PPU College of Engineering and Technology
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College of Engineering & Technology

Electrical and Computer Engineering Department

Graduation Project

LTE Network Planning And Optimizing
(Hebron, Ramallah and Nablus)

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Dedication

For God we only pray, for God we dedicate our deep thankful for the power he gave us to complete this modest work.

For our prophet Mohammed peace be upon him.

For our parents who granted us life , hope and raised us with curiosity and love for unbounded knowledge.

For the man who learned us how to research, how to dream, for our supervisor Dr. Khalid Hijjeh.

For our brothers and our sisters. We are proud to say that your pray was very valuable to us.

For our teachers, we appreciate all their effort with us .

For all our colleagues in the department of communication engineering.

For all our friends, we appreciate your encouragement all the time.

…

Acknowledgment

This report is the first and foremost a collective effort, which was not successful without these cooperative efforts. All praise and thanks to Allah , which we estimated to complete this work.

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To Engineers Arafat Tomezi and Ayman Dasht.

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Aleen Abu Rayyan

Rawan Arafeh

Lujain mahdi

Yasmeen swaity

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الملخص

مع النمو السريع لقطاع الاتصالات في الأعوام الأخيرة , وزيادة عدد المستخدمين لشبكات الاتصال اللاسلكية تزايد الطلب على أنظمة نقل البيانات ذات السرعة العالية والتي تقدم جودة عالية للبيانات. بالإضافة إلى ذلك فإنه من المتوقع أن تستطيع أنظمة الاتصالات اللاسلكية المستقبلية دعم نطاق واسع من الخدمات بما فيها الفيديو , البيانات والصور. هذه الحاجة دعت لتطوير تكنولوجيا جديدة تواكب متطلبات المستخدمين وتلبي احتياجاتهم في إمكانية نقل المعلومات بسرعة وجودة عالية وبتكلفة منخفضة.

LTE هي تكنولوجيا من الجيل الرابع , وهي اختصار لـ Long-Term Evolution أي التطور البعيد المدى. وهي أحدث تكنولوجيا في مجال الاتصالات والتي قدمت للمستخدمين إمكانية نقل بيانات بسرعات هائلة وبجودة عالية وبتكلفة منخفضة.

وقد قللت هذه التكنولوجيا عبء وتكاليف الانتقال من جيل إلى آخر , وقدمت تكنولوجيا جديدة من خلال التطوير على شبكات الاتصال من الجيل الثالث فهي توفر مجموعة من الحلول التي تدعم عمل الشبكة من الجيلين الثالث والرابع بصورة تضمن الحفاظ على البيئة الأساسية للشبكات.

في هذا المشروع , تم شرح خصائص ومميزات هذه التكنولوجيا , والتقنيات التي استخدمتها , لاستخدامها في تصميم شبكات اتصال لاسلكية لثلاث مدن: الخليل , نابلس ورام الله , وقد تركزت عملية التصميم على ثلاثة أهداف رئيسية: التغطية , السعة , الجودة. و تمت دراسة العوامل التي تساعد على تحسين هذه الأهداف إضافة إلى ذلك تم بناء برامج باستخدام برنامج ال Matlab وهي تساعد في تحسين التغطية والسعه والجودة وذلك باستخدام أحد مبادئ Self Organizing Network(SON) وهي شبكات تقوم بعملية التحسين والتطوير بنفسها عن طريق برمجة المعدات لتقوم بعمليات التطوير والصيانة عند الحاجة و دون تدخل المهندس وذلك يساعد على توفير الوقت والجهد في عملية صيانة الشبكة ومعالجة الأخطاء التي تتعرض لها . وقد قمنا بتوظيف شبكة ذكية تسمى Neural Network (NN) تساعد في تطبيق مزايا شبكات الSON .

Abstract

In the beginning of our graduation project we promised to make a planning network for Hebron city , but we actually could expand our goal to include two cities in addition to Hebron which are Ramallah and Nablus cities .

However, the experience we rushed into in planning and optimizing these three main cities, and the difficulties we faced in trying to optimize and fine tune their regions, motivated us to think in a new easier way for optimizing LTE network.

We programmed some Matlab codes which are based on using what is called Neural Network for self optimizing the coverage and capacity in the network to be planned , automatically, without any external entry from the planner side . No doubt that using such an intelligent way saves the planner effort, money, and time; since this way depends on itself in fine tuning and optimization processes .

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List of Abbreviations

A

AFP Automatic Frequency Planning

AMPS Advanced Mobile Phone System

ARIB Association of Radio Industries and Businesses

ATIS Automatic Terminal Information Service

AWGN Association of Additive White Gaussian Noise

B

BER Bit Error Rate

C

CN Core Network

CP Cycle Prefix

CPLM Composite Path Loss Matrix

D

DwPTS Downlink Pilot Timeslot

DL DownLink

E

EDGE Enhanced Data Rate for GSM Evolution

EARFCN Evolved Absolute Radio-Frequency Channel Number

ETSI European Telecommunications Standards Institute

eNodeB evolved NodeB

EPC Evolved Packet Core

EPS Evolved Packet System

F

FDD Frequency Division Duplex

FDPS Frequency-Domain Packet Scheduling

G

GBR Guaranteed Bit Rate

GIS Geographical Information System

GMSK Gaussian Minimum Shift Keying

GP Guard Period

GPRS General Packets Radio Services

GSM Global System for Mobile communications

H

HSUPA High Speed Uplink Packet Access

HSDPA High Speed Downlink Packet Access

HSS Home Subscriber Server

I

ITU International Telecommunication Union

ITU-R International Telecommunication Union Radio communication Sector

L

LOS Line Of Sight

M

MIMO Multiple Input Multiple Output

MISO Multiple Input Single Outputs

MU-MIMO Multi-User

MME Mobility Management Entity

MBMS Multimedia Broadcast Multicast Services

N

NRs Neighbor Relations

SON Self Optimizing Network

NN Neural Network

Nlos No Line Of Site

O

OFDM Orthogonal Frequency Division Multiplexing

OFDMA Orthogonal Frequency Division Multiple Access Technique

P

PDN-GW Packet Data Network Gateway

P-GW PDN Gateway

PCRF Policy Control and Charging Rules Function

Q

QCI QoS class identifier

QoS Quality of Service

R

RBS Radio Base Station

RBs Resource Blocks

RLB Radio Link Budget

RN Relay Node

RSS Received Signal Strength

S

SAE System Architecture Evolution

SNIR Signal to Noise and Interference Ratio

SC-FDMA Single Carrier Frequency Division Multiple Access

SMS Short Massages Service data transfer

SON Self Optimizing Network

SU-MIMO Single User

SAE System Architecture Evolution

S-GW Serving Gateway

SISO Single Input Single output

SIMO Single Input Multiple Output

T

TTC Toronto Transit Commission

TMA Transportation Management Area

TDMA Time Division Multiple Access

3GPP 3rd Generation Partnership Project
Tx Transmitted Power

U

UMTS Universal Mobile Telecommunication System

UpPTS Uplink Pilot

HSUPA High Speed Uplink Packet Access
UTRAN Universal Terrestrial Radio Access Network
UL Up Link

V

VOIP Voice over IP

W

WCDMA Wide band Code Division Multiple Access

WiMAX World Wide Interoperability for Microwave Access

.

Chapter 1
Introduction

Contents

1.1 Overview

This chapter explains the motivations behind the project and its objectives; it mentions some studies and previous works related to this project. It gives a summary about the expected outcomes and the required tools needed. Also it describes the future project plan.

1.2 General idea about the project

Recently, communications world witnessed rapid developments with the growing number of users and the increase of their needs and requirements for better services with higher data rates and lower costs. Moreover, with the limited bandwidth, the spectrum efficiency of the system has been improved by adopting some advanced technologies.

Long Term Evolution (LTE) is the latest step in moving forward from the cellular 3rd generation (3G) services. It was standardized by 3rd Generation Partnership Project (3GPP) as the successor of the Universal Mobile Telecommunication System (UMTS), to meet:

1) Demands for high data rate.
2) Low latency.
3) Optimize capacity of the system.

This project will work on planning and optimizing the coverage, quality and capacity requirements of LTE network in three cities Hebron, Ramallah and Nablus. It introduces latterly an alternative optimization method by Matlab codes using intelligent network called neural network which gives the network the ability to automatically optimize itself without any external modification by the planner .

1.3 Objectives

The key objectives of this project can be summarized as follow:

1) To plane and optimize the LTE network for Hebron city.
2) To plane and optimize the coverage estimation.
3) To plane and optimize the capacity estimation.
4) To plane and optimize the quality estimation.
5) To use the neural network in Matlab codes to apply some of Self Organizing Network (SON) techniques which allow the network to optimize itself automatically.

1.4 Coverage planning and optimizing

The main goal of LTE coverage planning and optimizing is to ensure the availability of the network and its services. It:

1) Is the first step in the process of dimensioning the network.
2) Calculates the area where base station can be heard by the users (receivers).
3) Gives the maximum area that can be covered by the base station.[1]

Coverage planning includes two main steps: Radio Link Budget (RLB) and coverage analysis. RLB is responsible for many calculations that important to specify the number of sites in the area to be covered. It computes the power received by the receiver, given a specific transmitted power from the base station. It also gives the maximum allowed pathloss, to calculate the cell size using a suitable propagation model. Many parameters are taken into account in RLB, such as the transmission power, antenna gain, system losses, diversity gain, fading margin etc.[1]

1.5 Capacity planning and optimizing

Capacity Planning Definition

The capacity planning process is a step of the LTE planning process, which deter-mines the number of recourses required to give the users in an area the traffic needed to let them send the maximum amount of date in a shortest time and less blocking.[2]

Capacity Dimensioning

Capacity dimensioning is a part of the capacity planning process in which the number of the sites that got from the coverage dimensioning and the RLB calculations is adjusted and increases or decreases depending at the number of the users in the covered area and depending on the services.[2]

Capacity Optimization

LTE technology used several ways to optimize the capacity of the cell:

1) MIMO and OFDM:

LTE combined both Multiple Input Multiple Output technology (MIMO) technology and the Orthogonal Frequency Division Multiplexing (OFDM) technology to increase the capacity, improve the spectral efficiency, and to achieve very high data rates which is reached to around 50Mpbs for UL, and becomes around 100 Mbps for DL which were not possibly achievable in the previous 2nd and 3rd generations.[2]

2) Multihops or relays:

Which are network devices used to enhance the capacity and coverage in LTE network by increase the Signal to Noise and Interference Ratio (SNIR) in the area.[3]

1.6 Quality planning and optimization

It is important to define the inputs of dimensioning and planning process which are divided into three categories; quality, coverage, and capacity inputs. Quality inputs include average cell throughput and minimum blocking probability. These parameters translated into Quality of Service (QoS) parameters.

QoS can be defined as the ability of a network to provide a certain level of service to a certain type of traffic. QoS becomes an important parameter in the Fourth Generation (4G) because of the increasing number of subscribers and the increase of traffic volume for each subscriber. LTE has been designed with QoS frameworks differ from those in the previous technologies which became not efficient for supporting the new mobile internet applications with a good user experience. Sometimes the user runs multiple applications at the same time, each of them have different QoS requirements. In order to support multiple QoS requirements, LTE follows a QoS mechanism that uses the Evolved Packet System (EPS) bearers. Each bearer associated with a QoS. Bearers are divided into two types depending on the application QoS, Guaranteed Bit Rate (GBR) bearers and Non-GBR bearers. [(2), (4)]

As mentioned before, different applications require different QoS levels, and to ensure getting the desired QoS for a specific application under the variation of channel conditions, radio link adaptation must be used, which helps in specifying the modulation and coding schemes that must be used for the current channel conditions. Radio link adaptation involves radio link quality measurements. These measurements need an estimation of some radio link measurements, such as the Signal to Noise Ratio (SNR), the Received Signal Strength (RSS) and the Bit Error Rate (BER).[(5)]

After finishing all these calculations, the planner will be able to know the current channel quality and then will be able to do all the required modifications to offer better services to the user with minimum blocking probability.

1.7 Motivations behind using LTE

The main target to evolve LTE technology is to deliver much more performance comparable to the existing 3GPP networks based on High Speed Packet Access (HSPA). LTE provides up to 100 Mbps in DL and 50 Mbps in UL, which is ten times more than HSPA Release 6.Also it reduces the latency by a factor of 2-3 times less than HSPA. LTE enhanced the network performance from several aspects, it:

1) Increases the spectral efficiency by a factor of 2-4 times more than HSPA Release 6.
2) Increases the data rate up to 100 Mbps in DL and 50Mbps in UL.
3) Is a packet switched technology.
4) Provides high level of mobility and security.

1.8 LTE Technologies

LTE depends on three fundamental technologies:

1) Multicarrier technology: LTE transmission scheme is based on Orthogonal Frequency Division Multiple Access technique (OFDMA) in DL, and on Single Carrier Frequency Division Multiple Access (SC-FDMA) in UL.

2) MIMO: which enhances the performance, also increases the data rate and capacity of the system.

3) The application of packet-switching to the radio interface.

1.9 Self Optimizing Network (SON)

Self Organizing Network introduced as part of the 3GPP Long Term Evolution (LTE) and it is a good solution for improving O&M, It aims to reduce the cost of installation and management by reducing the amount of manual processes involved in the planning, integration and configuration of new eNBs, this will lead to a faster network deployment and reduced costs for the operator in addition to a great management system that is less affected by human error, which improve the network performance and flexibility.(6)

3GPP initiated the work towards standardizing self-organizing capabilities for LTE, in Release 8 and Release 9, in order to automate the configuration and optimization of wireless networks to adapt to varying radio channel conditions by providing network intelligence.(7)

This project uses the neural network in Matlab codes to apply some of Self Organizing Network (SON) techniques which allow the network to optimize itself automatically.

[6] NEC Corporation,2009.Self-Optimizing Network ”NEC” proposals for next-generation radio network management.
[7] 4G Americas,2011.Self-Optimizing Network :The benefits of SON in LTE .

1.10 Neural Network (NN)

Neural Network consists of some elements operate in parallel. These networks can be trained to perform a function or a particular task, by adjusting the values of the connections (weights) between elements.(8)

Each input to the NN leads to a certain target (the desired output). It is trained and adjusted until the output (the response) matches the target by making a comparison between them and calculating the error.(8)

There are many reasons and benefits for using the NN, mainly its ability to learn and train.

which gives it the capability to solve complex problems in various fields.(8)NN can be constructed from number of information –processing units called neurons.(9)

As mentioned before, the NN has the ability to learn from its environment and it can improve its performance through learning . Training process can be defined as a process of simulation to adjust the weights and biases in order for NN to do a task. The weights and biases are adjusted to minimize the error.(8)

1.11 Related works

There was not that much studies on LTE planning networks since it is a new technology and not experienced in a broadcast range . Here there are some studies related to this project:

LTE planning procedure is similar to 2G/3G network planning procedure with some different details and parameters . Referring to previous studies LTE planning network procedure requires many basic inputs like Frequency ,bandwidth , area to be covered , QOS requirements , number of subscribers , etc . And it has many outputs like MAPL (Maximum Allowed Path Loss), cell range, number of sites and sectors, eNodeB configuration, etc.(10)

Some researches discussed LTE network planning procedure theoretically as in [2]. In this project Tems Cell Planner tool is used for executing the planning and optimization. The network could be optimized not just manually by the planning tool but also by the neural network codes that made the optimization done efficiently in a shortest time and minimum effort and cost .

[11] is a research showed the relation between the capacity MIMO and the signal to noise ratio depending on Eregdic capacity relation which is an average information rate over an unknown channel , which given by the following equation :

$$C=\epsilon \{\sum_{i=1}^{r} \log_2(1+\frac{\rho}{Mt}\,\boldsymbol{\lambda i})\}$$

We complemented the work on this relation by combining it with the decision of selecting the most suitable antenna configuration by using the neural network intelligence since LTE networking introduces MIMO from the first phase and antenna selection needs considering not only frequency band and HPBW (Half Power Beam Width), but also antenna element number.

[12] Worked on the effect of the antenna height on tilt angle tuning in a large cellular network .Depending on practical self optimization and LTE assumptions the simulation results showed that both those two factors -the vertical tilt angle factor and the antenna height factor- can be independently tuned and adapted . which is an important simplification for improving the-operation of large LTE networks. (Al Hakim -paper) This research employs the neural network in choose the appropriate antenna beam pattern depending on the antenna down tilt angle

1.12 Conclusion

This chapter introduced a new 4G technology, which is Long Term Evolution (LTE) technology, firstly it introduced an introduction about the LTE planning network and it took a brief round on each of the planning aspects (coverage, capacity, and quality) which all are the objectives of this project. The chapter also viewed a brief summary about the other goals of the project which is the optimization of the planning network from the angel of coverage, capacity, and quality.

Chapter 2

Literature review

Contents

2.1 Overview

This chapter will first review the generations of wireless communication and the main difference between the 4G and the previous generations. Then will introduce LTE and its technologies. After that the chapter will explain the main concepts of coverage, capacity and quality planning and optimizing. It also will explain briefly the SON and the neural network. At the end of this chapter a brief explanation will be introduced about the LTE network architecture and its main nodes, finally the main planning stages will be discussed.

2.2 Generations of Wireless Communication

2.2.1 First Generation(1G) and Second Generation (2G)

Telecommunication Wireless Systems are classified according into generations, which indicate the fundamental changes in services and data rates. Along last years, wireless communication system was evolved forward in three generations.

Basic mobile voice was introduced at the beginning of 1980s in the 1G called the Advanced Mobile Phone System (AMPS). 1G is an analogy FDMA voice transfer through 30 KHz channels.(13)After that at the beginning of 1990s the second generation 2G was launched. It used a digital communication technology, which provided better spectral utilization.2G was designed as circuit switched system for voice services, and Short Massages Service data transfer (SMS).(14)(15)

Global System for Mobile communications (GSM) standard introduced digital communication with a combination of Time Division Multiple Access (TDMA) and slow frequency hopping.(13)

In 2G there are a set of services such as: General Packets Radio Services (GPRS) and Enhanced Data Rate for GSM Evolution (EDGE) allowing additional data services. Both EDGE and GPRS are considered as 2.75G and 2.5G technologies. GPRS technology can be used for all packet data services, such as Internet browsing, WAP access, SMS and Multimedia Massage Services (MMS). Also it can provide data rate from 56 kbps up to 115 kbps. EDGE introduces 8-PSK modulation alongside Gaussian Minimum Shift Keying (GMSK) so it provides throughout 2 to 4 times more than GPRS.(15),(16),(17)

2.2.2 Third Generation (3G)

Third Generation is mobile broad band technology, which was introduced by 3GPP and 3GPP2, to develop the 2Gnetworks so that users are supported by different types of services such as voice, data, multimedia and video on Internet with high speed. In Europe, 3G was known as UMTS. 3G used different access technologies such as Wide band Code Division Multiple Access (WCDMA) and Time Division CDMA (TD-CDMA).(14)

2.2.3 Overview of 3GPP Releases

The 3GPP is formed by the standards bodies European Telecommunications Standards Institute (ETSI),Association of Radio Industries and Businesses (ARIB), Toronto Transit Commission(TTC), and Automatic Terminal Information Service (ATIS). 3GPP has introduced 3G technologies in order to be suitable with high data rate demand. In December 1999 Release 99 (Rel-99) was published, which introduced UMTS and WCDMA technologies that improved the data rate. Then in March 2001, Release 4 (Rel-4) was found, it did not have many major enhancement at WCDMA. [19]In March 2002, Release 5 (Rel-5) introduced some enhancements to UMTS; it included High Speed Downlink Packet Access (HSDPA). After that Release 6 (Rel-6) introduced further enhancements to UMTS including the Uplink Packet Access (HSUPA) in December 2004. The combination of HSDPA and HSUPA is called HSPA. [18][19]

Release 7 (Rel-7)at this release HSPA+ was introduced and EDGE was developed as EDGE Evolution, with downlink speeds of up to 1.2 Mbps became available and UL speeds of up to 473 kbps. These evolutionary enhancements are essential to provide service continuity with HSPA and LTE, since 68 percent of HSPA networks are deployed with EDGE and 83 percent of HSPA devices also support EDGE. [18]

3GPP Release 8 (Rel-8) provided new technologies such as OFDMA, and provided the capability to perform 64-QAM modulation with 2x2 MIMO on HSPA+. Also Rel-8 introduced Evolved Packet System (EPS) consisting of a new flat-IP core network called the Evolved Packet Core (EPC), coupled with a new technology called Long Term Evolution (LTE) .[18]

HSPA+ is also further enhanced in Release 9(Rel-9) and was demonstrated at 56 Mbps featuring multicarrier and MIMO technologies. Rel-9 will add new enhancements to both HSPA and LTE. For HSPA, additional multi-carrier and MIMO options are coupled. For LTE, there are additional features and enhancements to support different types of services such as emergency, location and broadcast services. [18]

Release 10 define new generation of technologies called LTE-Advanced (LTE-A), which provides further enhancement to LTE technology, in order to meet the requirements of International Mobile Telecommunications-Advanced (IMT-Advanced) that are issued by the the International Telecommunication Union (ITU). The key feature of LTE-A includes carrier aggregation, multi-antenna enhancements and relays. [18]

2.2.4 4G overview

4G telecommunication system is another transition in the broadband mobile system beyond 3G. Where 4G will provide higher data rate, lower latency and much better spectral efficiency.[20]Both IEEE 802.16. World Wide Interoperability for Microwave Access (WiMAX) and 3GPP LTE represent 4G technologies that desire to provide voice, data and video with low cost and with data rate up to 1Gbps.

2.3 Long term evolution (LTE)

Nowadays, a higher data rate and lower latency with low coast is the demand of the subscriber, in order to meet this demand 3GPP initialized an Evolved UTRAN (E-UTRAN) within the Rel-8 LTE project, LTE is a packet switched technology which exceeds the existing networks by some essential changes, LTE gives the subscriber a 100 Mbps in the DL and 50 Mbps in UL.[1][2]

The main reasons to introduce LTE summarized as follow:

1) Higher data rates against previous system .
2) Reduce latency to be less than 5ms. .
3) Increase the coverage by providing higher data rate over wider area.
4) Support new bandwidths such as 5, 10, 15, and 20 MHz.
5) Support real-time and non-real-time applications with low cost.[21]

2.3.1 LTE Duplexing schemes

Duplex scheme is an important way for radio communication systems that allows communication in both directions, where the transmitter and receiver can operate simultaneously using two schemes; Frequency Division Duplex (FDD) and Time Division Duplex (TDD).FDD uses two separate channels, one for transmission and the other for reception. TDD uses the same channel, but with different time slots for transmission and reception. [22]

The main difference Between FDD LTE and TDD LTE can be summarized in the table below:

Table 2.1 TDD versus FDD

Parameter	LTE-TDD	LTE-FDD
Paired spectrum	Does not require paired spectrum as both transmit and receive occur on the same channel.	Requires paired spectrum with sufficient frequency separation to allow simultaneous transmission and reception.
Hardware cost	Lower cost as no diplexer is needed to isolate the transmitter and receiver.	Diplexer is needed and cost is higher.
Channel reciprocity	Channel propagation is the same in both directions which enables transmit and receive to use on set of parameters	Channel characteristics different in both directions as a result of the use of different frequencies
UL / DL asymmetry	It is possible to dynamically change the UL and DL capacity ratio to match demand.	The capacity does not change , because it determined by frequency allocation by the regulatory authorities.
Guard period / guard band	Guard period required to ensure uplink and downlink transmissions do not clash. Large guard period will limit capacity. Larger guard period normally required if distances are increased to accommodate larger propagation times.	Guard band required to provide sufficient isolation between uplink and downlink. Large guard band does not impact capacity.
Discontinuous transmission	Discontinuous transmission is required to allow both	Continuous transmission is required.

	uplink and downlink transmissions. This can degrade the performance of the RF power amplifier in the transmitter.	
Cross slot interference	Base stations need to be synchronised with respect to the uplink and downlink transmission times. If neighbouring base stations use different	Not applicable

2.3.2 LTE technologies

LTE support various types of technologies such as multiple access and MIMO techniques. The use of such techniques has led to increase the data rate and utilize the channel bandwidth. (2)

2.3.2.1 Multiple Access Techniques

The selection of an appropriate modulation scheme and multiple-access technique for radio channel is critical in communication system to achieve good system performance. This section discusses the multiple access techniques that could be used in LTE technology. Which are OFDM in DL, and SC-FDMA in UL. (2)

2.3.2.2 OFDMA

LTE technology uses OFDM in DL, which divides the data stream over a number of sub-carriers. Each subcarrier is modulated using varying levels of QAM modulation, e.g. QPSK, QAM, 64QAM or possibly higher orders depending on signal quality. Since the carriers are orthogonal, the signals will not interfere .In order to overcome the overlap between two successive OFDM symbols, a guard interval which is filled by a Cycle Prefix (CP) is inserted between them, also its desirable to overcome the ISI and inter carrier interference, the CP consists of a copy of a fixed number of bits of the last symbol. (24)

Figure 2.1 illustrate the structure of OFDM symbol.

