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A NOVEL APPROACH FOR SELECTING AN OPTIMAL NUMBER OF CELL SITE LOCATIONS IN VARYING GEOGRAPHIC REGIONS FOR CELLULAR NETWORKS

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ABSTRACT

Facing the rapidly growing demand for mobile communication services and the limited available radio spectrum, a careful design of cellular networks in terms of coverage and capacity becomes of uttermost relevance. With the increasing demand for cheaper and better wireless communication services from customers, and the tendency to move toward smaller cell sizes it is becoming very important to optimally design the cell geometry and select the minimum number of cell sites to provide maximum possible coverage. In this paper, we consider how to optimally determine the cell site locations such that number of base stations (N) is minimum while coverage is maximum so that best possible service is possible with minimum infrastructural costs. An enhanced algorithm is presented here that determines the optimal locations of base stations without performing an exhaustive search. The algorithm simulates the network, uses the function to rank the cells, removes the cell with the highest ranking, and repeats the process until *k* cells are removed.

Keywords: *Cell Site, Network Design, Optimization, Coverage, Base Station.*

1. INTRODUCTION

The communication industry has suffered massive evolution throughout the past years. Everyone wants mobility and because of that the wireless concept is growing up and up and wireless network is changing day by day. Cellular networks are a type of networks that support wireless connection to mobile station (MS). Cellular networks is rapidly growing network in today's world because of a rapid growth in the population of mobile users [13]. With this demand for increased services at low costs, the service providers are looking to optimize their costs while being able to meet quality of service requirements. While zoning restrictions in placing base stations at the ideal locations can increase the cost of service, given the constraints for minimal costs, optimal base station location search becomes a more complicated task. The location of each base station in a given region determines not only the signal coverage provided but also the grade of service (GOS) available in the region dependant on the traffic intensity prediction in that region. While the number of inter- cell handoffs is directly affected by the number of base stations required for coverage, the cost of service is affected by the maintenance and land appropriation costs for placing the base station by the service provider. Preventing coverage holes, reducing co-channel interference effects and at the same time maintaining minimum number of inter-cell handoffs are some important points of concern for service providers. Thus, maintaining reasonably high traffic intensity to infrastructure cost ratio requires optimal design of cell geometry and intelligent placement of the base stations. Optimal coverage with minimum number of base stations is essentially a resource allocation/optimization problem.

Cell planning is regarded as the process of selecting the locations of base stations in the wireless network [1, 14]. Cell planning is a fundamental and challenging part of cellular network design process. A simplified from of cell planning problem is the assumption of similar geometric form and size for all cells [4, 5]. Due to non-uniform users' locations and traffic fluctuations, the automatic techniques that

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locate the optimal number of cell sites in a specified area are necessary.

2. PROBLEM STATEMENT

The problem of optimization of the base station locations can thus be stated as: Given an area to cover, identify the optimal cell geometry for locations of the base stations such that number of base stations is minimum while coverage is maximum so that best possible service is possible with minimum infrastructural costs. Our problem is to choose a set of *k* cells to delete among *N* possible candidate cells so as to maximize the performance of the network. Given the combinations of possible cells to choose it is clear that this is a combinatorial optimization problem [2] with possible solutions. In fact, if we place no restrictions on the behavior of the network performance function, then *cell deletion* is provably EXPTIME-hard [7].

3. RELATED WORK

Cell planning is a crucial part of designing a mobile communication network. Although, there are many proposed algorithms for this purpose, the problem has been remained challenging in non-uniform traffic situations. Several parameters exist for cellular network design. The most effective parameters are the number of cells and the coverage area of each cell supported by each cell. The classic method for this purpose is Genetic Algorithm (GA) and has been studied in different papers [11, 10]. Although, this algorithm is very useful for many practical optimization problems, however this method have some deficiencies for this special task, i.e. cell planning in wireless communication networks. The main deficiency of GA is that it is not applicable to large number of cells due to its computational complexity.

Previous work on the site selection problem focused on choosing cell sites using simulated annealing [11, 12], evolutionary algorithms [8], integer linear programming [10], and the greedy algorithm [6]. None of the mentioned previous work includes all the three vital parameters (in network planning): maximizing the network coverage, maintaining signal to interference noise ratio for satisfactory performance and reducing the cost of the network.

4. PROPOSED WORK

The structure of the proposed method lets several parameters be applied in cellular mobile communication network design simultaneously like *capacity, signal to noise (SIR) ratio and performance*. We are going to apply and enhance the general algorithm as provided by David Abusch-Magder [3] to focus on the related problem of optimally choosing the cell sites so as to provide maximum coverage while maintaining the performance or quality parameter. David is concentrating on the concept of cell site removal during the technology upgrade and has provided a general algorithm without considering any parameter whereas the novelty of this paper is to utilize the algorithm in planning phase where we are given number of candidate sites and we have to eliminate or neglect certain sites for economic reasons but still coverage and quality parameter like performance are top priority. The possible count of cell sites is provided as input to the algorithm. The task of the algorithm is to find the most suitable set of base stations among the predefined sites, taking into account the following objectives:

1. Maximizing the network coverage with the aim of covering all the test points.
2. Maintaining a certain signal to interference ratio for satisfactory performance.
3. Minimization of the cost of the network by using fewer sites.

