Multi-objective Model for IEEE 802.16e Network Planning and Optimization

Botan Mohammed
Department of Software Engineering, Salahadin University
Erbil, Iraq
botannmh@gmail.com

Shareef Maulod
Department of Software Engineering, Salahadin University
Erbil, Iraq
Shareef.shareef@su.edu.krd

Abstract—Service operators need to make every effort in designing and deploying the most cost-effective network planning in order to increase the financial return on the investment in internet service provider. In the last decade WiMAX (Worldwide Interoperability for Microwave Access) was appeared in Erbil. For maximizing the company profits, operators have to improve the quality of their networks, this can be done through setting a well-studied plan for their network infrastructures in terms of cost. Researchers proposed various models to solve the planning problem, but most of them ignored some performance measures that this paper used to evaluate the proposed method with the existing approach, those performance measures are upload consideration, some Key Performance Indicators such as throughput estimation, the total number of connected/rejected users (%) within all tried others and Block Error Rate (BLER). Previous method to solve network planning was manual method, but due to problematic complication and dealing with many factors, it is impossible to find optimal network configuration using a manual method. Thus, in this paper automated wireless network planning and optimization is used to solve the problem by sequential approach that divides the entire problems to sub-problems. This paper addresses the planning, evaluation, analysis, optimization, and multi-objective system performance of a network on the mobile WiMAX standard, namely (IEEE 802.16e) in the city of Erbil. A new model for planning problem of such network was proposed, the objectives of the proposed model are not only to identify optimal amount, but also the optimum location of Base Stations (BSs) in targeted areas. In addition, the proposed model decomposes the entire problem into three different phases dimensioning, frequency allocation and optimization. The feasibility of the final network designs evaluated by the FORSK-ATOLL simulator. Moreover, multi-objective network planning results demonstrate that the proposed model can reach high system performance with cost-effective network infrastructure. This has been achieved by comparing the proposed model with the existing model of Newroz Tel Company in the city of Erbil, which resulted in reducing cost by 20% of total cost.

Keywords-components: WiMAX; Planning; Optimization; IEEE 802.16e; Coverage; Capacity.

I. INTRODUCTION

The advancement of technology and, more specifically that of ICT have encouraged the public sector to utilize ICT to support its operations and functions. However, new concepts and opportunities for the government to utilize ICT in expanding their services and functions have arrived (e.g., e-government) along with the emergence of the internet. The use of ICT has a significant role in e-government initiatives to establish effective and efficient communication in the provision of services to citizens and other stakeholders. However, countries who have not initiated e-government or are at the early stage of the implementation process, and who have their ICT infrastructure not as a developmental requirement [1]. Such countries may have benefited more depending on the type of the concerns that faced by the governments. In the developing countries, WiMAX may become a vital means of reaching the people and encouraging communications, particularly when used in an isolated area. WiMAX is expected to be a practical alternative to traditional wired broadband techniques due to its cost efficiency. Wire line infrastructures are extremely overpriced and time-consuming to deploy compared to the wireless technology. An alternative way of receiving broadband access is satellite service but it is overpriced and there is a delay between the data transmission and reception. Wireless technology has also perfect benefit in rural areas and particularly in developing countries which not have enough of wire infrastructures for internet services [2,3].

In addition, WiMAX is a cost-effective solution to responding the difficulties caused by the digital divide. The Digital Divide was defined as the unequal access to ICTs. Were the developing countries are separated from the developed countries because of an absence of technology particularly ICT. The digital divide has continued to exist as a result of the high cost of putting up existing telecommunications infrastructure. This is because each service requires a specific technology and network [4]. The rest of the paper is organized as follows: the next section reviews the related work on the WiMAX. In section two, the system model for IEEE 802.16e network presented and explains how the model was
formulated. The SUI Propagation Model will be expressed in section four. In section five, planning criteria will be discussed. In section six, the proposed sequential model will be presented. In both sections seven and eight, the proposed model will be evaluated using Monte-Carlo algorithm along with comparison to the existing model in the city of Erbil. In section nine, the research findings will be analyzed and shows the results with respect to the critical KPIs according to each phase in the network optimization planning. The paper will conclude with a summary of the findings of this research.