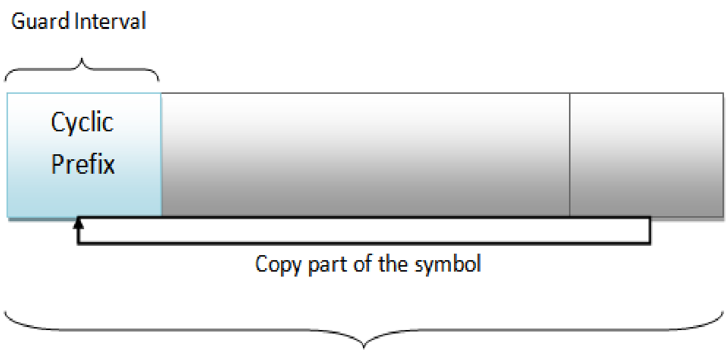


Figure 2.1 OFDM symbol

OFDMA is an ideal solution for broad band communication. Increasing the data rate is done by increasing the number of subcarriers. The orthogonally feature in OFDM avoid the need to separate two successive sub-carrier by guard band and allows them to overlap thus leads to increase the spectrum efficiency. (25)

In LTE the frame structure of OFDM symbol are different according the transmission mode .There is to type of OFDM frame FDD-OFDM mode and TDD-OFDM mode. FDD-OFDM frame is 10 ms radio frame which is divided into 20 identical slots each with duration 0.5 ms .Each two slot make a sub-frame. Figure 2.2 show FDD-OFDM frame structure. (21)

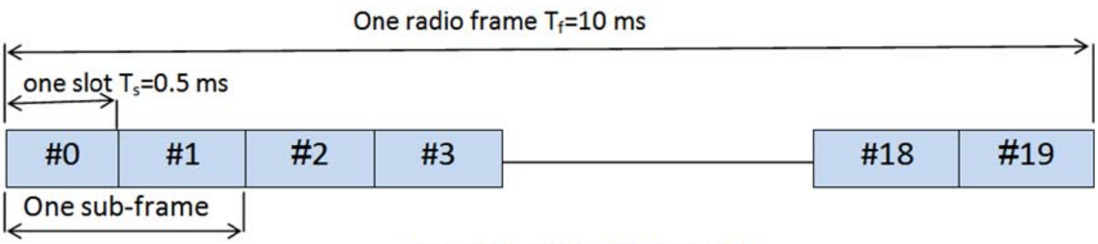


Figure 2.2 FDD-OFDM symbol

TDD-OFDM frame consist of two half frame. Each half frame is divided into 5 special and not special sub-frames. Special sub frames are divided into 3 fields Downlink Pilot Timeslot (DwPTS), Guard Period (GP), and Uplink Pilot (UpPTS). Figure 2.3 show TDD-OFDM frame. (21)

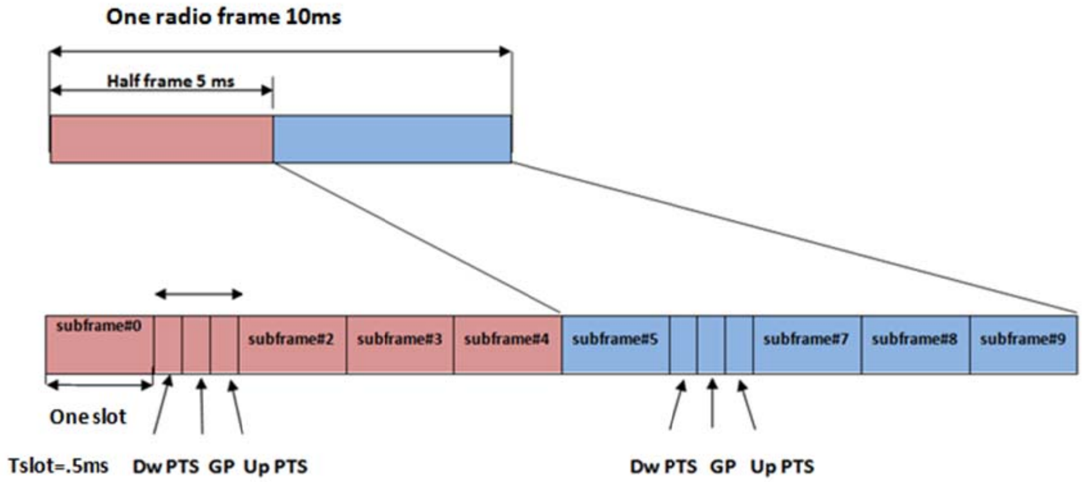


Figure 2.3 TDD-OFDM

LTE OFDM symbols consist of 12 subcarrier spacing between the sub-carrier is 15 kHz. So the minimum allocation bandwidth is (12*15) 180 KHz in frequency domain and 1 ms in time domain, with symbol time 66.68 microsecond. (19)

LTE Supported bandwidths:

LTE channels bandwidths are flexible and it provides six different bandwidths include 1.25, 2.5, 5, 10, 15 and 20 MHz, OFDM symbols are inserted at sub-frame each sub-frame consist of 6 to 7 OFDM symbols depending on the length of CP. Each sub-frame is either an uplink or downlink sub-frame. Table 2.2 summarized parameters for DL transmission schemes.(26)

Table 2.2:Downlink parameters[1]

Transmission BW	1.25MHz	2.5 MHz	5 MHz	10 MHz	15 MHz	20 MHz
Sub-frame duration	0.5 ms					
Sub carrier spacing	15 kHz					
Sampling frequency (MHz)	1.92 MHz (1/2x 3.84 MHz)	3.84 MHz	7.68 MHz (2x3.84 MHz)	15.36 MHz (4x3.84MHz)	23.04 MHz (6x3.84MHz)	30.72 MHz (8 x 3.84 MHz)
FFT size	128	256	512	1024	1536	2048
Number of occupied sub-carriers	76	151	301	601	901	1201
Number of OFDM symbols per sub-frame (Short/Long CP)	7\6					

2.3.2.3 SC-FDMA

Single-carrier frequency division multiple access technique is used for UL transmission. This technique also use the sub-carrier concept. it is sometimes called discrete Fourier transform spread OFDM. In some case the signals are allocated on 12 sub-carrier which mean 180 KHz of the bandwidth. As in OFDM cyclic prefix is added to each symbol. SC-FDMA transmitter and receiver architecture is very similar to OFDMA, and it offers the same degree of multipath protection. The main objective for this technique is to reduce power consumption of the user terminals.[19]

The sub-frame consists of six long blocks and two short blocks. Long block carried control or data information also short block used for the same purpose in addition to coherent demodulation. Figure 2.4 illustrates the UL SC-FDMA frame.[1]

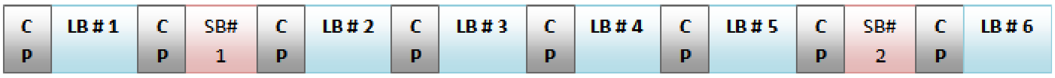


Figure 2.4 :UL SC-FDMA frame (1)

Fig (2.5) shows that OFDM transmits multiple symbols in parallel which lead to undesirable high PAPR. On the other hand SC-FDM transmits the M data symbols in series at M times which reduce PAPR. Each subcarrier in OFDMA symbol carries data related to one user ,but in SC-FDMA the user data is carried by all subcarriers in the symbol ,so each sub carrier carries data for more than one user.

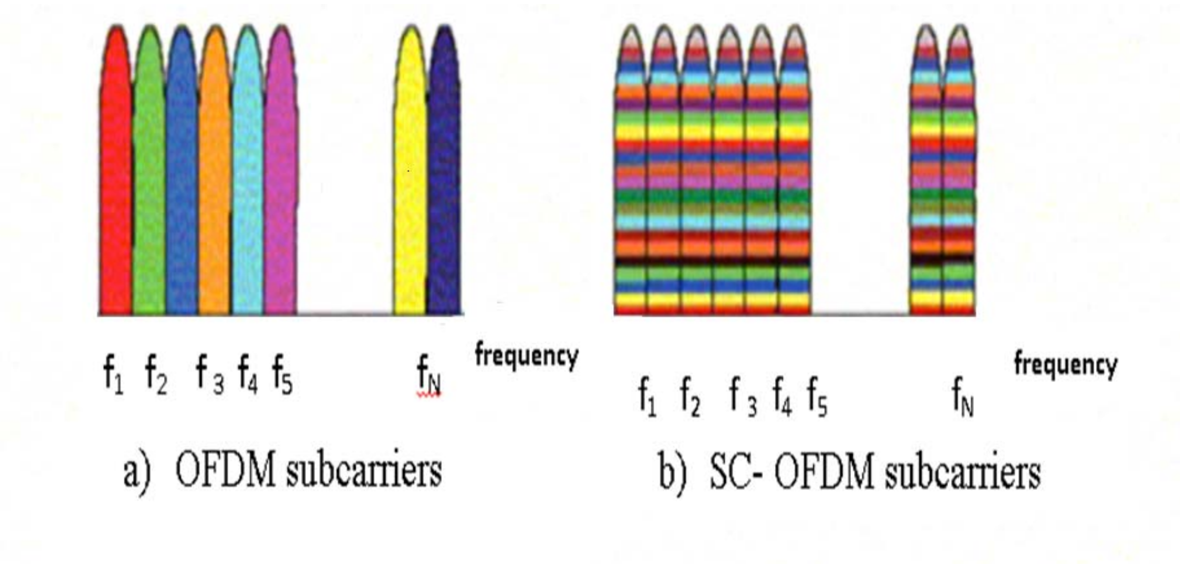


Figure 2.5 OFDM vs SC-OFDM

Table 2.3 shows values for different spectrum allocations for UL physical layer parameters. This table show the long block and short block size at different transmission bandwidth.

Table 2.3: UL Physical Layer Parameters (1)

Transmission Bandwidth (MHz)	Sub-frame duration (ms)	Long block size (ms/samples)	Short block size ms/samples
20	0.5	66.67/2048	33.33/1024
15	0.5	66.67/1536	33.33/768
10	0.5	66.67/1024	33.33/512
5	0.5	66.67/512	33.33/256
2.5	0.5	66.67/256	33.33/128
1.25	0.5	66.67/128	33.33/64

2.3.2.4 Multiple Input Multiple Output (MIMO)

MIMO technology depends on using many antennas at the transmitter and many antennas at the receiver to transmit and receive different data streams at the same frequencies simultaneously, thus higher data rates are achieved by using MIMO system. With appropriate space time coding, modulation, demodulation and decoding, MIMO can take the advantage of multipath propagation, which was limiting factor at conventional wireless communication, MIMO technology has been used efficiently at LTE.(27)(28)

This technology is summarized in four antenna schemes:(28)

1) Single Input Single output (SISO)

Uses single antenna at transmitter and single antenna at receiver.

2) Single Input Multiple Output (SIMO)

Uses single antenna at transmitter and multiple antennas at receiver.

3) Multiple Input Single Outputs (MISO)

Uses multiple antennas at transmitter and single antenna at receiver.

4) Multiple Input Multiple Output (MIMO)

Uses multiple antennas at transmitter and single antennas at receiver.

Multiple antennas can be used in a different ways, it based on three principles:

1) Diversity gain

Provide receiver with several copies of the same transmitted signal, in order to compact the multipath channel fading. This approach will not increase the data rate of the system it will enhance the average SNR at the output of receiver. Transmit the signal in a suitable way enables the receiver to extracting the diversity without need to channel acknowledgment. If all replicas are influence with independent channel fading the diversity order is equal to the product of transmitted and received antennas. [29]

2) Array gain

The MIMO receiver receives different copies of same transmitted signal different in amplitudes and phases due multipath. They will combine coherently at receiver so that will improve the resultant SNR which compact the multipath fading .The average increase in SNR due to this coherent combining of the received replicas is called array gain, which increases by increasing the diversity order .[29]

3) Spatial multiplexing gain

Transmission of multiple signal streams for the same bandwidth and with no additional power. By splitting the bit stream into lower-rate bit streams, modulated and transmitted simultaneously from the antennas. The receiver estimate the channel parameter so recover the original bit stream in a prober way. This lead to increase the data rate of the system. Spatial multiplexing increase the data rate according to the number of transmitter and receiver. [29]

Spatial multiplexing not limited at Single User MIMO (MIMO-SU) but it extends to MultiUser MIMO (MIMO-MU). For example, if two user transmit their stream simultaneously to the base station which equipped by two received antenna. The base station can recover the two signals also it can transmit two signals with spatial filtering so that each user can decode his or her own desired signal.[29]

After introducing the importance of LTE technology, and viewing its benefits , the steps of LTE coverage, capacity and quality planning will be discussed as below:

2.4 LTE Coverage Planning and Optimizing

2.4.1 Coverage planning, estimation and evaluations

Most technologies suffer from coverage problems especially in indoor coverage, such as WiMAX due to high frequency bands. LTE provides better global coverage and roaming capabilities, and it keeps compatibility with other generations of wireless networks. [30]

LTE coverage planning is the first step in the process of network planning. It used to:

1) Determine the coverage area of each base station.
2) Ensure the availability of the network and its services.

3) Find the cell radius.
4) Estimate base stations number for coverage requirements.
5) Give an estimation of the resources needed to cover the area under consideration. [31][32]

Coverage planning includes two main steps: coverage analysis and RLB. Coverage analysis is the most important step in the design of LTE network as with other generations, it consists of several steps and stages, and it manipulates several factors to accomplish a good coverage for the required area.[2]

2.4.2 Coverage Dimensioning

To have an effective cell range with suitable number of sites, it required a selection of an appropriate propagation model to calculate the pathloss. Depending on the value of the transmitted power from the transmitter, RLB determines the power received by the user, and it gives the maximum allowed pathloss which calculated based on the required SINR level at the receiver, taking into account the extent of the interference caused by traffic.[2]

The Algorithm of LTE coverage dimensioning is illustrated in Figure 2.6.

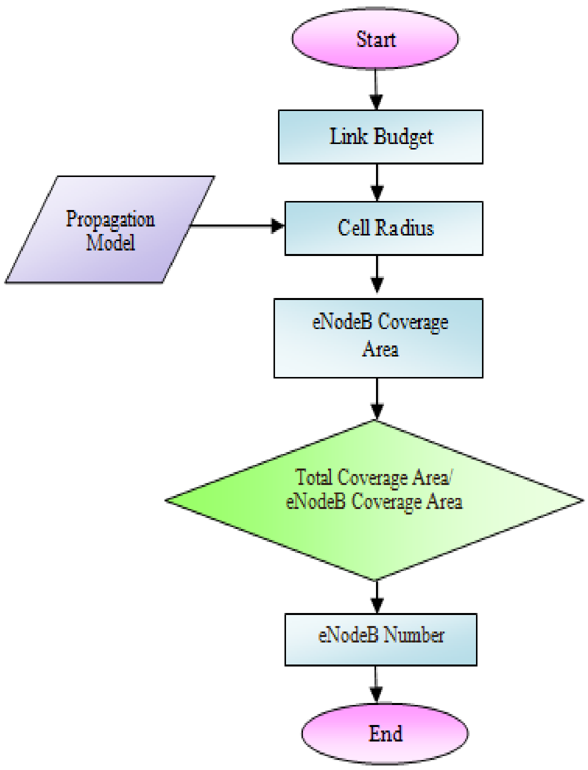


Figure 2.6 Coverage Dimensioning

The number of eNodeB's required to cover the required geographical can be found by dividing the area under consideration by the coverage area of each base station.

2.4.3 Radio Link Budgets RLB

Radio Link Budget is a process of calculating all the gains and losses from the transmitter, through the medium (free space, cable, waveguide, fiber, etc.) to the receiver in a telecommunication system. It accounts the attenuation of the transmitted signal due to propagation. Link budget calculations are used for calculating the power levels required for cellular communications systems, and for investigating the base station coverage. (2)

RLB includes evaluation of DL and UL radio link budgets. This evaluations estimate the maximum allowed pathloss between the mobile and the base station antenna, which allow getting the maximum cell range that gives the number of sites required to cover the required geographical area. This can be done by using a suitable propagation model, such as Okumura and Hate models. (2)

RLB is used to make a comparison between the relative coverage of the different systems and technologies; by indicating how well the LTE technology will operate under the existing technologies, and shows how its performance will be when it has deployed on the existing base station sites which are designed for GSM and WCDMA, assuming that the same frequency is used for LTE as for GSM and HSPA. (19)

There are many parameters taken into account in LTE link budget like: transmission power, antenna gain, base station Radio Frequency(RF) noise figure, SNR, interference, system losses, diversity gains and fading margins. Table 2.4 shows the UL budget for different technologies .(19)

Table 2.4 UL budget for different technologies (19)

Uplink	GSM voice	HSPA	LTE
Data rate (Kbps)	12.2	64	64
Transmitter –UE			
Max Tx power(dBm)	33.0	23.0	23.0
Tx antenna gain(dBi)	0.0	0.0	0.0
Body loss (dB)	0.0	0.0	0.0
EIRB (dBm)	33.0	23.0	23.0
Receiver _Node B			
Node B noise figure(dB)	_	2.0	2.0
Thermal noise	-119.7	-108.2	-118.4

(dB)			
Receiver noise (dBm)	_	-106.2	-116.4
SINR (dB)	_	17.3	-7.0
Receiver sensitivity	-114.0	-123.4	-123.4
Interference margin (dB)	0.0	3.0	1.0
Cable loss (dB)	0.0	0.0	0.0
Rx antenna gain(dBi)	18.0	18.0	18.0
Fast fade margin(dB)	0.0	1.8	0.0
Soft handover gain (dB)	0.0	2.0	0.0
Max path loss (dB)			
	162.0	161.6	163.4

If user's equipment (UE) moves away from an urban area and loses LTE coverage - Such as UMTS and GSM-, the network hands over the connection to the second preferred eNodeB which has been detected by UE.[(28)]

There are many techniques used in LTE technology to improve the coverage and the capacity and to achieve high data rate, such as MIMO technique and diversity. LTE has devised a method of combining between diversity and MIMO technology. MIMO has been developed to improve the outdoor services and there is a lot of studies that focused on using it within the buildings. There are also no conclusive studies to prove if it is economic. To ensure the cell edge performance needed by the handset user -to delivers the suitable bandwidth-, Careful planning of antenna locations and RLB of the coverage solution are required. [(33)]

2.4.4 LTE improvement of indoor coverage

Nowadays, poor indoor wireless coverage for subscribers is one of the biggest challenges that face operators. In many countries, more than 70% of the traffic on cellular networks originates or terminates inside buildings. For example, Vodafone recently reported that 90-95% of its mobile data traffic is generated indoors, so it can be seen that most of the mobile data revenue opportunity established in buildings, which indicates the importance of improving the indoor coverage, so the indoor is an important issue that has to be addressed for both the service provider and subscriber alike. 2G and 3G technologies use some traditional solutions to improve indoor coverage. For example, they use macro cell penetration coverage, signal source plus distributed antenna system, and repeaters.[34), (35]

In 3G, the service providers use the outdoor macro cell to penetrate buildings, it is a good selection with low frequency band and low data rates. However, for indoor coverage, high frequency band and high order modulation are not suitable. Since LTE used a frequency of 2.6GHz, it cannot have a good penetration for indoor data services using macrocells. [(34)]

2.4.4.1 LTE solutions for indoor coverage

LTE devised several solutions to the problems and challenges that face indoor coverage. There are number of techniques used for improving coverage within a building and each has its applications, advantages, and limitations. There are many examples of in-building system technologies such as: DAS, repeaters, pico cells, and femtocells. [(34)]

The three distributed antenna systems are passive, active, and fiber distributed antenna system. They are usually used to provide a good coverage and capacity throughout large buildings. In addition, it distributes the RF signal equally with enough strength (power) inside a building to provide 3G voice and data services. Since Operators only need to install one central LTE base station from each operator around the buildings, DAS systems are much easier to install than installing many independent LTE femtocells from each operator around the buildings.[(33), (36)]

Passive Distributed Antenna System: it consists of a network of coaxial cables, couplers, and power splitters to distribute the wireless signal. [(33), (34)]

Active Distributed Antenna System: After the antenna receives the signal from the base station, antenna amplifies and radiates the signal due to a fiber or RF cable, to radiate the antenna units in the building. [(34)]

Fully Active DAS: It gives maximum power that transfer to the antenna and minimum loss over any passive components by using a fiber connection directly to the remote unit which is usually located next to the antenna location. [(34)]

Hybrid DAS: A hybrid system contains a mix of active and passive components. [(34)]

Repeaters: These amplify a signal from a nearby cell base station and providing sufficient signal level inside buildings through a passive network, but repeaters have some problems due to hysteresis, oscillations and interference etc. [(34)]

Pico cells and Femtocells: Pico and Femtocells are small cellular base station covering a small area. They contribute to extend indoor coverage where the outdoor signals do not reach well, if network access is limited or unavailable, and they can provide additional capacity and coverage in a network. [(37), (38)]

2.5 LTE Capacity planning and optimizing

2.5.1 Capacity planning

The capacity planning and analysis come after coverage planning, and after finishing the coverage calculations required for the area to be planned. So, these two stages are sequenced and interconnected with each other. In capacity planning the aim is to estimate the number of recourses required to provide the users a specific amount of traffic; to make them able to transfer an amount of data in a shortest time -less delay- and less blocking.(2)

In capacity analysis of LTE network, it's very important to select the system type -urban, suburban ,etc-, site design, channels used, channel sectors, and elements.(2)

Theoretically, the number of the base stations in the network limits its capacity. As the number of base stations increases, the users who can be served increases too. By capacity evaluation, it's possible to get an estimation of the number of sites needed to carry the predicted traffic that required to serve the users over the covered area.(2)

To evaluate the capacity there are two tasks needed as cited in [2]:

1) To make an estimation of the cell throughput that is meeting with the settings used to derive the radius of the cell.
2) Analyze the traffic inputs to derive the traffic demand, which includes the amount of subscribers, the traffic, and data about the subscribers geographically spread in the deployment area.

