Optimizing Performance of WIMAX Networks

Nisha Sagar,Vijay Maheshawari and Akhilesh Kumar

Abstract- **This paper demonstrates design procedure of mobile cellular networks using an optimization framework based on meta-heuristic techniques to produce a network of good quality utilizing WiMAX technology characteristics for base station configurations. Next, the simulations of the obtained cell plans are carried out in order to evaluate the correlation of the optimization measures such as coverage and interference with actual performance indexes, like throughput, delay and losses. Results are presented for three network designs generated from a simple optimization framework and ten randomly constructed.**

Keywords— Cell Planning, Radio network design, Radio frequency assignment, Heuristics, WiMAX.

1. INTRODUCTION

The explosive growth in broadband demand and wireless technologies have created a difficult environment for xisting wireless standards and companies competing in this market. Consequently, in order to satisfy market needs a new approach needs to be introduced to unleash the mobile information and entertainment markets. A possible solution is the WiMAX broadband wireless standard [1] which is a fast emerging technology developed as an alternative to cable and DSL. The objectives of WiMAX include: delivering service in the most cost-efficient way and lowering the expenditures for service providers as well as for users; providing service in suburban and rural areas where other technologies are not presented; increasing coverage (for mobile application 802.16e up to 3 km); increasing capacity - up to 15 Mbps; providing high security etc.

This paper considers an optimization framework based on meta-heuristic techniques to produce a network of good quality utilizing WiMAX technology characteristics for base station (BS) configurations.

In spite of the fact that cell planning for mobile systems (such as GSM, UMTS) is well studied it is a complex multiobjective optimization problem [2]–[5]. It involves the selection of sites at which to deploy infrastructure and the subsequent configuration of base stations at these sites in order to optimize some Key Performance Indicators (KPI) for the network. Example KPI's include maximizing area coverage, i.e. ensuring that the network covers enough potential subscribers; providing the required quality of service; as well as taking into account economics, such as minimizing the number of locations used, thus minimizing infrastructure capitol and operating costs, which service providers are keen to reduce; maximizing expected throughput. These example KPI's are in addition to satisfying hard constraints concerning high traffic capacity, interference etc. To accurately assess the technical and economic performance of the network detailed data concerning the demographics and propagation within the given region incorporating terrain data must be used. The configuration for each base station involves selecting antenna type, power configuration, azimuth, and tilt. The frequencies used at each BS must also be carefully assigned in order to mitigate the effect of interference within the network. There are a number of published scientific papers related to network design and development of automated software tools based on 2/2.5/3G systems concentrating on development of algorithms and approaches to tackle the NP-hard nature of problem [6]–[8], but not many carry out the simulation to evaluate the actual performance of the network. Simulation plays an important role in the planning stage to allow investigations on the impact of using different KPI's in the design process. For successful optimization, it is important that the objective functions used are closely correlated with the performance measures obtained under simulation.

This paper presents simulations of the designed cell plans obtained from a simple optimization framework and ten random cell plans (RCP) in order to evaluate the correlation of the optimization measures with actual simulation performance. The entire experiment framework is depicted in Figure 1.

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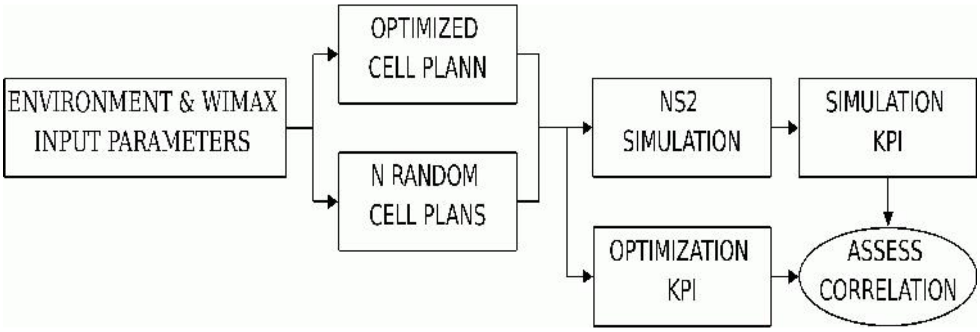

Fig. 1. Experiment framework

II. Model and approach

In order to produce a good network solution, N, the information concerning potential site locations for base stations as well as propagation is needed prior to using cell planning framework. The network area is presented as a grid of points P with m x n topography size which are defined by its Cartesian coordinates and may be divided on elements in hierarchical order as follows:

1. Candidate sites

Represents information about the potential locations for cells that is usually provided by network operators. A set of candidate sites is defined as C = {C1,C2, ...,Cncs}, where ncs is the total number of locations in the network each of which has a geographical position on the working space presented by (Xi, Yi,Zi) coordinates. To define a network, a selection is made from the list of available sites, therefore a configuration coefficient, CC, is assigned to the set of locations, where CC = {cc1, cc2, ..., ccnc} and cci is set to value 1 (site is active - infrastructure is to be deployed), or set to zero (site is inactive site - infrastructure not deployed).