II. RELATED WORK

The past few years have been witnessed a remarkable growth number of the service providers were starting new network technology investment such as WiMAX in Iraq in general and Kurdistan region in particular mainly due to lack of ICT infrastructure. In less than a decade, broadband subscription, in Iraqi-Kurdistan region has been developed from nearly zero to above one million and WiMAX service providers from zero to almost ten in which eight of the service providers is in the city of Erbil. However, there are very rare researches on the network planning of mobile WiMAX, particularly in developing countries. In [5], focuses the design, analysis and system performance of a WiMAX IEEE 802.16d which installed in the region of Athens. The proposed WiMAX network system consists of 11 hub sites which are operated in licensed band of 3.5GHz. The research only focuses on the hub sites without considering entire required BSs. In [6], proposed a dimensioning method that includes coverage dimensioning and a joint estimation with capacity dimensioning. First, the input parameters are defined, consisting of the business plan, the assets, and the Key Performance Indicators (KPI). Next, the coverage analysis is performed. Following the coverage analysis and the capacity estimation checks for sufficient capacity resources as dictated by customer numbers and services profiles have accomplished. They didn’t consider estimating average sector, throughput, and estimate the subscriber number that can be accommodated in a sector, for specific scenarios. Also the impact of advanced antenna systems on coverage and capacity that has not been considered. In [7], a multi-objective optimization framework that deals with mobile WiMAX network design presented. Where a QoS-based, coverage, interference and cost criteria dedicated to the BS location problem in Mobile WiMAX deployments has been addressed. Computer simulation was used to predict the network performance. They simplified the problem and translate it into a formal optimization routine with consideration of economic factors in Mobile WiMAX networks. It can help the network provider in small to medium sized scenarios. In [8], a concept of WiMAX network performance for QoS monitoring and optimization solution for a base station with the multimedia application has been presented. In this work six scenarios have been made with two BSs between Bhusaval and Jalg in India. The entire scenarios are based on the theoretical survey. The research is dedicated to the rural area without interference concern. The network plan has valued based on delay and throughput by using OPNET simulation. In [9], developed an approach to be used in dimensioning and planning process for an existing network structure in the Tripoli area in purpose of reducing the number of BSs used from two different points of views, coverage and capacity planning. Most of the information was obtained from the operators. As a result, the required number of BSs to cover the area is lower than the number of base stations of the existing operating network. In [10], applied FR-of-1 and Fractional Frequency Reuse (FFR) of network deployments, evaluated, and compared in a grid of 19 BSs, where band adaptive modulation and coding (band-AMC) is used in each cell. Users resource and burst profile selection are determined based on the reported signal to interference plus-noise ratio (SINR). The simulation results proved that FFR shows better performance than FR-of-1 in terms of variety of metrics. But they most likely focused on frequency planning without considering other control factors. In [11], proposed analytical method and software program for estimating Mobile WiMAX capacity in network planning and optimization to evaluate IEEE 802.16e Mobile WiMAX system’s capacity, throughput and a traffic model. Various overheads that impact the capacity of the system are analyzed. A simulation of the software is used for the determination of the maximum number of subscribers that each specific Mobile WiMAX sector can support. One of the drawbacks of this work is focused on a Download (DL) centric traffic pattern for their proposed method without considering the Uplink (UL) traffic. In [12], presents the novel access network planning model for WiMAX. The proposed model aims to optimize the amount and location of BSs in the study area. Integer Linear Programming is used for formulating the optimization problem which objectives have minimized installation cost and maximize service coverage only. They considered that every BSs have the same infrastructure and transmitting power. The network performance was evaluated in term of the physical receive a signal strength guarantee and the SNR guarantee at the specified parameters without considering Scheduler Saturation and Resource Saturation. Also, their experiment was not on the realistic study area.