However, it is possible to get an accurate estimation of the cell capacity by a modified Shannon formula and G-Factor distribution according to a certain cellular scenario. (2)

2.5.2 Capacity Dimensioning

Capacity dimensioning is a part of the capacity planning process, this step determines the number of base stations required in the covered area based on the number of users and services nature there. The process of capacity dimensioning is shown in the flow chart below figure 2.7.(31)

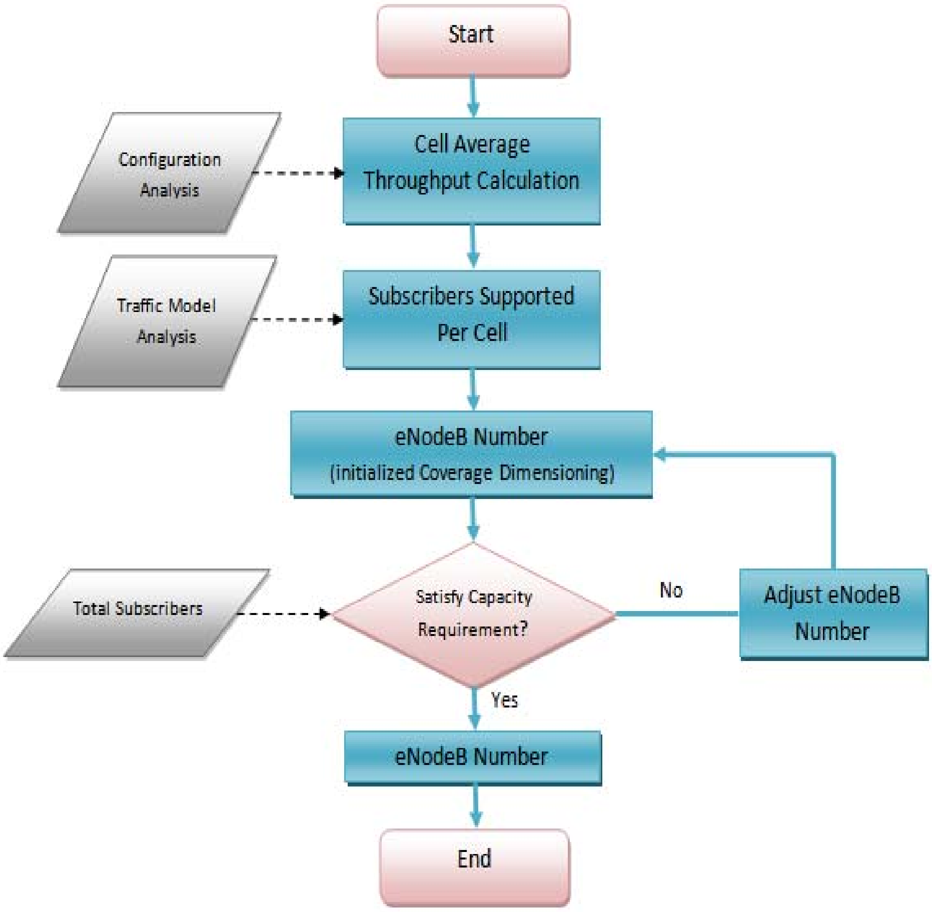


Figure 2.7 Capacity Dimensioning

The first step: to calculate the average throughput of UL and DL. This can be done by the simulation after entering many inputs to the simulator such as the bandwidth, the frequency, and others. Table 2.5 shows the average throughput results for both of the UL and DL in each cell.[31]

Table 2.5 Cell average throughput[31]

LTE cell average throughput(Urban Area)			
Frequency band (MHZ)	**Bandwidth (MHz)**	**DL (Mbps)**	**UL(Mbps)**
2600	**20**	**34.344**	**19.814**
1800	**20**	**34.719**	**21.675**
800	**20**	**35.218**	**24.704**

The second step: to determine the number of users and services in each cell. This can be done by the traffic model analysis, which is mainly used to calculate busy hour throughput for each user. [31]

The third step: to get the number of base stations that calculated from the radio link budget calculations which already have been done in the coverage dimensioning process. [31]

The fourth step: to compare the number of base stations that obtained from radio link budget calculations with the number of base stations that must be available to support the users and services in the covered area. So, if the number of base stations is enough to achieve that, it will be fine and that what is required. If the number of base stations is not enough to support the users and services there, that means additional number of base stations have to be added to make all the users able to transfer the data they want in a minimum time, and to avoid them the problem of blocking and long delays.[31]

2.5.3 Capacity Improvements

2.5.3.1 Multihop or Relays

LTE enhanced the capacity by many ways, for example it uses the Relaying or Multihops which are network devices used to achieve the improvement of coverage and capacity at cheap costs. Relays or Multihops can provide huge gains for both the –coverage and capacity – without needing a cables or fiber access. [3]

Relays are efficient to be used to cover the locations where the path loss from the base station is very large, it is also useful to be used in the locations have obstruction.[3]

Even in term of capacity, multihop techniques play an essential role in enhancing the spectrum efficiency, because for all covered areas there is only one needed radio channel. (3)

In the case of existing some overhead due to the radio resource high usage, there are even so, impressive gains in the capacity and coverage of the whole radio cell compared to a BS alone. (3)

In the area near the Relay Node (RN) which is -as mentioned before- a system element, the capacity is better, and the RN has similar function as the base station so there is not only better SINR to the user, but it is often more efficient to associate to a RN instead of the BS. Therefore this is a cheap measure to increase the efficiency of the system. (3)

In general, relays are classified into two types:

1) Fixed relays.

2) Mobile relays.

Both of these types are not mobile terminals but dedicated network devices.(3)

In fixed relays the RN is located in each sector; this type of relays is used for several purposes for example to cover hotspot or shadowing areas, and to increase the cell edge throughput. The number of RNs and the way they are inserted, have a huge influence on the system capacity.(3)

In 4G cellular systems, the usage of the advanced technologies such as OFDM, MIMO, Pre-coding and many others, increased the peak data rate greatly in comparison with the third generation. But the average user throughput is not improved as much as the peak rate, so it is very important to improve not only peak rate but also the cell edge data rate. This is the key reason for why to use the fixed relays.(3)

The second type of relays is the mobile relay, in this type the relay node are exist on the moving articles like vehicles, buses and trains -as it shown in Fig (2.8) below- to facilitate obtaining higher throughput and lower handover stoppage for the passengers.(3)

In this type, the user distribution is non-uniform, not as the common situation in which the users are uniformly distributed in the cell. This is sensible; because the public vehicles are more crowded than other areas and the people in buses and vehicles may browse, gaming, to enjoy their time while waiting, so they may need high data rate services while travelling. Therefore, it's very essential to investigate the capacity gain if the mobile relay is deployed. (3)

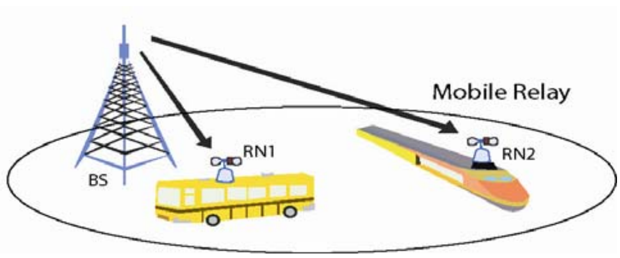


Figure 2.8 Mobile relay

2.5.3.2 LTE Capacity MIMO

LTE promised to reduce the delay, to increase the spectrum efficiency and to minimize the cost per bit for the end user. To fulfil these promises LTE used many technologies such as MIMO technology, which utilizes the multipath between the transmitter and receiver to achieve higher data rates and throughput, to get better cell coverage even without increasing average transmit power or frequency bandwidth, and to improve the overall capacity of the wireless system.[39],[40]

As a result, MIMO complements LTE, and plays a very essential role in this technology-LTE-, even it adds a kind of complexity -due to the required digital signal processing and the number of required antennas at both the transmitter and receiver- but it improves the system capacity efficiently.[40]

However, LTE defined many technologies of MIMO, for example it defines spatial multiplexing, transmit diversity, and beam-forming. Which all aims to improve the data rate (provide higher peak rate) and achieve much better system efficiency, to meet the users requirements of broadband data services over these wireless networks.[34] An enhanced and advanced vision of LTE MIMO technologies is standardized by the 3GPP which is called “LTE-Advanced”. It was found to meet the requirement of IMT-Advanced that set by International Telecommunication Union Radio communication Sector (ITU-R). [41]

In LTE, MIMO technologies are used in DL and UL. For DL, the baseline consists of two antennas -at the base station- for transmitting, and two antennas on the mobile terminal for receiving. [33]Its usage in the DL is to optimize the peak rate, cell coverage, and also the average throughput of the cell. To achieve all these objectives, LTE used several MIMO technologies such as: dedicated beam-forming, closed-loop rank-preceding, transmit diversity, Single User (SU-MIMO), Multi-User (MU-MIMO).

For the UL, a scheme called MU-MIMO is employed from the mobile terminal to the base station.[41]

2.5.4 Capacity MIMO and antenna configuration

Depending on capacity MIMO relation; the increment of the SNR value means increment in the capacity, such signals don’t need large number of antenna to transmit due to it’s high power while the case is totally the opposite for the weak power signal which needs to be transmitted with a suitable number of antennas that guarantees its arrival . This is simply clarifies the relation between the capacity and antenna configuration which depends basically on the incoming SNR value .[42]

2.6 LTE Quality Planning and Optimizing

2.6.1 Quality of Service and bearers

Before starting the dimensioning and planning process of LTE network, it is important to define the dimensioning inputs, which are divided into three categories: quality, coverage, and capacity inputs. Inputs related to quality include: average cell throughput and blocking probability. These parameters help the customers to provide a certain level of service to their users. These parameters translated into QoS parameters.[2]

QoS can be defined as the ability of a network to provide a certain level of services to a certain type of traffic. The network divides the streams of traffic into different classes, and processes them differently; to achieve the desired service level for each traffic class, where services levels are classified in terms of throughput, latency, jitter and packet error or loss.[4]

QoS becomes an important parameter in 4G; as a result of the increment in subscribers number, and the increment of the traffic volume for each subscriber. Operators are moving from a single-service offering in the packet-switched domain (internet access) to a multi-service offering, by adding new advanced services which use mobile broadband access. For example: multimedia telephony and mobile-TV. These services have different performance requirements in terms of bit rates and packet delays.[43]

Sometimes, the user may run multiple applications at the same time, each with different QoS requirements. Some of these applications require less delay, like , Voice over IP (VOIP) calls, and others require less packet loss, like downloading a file. LTE has been designed with a QoS mechanism that helps with supporting multiple QoS requirements and with providing more sufficient user experience in comparison with the previous technologies. This mechanism uses " EPS bearers", each bearer is associated with a QoS by the eNodeB over the radio interface. EPS QoS concept based on dividing the traffic stream into classes, where each bearer belongs to a certain class, which is specified by a scalar assigned to the bearer which is called QoS Class Identifier (QCI). In LTE EPS the packets flow between the Packet Data Network Gateway (PDN-GW) and the user terminal, all packets that are related to the same bearer treated in the same way. The procedure is explained in figure 2.8.[28],[4]

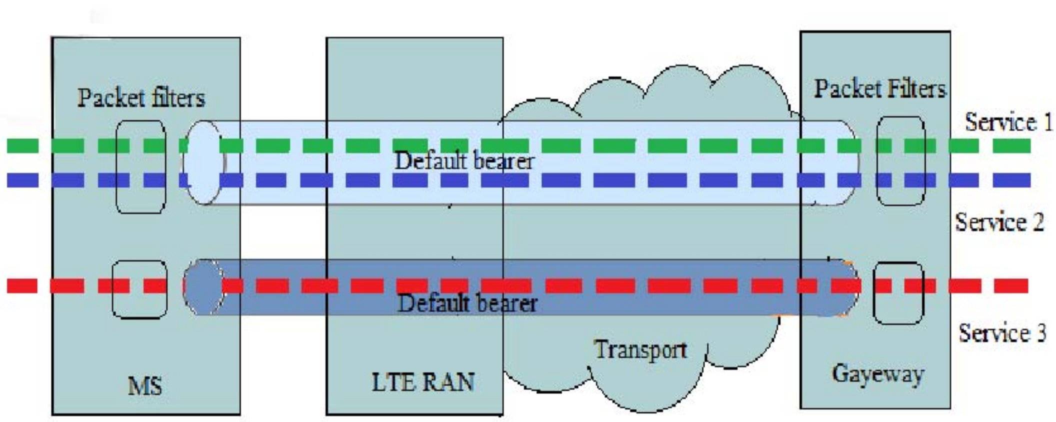


Figure 2.9 EPS bearers transferring[4]

Bearers are divided into two types :

GBR-bearers: This type of bearers has a minimum bit rate value guaranteed by the network. These bearers can be used for applications like VOIP.[28]

Non-GBR bearers: These bearers are not associated with a guaranteed bit rate value and can be used for applications like downloading files and browsing web pages.[28]

In addition to QCI, each bearer is also associated with an Allocation and Retention Priority (ARP). Each QCI is characterized by priority, packet delay budget and packet loss rate. Table 2.6 shows a set of standardized QCIs and their characteristics.[4]

Table2.6 standardized QCIs and their characteristics.[4]

CI	Resource type	Priority	Packet delay budget	Packet error loss rate	Example services
1	GPR	2	100ms	10-2	Conversational voice
2		4	150ms	10-3	Conversational video (live streaming)
3		3	50ms	10-3	Real time gaming
4		5	300ms	10-6	Non-conversational video (buffered streaming)
5	Non_GBR	1	100ms	10-3	IMS signalling
		6	300ms	10-6	Video(buffered streaming) TCP based (e.g. www, e-mail, chat, ftp, p2p file sharing, progressive video, etc.)
		7	100ms	10-6	Voice, video (live streaming), interacting gaming
		8	300ms	10-3	Video (buffered streaming) TCP based (e.g. www, e-mail, chat, ftp, p2p file sharing, progressive video, etc.)
		9		10-6	

2.6.2 Quality dimensioning

The process of quality dimensioning is shown in the flow chart below figure (2.10).

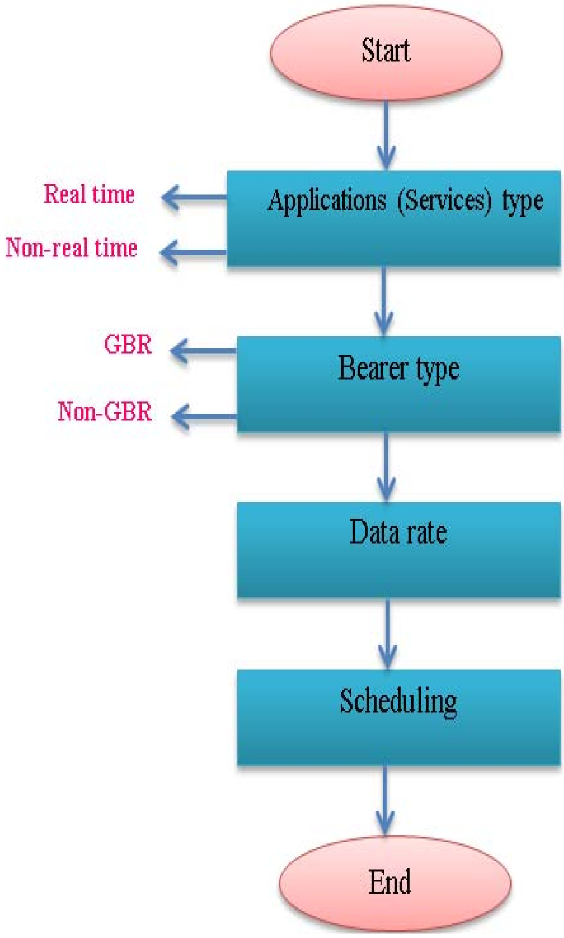


Figure: 2.10 Quality Dimensioning

The process begins with specifying the application or the traffic type requested by the user is it real time or non-real time application because each type has specific QoS requirements.

The second step is to determine the type of the bearers which will carry the traffic packets is it GBR or Non-GBR bearers depending on the traffic type that specified in the first step. This step also includes specifying the QoS level for each bearer, this means specifying the priority, packet delay budget and the packet error loss rate depending on the QCI for each bearer. The next step is to determine the appropriate data rate that the user needs.

The last step is scheduling the users and sorting them in lists depending on specific priorities to allow them to connect with the network and assign them resources or block them .Scheduling and blocking process depends on the cell capacity , the data rate requested by the user and on the QoS and priority settings for the packets' bearers. It also depends on the signal quality depending on the subscriber position from the serving cell. Also this depends on the used scheduling algorithm.

Scheduling process decreases the blocking probability ,hence it contributes in improving the quality of service on the system.

The communication over the radio channel is affected by many factors which cause losses in the received information and reduction in the quality of service. These factors are: Additive White Gaussian Noise (AWGN), fading, and log-normal shadowing. [5]

Achieving the desired QoS level for a specific application under the variations of channel conditions is an important issue. So, radio link adaptation must be used to achieve such a purpose. In radio link adaptation, the appropriate modulation and coding schemes and other signal parameters and protocols are specified for the current channel conditions. [44]One problem with channel quality measurement in LTE is how to define channel quality. Another is how to report it.

In [5],the authors presented a new framework for calculating the Channel Quality Indicator (CQI) which is a feedback from the UE to the eNodeB to indicate the current channel quality. Also they described a method for efficient QCI reports.

Radio link adaptation, involves several radio link quality measurements, such as: the SNR, the Received Signal Strength (RSS), and the BER before and after the decoder; to maintain a QoS value close to the target value. [5]

2.6.3 System Performance

Improving the system performance compared with the existing systems is an important requirement from networks operators; to ensure the competitiveness of LTE with the other technologies. This section explains the main performance metrics used in LTE performance assessment. The requirements are discussed and explained in more details below: [28]

Peak Rates and Peak Spectral Efficiency

When comparing different radio access technologies, the peak data rate per-user is the first essential parameter. The peak rate can be defined as the maximum throughput that achieved by the user, assuming the whole bandwidth being used by the user that has the highest modulation and coding and the maximum number of antennas. [28]

In LTE system, the peak data rate for downlink is 100 Mbps with a spectral efficiency of 5 bps/Hz, and for uplink is 50Mbps with spectral efficiency of 2.5 bps/Hz within a 20 MHz bandwidth in both. Where the maximum spectral efficiency is obtained by dividing the peak rate by the used spectrum. [28]

By using multiple antenna configurations, a higher data rates can be obtained. Higher peak spectral efficiency which is up to 16.3 bps/Hz for downlink can be achieved by using 4×4 MIMO, and up to 4.32 bps/Hz for uplink by using 64 QAM SISO. Higher values can be obtained in LTE-Advanced system reach to 1Gbps for downlink with peak spectral efficiency of 30 bps/Hz (up to 8×8 MIMO), and 300Mbps for up link with 15 bps/Hz (up to 4×4 MIMO) [45] [46]

1. Cell Throughput

Performance at the cell level is an important metric; because it contributes in determining the number of cell sites in the network and in determining the costs of the system deployment. For LTE, full-queue traffic models are used to specify cell level performance, where there is no shortage in the transmitted data, and also a high system load is used. Average cell throughput, average user throughput, cell-edge user throughput, and spectral efficiency are defined the requirements at the cell level. (28)

2. Voice Capacity

In the case of full queue traffic such as, file download, the delay is not an essential issue and it does not require a guaranteed bit-rate, unlike real-time traffic such as, VOIP which has strong delay constraints. It is a big challenge to set system capacity requirements for these services especially in the fully packet-based systems like LTE. System capacity requirements can be defined as the number of satisfied VOIP users, using a particular traffic model and considering delay constraints. The user considered to be not satisfied if more than 2% of VOIP packets do not arrive to the receiver without any loss within 50ms. This will lead to 200ms delay or below between end terminals. The system capacity for VOIP then can be defined as the number of users per cell when more than 95% of the users are satisfied. VOIP capacity in LTE reaches to 80 users per sector/ Hz for FDD LTE, and more than 80 users in LTE-Advanced system. (28)

3. Mobility and Cell Range.

Providing high data rates with good coverage and mobility are important aspects, and contribute in user's satisfaction. In terms of mobility, LTE system is required to support communications with terminals moving at speeds ~~of~~ up to 350 km/h, or even up to 500km/h depending on the frequency band. This means that the handover between cells must be smooth, without interruption, and with very small delay and packet loss for voice calls. LTE achieves this by using cells of radius up to 5km. (28)

4. Broadcast Mode Performance

Broadcast mode enables the master to send data to any number of slaves. The salves receive the data, but the master does not receive any reply from the slaves. (47)

LTE combined an efficient broadcast mode for high rate Multimedia Broadcast Multicast Services (MBMS) which designed for situations when several users want the same content at the same time such as, Mobile TV. Single frequency network mode of operation is used here to support efficient multi-cell transmission. When similar signals are transmitted at the same time from multiple cells, they will be seen as one transmission by terminal devices. This mode of operation can support broadcasting and uncasing transmissions. LTE MBMS supports channel bandwidths of 1.4 MHz, 3 MHz, 5 MHz, 10 MHz, 15 MHz, and 20 MHz .(48)

5. User Plane Latency

It is an important performance criterion for real-time and interactive services. One-way user plane latency can be defined as the average time from the instant the data packet is transmitted till the reception of a physical layer Acknowledgement (ACK). Multiplying it by a factor of two will obtain the round-trip latency. [28]

LTE system can operate with a user plane latency less than 5 ms in unload condition, which means single user with a single data stream, for small IP packet. The actual delay in any system depends on system loading and radio propagation conditions. There is a trade-off between maximizing spectral efficiency and reducing latency. In other words, when a minimum latency is required in some situations, maximum spectral efficiency may not be essential. [28]

6. Control Plane Latency and Capacity

In addition to reducing the user plane latency, it is also important to reduce call setup delay compared to existing cellular systems. This will provide a good user experience; also will affect the battery life of terminals when performing the transition from idle state to active state. [28]

In LTE, control plane latency can be defined as the transition time from idle state 'RRC_IDLE' to active state 'RRC_CONNECTED'. LTE system makes this transition in less than 100 ms and less than 50ms in LTE-Advanced. [28]

LTE system capacity depends on the supportable throughput as well as the number of users located in a cell at the same instant. At least 200 active users per cell should be supported for spectrums up to 5 MHz, and at least 400 users per cell for wider spectrum allocations. [28]

In recent years, the number of users of wireless networks around the world has increased dramatically and their demands for wireless access to the Internet and Internet-based services are expanding, this leads to many mobile wireless network elements and parameters configurations, tuning and management operations, in recent mobile network, they are manually configured.

Planning, configuration, optimizing, and management of these parameters are necessary for reliable network operation; however, the manual process is time and efforts consuming ,and with high probability of error.

2.7 LTE Architecture

LTE network as shown in the figure 2.13 below contains many types of equipments and many parts. It consists of the radio access -through the E-UTRAN- and the non-radio access which is called System Architecture Evolution (SAE).

LTE network includes both of:

1) Core Network (CN): which is called Evolved Packet Core (EPC), and it is included in SAE.

EPC is the part which takes the control of the UE and establishes the bearers.
It includes several of main logical nodes, such as:

1) PDN Gateway (P-GW): which is an abbreviation of Packet Data Network Gateway. Its function is to provide the LTE/SAE network typical gateway functions, such as IP address allocation and others.

2) Mobility Management Entity (MME): it is the part that provides mobility and idle mode to the UE as well security and user plane gateway selection.

3) Serving Gateway (S-GW): the functions of the (S-GW) are: data buffering and routing. In addition of the previous parts of EPC it also includes other nodes and functions, such as: Home Subscriber Server (HSS), Policy Control and Charging Rules Function (PCRF).

4) Access network (E-UTRAN): This contains the eNB. It is the air interface in the LTE network and consists from The E-UTRA, eNB and respective interfaces. [49]

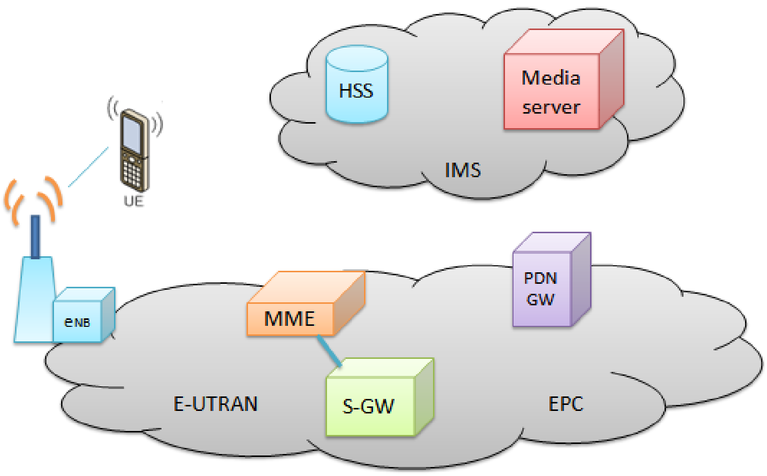


Figure 2.11 LTE network Architecture

2.8 Planning Stages

Network planning is not limited to coverage and capacity estimation, also the data services are considered to be an important factor in planning. For each service in the network the QoS must be defined, also it should be suitable for the nature of the service.

LTE network planning is designed to maximize the network coverage and to achieve the desired capacity and QoS. In order to a achieve these purposes, there is a number of network planning stages which include: initial planning, detailed planning, and optimization.

2.8.1 Initial Planning (Dimensioning)

Gathering information is the most important stage in network planning. Dimensioning provides the planner the first vision about coverage and capacity estimation, and radio link budget calculations. In this stage, there are some information must be taken into consideration such as: estimated traffic, coverage estimation, capacity estimation, quality, number of sites, and cell range. (51)(32)

The cell range is directly related to the number of simultaneous active users, so the coverage and capacity depend on each other. (50)

2.8.2 Detailed planning

The second stage of LTE radio network planning is the detailed planning. In this stage the planning tool is used to analyse the collected data. The input parameters to the planning tool are related to quality, coverage and capacity. The network planners need a specific tool for each stage; in order to have a complete vision of network. (50)

The planner should have fully understanding of various network elements and combining them with network parameters in a Plan .These elements are: (50)

1) Digital network map.
2) Target area.
3) Radio access technologies.
4) Input parameters.
5) Antenna configuration.
6) Plan, which is created and defined before the actual network is stated.