2. Base stations

Each active site will in turn consist of one or more BS depending on the traffic demand from the area to be covered and the type of antennas used. The antennas are also considered as a set B = {B1,B2, ...,BnB}, where nB is the total number of operational base stations. The configurations available for a base station are:

- frequency band Fi: 2.3, 2.5, 3.5 GHz;
- RF channel size Fchi : 1.75, 3.5, 7, 14, 20 MHz;
- modulation type Mi: BPSK, QPSK, 16QAM, 64QAM;
- coding rate CRi: 1/2, 2/3, 3/4;
- transmission power P_{Bi} : 26 < P_{Bi} <55, dBm;
- antenna type: 1< ATBi< nAT , different types of antennas are available;
- angle of tilt of antenna: 15o < Bi _ 0o;
- azimuth of antenna: 0^o < Bi < 359^o;
- number of sectors, TRX devices: 1 < TRXBi < nTRX,, define the number of transmitters in the base station denoting the number of channels used.

3. Service test points

Within the working space P the points representing the precise information about propagation and service are known as service test points STPs. These are represented by S = {S1, S2, ..., Sns}, where ns is the total number of service test points in space P. The propagation loss from each BS to each STP is required as an input to the cell planning process.

4. Subscribers

Subscribers have corresponding service and traffic demands as well a geographical position. A uniform distribution of subscribers is used in this initial stage of the research which are located at the grid points of working area of the network and are denoted as Sc = {Sc1, Sc2, ..., ScnSc}.

A. Optimization objectives and objective function

1. Coverage

To cover a maximum area as possible of the network is critical for service providers, therefore it is considered to be one of the most important objectives. If any cell provides a sufficient enough level of power so that the strength of the received signal is above some certain service threshold, or receiver sensitivity Rxthresh (dBm), then a STP within the range of that cell is said to be covered. To evaluate the coverage of the entire network the percentage of all covered Si is taken. The number of not covered Si should be minimized:

$$F_1 = w_1 \left[\frac{n_S - S_{covered}}{n_S} \right]$$

2.Interference

Interference occurs when cells are overlapping, which means they have common Si receiving signals above the sensitivity threshold. The effect of interference has a negative impact on the network performance, which increases the number of base stations needed to cover the region to be planned, consequently increasing the cost of network and which leads to the necessity of channel assignment and furthermore the distribution of the Si between the overlapping cells. However to provide maximum coverage and maintain mobility of users it is inevitable that some overlap will occur. The case when a cell is completely covered by other stations, can be removed.

The aim of cell planning is to minimize the interference effect, in our case overlapping of the cells, or in other words to minimize the number of Si receiving signals above a significant level from more than one Bi. For that reason another coefficient, _, called the interference threshold, encapsulates interference and defines the maximum number of cells covering given STP that must not be exceeded.

$$F_2 = w_2 \left[\frac{S_I}{n_S} \right]$$

3.Traffic capacity

In all wireless systems the traffic load is an important issue for planning purposes and has a limited value that can be carried through multiplexing. The maximum traffic supported by a cell corresponds to its capacity. Depending on the type of service to satisfy the subscribers' various traffic demands can be defined.

```
While T > T_min do
  For 1 to N_m do
    Site = randomly select Site
    Toggle(Site) = change operational state
    F_cur = F_new
    F_new = evaluate new cost function
    δ = random real value in [0, 1)
    If F_new < F_cur
      accept new configuration
    Else If δ < exp(-(F_cur - F_new)/T)
      accept poorer configuration
    Else
      Toggle(Site)
      F_new = F_cur
    End If
  End For
  T = T x γ reduce temperature
End While
```

Fig. 2. SA algorithm

$$F_3 = w_3 \left[\frac{T_{required} - T_{capacity}}{T_{required}} \right]$$

4. Site cost

The economic factor of a network is crucial for operators. This is directly linked to the costs of the deployed Bi. That is why, the number of base stations used in the network or the costs associated with their deployment should be minimized.

$$F_4 = w_4 \frac{\sum_{i=1}^{n_{sites}} f_i cc_i}{\sum_{i=1}^{n_{sites}} f_i}$$

where fi defines the cost value of the selected site.