III. SYSTEM MODEL

In this section, the problem and the model for IEEE 802.16e network was formulated and a service area (M) is modeled as a grid or mesh and all points located within M are defined by their Cartesian coordinates. The network modeled using the following components [13]:

A. Reception test points (RTP)

The reception test points located in a portion of the zone called target area, which represents the demand of users and expressed as follows.

\[ T_i = (x,y,z,\text{rev}), T_i \in T \quad (1) \]

Where x, y, z are the coordinates of RTP Ti, z is the elevation above the sea level measured in meters, d is the traffic demand and rev is the revenue.
B. Base Stations (BS)

The BSs distributed over a number of sites to provide connectivity to a set of RTPs’ equipment. BS placement is a great value process to optimize investment cost and performance of the network by increase the coverage area and capacity, which is expressed as follows.

\[ B = \{ x, y, z, \text{CapEx}, \text{OpEx} \}, B_i \in B \] (2)

\[ B_i \] is a subset of sites selected from \( S \) the set of all candidate sites. These are the sites that are operational, where \( x, y, \) and \( z \) are the coordinates, OpEx (operational expenditures), CapEx (capital expenditures) related to the installation and maintenance costs of the site. The installation costs are unrepeatable payments while operational costs are yearly based payment.

C. Sector/Antenna

The antennas located in the BSs as an access point between RTPs and BS, which is expressed as follows.

\[ S_i = \{ B_j, H, AT, G, L_h, L_v, P, \alpha, \beta, \text{CapEx} \}, B_j \in B \] (3)

\( B_j \) is site location, \( H \) is the height of the antenna by meter, \( AT \) is antenna type, \( G \) is antenna gain in dBi, \( L_h \) and \( L_v \) are horizontal and vertical losses of the antenna in dBi respectively, \( P \) is BS transmitting power of a set of 10 levels is defined ranging from 27 to 45 dBM [13]. Tilt \( \alpha \) of each antenna (denoted \( \text{Sia} \in \{ 0, -1, -2...-15 \} \) where -15 is the maximum available down tilt), \( \beta \) is the azimuth angle of antenna, ranging from 0 to 360 degrees, and CapEx is antenna cost.

IV. STANFORD UNIVERSITY INTERIM (SUI) MODEL

This model is called that, because is developed by Stanford University for frequency range 1900 – 6000 MHz. The base model has three models in one and each one account for specified terrain type (terrains – A, B and C). Terrain A for urban area. Terrain B for suburban areas. Terrain C for rural as showed in Table 1. The expression of SUI model is given by [14].

\[
R = 20 \log_{10} \left( \frac{4 \pi d \lambda}{\lambda} \right) + 10 \lambda \log_{10} \left( \frac{d}{d_0} \right) + 6.0 \log_{10} \left( \frac{f}{2000} \right) + X_h + S \quad d > d_0
\] (4)

Where:
\( R \) : Maximum cell radius.
\( d \): Distance between transmitter and receiver [km],
\( d_0 \): 0.1 [km],
\( f \): frequency [MHz],
\( X_h \): Correction for receiving antenna height [m],
\( S \): Correction for shadowing [dB].

\( \lambda \): Path loss exponent.
Correction of shadowing varies between 8.2 and 10.6 dB.

\[
\lambda = a - bh \quad \text{and} \quad X_h
\] (5)

Where:
\( a \) and \( b \) are described below:
\[
\lambda = a - bh + \left( \frac{c}{h} \right)
\] (6)

\( X_h \) is the transmitter antenna height, and \( h_b \) is the receiver antenna height.

A. Coverage and capacity area calculation

The targeted area divided into several local areas based on the RTPs density. Each of this area should be seen from two distinct aspects, which are coverage and capacity. We have used previous result of maximum cell radius (R) in km to find the coverage area in km2, as follows [15]:

\[ S = k, R^2 \] (7)

Where, \( S \) is the coverage area in km2 and \( k \) is a constant, depend on the number of sectors, it is 3 in this research. Lastly, to find a number of sites in the targeted area, the total targeted area divided by coverage area.

\[ N_{\text{coverage}} = \frac{\text{targeted area}}{\text{coverage area}} \] (8)

\( N_{\text{coverage}} \) is the minimum number of BS to cover the target area in coverage point of view. Despite the finding number of BS to cover the target area, the planning problem should be also seen from the capacity point of view. The first step to finding the minimum number of BSs that offers WiMAX bandwidth for the targeted number of RTPs is site throughput calculation as follows:

\[ R_{\text{data}} = N_{\text{data}} \times N_{\text{mod}} \times \text{FEC} \times f_{\text{s-eff}} \] (9)

Where \( N_{\text{data}} \) is a number of data subcarriers, which is 48 in 5ms frame. \( N_{\text{mod}} \) is the number of bits for each modulation level, which equal 2 for QPSK, 4 for 16 QAM, and 6 for 64
QAM. FEC is the Forward Error Correction factor, \( f_{\text{eff}} \) is calculated as follows.
\[
f_{\text{eff}} = \frac{1}{T_s} (1 + CP)
\]  
(10)

Where \( T_s \) is a symbol time, and \( CP \) is the cyclic prefix.