2.8.3 Optimization

This is the last step of the network planning procedure. It provides exact estimation of the cell range and starts the network planning on the planning tool. Also it aims to evaluate and maximize the quality of service in the network. In this stage there is a number of parameters must be optimized which are capacity, coverage, quality. (50) (32)

2.9 Conclusion

To generalise the ideas discussed in chapter one, this chapter highlights the previous efforts and studies of planning and optimizing a network uses LTE technology. It viewed the evolution of the cellular network from the 1st generation -which was able to support the voice only-, passing by the 2^{nd} and 3^{rd} generations and finally up to the fourth generation which includes LTE technology. As this chapter introduces a general description about LTE technology it introduces the technologies used for optimizing the network such as MIMO technology, OFDM for DL, SC-OFDM for UL, which all of them are used for optimizing the capacity of the LTE network. Then, it discussed the main concept of SON and neural network . Finally it viewed the planning steps of the coverage, capacity and quality, and also specified the technologies used to optimize all of them.

Chapter 3

Contents

3.1 Overview

This chapter illustrates the steps of network planning and optimizing process for three main cites (Hebron, Ramallah, Nablus). Also it explains TEMS Cell Planner tool which used in planning and optimizing process. Moreover it illustrates LTE system parameters that must be defined in the planning such as: LTE carrier mappings, frequency bands, traffic demand, etc.

3.2 TEMS Cell Planner

TEMS Cell Planner is an advanced network graphical tool that used for designing, implementing and optimizing mobile radio networks in Hebron, Ramallah and Nablus cities. It enables the planners to perform many complicated tasks, such as: network dimensioning, traffic planning, site configuration, frequency planning, and network optimizing, which leads to save time and money during network deployment.

TEMS Cell Planner is developed and implemented by Ericsson. It supports several radio networks with different technologies, such as: GSM, WCDMA, HSPA, WiMAX and LTE. Each of these technologies needs an installed and activated license. TEMS Cell Planner allows the planner to design and analyze the network in different propagation models. The results will be shown as plots and reports.

It has many important features, such as:

1) Improved antennas and frequency planning.
2) Includes new Automatic Frequency Planning (AFP).
3) Radio propagation modelling using Ericsson urban and 9999 models.
4) Quality prediction indication. It's an indicator used to predict the effect of changes in the network in terms of QoS.
5) Provides the relations between the neighbour cells in some manner using propagation prediction.
6) Geographical presentation: digital mapping data displayed as Geographical Information System (GIS):
    1) Displays 3D building height.
    2) The nature of geographical area urban, sub-urban, forest, industrial.
    3) Shows the name of the roads, cities and rivers etc.[51]

3.3 Factors influencing LTE cell planning

Since LTE is a new technology with properties completely different from the previous technologies, the service providers have to buy new and suitable equipments for LTE networks. On other hand many providers are attempted to reuse the infrastructure of the previous technologies like GSM to support LTE services. [32]

LTE is a very flexible technology; it can be built in several ways in order to achieve effective performance and mobility. The LTE network planning decisions are affected by several

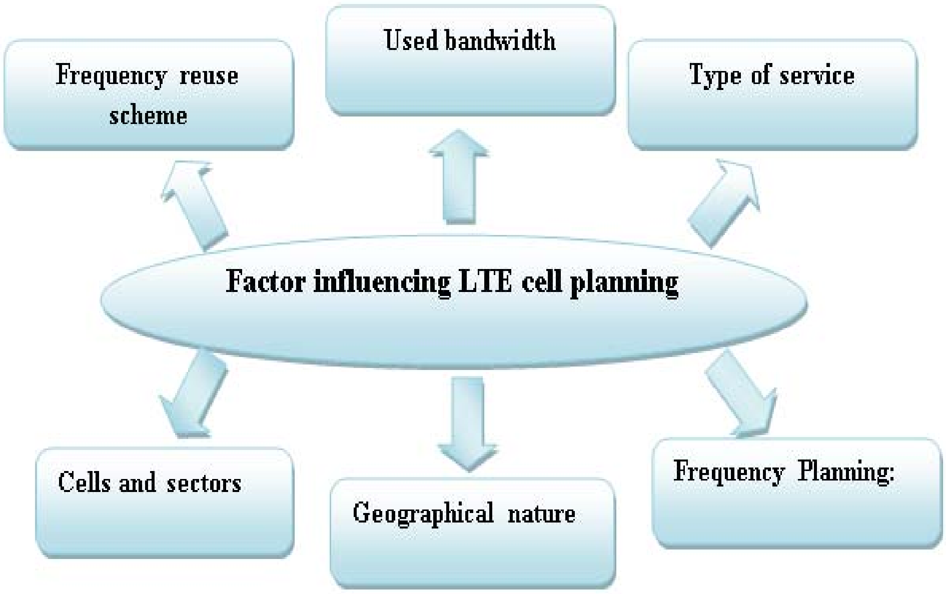


Figure 3.1 Factors influencing LTE cell planning

3.4 LTE Network planning process

Network planning aims to achieve a maximum capacity with acceptable grade of service. To get sufficient network planning and to provide good services to the end user, many steps should be followed for planning the main three cities (Hebron, Ramallah ,Nablus). Figure 3.2 illustrates these steps.

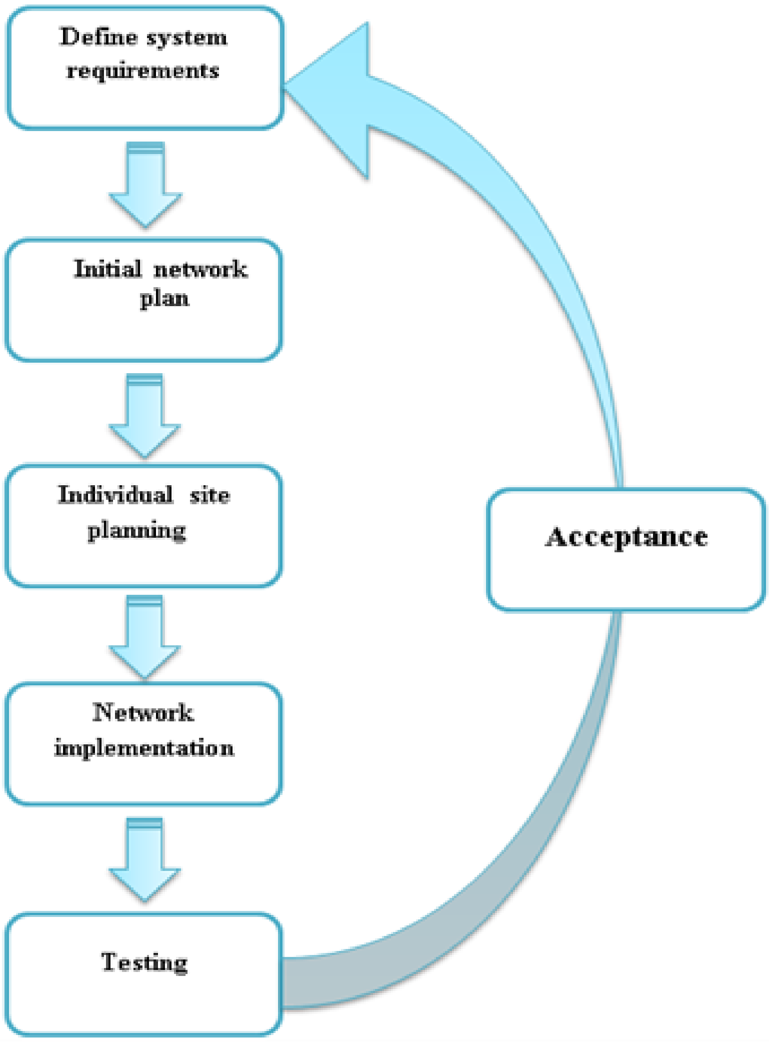


Figure 3.2 Planning process

We started our Planning process with defining system and subscriber parameters using TEMS Cell Planner tool, which include: Customer requirements, number of subscribers at the cell, traffic per subscriber, Grade of service, available spectrum, RF parameters and Signal strength.

3.5 LTE system data

There are some parameters that must be defined before adding the sites and cells to the network called ***network system data***. These data can be summarized as:

1) LTE carrier mapping.
2) LTE frequency bands.
3) LTE bearers.
4) Propagation models.
5) Traffic density maps.
6) Traffic demand mixes.

3.5.1 LTE carrier mappings

In LTE carrier mapping, the planner configures all parameters that are related to the carrier of an LTE frequency band. Planner should set the time fraction parameter of the carrier mapping, which is defined as the percentage time used for downlink and uplink traffic respectively on this carrier. The fraction time depends on the duplex type of frequency band, if the carrier mapping shall be used for full or half FDD or S-TDD.

In full and half-duplex FDD, each of the DL and UL time fraction parameters must be less than or equal to 100%. In an S-TDD, The sum of the DL and UL time fraction parameters must be less than or equal to 100%.

In our planning we chose FDD-duplex scheme, because it is suitable for some applications, such as bi-directional voice that generates symmetric traffic, it occupies a symmetric downlink and uplink channel pair, while TDD is more suitable for burst and asymmetric traffic, such as internet or other data centric services.

TDD systems are often used in scenarios where short distances are required, with the possibility of unbalanced data traffic. FDD schemes are better over greater distances and where the traffic is balanced, i.e. similar in both directions, so it is commonly used in cellular networks (2G and 3G).

Fig(3.3) shows the definition of FDD Carrier mapping and the time fraction that used for UL and DL traffic according to FDD duplex scheme.

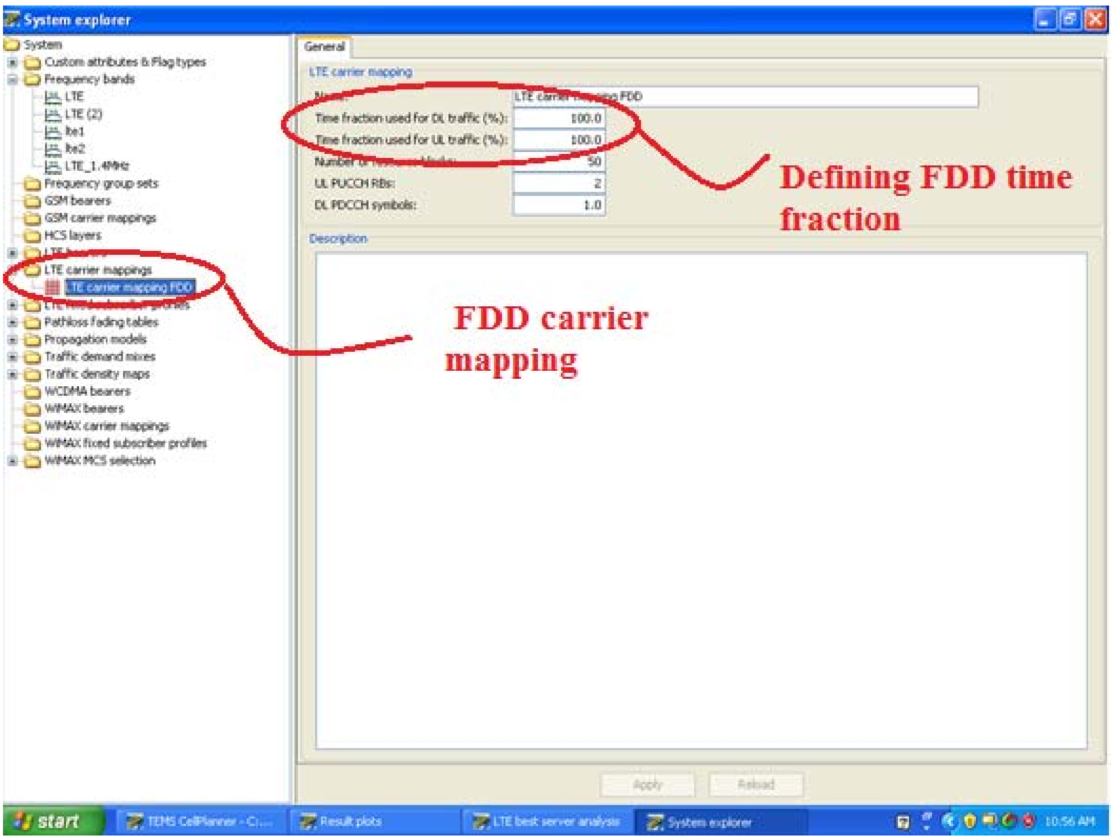


Figure 3.3 The definition of FDD Carrier mapping

3.5.2 LTE frequency bands

we need to configure the frequency band and select the Evolved Absolute Radio-Frequency Channel Number (EARFCN) which will be used in the network.

The frequency band of FDD is a paired band with separate limits for downlink and uplink, while S-TDD frequency band consists of one shared band for uplink and downlink traffic. In both cases the downlink frequency band only is the one that should be identified in TEMS Cell Planner tool, by entering the downlink base channel, base frequency and the carrier bandwidth . When the planner configures the DL frequency band, the UL frequency band is automatically calculated, starting from the lowest downlink frequency minus the duplex distance .

Fig (3.4) shows defining downlink base channel, base frequency, the carrier bandwidth and duplex distance.

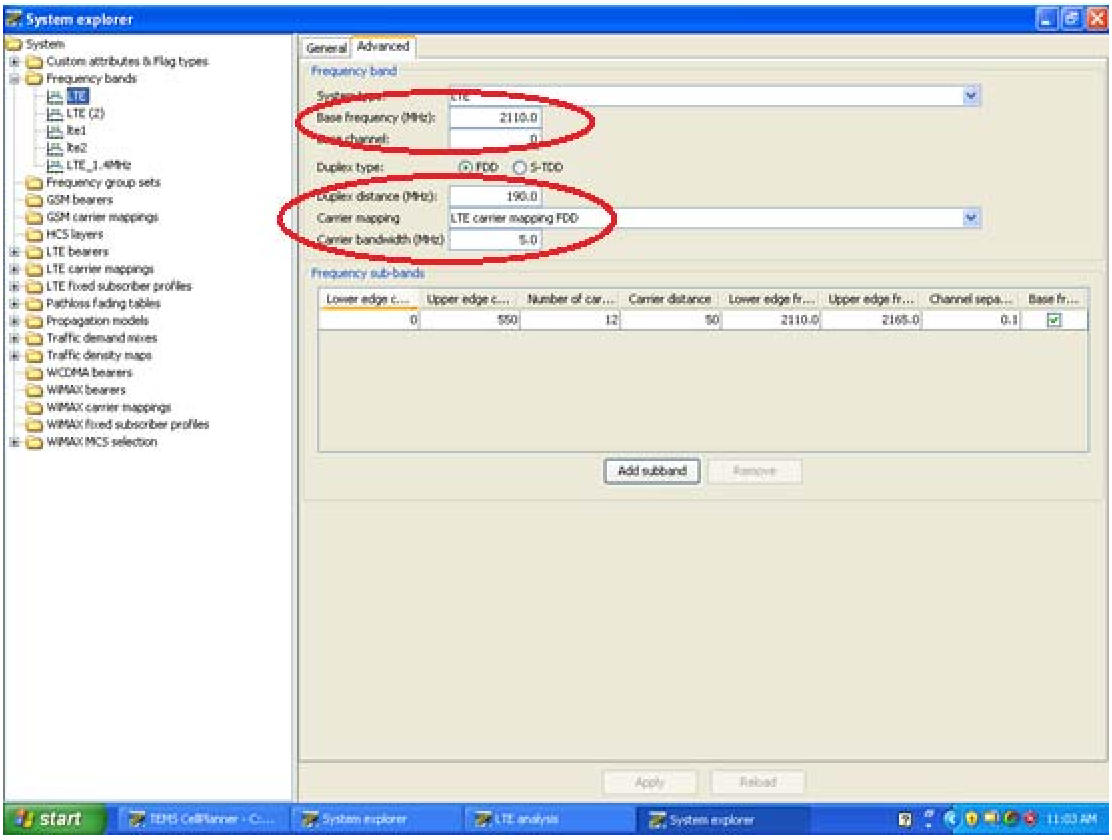


Figure 3.4 defining frequency band parameters

As shown in previous figure we defined 5 MHz carrier bandwidth and 900 MHz frequency band in the three cities, which provide an appropriate coverage and capacity with good level of quality. Moreover, its recommended by Jawwal providers since this band is close to the used carrier bandwidth, which is 4.8 MHz, so they are attempted to reuse the GSM infrastructure to support LTE services without need to new equipments. And it suits the current economic situation and gives the desired data rate to meet the users' needs with affordable cost.

After we initialized the carrier bandwidth which indicates to channel bandwidth, the number of Resource Blocks (RBs) should be defined depending on the channel bandwidth. For 5MHz carrier bandwidth the number of resource blocks are 16-25 blocks.

3.5.3 LTE bearers

Before we configure the terminal types, traffic cases and traffic demands mix, we defined the supported bearers. LTE bearer is characterized by its bit rate and priority. We adjusted the average UL and DL bit rate and the maximum bit rate of each bearer, we also defined the priority of bearer, thus high priority bearers will be scheduled first.

Fig (3.5) shows that the average DL and UL bit rate set to 256 kbps and 128 kbps respectively ,and also shows the adjustment of the highest priority to the bearers.

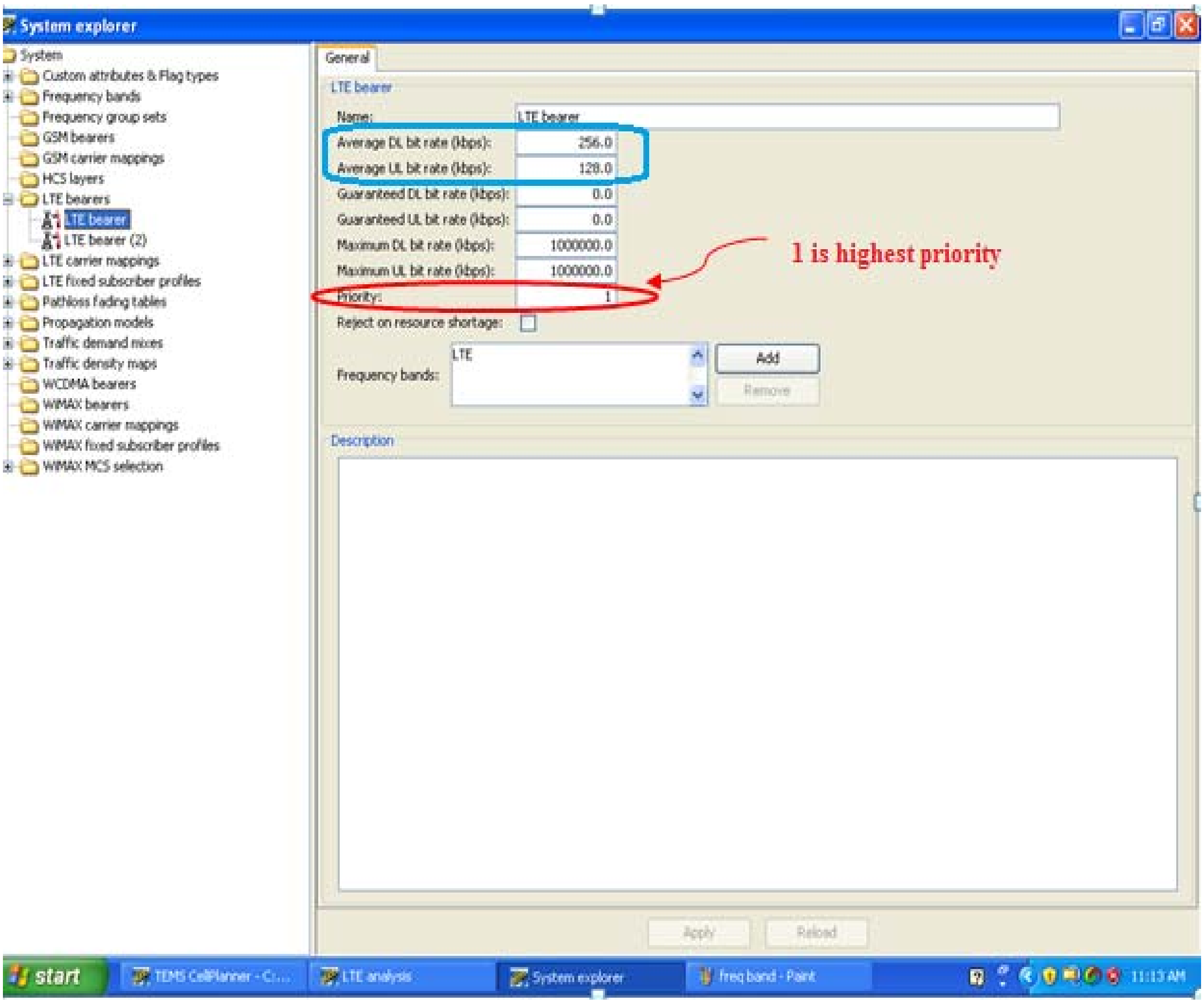


Figure 3.5 LTE bearers

3.5.4 Propagation models

Propagation models are one of the most important foundations for the pathloss predictions, they perform the following:

1) Give better knowledge about the coverage in the network.
2) Describe the average signal propagation.
3) Convert the maximum allowed propagation loss to the maximum cell range.

Pathloss depends on:

1) Environment: urban, rural, dense urban, suburban, open, forest or sea.
2) Distance.
3) Frequency.
4) Atmospheric conditions.
5) Indoor, outdoor.

TEMS Cell Planner supports the following propagation models:

1) Ericsson 9999 model (macro cell model).
2) Ericsson Urban propagation model (macro cell/microcell model).
3) Okumura-Hata (OH) model.
4) Walfisch-Ikegami (WI) model.

We selected the most suitable propagation model type according to the nature of the analysis cities (Hebron, Ramallah, Nablus). Here we selected Ericsson 9999 propagation model since it is recommended for urban and rural areas, which suits Hebron, Ramallah and Nablus cities nature.

3.5.4.1 Ericsson 9999 Propagation Model

We used Ericsson 9999 propagation model in planning Hebron, Ramallah and Nablus.

Ericsson 9999 propagation model is recommended for rural coverage areas where the site-to-site distance is greater than 1000 meters, and antennas are placed above the rooftops. Ericsson 9999 model calculates the expected pathloss for radio waves between the transmitting base station antenna and the receiving subscriber equipment using the terrain profile, which is a cross-section of the earth along the straight line between the transmitter and the receiver. RF propagation models require a set of mapping data and a set of continuous wave measurement data for modelling the RF environment, and tuning the model. This combination of these two kinds of data is called a propagation model.

Pathloss value obtained from Ericsson 9999 model consists of the following three input sources:

1) Okumura-Hata's wave propagation equations with modifying parameters A_0, A1, A_2, A_3.

2) Extra loss, occurring when wave propagation is disturbed by obstacles such as, mountain peaks. When the distance between the transmitter and receiver becomes sufficiently large, a correction due to earth's curvature is necessary.

3) Land use code loss.

Figure 3.6 illustrates Ericsson 9999 model inputs.

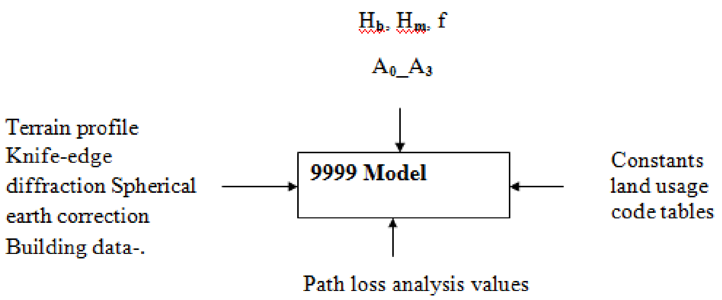


Figure 3.6 Ericsson 9999 model

TEMS Cell Planner tool used the following equation to calculate the pathloss Where:

$$\text{Lb} = \text{HOA} + \text{mk[mobile]}\sqrt{(\alpha.KDFR)^2 + (\text{JDFR})^2} \ldots Equation\ 3.1$$

Lb = pathloss.
mk [mobile]: the land use code at mobile [dB] which specified by the tool.
α: A parameter connected to Knife-edge diffraction.
KDFR: The contribution from knife-edge diffraction [dB].
JDFR: The diffraction loss due to spherical earth [dB]
HOA= A_0+ A_{11}+A_2log HEBK +A_3 log (d) log (HEBK) – 3.2[log (11.75hm)]^2 +g(F)… Equation 3.2

Where:
HOA: Hata Open Area.
A_{11} = A_1 * log (d)…. Equation 3.3.
g(F) = 44.49 * log (F) – 4.78 * (log F)^2,
HEBK: Effective antenna height in meters as defined in the Ericsson 9999 propagation model.
d:distance from base antenna to mobile in km.
A_0, A_1, A_2 and A_3: mobile tuning parameters.
A_0 = 36.2, A_1 = 30.2, A_2 = 12.0,A_3 = 0.1.
H_b : Height of the base station.
H_m: Height of mobile station.
F: Frequency.