5. ENHANCED ALGORITHM

At the core of our algorithm is a function which ranks the cells based on signal to interference noise ratio. The algorithm simulates the network, uses the function to rank the cells, removes the cell with the highest ranking, and repeats the process until *k* cells are removed. If a cell were to be removed the chance that a mobile would be left uncovered is correlated to each mobile's hand-off state; we exploit this correlation when constructing our sample ranking function. Mobiles that are in hand-off with two or more cells (soft hand-off) are unlikely to be abandoned if one of those cells is removed from the network configuration. The choice of the ranking function will depend on the three parameters: *capacity, signal to interference noise (SINR) ratio and performance*. This algorithm may be used independently of the models adopted to simulate the network, as long as an appropriate ranking function can be

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defined. Following are the algorithmic steps for the approach that we have followed.

Step 1: Consider a network that constitutes a set of M cells $C = \{ C_i \mid 1 \le i \le M \}$, for which the three parameters: *capacity, signal to noise (SIR) ratio and performance* are calculated respectively.

Step 1a: Capacity of any cell is given by:
capacity=(calls/3600)*htime;
where, calls=55+random(5);
htime=360+random(60); /

Step 1b: SINR of any cell is given by:
sir1=1/((users-1)+(noise/signal));
where, users=55+random(5);
noise=10+random(5);
signal=90+random(5);

Step 1c: Performance of any cell is given by:
P_i = (tempcap + tempsir)/2;
where, tempcap = (c1/7)*100;
tempsir = 100 - (((s1-0.0169)/s1)*100);
and the overall performance of network is given by the average of each individual cell performance.

Step 2: For each cell, we identify the base station(s) that cover the given mobile node. It may happen that one mobile node is covered by more than one base station. But the intention is never to lead any mobile station isolated.

Step 3: We are provided with a *ranking function*: $C \mapsto \mathbb{R}^{|D|}$ which returns a rank for all the candidate cells based on the data gathered based on SIR factor.

Step 4: Out of total M cells, a set of first N cells, $D = \{ C_i \mid 1 \le i \le N \} \subseteq C$ are candidates for removal (where, *isolation = 0;* isolation is the function that updates the isolation array of each base station).

Step 5: Define a set $R \leftarrow \emptyset$ that contains set of cells to remove. We must choose a set $R \subset D$ containing k of the N candidate cells that does not allow the network performance to degrade much.

Step 6: Define another set $D_0 = \{ C_i \mid 1 \le i \le N \}$ that contains set of cells which are candidates for removal, i.e. the cells that are not at all covering any mobile station.

Step 7: A variable $l \leftarrow | R | = 0$, keep track of the number of cells deleted so far.

Step 8: Repeat the following steps **while** ($l < k$)

Step 8a: calculate the ranking of all candidate cells based on a SIR with cells in R_l removed. $(r_{l,1}, r_{l,2}, r_{l,3}, \ldots\ldots\ldots, r_{l,N}) \leftarrow \text{score}(C - R_l)$

Step 8b: $j \leftarrow \text{argmax}_{i \in \{m|Cm \in Dl\}} (r_{l,i})$, choose cell $C_j \in D_l$ which has the maximum $r_{l,j}$ for removal

Step 8c: $R_{l+1} \leftarrow R_l \cup \{C_j\}$, this is the set of cells removed in the $(l+1)^{st}$ step

Step 8d: $D_{l+1} \leftarrow D_l - \{C_j\}$, remove C_j from candidate list

Step 8e: $l \leftarrow | R_{l+1} | = l + 1$, update count of cells already deleted

endWhile

Output: The suggested deletions from 0 to k $\{ R_l \mid 0 \le l \le k \}$ and all the ranks $\{ r_{l,i} \mid 0 \le l \le k \}$, $C_i \in D_l$ associated with each deletion list.

6. IMPLEMENTATION OF ALGORITHM

Flowchart 1 described next clearly depicts the flow of how to select an optimal number of cell site locations for cellular networks. A step by step execution is described thereafter. We are also providing the snapshots of the actual results obtained during the implementation phase that gives clear idea of the work done.