Next, we should find the average throughput from the summation of multiplying the throughput to each modulation level by the percentage of a number of RTPs which use this modulation scheme. If 2*2 MIMO and 3 sectors used as in our research, the overall BS throughput \( R_{\text{data}} \) is:
\[
R_{\text{data}} = R_{\text{data-avg}} * 2 * 3
\]
(11)

Finally the required number of sites from a capacity point of view is \( N_{\text{capacity}} \)
\[
N_{\text{capacity}} = \frac{\text{no. of RTPs in each local area-average of one RTP data rate}}{R_{\text{data}}} \quad (12)
\]

V. PLANNING CRITERIA

The main objective of this research is to achieve a performance close to optimum, reliable and cost-effective mobile WiMAX networks. The cost function in Eq. (13) and Eq. (14) represents a profitable model that gives a picture of the possible benefit of the network provider with three key factors.

\[
\text{Benefit} = \text{Income} - \text{TotalCost}
\]
(13)

Where \( \text{TotalCost} \) includes the network infrastructure costs such as OpEx, CapEx, and some penalty costs due to the different network performance of the network configurations tested. The aim of the network provider is to minimize the \( \text{TotalCost} \) such as mentioned in [7] by detail:

\[
\text{Min} \left\{ F_{\text{costs}} + F_{\text{pen(CINR)}} + F_{\text{pen(TH)}} \right\}
\]
(14)

A. Infrastructure Costs (\( F_{\text{costs}} \))

Infrastructure cost includes the cumulative of the installation and yearly maintenance payment for BSs specifically for coverage. An RTP is covered if the received pilot signal can be demodulated by the RTP. Therefore, as indicated in Eq. (15), the received pilot power \( (C_{\text{pilot}}^{b_{\max}}) \) must be higher than the sensitivity of the receiver \( (S_R) \) plus the noise power \( (N) \). The RTP checks the signal from the best server \( (b_{\max} \in B) \).
\[
C_{\text{pilot}}^{b_{\max}} \geq S_R + N
\]
(15)

In this work, the calculation of the infrastructure parameters of one BS \( (B_{\text{cost}}) \) is made from a set of economic parameters \( L = \{1, ..., 1 \text{ total} \} \) over 1 year. Where \( i \) is from zero to the total number of base stations.

\[
F_{\text{costs}} = \sum_i f_{\text{cost}}^i
\]
(16)

B. Interference \( F_{\text{pen(CINR)}} \)

Interference based on the position and the amount of the users/BSs and resource available, a certain level of interference occurs. In addition, to define the interference we should consider only users, who use the same sub-channel and symbol and if they are close sufficient. Moreover, a single user is allocated a contiguous set of resources with the same modulation and coding known as a burst.

In this research, the penalty function is performed over entire users (t) for DL communication as illustrated in Eq. (17) and Eq. (18). The data listed in Table 2 corresponds to the default parameters found in [8]:

\[
m_{\text{dl}}^t = \begin{cases} 1 & \text{if RTP t is receiving;} \\ 0 & \text{otherwise.} \end{cases}
\]
(17)

\[
F_{\text{pen(CINR)}} = \sum_t c \in T f_{\text{pen(CINR)}} \cdot m_{\text{dl}}^t
\]
(18)

Table 2: WiMAX bearer threshold[8]