Figure (3.7) shows the selected propagation model , the mobile antenna height, frequency, the used algorithm and its parameters.

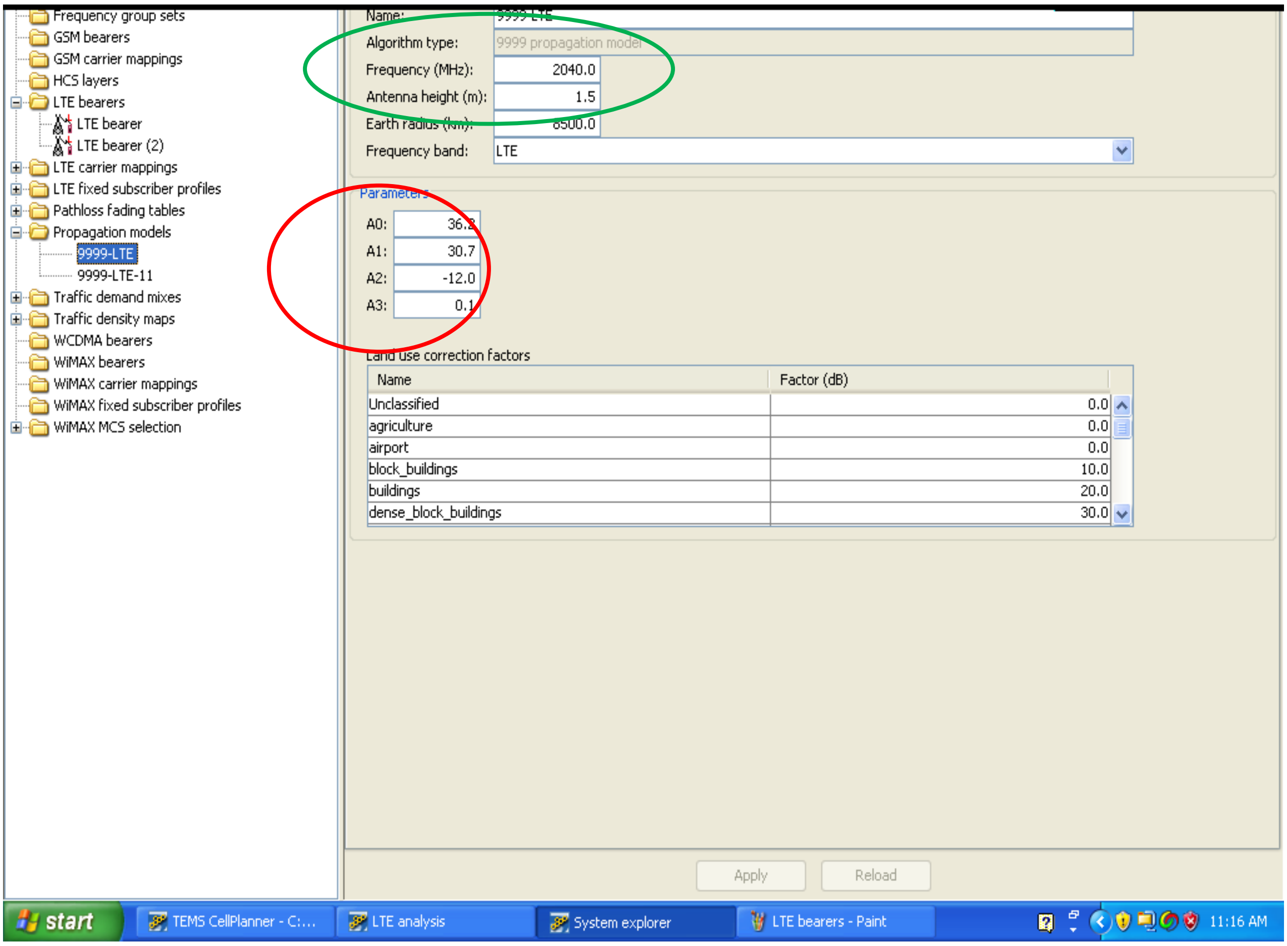


Figure 3.7 propagation model

3.5.5 Traffic demand mixes

The interference and performance of a network are highly affected by the types of services and the amount of traffic in the network. The number of users and the average bandwidth that available for each subscriber are good indicators for the interference and traffic performance in the network.

In network planning, in order to configure the traffic demand mix model, we must define the following information:

1) The type of services provided by the network such as voice, video game, mobile TV.
2) The terminal type.
3) The geographical distribution of subscribers.

For all services in the network, the combination of the traffic demands is called traffic demand mix. The subscribers and traffic in the network are distributed according to a certain pattern, either uniform or non-uniform.

The subscriber density defined as the number of simultaneously active subscribers, its calculations depend on user's traffic type per square kilometre.

As shown in figure (3.8) traffic demand we chose the type of bearer which is LTE bearer and we selected the demand type as Uniform, also we set the traffic density to 1.

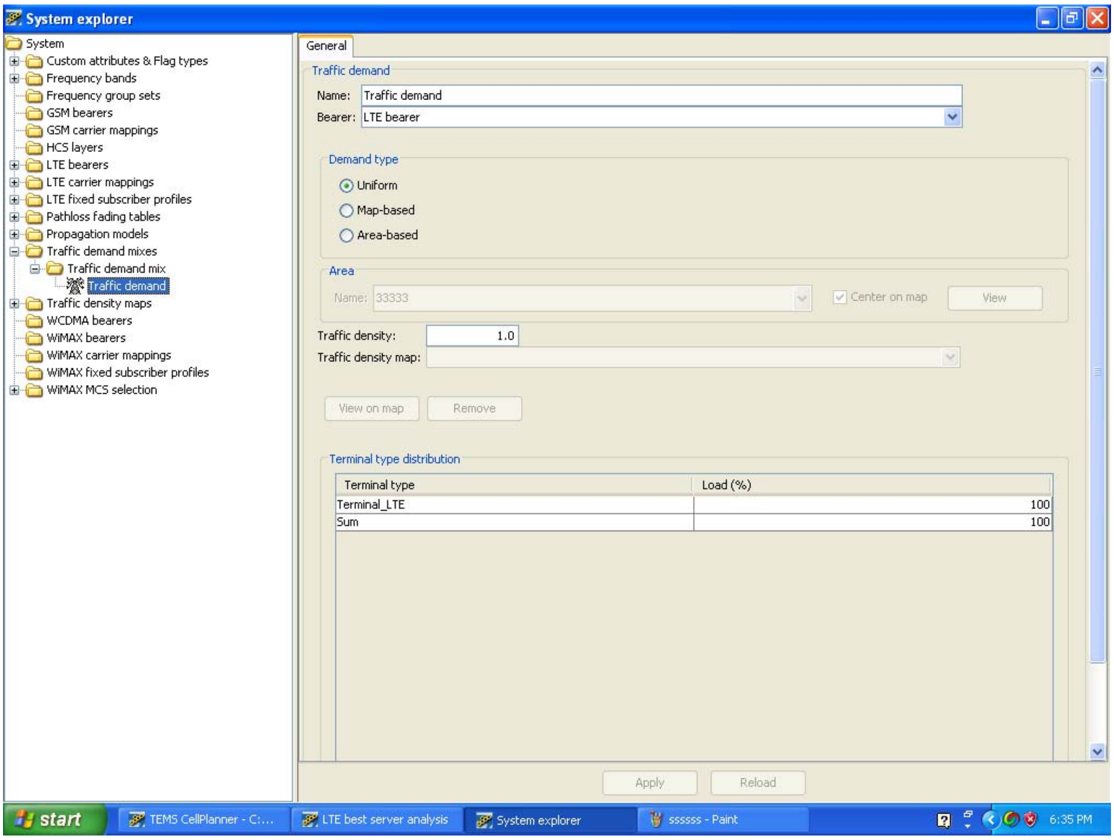


Figure 3.8 Traffic demand

3.6 LTE equipment types

Before defining sites and cells with physical equipments, we defined the equipment types. We first defined the antenna types and then LTE terminal types for mobile UEs and fixed subscribers.

- **Antenna types:**

Each cell (or sector) has an antenna supports the carriers of the cell's frequency band. Each antenna of a certain type has antenna bands and vertical lobes. An antenna band is valid for one or more frequency bands. The antenna vertical lobe represents the antenna lobe in the vertical plane for a given electrical down-tilt angle. Planner can manually adjust the down-tilt angle.

Firstly, we defined several antenna types and antenna bands. In antenna band, we defined the upper and lower frequencies of the band, the antenna gain, half power beam width in degrees for horizontal and vertical beams and other parameters, then we defined the antenna lobes and put the electrical down-tilt. Finally, the antenna patterns must be defined, where the propagation model usually builds a three-dimensional pattern based on the vertical and horizontal patterns.

- **LTE terminal types:**

To get accurate LTE analysis results we need to define the most common terminal types that are expected in the radio network, for mobile or stationary UEs and for fixed subscribers. Terminal type could be *indoor, in-car low-speed, in-car high-speed, or outdoor*. Each defined terminal type is characterized by its supported bearers, number of RB, data rate mappings, and UE category. We set these parameters to give correct inputs to the analysis calculations.

When LTE terminal type is defined, the data rate mapping corresponds to it has to be selected. Each combination of UE speed (corresponding to Doppler shift), channel model and spectral efficiency technique has its own data rate mapping table in UL and DL. We selected a UE category, where each category has its own DL and UL peak rate, also chose the maximum DL and UL modulation as 64 QAM and 16 QAM for DL and UL respectively, and finally defined the number of RX and TX antenna .

After we defined all input data that related to the system and subscribers parameters at TEMS Cell Planner tool, we started the network implementation by adding sites to the desired area for the three cities. In this stage we took in consideration the location of the site which depends on the nature of the area , elevations and the users' density .Then we planned each site separately by defining site parameters, such as: antenna type, tilt and azimuth , transmission power, antenna height and transmission type.

3.7 LTE network sites

Before analyzing the network plan, we added actual sites with their equipments and place them geographically in the network. LTE network may include:

1) LTE Radio Base Station (RBS) sites.
2) Multi-technology RBS sites (LTE RBS co-sited with RBS of other technology such as GSM).
3) LTE fixed subscriber sites for non-mobile LTE terminals.
4) Radio repeater sites amplify the radio signals.

3.7.1 Define sites in an LTE network plan

We defined a pure LTE RBS site which includes the following network elements:

1) One antenna system .
2) One LTE RBS hosting each with two or three sectors, each with one cell and one antenna branch.

After the step of adding the LTE RBS we:

1) Added LTE cells.
2) Added two or three LTE sectors for each LTE RBS.

Here we:

1) Specified the frequency band of the cell, and the hexagon radius of a nominal site as displayed on the map in meters which has a range from 300 to 500 m which is the most proper radius for the three cities.
2) Specified DL LTE absolute radio frequency channel number as 50.

After we implemented our network in each city, we analyzed the planned network to examine its performance and robustness.

3.7.2 LTE cell analysis

We defined many fields such as:

1) Number of TX antennas: we specified number of transmitting antenna as two.
2) Transmission schemes: we chose FDD as Transmission scheme.
3) TX power (dBm): we defined TX power as 45 (dBm):
4) Number of RX antennas: we specified number of RX antenna as two
5) RX noise figure (dB).
6) DL load and UL load.

3.8 LTE transmission schemes

To achieve a certain signal quality of best serving cell for each position in the covered area. LTE Analysis algorithm calculates the achieved SINR for the best server coverage area of all cells and evaluated the best possible transmission scheme to be applied for data rate calculations. TEMS Cell Planner LTE Analysis supports the following transmission schemes:

1) 1x2 MRC also called SIMO: Single transmitting antenna at the eNodeB and receiver diversity at the terminal, which is used in UL and DL.

2) 2x2 transmitter diversity: two transmitting antennas with transmitter diversity at the eNodeB and receiver diversity at the terminal, which are used in DL.

3) 2x2 transmitter diversity is combined with 2x2 MIMO: Two transmitting antennas at the eNodeB with transmission of independent data streams on each antenna and corresponding spatial multiplexing at the terminal side, which is used in DL.

We chose the combination of diversity and MIMO as a transmission scheme, the TEMS Cell Planner tool uses LTE analysis algorithm to evaluate the best-transmission scheme that must be used in each area of the three cities depending on-the nature of area.

3.9Antenna systems and antenna branches

We added an antenna system to each site and created antenna branches to each sector. Antenna system contains all objects of antenna-related equipment, each site must have one antenna system, and it requires one antenna per sector, normally three antennas are used with three sectors. We defined the antenna type, propagation models, and TX power in the cell. Although the fixed subscriber is treated as a site due to its fixed position, the LTE fixed subscriber site does not have any antenna system object related to it, the antenna parameters are defined in the configuration of the terminal type and the fixed subscriber objects.

3.10 Pathloss

Pathloss calculations are such very important step for coverage prediction in planning a network, given the suitable propagation model and the landscape. Making the pathloss calculations enable knowing the antenna or repeater that provides the maximum received power in every user location (or bin), either the power received directly in the bin or from the antenna branch of the cell. The output got from the pathloss calculations is a prediction for the coverage of the cell and the coverage of the additional antenna(s). The pathloss algorithm uses many factors such as: the propagation model, land use, antenna gain and others; to calculate the attenuation in each bin. The prediction of the radius gives the maximum operating distance of the-selected propagation model.

3.10.1 Pathloss, predictions, and fading margins

In the case of the propagation model of a standard macro cell radio wave, the coverage probability will be around 50%, but most operators need coverage probability beyond the 95%. Therefore, to increase the coverage probability and make it reaches the required values the log-normal fading margin should be added to the predicted pathloss. The predicted pathloss accuracy depends on verifying the-propagation model and tuning it based on drive test measurements.

3.10.1.1 Propagation model tuning

The applied fading margin should be close to the standard deviation of the predicted pathloss. In the case of standard macro cell propagation model, the standard deviation is between 6 to 14 dB. In this case, when the propagation model is tuned toward the local radio wave propagation conditions, the standard deviation gets much lower, it comes around 4 to 6 dB. It is often used to perform the detailed network planning and LTE analysis based only on the tuned propagation models in order to reduce the error margin in the predicted pathloss.

3.10.1.2 Fading margins

To enhance the accuracy of pathloss data, it is better to use both the propagation model tuning and puncturing of pathloss data with the drive test measurements. To achieve more reliable coverage, fading margins are used when making link budget calculations. If a tuned propagation model and detailed map data are used to run the predictions of the pathloss, the need of fading margins decreases.

3.10.1.3 Pathloss prediction

To calculate the pathloss, it is important to determine many parameters, such as:

1) Override site-defined radius: to specify a specific value of the radius instead of the defined radius for the site.

2) Optimized radius: to indicate the usage of an optimized prediction radius for pathloss calculations.

3) Resolution: the bin size in meters. It determines the prediction resolution.

In pathloss prediction as shown in figure(3.9), we selected the option (filter) because the pathloss prediction is for the whole region, we assigned the override site-defined radius to 500m , determined the finest resolution and finally set the recalculate to Only if out of date .

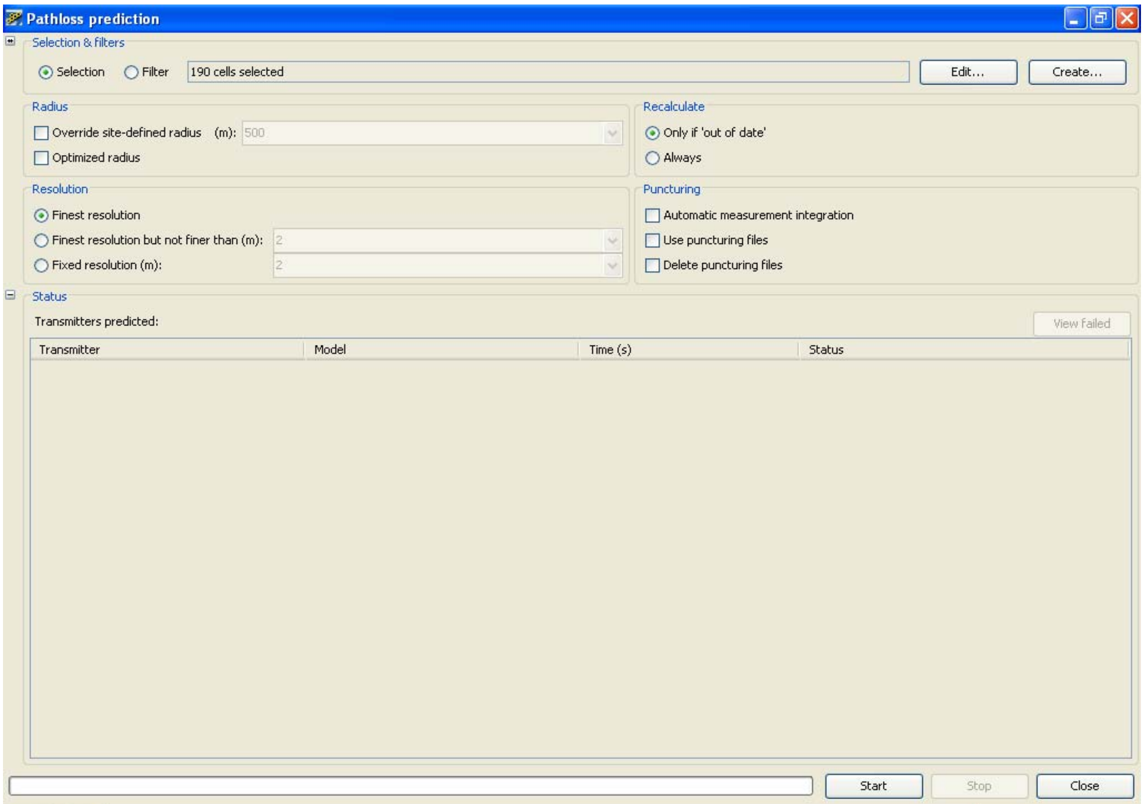


Figure 3.9 Pathloss prediction

3.11 Optimized prediction radius

The optimized prediction radius of the cell should be calculated , it based on:

1) Antenna's effective radiated power and free space propagation model.
2) The maximum distance for a useful signal, when calculating pathloss for the selected propagation model.
3) Analysis: if there is Line Of Sight (LOS) or No Line Of Sight (NLOS) between the border areas. The prediction radius is decreased from LOS to NLOS distance if it is required.

The optimized prediction radius is calculated in TEMS Cell Planner when the signal strength has become -120 dB.

3.12 LTE Network Analysis

In order to analyze the LTE network planning, we followed the following steps in order:

1) Calculated pathloss as explained before.
2) Calculated LTE best servers.
3) Analyzed LTE traffic and interference.
4) Generated LTE neighbour lists.

First of all, we selected an analysis area and a surrounding border area to make the analysis steps over these two areas. The results displayed in plots are limited to the analysis area**.**

3.12.1 LTE best server analysis

The purpose of LTE best server analysis is to find the best serving cells and to provide plots display the best servers per bin. Here, the interference from surrounding cells is not taken into account. The best server analysis first calculates the composite pathloss for every bin, the results are stored in a Composite Path Loss Matrix (CPLM) which contains an ordered list of cells with their predicted pathloss of the bin. Then, we evaluated the best servers for all traffic cases. For every bin, the best server cell is the cell with the strongest received signal. Also there are cells that might act as second or third best server, so the output of the best server analysis is a list of best and n-best servers and with the achieved SINR for every bin in the unloaded network.

3.12.2 LTE analysis (including interference)

The purpose of LTE Analysis (Including Interference) is to calculate uplink and downlink interference and traffic performance taking into account the load from surrounding users and cells. The analysis is performed by algorithms in a Monte Carlo Simulator. In a planning tool simulation algorithms are used to model the expected users and network behavior under varying traffic load and radio conditions.

For this purpose, TEMS Cell Planner uses the Monte Carlo simulator**,** which is used to model LTE networks with load. This simulator randomly distributes mobile UEs over the analysis area and performs calculations in a number of trials (default 10) using a random UE distribution in each trial. We entered some parameters to Monte Carlo such as number of trials (which is the number of times to run the analysis with different UE distribution) , fading model, and other parameters. During the analysis, we selected: a frequency, UL and DL scheduling, a scheduler type and power control settings.

3.12.3 LTE neighbour analysis

According to 3GPP specifications, the purpose of specifying Neighbour Relations (NRs) is to relieve the operator from the burden of manually managing NRs.

Generated neighbour lists are necessary to show the neighbour relations between cells. There are two types of neighbour lists, the neighbour list that is generated manually for each cell from a tree structure, and the neighbour list that is generated automatically due to handover possibility, each cell is included in the neighbour list of any other cell if handover is possible between them.

The LTE neighbour lists typed into the following types:

1) LTE/LTE intra-frequency relations.
2) LTE/GSM inter-frequency relations .
3) LTE/WCDMA inter-frequency relations.

The neighbour statistics of the analyzed traffic case:

1) Number of cells.
2) Number of cells with no neighbours.
3) Number of cells with waiting list or “Observation” list of candidate neighbor cells. This list initially includes candidate neighbors found when you Generate LTE Neighbor Lists.
4) Number of cells with error list This list includes cells rejected as neighbor cells. It is initially includes possible neighbors found when the neighbor list is already full .[45]

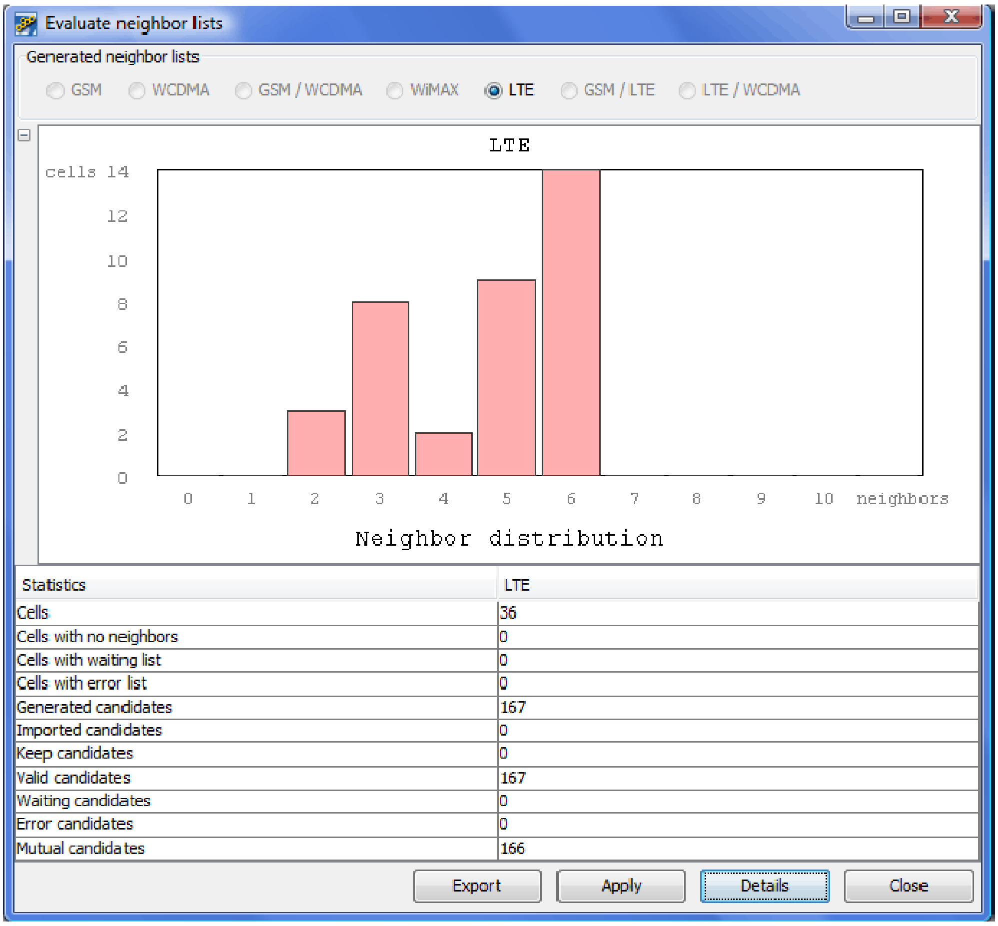


Figure 3.10 Generated neighbour list

Figure (3.10) shows a summary of generated neighbour list. It consists from a graph and table, the graph shows the neighbour distribution and the table shows other details .

Finally, the last step in the planning process is the network optimization. Which can be defined as continuous process of improving the overall network coverage, capacity and quality. We performed this step manually by tuning some parameters related to antennas and other equipments.