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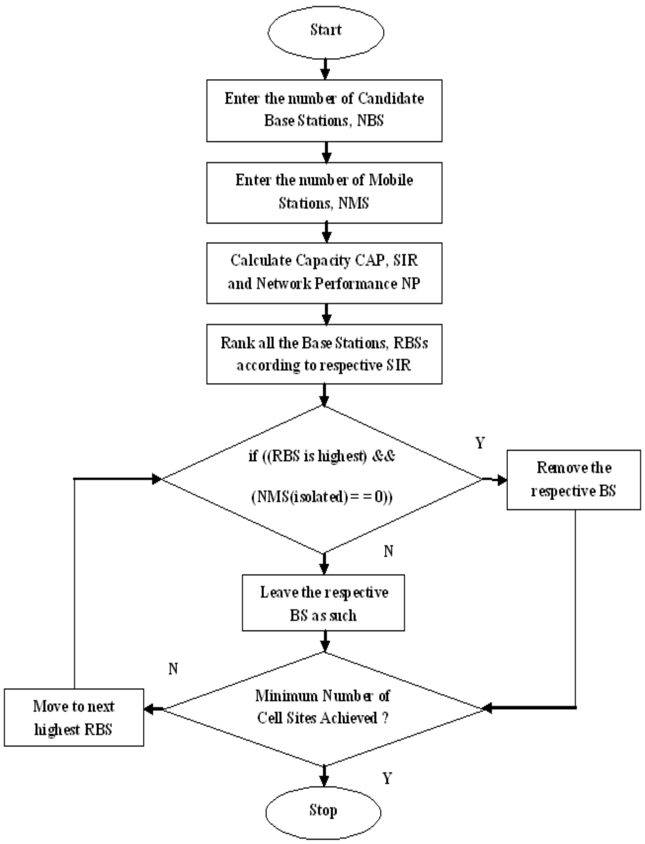

Flowchart 1: Selecting an Optimal Number of Cell Site Locations in Varying Geographic Regions for Cellular Networks

Step 1: The two inputs are taken initially in the form of maximum (candidate) number of base stations NBSs (8 here) as well as the number of mobile stations NMS to be served (8 here). Based on this data, the capacity, SINR and performance of the individual MS are calculated.

```
Enter no of base stations:8
Number of mobile stations :8
base stations statistics [before ranking]

sno        cap         sir         performance

1          5.874166    0.017196    91.096916 %
2          6.113056    0.017199    92.794083 %
3          5.988889    0.017203    91.896812 %
4          6.057778    0.018475    89.007706 %
5          6.618333    0.017819    94.694839 %
6          6.428333    0.018475    91.654541 %
7          5.848333    0.018477    87.507095 %
8          5.921667    0.018135    88.892021 %
```

Snapshot 1: Input of NBS, NMS

Step 2: All the 8 MSs are checked, whether they are served by one (or more) BS(s) or they are left isolated. Then the raking of all BSs is done based on rank function (signal to interference noise ratio).

```
Total Network performance  :  90.943001 %
S.NO      BST1        BST2
1         5           0
2         5           0
3         4           0
4         4           0
5         8           0
6         6           7
7         2           0
8         6           0

base stations statistics [after ranking]

sno        cap        sir        performance    rank[for removal]

7          5.848333   0.018477   87.507095 %    1
6          6.428333   0.018475   91.654541 %    2
4          6.057778   0.018475   89.007706 %    3
8          5.921667   0.018135   88.892021 %    4
5          6.618333   0.017819   94.694839 %    5
3          5.988889   0.017203   91.896812 %    6
2          6.113056   0.017199   92.794083 %    7
1          5.874166   0.017196   91.096916 %    8
```

Snapshot 2: Implementation of Rank Function on BSs

Step 3: Then the optimization phase starts, where we continue on rejecting the cell sites with highest rank but keeping the logic intact that no MS is left isolated because of this reduction. Here such rejected cell sites are 1, 3 and 7 out of total 8.

```
DELETION
 The eligible base stations for removal [ isolation=0 ]

1
3
7
Removed nodes [ R set ] :
1
3
7
```

Snapshot 3: Cell Site Optimization Phase

Step 4: Finally we obtain 5 mandatory cell sites that still cover all the 8 MSs with an improved network performance of 91.4063% from 90.9430%.

```
base stations statistics [after deletion]

sno        cap        sir        performance    rank[after removal]

6          6.428333   0.018475   91.654541 %    2
4          6.057778   0.018475   89.007706 %    3
8          5.921667   0.018135   88.892021 %    4
5          6.618333   0.017819   94.694839 %    5
2          6.113056   0.017199   92.794083 %    7

Total Network performance [ after removal ]  :  91.40863 %
S.NO      BST1        BST2
1         5           0
2         5           0
3         4           0
4         4           0
5         8           0
6         6           0
7         2           0
8         6           0
```

Snapshot 4: Resultant List of Mandatory Cell Sites

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7. CONCLUSION

To find good network designs we have developed an algorithm that will guide us through the vast number of possible solutions. Like other optimization problems we were seeking algorithm whose results are optimal as well as reliable to produce good solutions in a reasonable amount of time. We have successfully implemented the task of finding the most suitable set of base stations (5 here) among the predefined sites (8 here), taking into account the following objectives of maximizing the network coverage, maintaining a certain signal to interference ratio for satisfactory performance (an increase from 90.9430% to 91.4063%) as well as minimization of the cost of the network by using fewer sites.

Further, we are planning to show a modification to the proposed algorithm, which allows for the screening of the deletion candidate before the deletion is allowed. An additional function is to be designed that will further determine whether the proposed network has acceptable performance; if it does not, the algorithm rejects the highest ranked candidate and seeks the candidate with the highest ranking that passes the screening function. The screening criteria, like the ranking function, will depend on the provider's goals (like coverage) and on the data provided as an input.

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