<table>
<thead>
<tr>
<th>Radio Bearer index</th>
<th>Modulation</th>
<th>Code Rate</th>
<th>CINR threshold (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>QPSK</td>
<td>0.5</td>
<td>0 = minimum</td>
</tr>
<tr>
<td>2</td>
<td>QPSK</td>
<td>0.67</td>
<td>2.5</td>
</tr>
<tr>
<td>3</td>
<td>QPSK</td>
<td>0.75</td>
<td>6.5</td>
</tr>
<tr>
<td>4</td>
<td>16QAM</td>
<td>0.5</td>
<td>9</td>
</tr>
<tr>
<td>5</td>
<td>16QAM</td>
<td>0.67</td>
<td>13.25</td>
</tr>
<tr>
<td>6</td>
<td>16QAM</td>
<td>0.75</td>
<td>17.4</td>
</tr>
<tr>
<td>7</td>
<td>64QAM</td>
<td>0.5</td>
<td>17.8</td>
</tr>
<tr>
<td>8</td>
<td>64QAM</td>
<td>0.67</td>
<td>19.8</td>
</tr>
<tr>
<td>9</td>
<td>64QAM</td>
<td>0.75</td>
<td>23 = maximum</td>
</tr>
</tbody>
</table>

The minimum CINR value is a necessity to get the minimum bearer that will allow transmission. Similarly, we set maximum CINR to the minimum CINR value to get the maximum bearer, which allows the peak data rate. Moreover, in [16] the authors present IEEE 802.16e interference results of packet error rate (PER) measurements in variable interference scenarios.

C. The quality of Service (QoS) \( F_{\text{pen(TH)}} \)

The QoS such as: throughput (TH) per user and packet loss, with reduced interference between cells, the users can achieve higher CINR. Users with higher CINR can use high
modulation order (see Table 2) and that would increase the number of data bits in their subcarrier (see Eq. 9) to achieve high spectral efficiency. Thus, obtains the highest data rate [8]. The effective throughput of the user has to meet a target throughput defined by a certain service, as shown in Eq. (19).

\[ M_t \geq M_{\text{min}} \tag{19} \]

Where:

- \( M_t \): is the current throughput of RTP \( t \).
- \( M_{\text{min}} \): is minimum throughput that the RTP must get to use the service.

<table>
<thead>
<tr>
<th>Name</th>
<th>Maximum throughput Demand</th>
<th>Minimum throughput Demand</th>
</tr>
</thead>
<tbody>
<tr>
<td>FTP download</td>
<td>1000</td>
<td>0</td>
</tr>
<tr>
<td>Video</td>
<td>64</td>
<td>64</td>
</tr>
<tr>
<td>VoIP</td>
<td>12.2</td>
<td>12.2</td>
</tr>
<tr>
<td>Web browsing</td>
<td>128</td>
<td>64</td>
</tr>
</tbody>
</table>

Table 3: Mobile WiMAX services (KBPS) [2]

Moreover, \( F_{\text{pen}}(TH) \) is the penalty function for QoS represented by the throughput. We consider the services as listed in Table 3, which make use of the different standard service classes in Mobile WiMAX.

\[ l^t_q = \begin{cases} 1 & \text{if user } t \text{ using service } q; \\ 0 & \text{otherwise.} \end{cases} \tag{20} \]

\[ F_{\text{pen}}(TH) = \sum_{q \in Q} \sum_{t \in T} f_{\text{pen}}(TH_q) \cdot l^t_q \tag{21} \]

Finally, by minimizing these factors illustrated in Eq. (14), the system:

- Minimizes the number of BSs;
- Ensures coverage for RTPs;
- Maintains separation between BSs;
- Ensures a certain QoS for the RTPs.

VI. THE PROPOSED SEQUENTIAL MODEL

Normally, there are two main approaches to tackling the planning problem, the sequential and the global. The sequential approach reduces the problem complexity, it neglects the interactions between sub-problems while the global model is more complex [17].

In the proposed network planning a sequential approach, which is a type of decomposition method is used to solve the problem, by breaking the entire problem up into smaller ones and solving each of the smaller sub-problem separately, either in parallel or sequentially, as in the [18] all detail available.

Moreover, the following are the advantages of sequential approach.

The sequential method advantages over the globe are summarized as follows:

- Reduces the complexity of the problem.
- Reduce the overall time.
- Improve sub-problem solution quality.
- The trade-off between solution qualities.

Because of these discussed advantages of the sequential (or decomposition) approach, the proposed model subdivided the entire planning problem of WiMAX network into three easier manageable sub-problems, as follows:

1. Dimensioning.
2. Frequency planning.
3. Optimization.

Despite the input of each sub-problem, the output of the previous sub-problem is also used as input to the next sub-problem. As shown in Figure 1.