We passed through the previous planning process for the cities Hebron, Ramallah and Nablus .

Finally, after implementing the network, the steps made during planning need to be corrected through an optimizing process which includes:

1)Changing antenna tilt (down-tilt, up-tilt)
2) Changing base stations parameters.
3) Dimensioning base stations equipment.
4) Adding new cells for coverage.[51]

3.13 Conclusion

In this chapter we introduced the steps of network planning and optimizing processes for three main cites (Hebron, Ramallah, Nablus). We also explained the tool we used in the planning and optimization which is TEMS Cell Planner. Moreover, there are some figures we embedded to illustrate the definition of some LTE system parameters that must be defined in the planning process such as: LTE carrier mappings, frequency bands, traffic demand, etc.

CHAPTER 4

Content

4.1 Overview

This chapter will show the optimized results of LTE network in the main three cities (Hebron, Ramallah, Nablus). Also it will show the points of weakness in the network coverage , capacity and quality planning. In addition it will discuss some case studies for some chosen sites in Hebron and Ramallah which have bad planning results and the suggestions to improve their.

4.2 system setup

LTE network planning is based on some parameters such as: area under consideration, expected data rate and required QoS. For these parameters we defined the cell radius in the city which based on two evaluation :the ability of the network to provide services to the users with desired level of quality, and the maximum allowed path loss in the cell (-120 dB). These parameters are used to calculate the cell radius by using a suitable propagation model Ericsson 9999 model is used to compute the path loss for the cell radius depending on the carrier frequency, which is 900 MHz. After we defined the cell radius we found the desired number of sites, which provide the desired coverage and capacity in the cities.

LTE network dimensioning and planning in three cities required fundamental data elements such as:

- Carrier frequency (900 MHZ)
- Bandwidth (5MHz).
- Number of served subscriber per cell (300 user).
- traffic distribution (Uniform).
- geographical area to be covered.
- Propagation models according to the area (9999 Ericsson).

4.3 Plots

The last stage in the network planning process for any city is displaying the results in plots to get the feedback from the optimizing steps . So we can know the areas of weakness in the planned network and try to modify it, but without infringing on some limitations. In the following some important plots that can be generated :

1. (Instantaneous) DL and UL Data Rate (with Interference)

This plot displays for each bin the instant DL and UL data rate in kbps received in all resource blocks (RBs) sent on the carrier frequency for the selected traffic case, with Interference from surrounding users and cells taken into account. The DL and UL data rate of the whole carrier is calculated by multiplying the (Instantaneous) data rate per RB (with Interference) with the number of RBs set in the LTE carrier mappings. This plot shows the data rate given to users at connection establishment.

2. DL and UL C/(I+N)

These plots display for each bin the average signal to interference ratio (C/(I+N)) in dB, for the selected carrier frequency .

3. Signal Strength

This plot displays for each bin in the area the received signal strength in dBm from the best server cell for the selected carrier frequency. For every bin, the cell with the strongest received signal is the best server cell.

The next sections of the chapter show the final optimized planning results in three cities (Hebron, Ramallah and Nablus) after many trials of optimizing and fine tuning with existence of many limitations on the parameters we can tune ,such as : Antenna gain set in between 12-15 dB, transmitted power as 43dBm and the antenna height which was (15-20)m .We fundamentally concentrated our tuning process on changing the azimuth, the mechanical tilt depending on the geographical nature. And changing the site location as a final choice.

We got these optimized plots after we chose more suitable system parameters for each site separately. These parameters depended on the site location, height and area.

4.4 Hebron

Hebron is a Palestinian city that located in the southern West Bank, 30 km south of Jerusalem. It is the largest city in the West Bank, which is 17km^2 with population of 75,000 residents. The mountainous nature is the prevailing nature in the city , where the height of the city above sea level more than 930 meters.

Hebron city distinguished by its high population density and crowded buildings in the most regions. This created lots of challenges in planning and optimizing the network . In this city we distributed 65 sites, for coverage and capacity requirements, with radius 500 m , antenna height (15m in the city and 20m around its edges , transmitted power 43dBm, and antenna gain as 12dB on the centre of the city and 15 dB in the edges. These limitations and difficulties made needing the survey for some sites mandatory.

Figure 4.1 Hebron City.

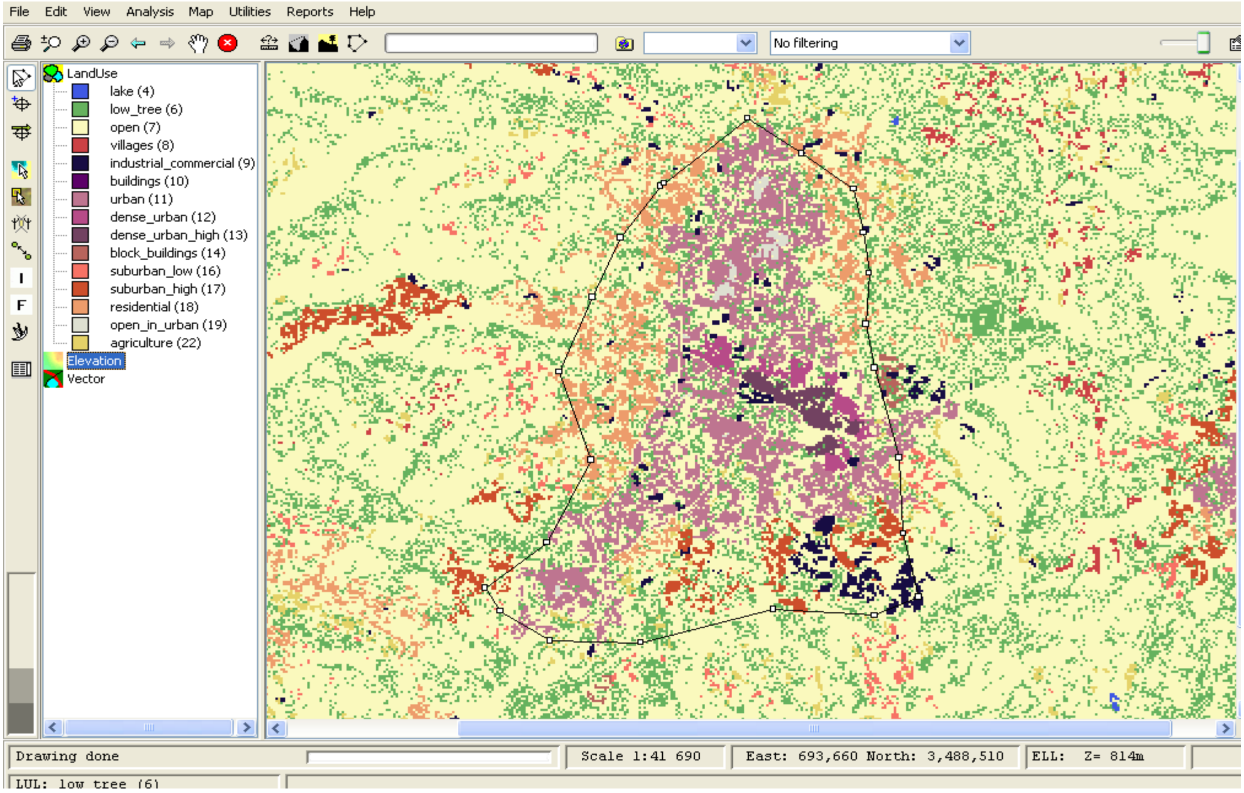


Figure 4.2 The resident distribution in Hebron city

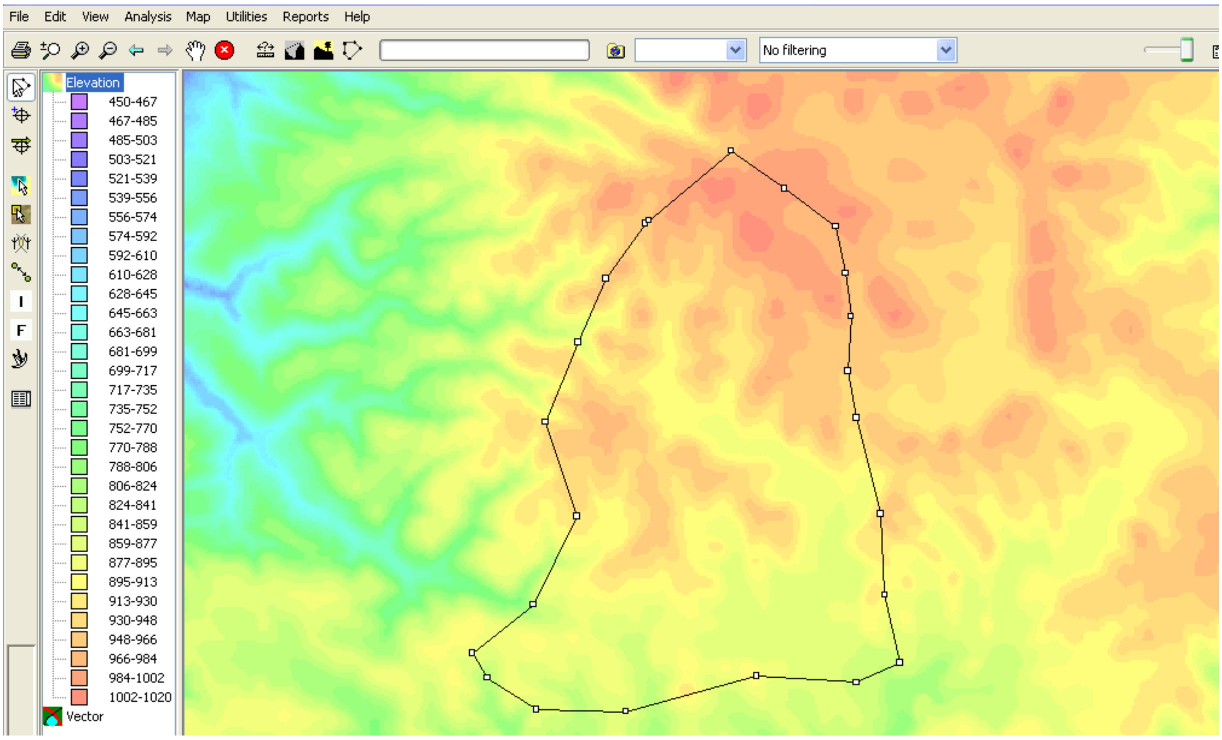


Figure 4.3 The elevation in Hebron city

4.4.1 Hebron results

The final optimized results shown in the following plots :

1) DL Data Rate

Figure 4.4 shows the final results of DL data rate. It seems high in general even it seems bad in some regions such as regions 1 and 2 that shown in this figure , which is predictable due to the nature of Hebron city and the limitations that limits the optimizing process. Data rate values range from 50000 kbps to almost 5000 kbps in few regions. Appendix A shows the levels we passed through to get the optimized data rate result.

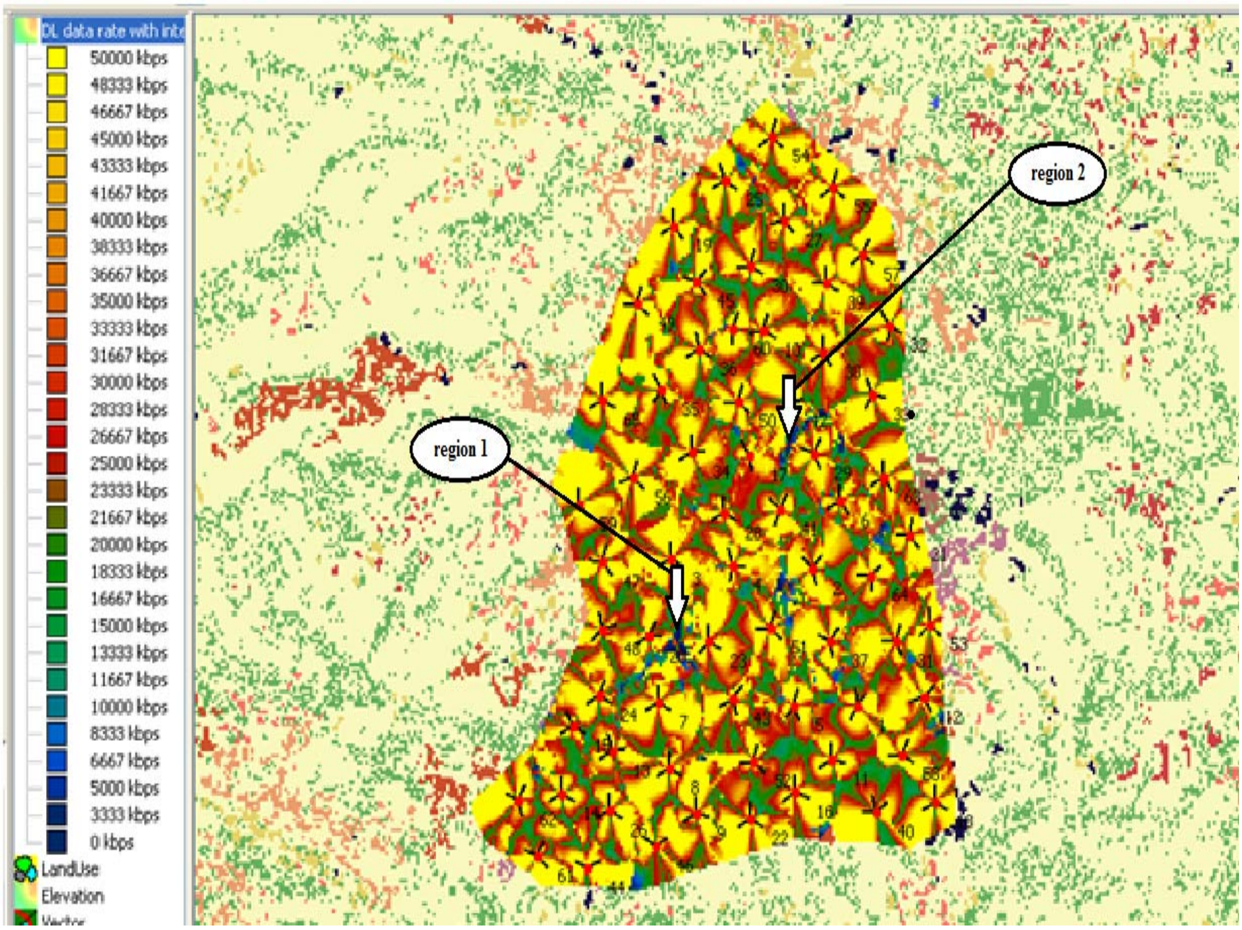


Figure 4.4 Hebron DL data rate.

2) UL Data Rate

Figure 4.5 shows the UL data rate which seems very high in almost regions with value of 25000 kbps after many trials of fine tuning and optimization. In some regions the data rate reaches 1670 kbps due to the mountainous nature in that regions which limits the signal strength that influence on data rate.

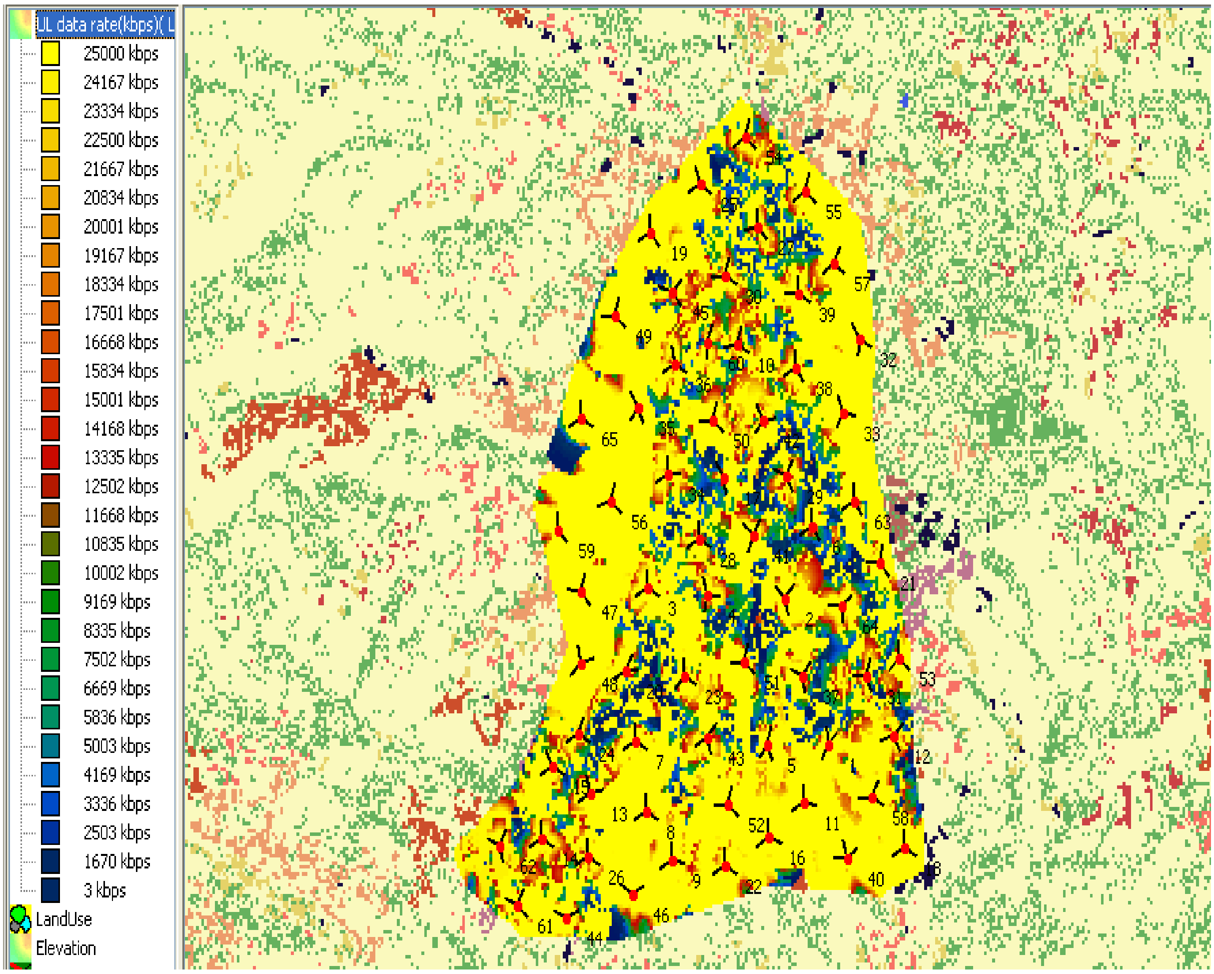


Figure 4.5 Hebron UL data rate.

3) DL C/(I+N)

Figure 4.6 shows the DL signal to interference ratio C/(I+N) . The values range from 46 dB to almost 10 dB. As is clear most regions have values from 20 dB to 14 dB .This is due to the over-population in the city which led to add more sites and cause to reduce signal to interference ratio in some regions. As in DL data rate , region 1 and 2 have the worst values reach to almost 1dB due to the same reasons we have mentioned before.

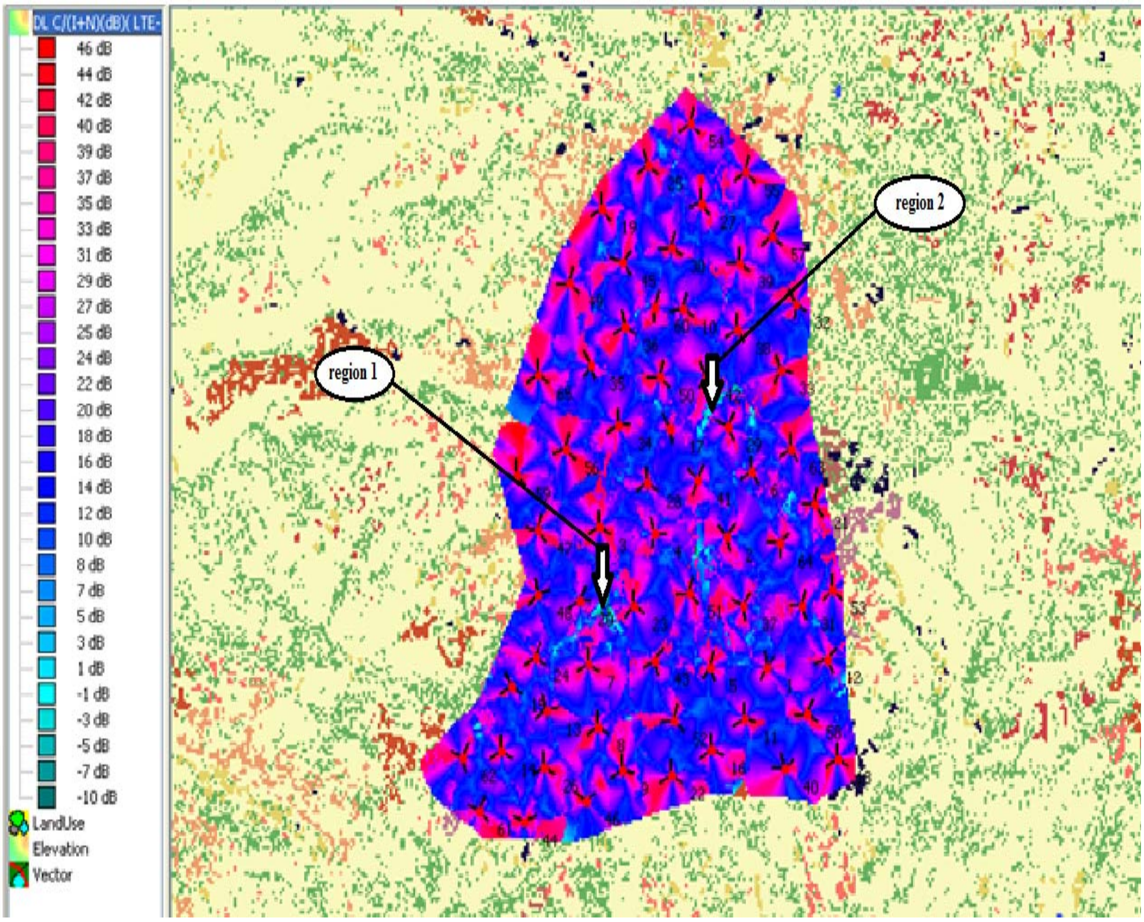


Figure 4.6 Hebron DL signal to interference ratio C/(I+N)

4) UL C/(I+N)

Figure 4.7 shows the UL signal to interference ratio C/(I+N). The values in most regions range from 20 dB to almost 12 dB, but there are some regions have lower values range from 7dB to almost 1 dB.

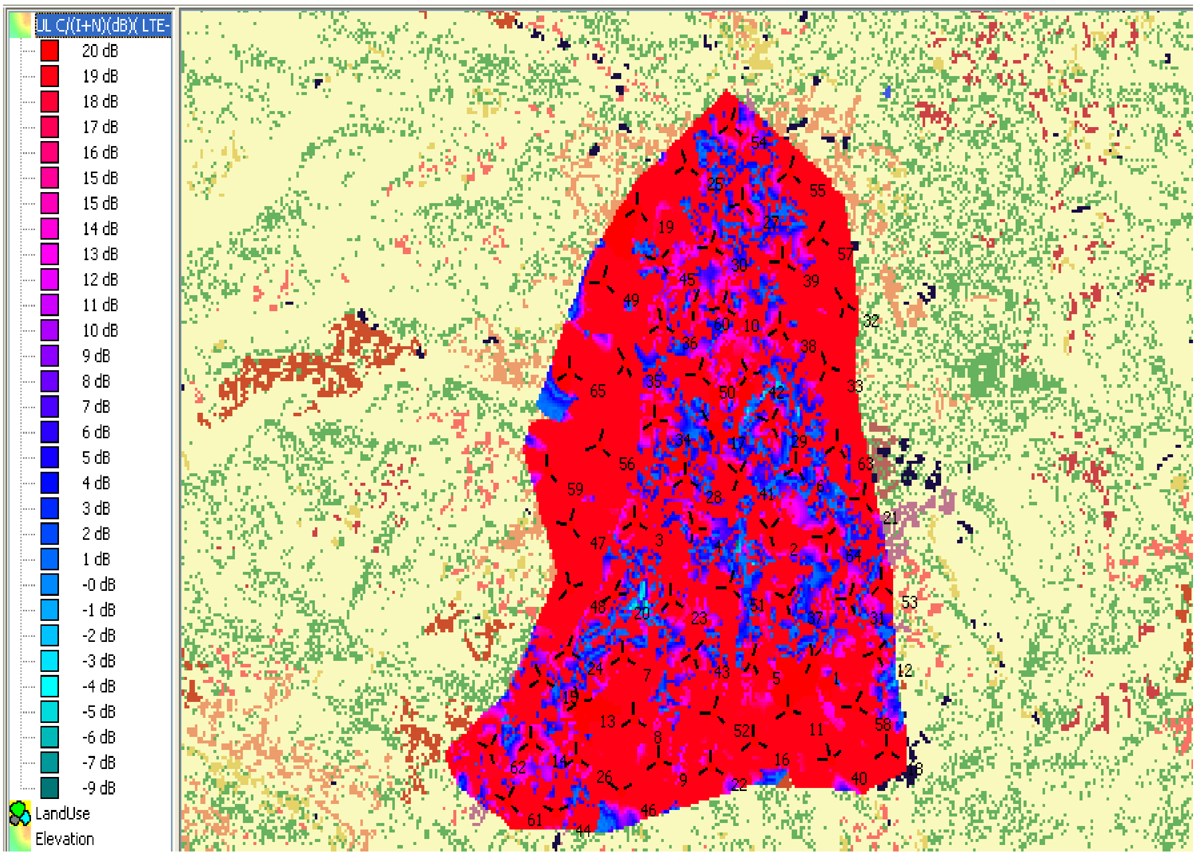


Figure 4.7 Hebron UL signal to interference ratio C/(I+N)

5) Signal Strength

Figure 4.8 shows the signal strength. The values look in average in almost regions ,and range from -30.6 dBm to almost -90 dBm in few regions. The lowest values range between -71.3 dBm to -90 dBm return to the existence of many obstacles due to the crowded buildings and mountainous nature. Also because of the short distances between sites to achieve the desired data rate and coverage for end user. Appendix A shows the levels we passed through to get the optimized signal strength result.

