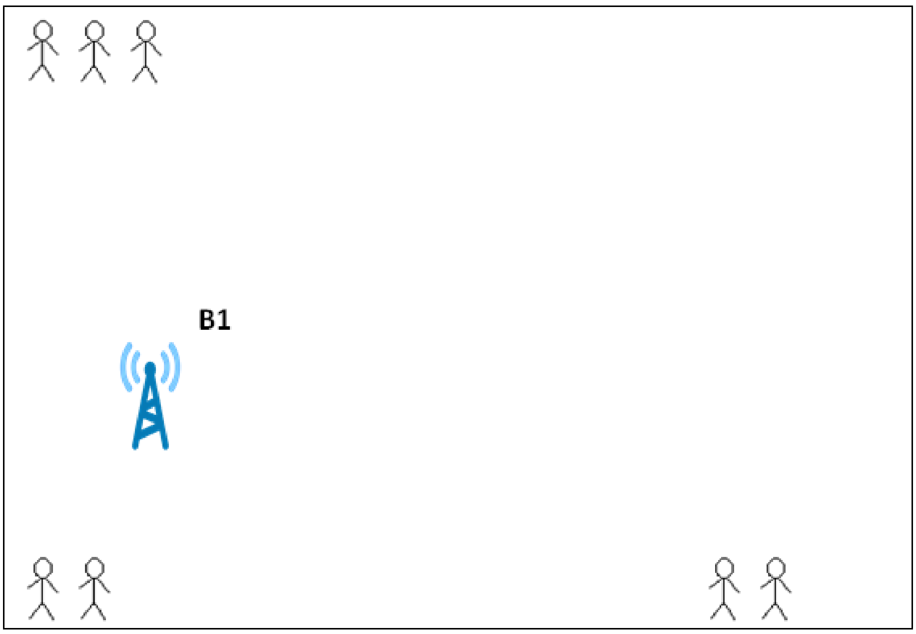


Figure 3.7: Selecting Candidate locations

3.1.3 Applying Local Search Algorithm

- Selecting a location among the candidate locations which gives the highest efficiency and deploy micro base station there. Here efficiency is the ratio between capacity and consumed power.
- Continue the process of deploying micro base stations in those candidate locations till there is improvement in the efficiency.

3.2 Performance Evaluation

Applying Local search algorithm in stead of greedy algorithm we found better performance in efficiency and capacity. Our algorithm works well in both clustered and dispersed scenarios. Though for lower density of users we found almost same performance for both local search and greedy algorithm. But for the high user density scenario we found far better performance than the greedy approach. Our performance evaluation table is given below -

3.2.1 Tables

Simulation values(Macro : 5 , Location :2000)				
Micro bss	Cap(Ori)	Eff(Ori)	Cap(new)	Eff(new)
1	41607	9.53	41607	9.53
2	65161.5	14.80	82712.8	18.79
3	88556.2	19.94	106194	23.92
4	110151	24.60	129589	28.94
5	129246	28.62	151298	33.51
6	148153	32.53	170617	37.47
7	166758	36.322	189507	41.27
8	183246	39.58	208083	44.95
9	199559	42.75	224599	48.12
10	215763	45.85	240912	51.20

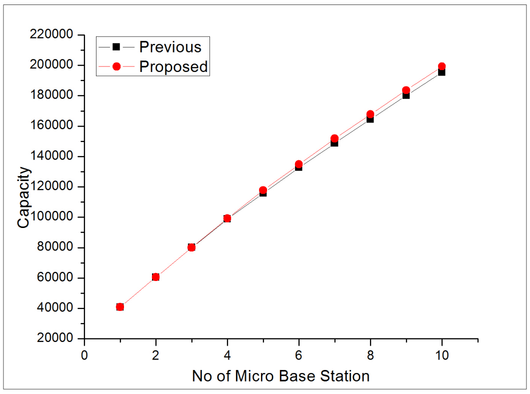
Simulation values(Macro : 3 , Location :2000)				
Micro bss	Cap(Ori)	Eff(Ori)	Cap(new)	Eff(new)
1	41565.4	15.78	41565.4	15.78
2	64987.8	24.33	64987.8	24.33
3	84406.7	31.15	84508	31.22
4	103314	37.60	103198	37.56
5	119628	42.95	119711	42.98
6	133965	47.45	134053	47.51
7	147942	51.70	147981	51.72
8	161417	55.68	161459	55.69
9	174346	59.36	174388	59.38
10	186536	61.70	186561	62.64

Simulation values(Macro : 3 , Location :3000)				
Micro bss	Cap(Ori)	Eff(Ori)	Cap(new)	Eff(new)
1	73794.4	28.02	73794.4	28.02
2	119329	44.67	119329	44.67
3	149900	55.33	149900	55.33
4	168072	61.18	168072	61.18
5	185866	66.73	185866	66.73
6	203093	71.94	203538	72.09
7	219659	76.77	220765	77.16
8	233779	80.64	237330	81.86
9	246584	83.95	251451	85.61
10	258271	86.81	260925	88.15