B. Network optimization framework

The network design is a complex multi-objective optimization problem involving the selection of all decision variables in order to meet any constraints and optimize the objectives. The concept of neighborhood search is used in the initial work, which incorporates iterative improvement (II) and simulated annealing (SA) algorithms. In order to lead the search in the direction of better solutions and to evaluate the cell plans a weighted objective cost function F is used:

$$F = F_1 + F_2 + F_3 + F_4$$

Parameters	Values
Region size	1750 m x 1750 m
Grid size	15 x 15
BS transmit power	0.281838 W
Reception threshold	2.098e-10 W
Central frequency	3.5e+9 Hz
Frequency bandwidth	20e+6 Hz
Cell range	250 m (2 pt on the grid)
Modulation	OFDM 64QAM 3/4
Traffic protocol	CBR
Packet size	1000 byte
Bit rate per subscriber	20 KBps
Simulation duration	14 sec
Propagation	TwoRayGround

TABLE I
Network and simulation settings

Simulated annealing

The algorithm used in the experiment is a SA also known as Monte Carlo annealing, which is an improvement over II.

The discrepancy lies in the procedure of new configuration acceptance that consists in introduction of an additional parameter, called temperature, that changes the probability of moving from one point of the search space to another, consequently forcing the algorithm to explore new areas of the search space to escape from local optima.
It is based on the principal of acceptance of some number of configurations (network designs) that have a worse objective function value in order to get a chance of reaching the global optima.
The details of this operation can be found in [9]–[10] and the procedure is depicted in Figure 2.

III. Design simulation and KPI evaluation

It is critical to have an independent evaluation of the optimized network design to ensure any improvement in the objective function is reflected in an improvement in operational performance. As we develop potential metrics, we are using the simulation tool NS2 to simulate the network performance under the range of usage patterns to evaluate the correlation of the optimization measures with actual simulated performance. The network simulator 2 (NS2) is a popular and powerful simulation tool for the simulation of packet-switched networks and is widely used in both
academia and industry [11].

This part of the research deals with developing and evaluating different simulation approaches for theWiMAX network and cell plan analysis. In Table I an overview of all relevant parameters in terms of system related parameters and configurations, traffic, users and services are summarized.

The initial phase of research considers static simulations using the FTP source traffic model and considering downlink (DL) connection, in order to simulate different network design scenarios from the optimization framework. However, detailed quality of service requirements are not taken into consideration. The same holds for the users' mobility, which will be included into the conceptual design in later research.

The output that NS2 provides, representing precise information concerning all events during simulation, is filtered in order to extract the KPI, for example throughput, delays and losses. On the basis of these results comparison of different planning scenarios is carried out.