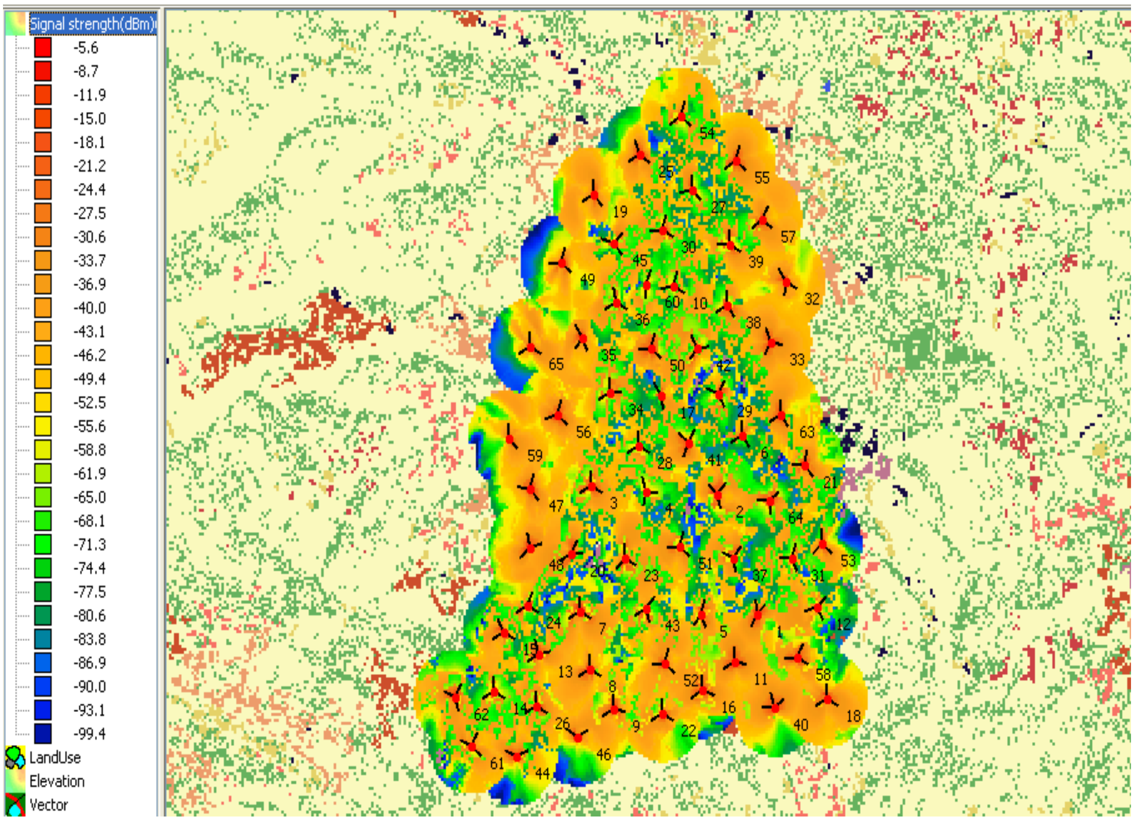
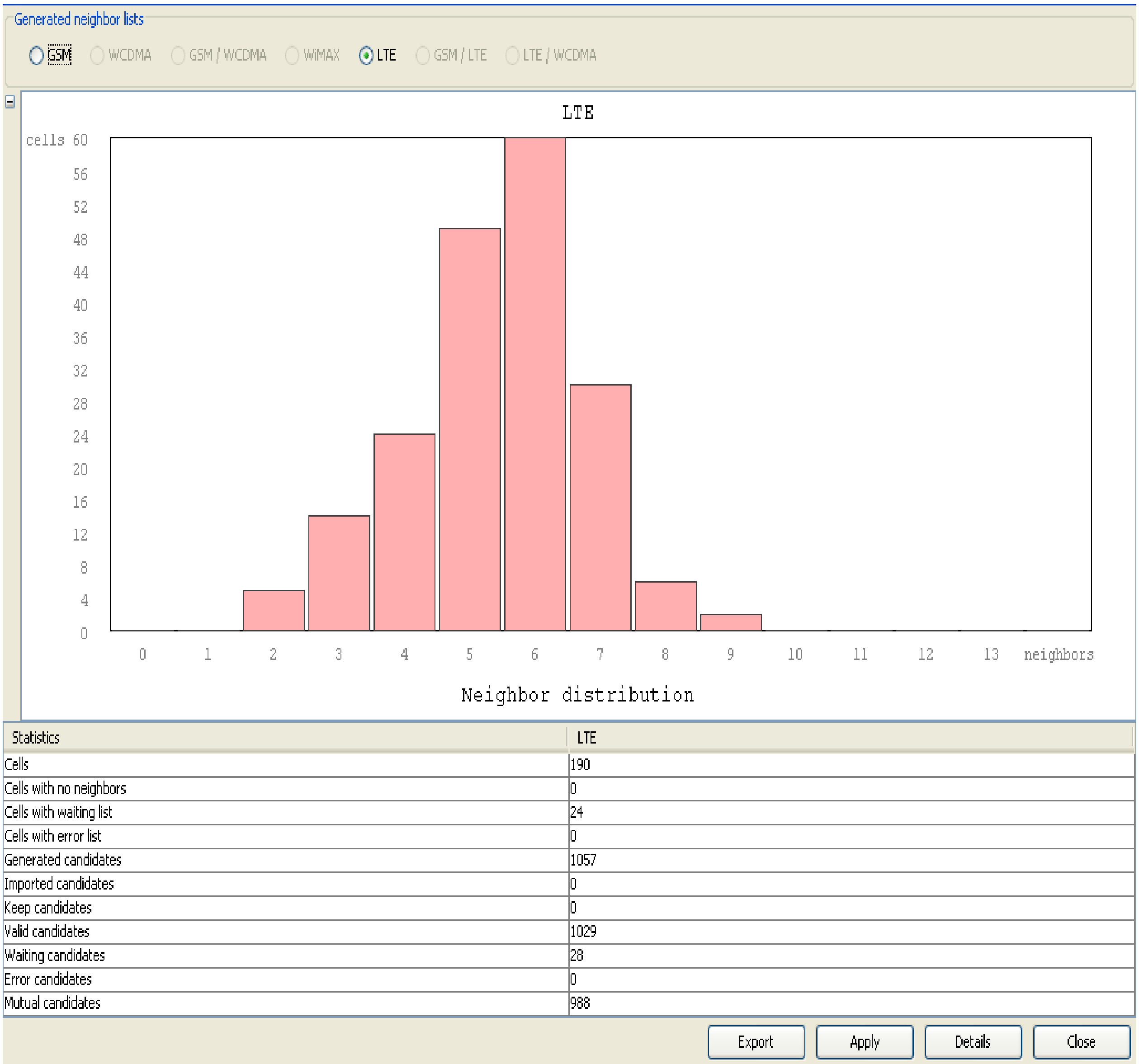


Figure 4.8 Hebron Signal Strength

6) Hebron neighbor list

Generating neighbor lists is an important step in the planning process .Neighbor lists are necessary to show the neighbor relations between cells. Figure (4.9) shows a summary of generated neighbor list for Hebron city. It consists of a graph and a table, the graph shows the neighbor distribution. For example, There are 24 cells have 4 neighbors and 60 cells have 6 neighbors. The table shows some statistics about the number of all cells in the city, cells with waiting list, cells with error lists and other details.



Statistics	LTE
Cells	190
Cells with no neighbors	0
Cells with waiting list	24
Cells with error list	0
Generated candidates	1057
Imported candidates	0
Keep candidates	0
Valid candidates	1029
Waiting candidates	28
Error candidates	0
Mutual candidates	988

Figure 4.9 Hebron neighbour list

4.4.2 Survey Results

We took two sites in Hebron city as a case study to show the reasons of the weakness in their coverage and the suggested solutions to improve it. We chose sites 20 and 42 because they have the worst results in the five plots. We took the coordinates of the two sites from Google Earth to know their real locations . Then we visited the places they were put in and took many photos clarify the exact location of them .

4.4.2.1 Site 20

Figure 4.10 shows site 20 location on Google Earth. It shows the location we chose and the new suggested location which improve the results.

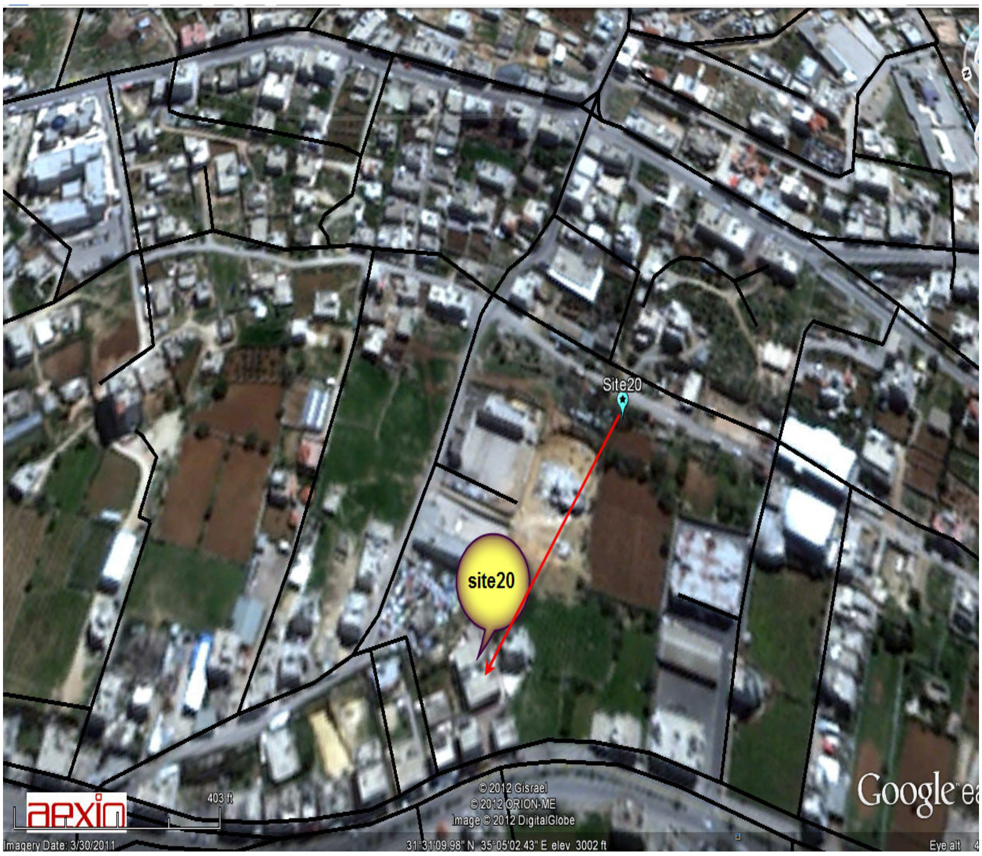


Figure 4.10 Site 20 location on Google Earth

Figure(4.11) shows the real location of site 20 .We located it through the tool in a bottom of a mountain in a middle of a street, this made both of the data rate and signal strength bad in that location, to solve this problem we suggest to change its location as will be shown.

Figure 4.11 Real Location of site 20

Figure 4.12 shows the first and the suggested location of the site. We suggest to move the site from location 1 to location 2. As it is clear the site was located in a bottom of a mountain , this caused low data rate and weak signal in our planning results due to the obstacles that face the transmitted signal .But if we move the site to the new location and change the azimuth , the tilt and the antenna height the signal will be strengthened as a result of the coverage improvement because we moved away from the mountain .This will improve the signal quality and the data rate as well.

Figure 4.12 First and suggested location of site 20

After we moved the site to the suggested location which is more proper for the nature of the region and the coverage requirements we got improved results for data rate and signal strength.

Site 20 data rate before and after optimization

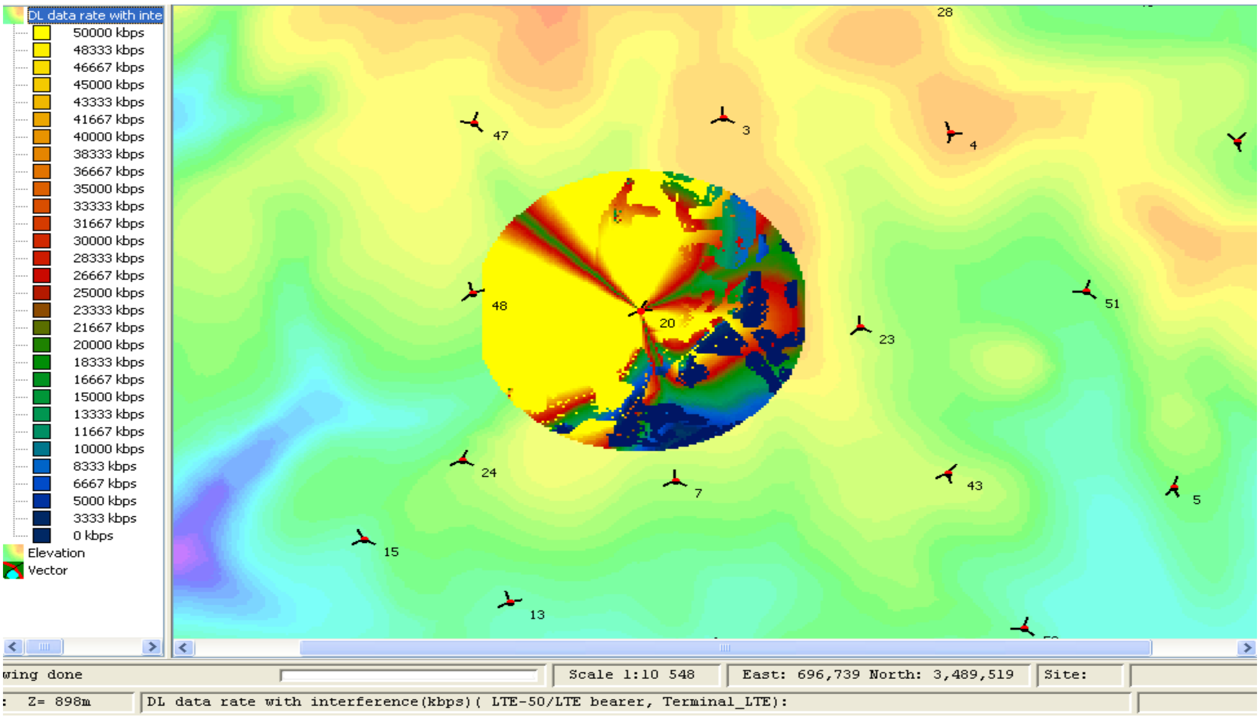


Figure 4.13 site 20 data rate before optimization.

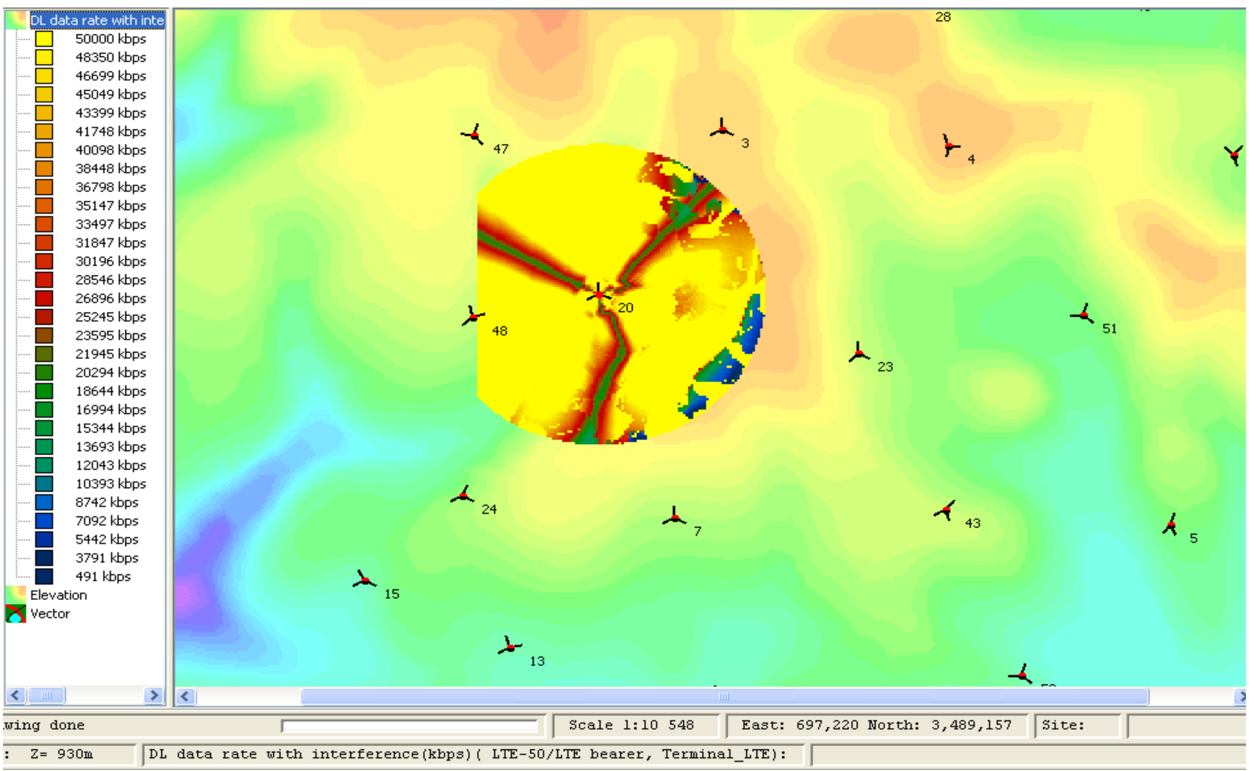


Figure 4.14 site 20 data rate after optimization.

Site 20 signal strength before and after optimization

Figure 4.15 shows signal strength before optimization. There are uncovered areas due to the mountain.

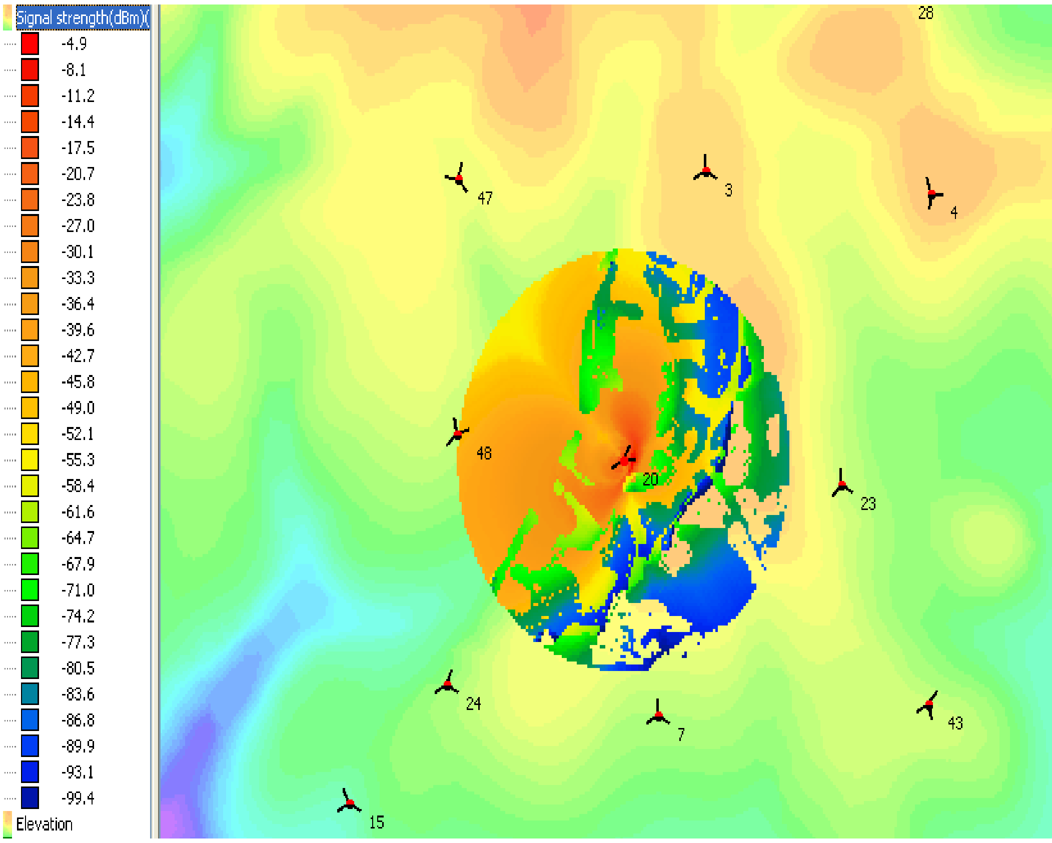


Figure 4.15 Site 20 signal strength before optimization

Figure 4.16 shows signal strength after optimization. After moving the site and fine tuning the uncoverd areas became covered.

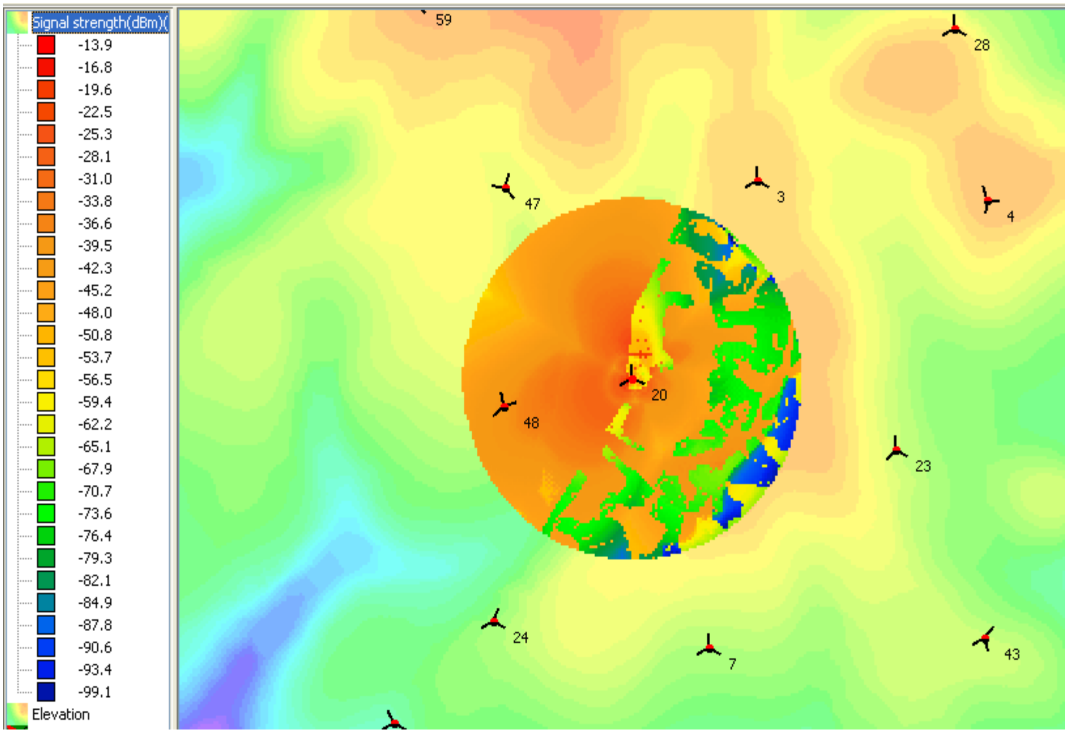


Figure 4.16 Site 20 after signal strength optimization

After we moved the site away from the obstacles around and changing the the site tilt to -5 for sector A and -15 for sector B. the data rate and signal strength results are optimized as shown in the previous figures. Appendix A shows the characteristics of site 20 after optimization.