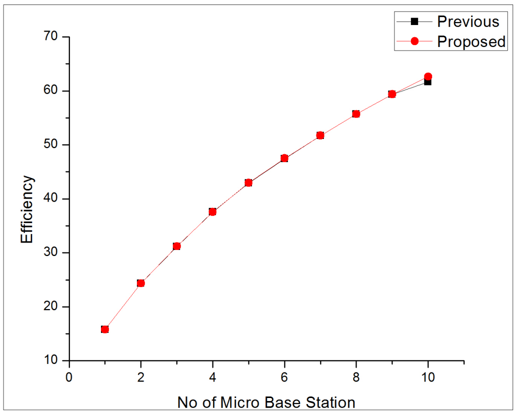
Simulation values(Macro : 1 , Location :3000)				
Micro bss	Cap(Ori)	Eff(Ori)	Cap(new)	Eff(new)
1	73788.6	81.715	73788.6	81.715
2	119324	126.806	119324	126.806
3	136552	139.48	136552	139.48
4	148239	145.76	148239	145.76
5	159008	150.719	159008	150.719
6	176285	161.28	176285	161.28
7	203119	179.593	204120	180.45
8	212904	182.12	216440	183.98
9	222293	184.17	232242	186.21
10	230372	185.038	238254	187.003

3.2.2 Graphs

Here are the graphs for low, medium and high User Density for performance evaluation. For low user density the performance of the local search algorithm is almost same as the greedy algorithm.

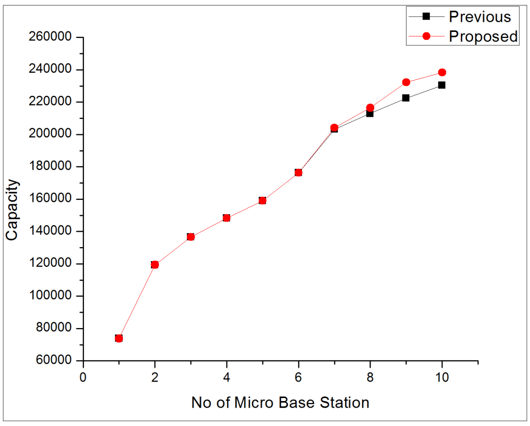


User Density : Low

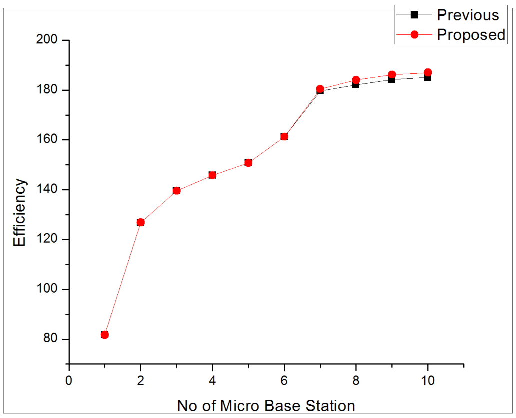


User Density : Low

For medium user density the performance of the local search algorithm is better than the greedy algorithm.

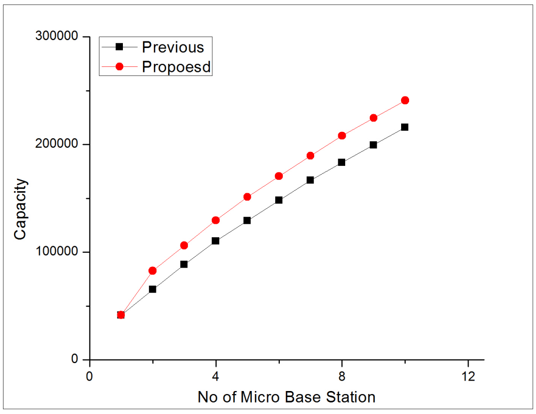


User Density : Medium

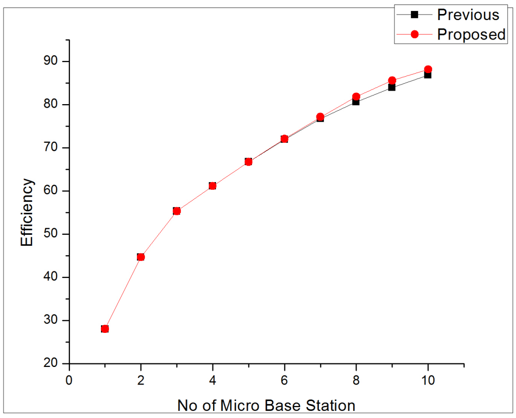


User Density : Medium

For high user density(pick hour) the performance of the local search algorithm is much better than the greedy algorithm. The local search algorithm works better for high user density.



User Density : High



User Density : High

3.3 Future Works

As there are scopes to improve the existing base station deployment algorithms in cellular network.So our goal is -

- Developing a more sophisticated algorithm that will improve
  - Total capacity
  - Energy efficiency
- Continue our work to get better result in all three scenarios (low, medium, high) of user density.

3.4 Conclusion

A Local search BS deployment algorithm is proposed to improve the energy efficiency of the network.Imprudent increase of the number of micro BSs may harm the energy efficiency of the network. The proposed algorithm first selects a set of feasible micro BS locations wisely, and then using local search algorithm it deploys a subset of them until the required capacity of the network is satisfied. Due to the heuristic nature of the algorithm, the complexity of the algorithm is significantly reduced. The simulations show that the proposed algorithm increases both the energy efficiency and the throughput of the network, while satisfying the capacity requirements.

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