The output of the dimensioning is used as input for the frequency planning. In a similar way, the output of the frequency planning is used as an input for the optimization. The final solution is a topology which satisfies all three sub-problems. Each phase is dedicated to achieving a specific set of goals in order to simplify the overall optimization procedure and gain better results compared to a single phase optimization which solves the complete problem.

In the following sub-sections, each sub-problem is explained as separated phase and the major works in solving them are presented briefly.
A. Phase 1 (potential site locations)

This phase is a dimensioning phase, which includes estimation of the required number of sites. Also determines the best possible site locations which optimally cover the network area by considering all objectives.

In addition, this phase includes partitioning the network into local areas that can be serviced from the obtained sites to achieve the following aims:

- Maximize coverage.
- Minimizing interference.
- Minimizing overall cost.
- Determine Center-Mass to each BS.

The outputs are:

- A subset of site locations.
- A set of covered RTP.

Moreover, accuracy in this phase is crucial because the poor quality of the initial design will eventually drive the subsequent optimization phases to struggle to converge to an efficient and profitable final network solution.

B. Phase 2 (frequency planning)

The identification of site locations and a center-mass for the traffic distribution of users to be serviced by each site has been done. In this phase, each BS will be sectorized separately in the way that the number of sectors corresponds to each BS must not exceed of 3 sectors.

\[ S = \sum_j \sum_i S_{ij} \]  

Where \( j \) is from zero to the total number of BS and \( i \) is the sector number from 1 to 3.

Despite sectorization, the main configuration jobs that were performed in phase two are (allocate neighbors, frequencies, and preamble indexes). Figure 2 depicts the WiMAX network planning workflow that performed in the phase two.

1) Planning Neighbors

You can set neighbors for each cell manually, but with this research neighbors were allocated automatically, based on the parameters that were defined, which are Max inter-site distance where set the maximum distance between the reference cell and a possible neighbor, Max no. of neighbors, Handover start, Handover end and % min covered area where set the minimum surface area, in percentage, that a possible neighbor cell’s coverage area must overlap the reference cell’s coverage area, as depicted in Figure 3. The assumed value of these parameters can be seen in Table 4.

The sector to which you are allocating neighbors is referred to as the reference cell. The cells that fulfill the requirements to be neighbors are the possible neighbor. The
The main benefit of this process is to facilitate handover between the reference cell and possible neighbor.

Fig. 3 The handover area between the reference cell and possible neighbor [19]

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max inter-site distance</td>
<td>1000 m</td>
</tr>
<tr>
<td>Max no. of neighbors</td>
<td>16</td>
</tr>
<tr>
<td>Handover start</td>
<td>0 dB</td>
</tr>
<tr>
<td>Handover end</td>
<td>5 dB</td>
</tr>
<tr>
<td>% min covered area</td>
<td>%10</td>
</tr>
</tbody>
</table>

### Table 4: Main neighboring parameter set values

<table>
<thead>
<tr>
<th>Frequency Planning</th>
</tr>
</thead>
<tbody>
<tr>
<td>The Automatic Frequency Planning (AFP) tool was used to automatically allocate channels to the sectors to minimize the overall interference. Furthermore, in AFP, FR-of-1 was used, in which each sector is assigned a unique channel. Also the network frequency range and center frequencies of each channel that are assumed can be seen in Table 5. Moreover, these parameters that considered in this part of planning are existing neighbors and minimum reuse distance. We tried to allocate a different channel to a sector and its neighbors to minimize interference and min reuse distance was set to 1000 meter radius within, which two sectors must not have the same channel assigned.</td>
</tr>
</tbody>
</table>