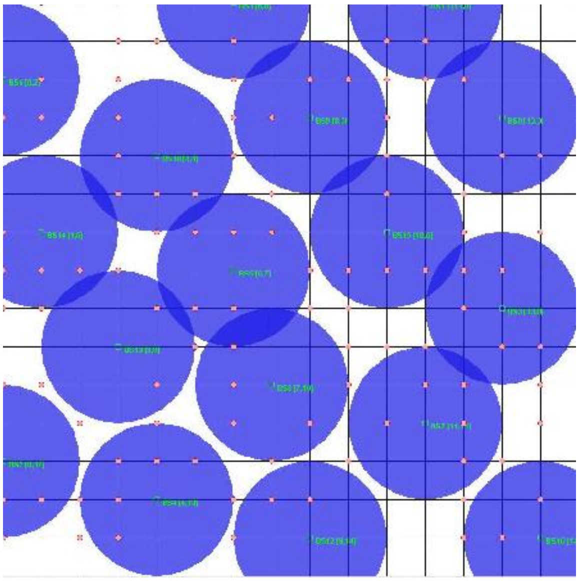

Fig. 3. Network design using SA algorithm

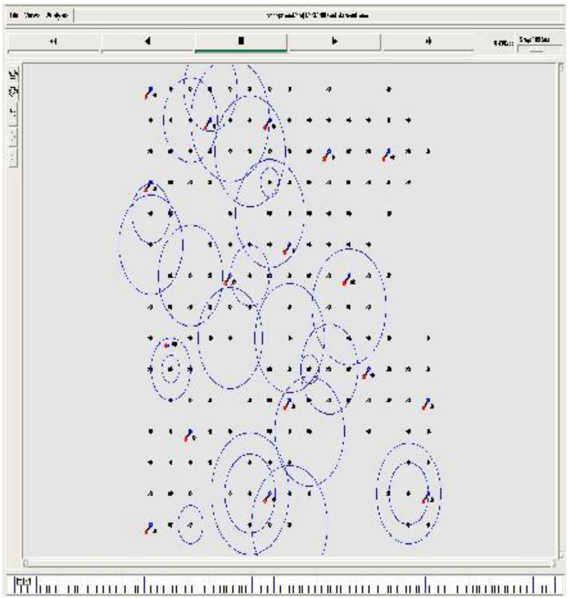

Fig. 4. Simulation of RCP

IV. Results

For the experiment three network designs were generated using the SA algorithm following by generation of ten cell plans generated by the randomized greedy procedure as follows. BS are iteratively selected at random, and only added to the cell plan if their distance to each previously selected BS is less than 3/4 of its cell diameter. This avoids

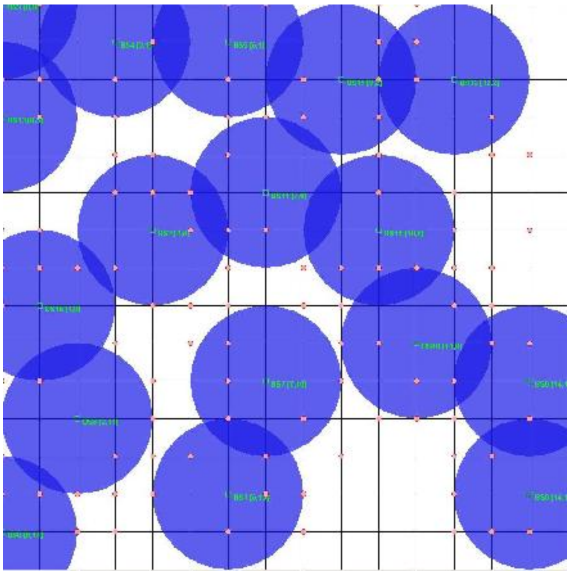

Fig. 5. Network design randomly generated

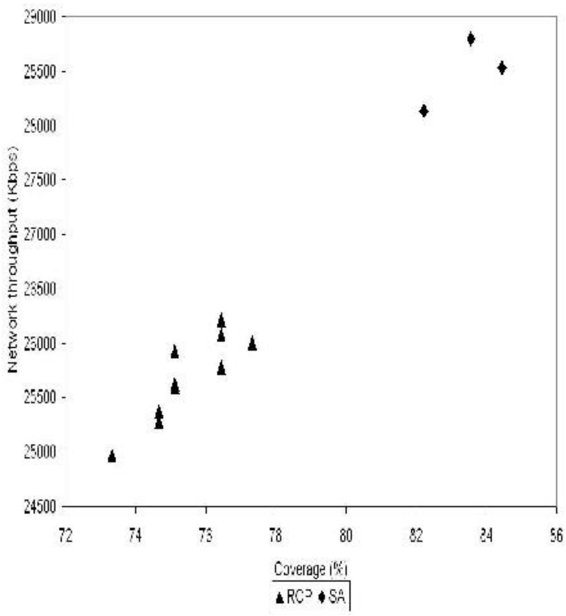

Fig. 6. Comparison of KPI between optimized esign and RCP

V. Conclusions

A two stage experiment was presented in this paper, incorporating optimization and simulation frameworks for radio network planning based on WiMAX technologies. The simple model was used considering coverage and interference objectives.

Results indicate that optimization framework based on SA algorithm is capable of producing high quality solutions that also can be outlined in simulation framework showing high correlation between their KPI. Future work will include next issues:

1. Development of different scenarios generating subscribers' behavior with different service and traffic demands as well as generating different density patterns. Take into account mobility of users.
2. Improve optimization framework by utilizing the selection of available modifiers and configurations for BS.

3.Development of traffic source models for simulation purposes to create realistic scenarios considering both UL and DL connections.

4. Consider the frequency assignment issue on a higher level. Encapsulate and develop algorithms producing near optimal solutions.

5. Examine correlation between all KPI from optimization and simulation frameworks.

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