### Table 5: Frequency range and frame configuration

<table>
<thead>
<tr>
<th>Frequency Range</th>
<th>2300 – 2340 MHz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total bandwidth (BW)</td>
<td>40 MHz</td>
</tr>
<tr>
<td>Channel bandwidth</td>
<td>10 MHz</td>
</tr>
<tr>
<td>Number of channels</td>
<td>4 channels</td>
</tr>
<tr>
<td>Number of sectors</td>
<td>3 sectors</td>
</tr>
<tr>
<td>Center frequency of each channel</td>
<td></td>
</tr>
<tr>
<td>Ch1-2305 MHz</td>
<td></td>
</tr>
<tr>
<td>Ch2-2315 MHz</td>
<td></td>
</tr>
<tr>
<td>Ch3-2325 MHz</td>
<td></td>
</tr>
<tr>
<td>Ch4-2335 MHz</td>
<td></td>
</tr>
<tr>
<td>FFT size</td>
<td>1024</td>
</tr>
<tr>
<td>Frame Duration</td>
<td>5ms</td>
</tr>
<tr>
<td>Number of OFDM Symbols</td>
<td>48.6 (in frame of 5ms)</td>
</tr>
<tr>
<td>Number of Sub-channels per OFDM Symbol</td>
<td>48</td>
</tr>
<tr>
<td>Number of Subcarriers per Slot</td>
<td>48</td>
</tr>
</tbody>
</table>

### 3) Index Planning

In WiMAX, 114 preamble indexes are indexed from 0 to 113 that control the allocation of subcarriers to a sub-channel in the sector of a cell. It implies that the same sub-channel in two different sectors, using the same frequency band, but different preamble, will comprises of different subcarriers, thereby reducing interference [19].

The preamble index provides the segment number (0, 1, or 2) and the cell perm base (also called Cell ID, which is a value from 0 to 31). Therefore, the mobile recognizes which subcarriers to listen, as illustrate in Figure 4, which shows how distribute parameters on BSs.
C. Phase 3 (optimization)

The objectives in this phase after site sectorization and pre-configuration in phase two are to increase profits by optimizing second phase using Automatic Cell Planning (ACP), in which designs the WiMAX networks in order to automatically calculate the optimal network settings in terms of network coverage and capacity. The optimum or close to optimum planning could be achieved by improving the existing network deployment via reconfiguring the main parameters that can be remotely controlled by operators such as antenna electrical tilt and cell pilot power.

ACP can also be used during the initial planning stage of a WiMAX network by enabling the selection of the antenna, and its azimuth, height, and mechanical tilt by performing the procedure that is illustrated in Figure 5 to get the aims of maximizing coverage and service of phase two.

VII. WiMAX Traffic Simulation

In this research, Monte-Carlo algorithm is used as simulation, which is based on a scattering of RTPs at a given interval. The scattering of RTPs at a certain moment referred to a snapshot. Based on this snapshot, various network parameters are calculated such as coverage, service level, application channel throughput, and the quality indicator of Block Error Rate (BLER).

VIII. Experimental Network Scenario

In this paper the planning tool is used to design 2.3 GHz WiMAX networks in the Erbil city, a rural/urban/suburban scenario covering 210.93 km² with 26,551 users and 98 sites, the graphical illustration of the network are shown in Figure 6. Each black circle in the figure symbolizes site location, each user is represented by a single Reception Test Point (or RTP); they are randomly distributed in this area, according to an urban, suburban and rural density, all users here are considered to be a household (HH) class.
The traffic demand and service parameters are consistently defined for all RTPs as listed in Table 6. User economic parameters are listed in Table 7, economic values have been found in [20]. The connection tariff is a one-off cost, whilst the subscription is an annual charge.

The base station economic parameters are listed in Table 7 and are split into capital expenditure (CapEx) and operational expenditure (OpEx) for both the site and sectors respectively. Table 8 reviews the main parameters used in this scenario.

Table 6: Web browsing and FTP download Traffic Parameters [13]

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Web browsing service</th>
<th>FTP download service</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Uplink</td>
<td>Downlink</td>
</tr>
<tr>
<td>Highest bearer</td>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td>Lowest bearer</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Max throughput demand</td>
<td>64 kbps</td>
<td>128 kbps</td>
</tr>
<tr>
<td>Min throughput demand</td>
<td>32 kbps</td>
<td>64 kbps</td>
</tr>
</tbody>
</table>

Table 7: Economic parameters for the User and the Base Stations[20]

<table>
<thead>
<tr>
<th>Economic parameters</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>RTP CPE CapEx (€)</td>
<td>350</td>
</tr>
<tr>
<td>Connection Tariff (€)</td>
<td>50</td>
</tr>
<tr>
<td>Annual subscription (€)</td>
<td>600</td>
</tr>
<tr>
<td>BS Base site CapEx (k€)</td>
<td>31</td>
</tr>
<tr>
<td>BS Base site OpEx (k€)</td>
<td>1.5</td>
</tr>
<tr>
<td>Sector CapEx (k€)</td>
<td>5</td>
</tr>
<tr>
<td>Sector OpEx (k€)</td>
<td>0.5</td>
</tr>
</tbody>
</table>

Table 8: Network simulation parameters

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency range and BW</td>
<td>Table 5</td>
</tr>
<tr>
<td>Max number of users per sector</td>
<td>67 users</td>
</tr>
<tr>
<td>UL/DL duplexing scheme</td>
<td>TDD</td>
</tr>
<tr>
<td>Frequency reuse</td>
<td>Reuse of 3, i.e. (1, 3, 3)</td>
</tr>
<tr>
<td>Max BS transmits power</td>
<td>43 dBm</td>
</tr>
<tr>
<td>BS antenna gain</td>
<td>18 dBt</td>
</tr>
<tr>
<td>Max RTP transmits power</td>
<td>23 dBm</td>
</tr>
<tr>
<td>RTP antenna gain</td>
<td>0 dBt</td>
</tr>
<tr>
<td>Path loss model</td>
<td>SUI model</td>
</tr>
<tr>
<td>Rate per user</td>
<td>Table 6</td>
</tr>
<tr>
<td>User and BS economic parameters</td>
<td>Table 7</td>
</tr>
</tbody>
</table>

IX. ANALYSIS OF FINDINGS

This section finalizes all the findings and results along with the analysis of the findings with respect to the critical KPIs according to each phase in the network optimization planning and comparing the proposed network planning with Newroz Telecom Company planning also will be tackled in this section.

The first performance indicators to be analyzed are service level, application channel throughput, BLER and rejected users to connect the network of the selected plan. The coverage level, BTS number, sector number and expenditure KPI are not included in the analysis because the entire network plans have been achieved with a preferred service level and contain the same amount of equipment including BTSs and sectors.
The comparison of service level, throughput, BLER and rejected users is shown in Figure 7 in the form of a histogram. The research findings revealed that the service level, throughput, BLER and rejected users in phase two and phase three are nearly identical, and upper than phase one, which proves the ability of phase two to produce a high quality network plan as a worthy initial point for the final optimization phase. Also the improvement between phase two and phase three is not a large amount, it shows that phase two doesn't leave large opportunity for improvement.

Moreover, a converse relationship can be noted between service and throughput KPIs against BLER and rejected others. Phase three has an absolute maximum service level and throughput within the whole range of network plans while in the opposite, achieved minimum BLER and rejected users that are 3.3% and 3.8% of focused zone respectively.

Secondly, in comparison to the Newroz Tel Company, the proposed network model of Ainkawa had a reduction of the expenditure by 20% as presented in Figure 8 while improves all other KPIs. The most notable result, however, was shown by the PN, where almost identical service level in the NT and PN, results in the throughput greater than 5Mbps peaking at the level of 96.4%.

Finally, the research findings revealed through the above analysis and comparison between PN and NT that PN is better than NT regarding all KPIs with reduction of expenditure in great level. From these results, one conclusion can be noted that Newroz Tel service provider leaves a large opportunity for their improvement planning.

X. CONCLUSION

A model for the planning problem was proposed which address these problems which is ignored or gets a little attention by most of the researchers. In the proposed network planning a sequential approach is used to solve the optimization problem that is a type of decomposition
approach, which divides the entire problem into three different sub-problems consisting of dimensioning, frequency allocation and optimization. The proposed WiMAX network consists of 98 sites with optimal site location which are providing service to the almost entire area of the real scenario in Erbil (210.93 km² with 26,551 users) that operates on 2.3 GHz licensed band.

The research findings revealed that the service level, throughput, BLER and rejected users in phase two and phase three are nearly identical, and upper than phase one, which proves the ability of the proposed model to produce a high quality network plan as a worthy initial point for the final optimization phase.

The proposed network model (PN) was compared to the sample of the Newroz Tel Company (NT) realistic data network in Ainkawa area. The result of this comparison showed that PN had a reduction of the expenditure by 20% while improve all other KPIs. From these results, one conclusion can be noted that Newroz Tel service provider leaves a large room for improvement and further enhancement.

References