4.4.2.2 Site 42

Figure 4.17 shows site 42 location on Google Earth. It shows the location we chose and the new suggested location which improve the results.

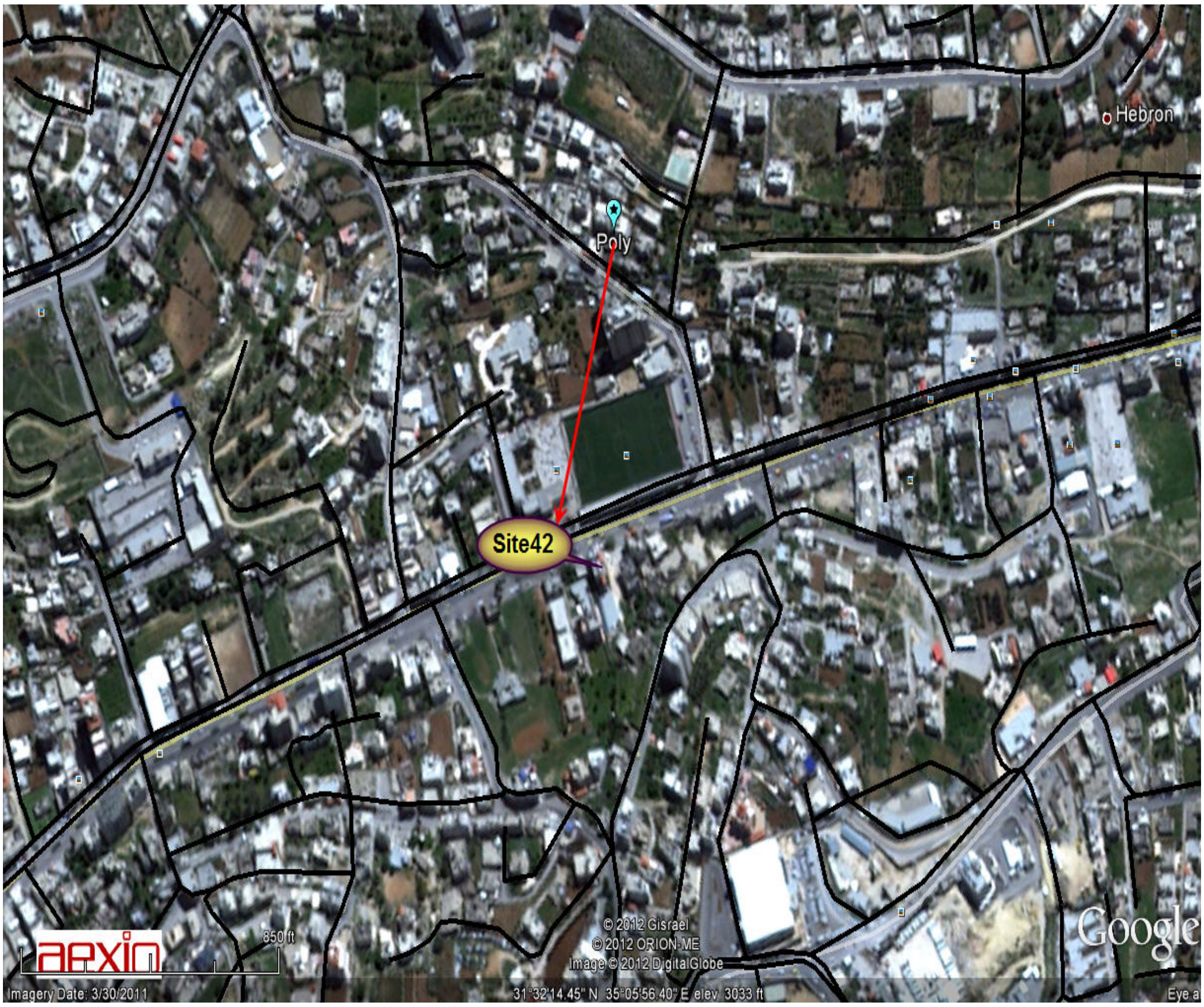


Figure 4.17 site 42 location on Google Earth.

Figure 4.18 shows the real location of site 42 . We found that the site was located in a terrible location, where there are two high buildings in front of it and a mountain in the back. This made both of the data rate and signal quality bad in that location.

Figure 4.18 The real location of site 42 in Hebron

Figure 4.19 shows the two locations of the site, the first and the suggested one. We suggested to move the site to the new location because it is higher and there are no obstacles that may affect the signal quality and weaken it. By moving the site to the new location and change the azimuth , the tilt and the antenna height all results improved.

Figure 4.19 the first and the suggested location of site 42

Site 42 Data rate before and after optimization

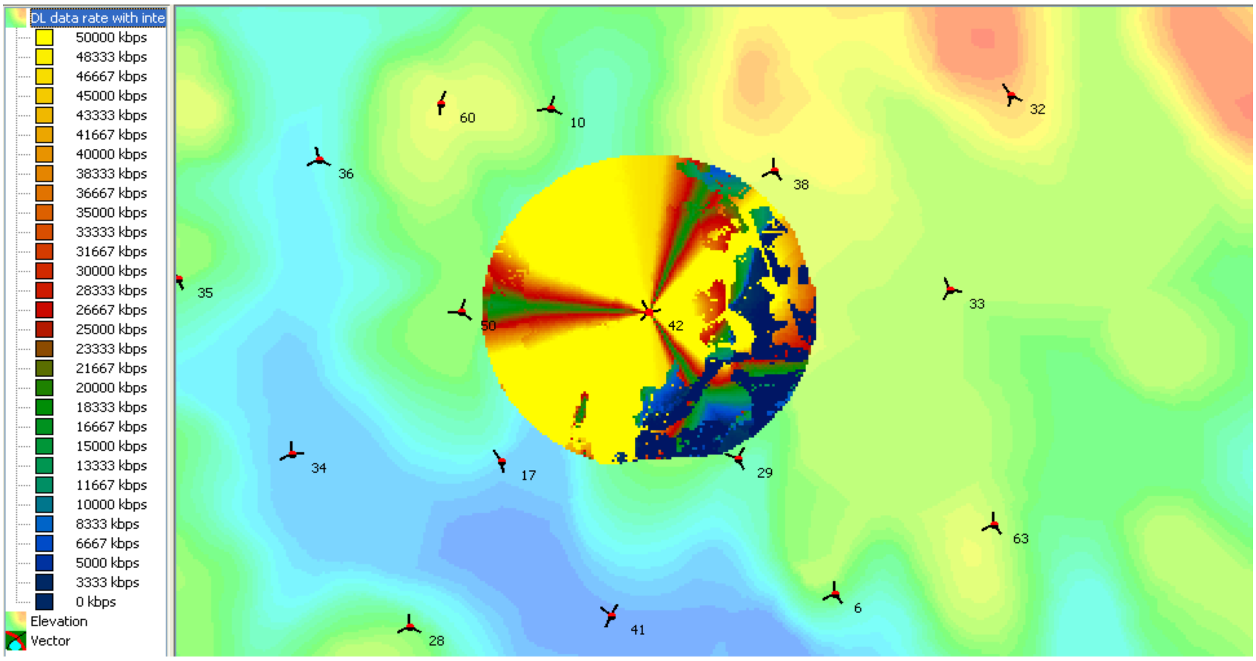


Figure 4.20 site 42 data rate before optimization.

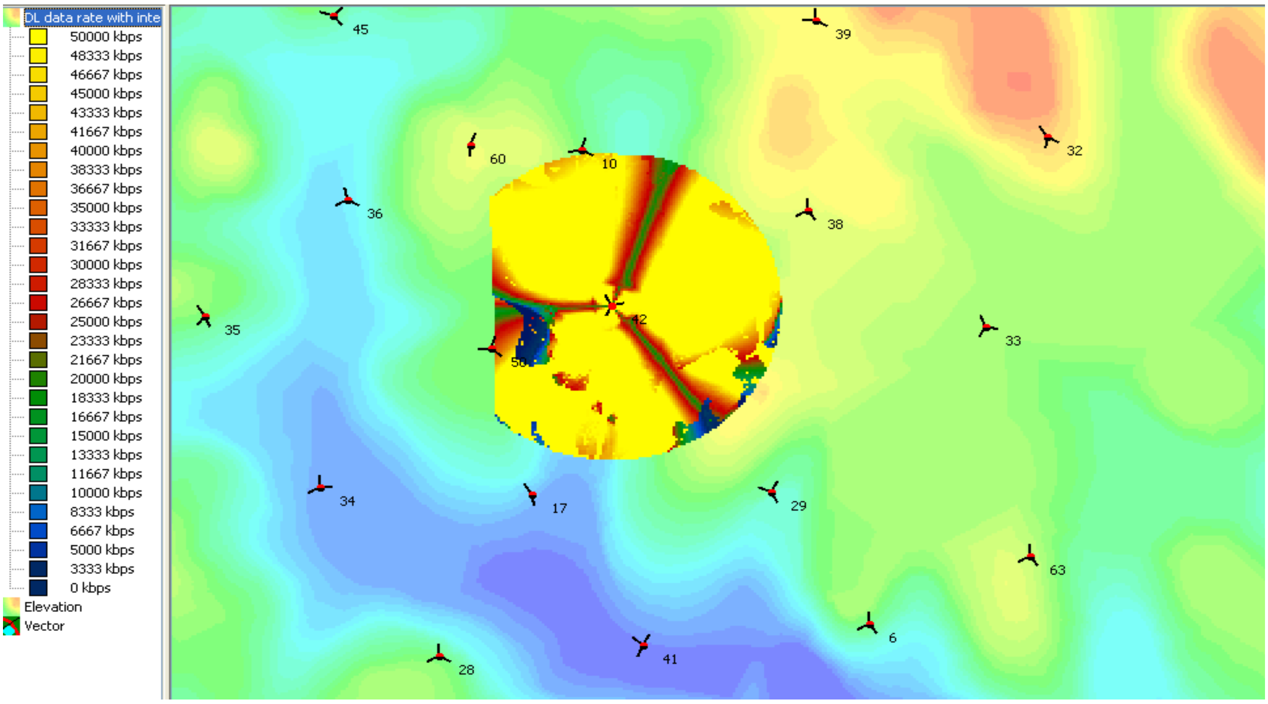


Figure 4.21 site 42 data rate after optimization.

Site 42 Signal Strength before and after simulation

Figure 4.22 shows signal strength before optimization. There are uncovered areas due to the mountain

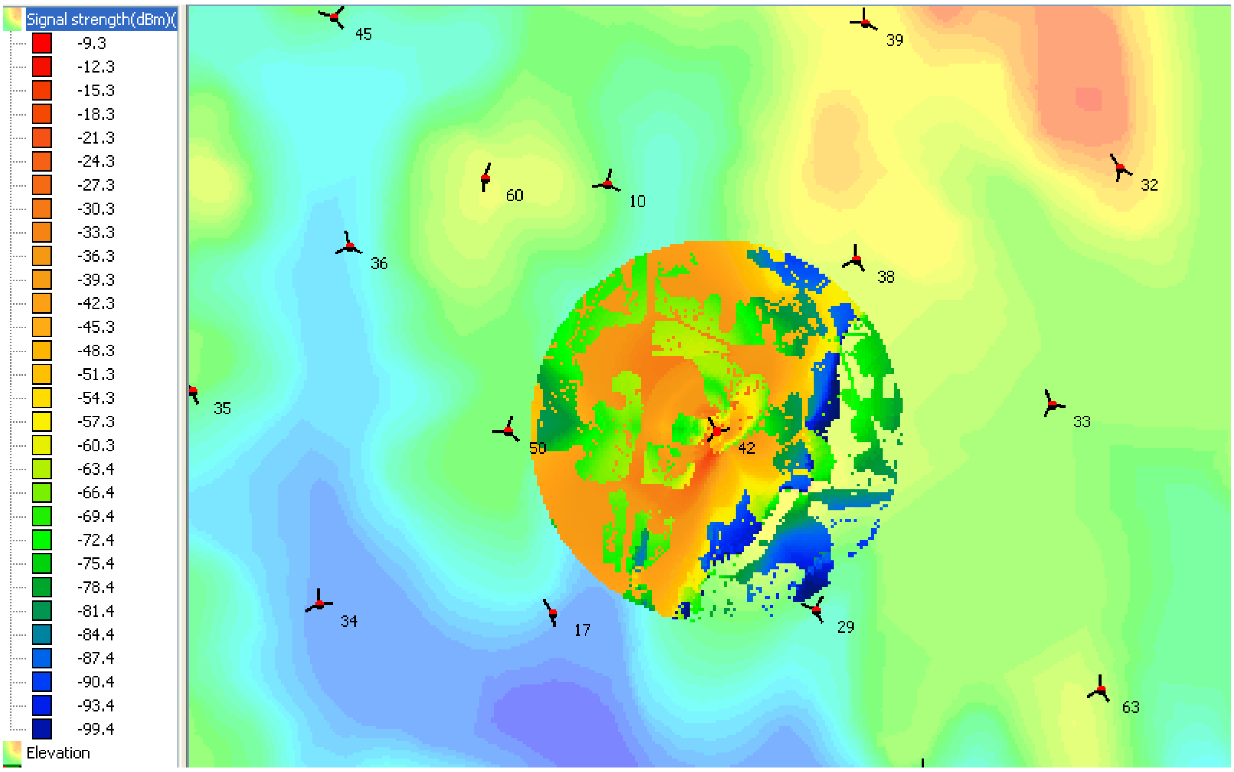


Figure 4.22 signal strength before optimization

Figure 4.23 shows signal strength after optimization. After moving the site and fine tuning the uncoverd areas became covered.

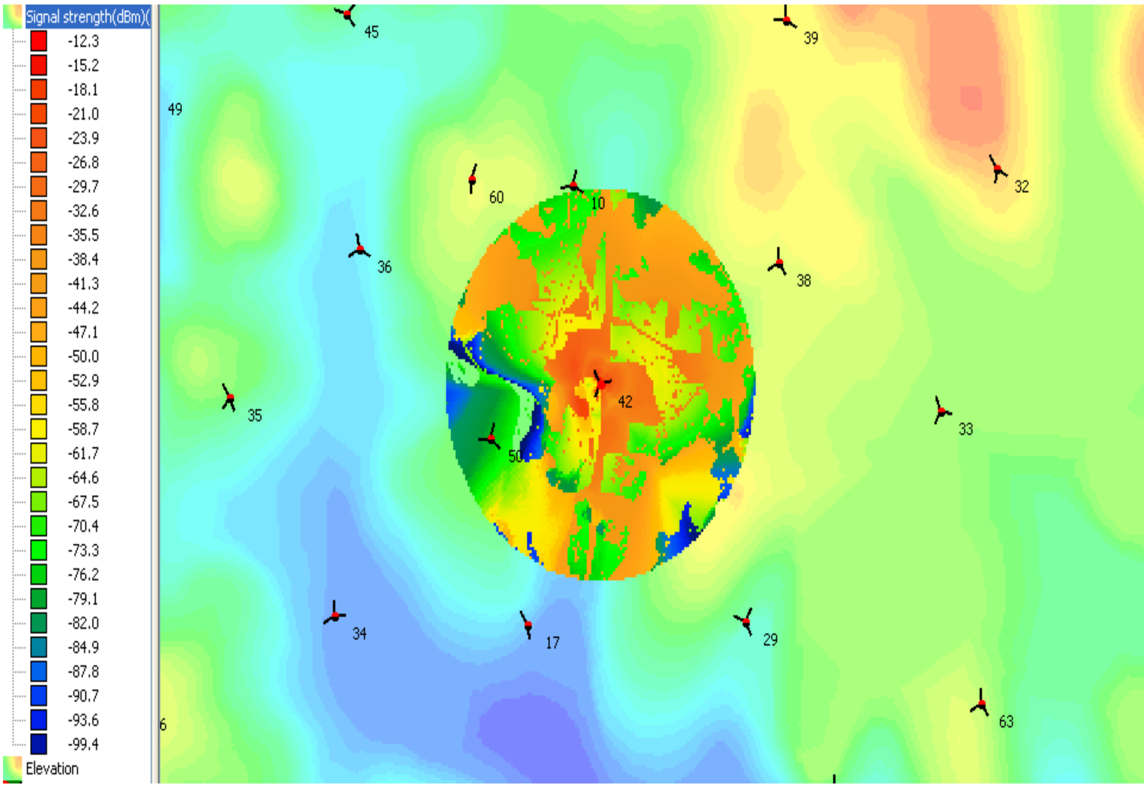


Figure 4.23 signal strength after optimization

After we moved the site away from the obstacles around and changed the site tilt to -10 and the azimuth, the data rate and signal strength results optimized as shown in the previous figures.Appendix A shows the characteristics of site 42 after optimization.

Appendix A consist of more figures for hebron city.

4.5 Ramallah

Ramallah is a Palestinian city in the central West Bank and is located about 10 kilometers (6 miles) north of Jerusalem, its population consists of approximately 23,000 residents. It is a modern built city and is considered the unofficial capital of the Palestinian Authority. The big challenge in this city was in the existance of so many high buildings distributed along the middle of the city. In this city we distributed 60 sites with radius 500 m , antenna height (15-20) m, transmitted power 43dBm, and antenna gain as 12dB on the centre of the city and 15 dB in the edges. These limitations and difficulties made needing the survey for one site mandatory**.**

Figure 4.24 Ramallah City

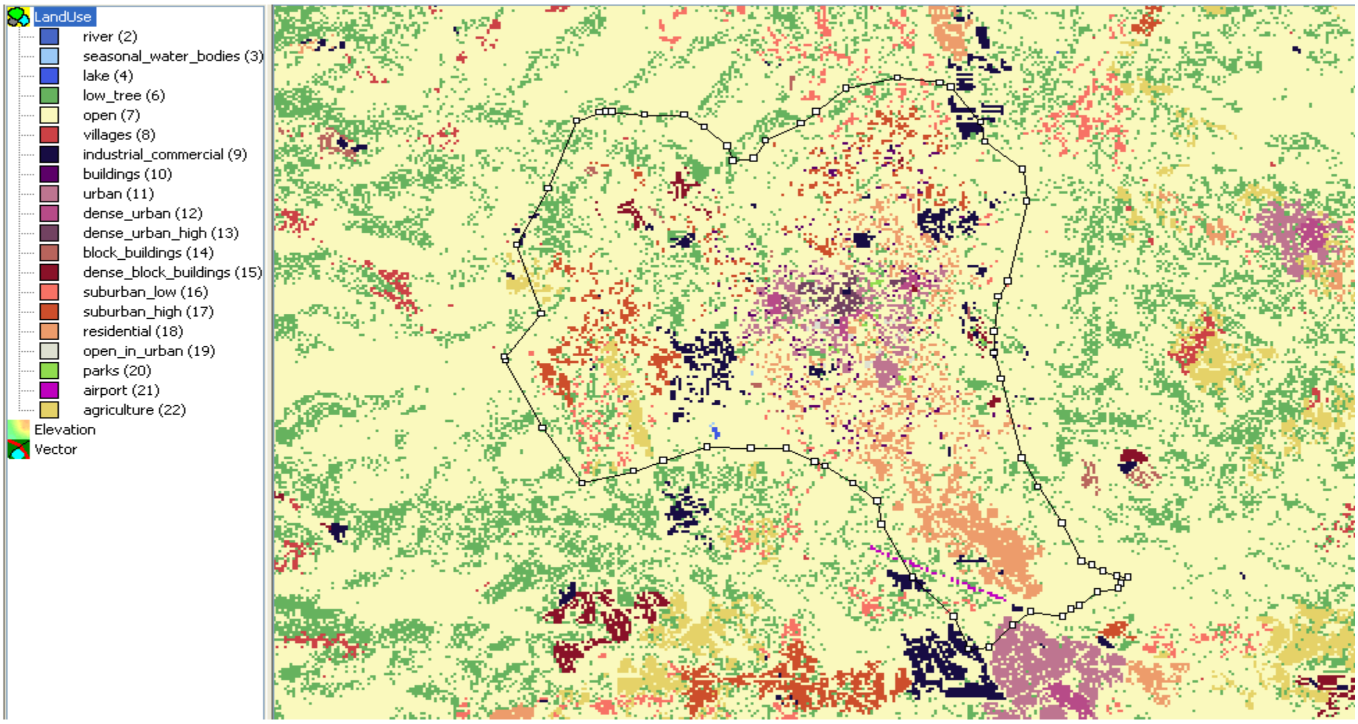


Figure 4.25 the resident distribution in Ramallah city

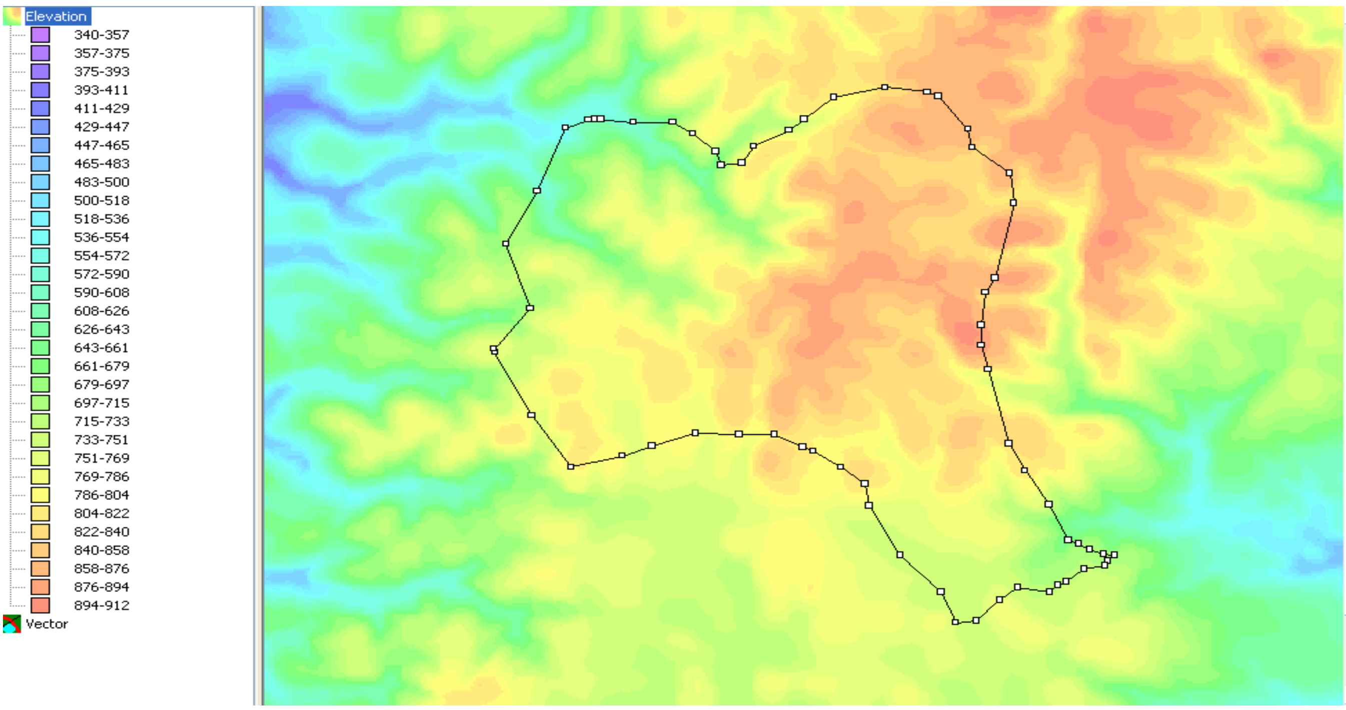


Figure 4.26 the elevation in Ramallah city

4.5.1 Ramallah results

The final optimized results of Ramallah are shown in the following plots :

1) **DL Data Rate** :

Figure 4.27 shows DL data rate which seems high in most regions and low in few others which is predictable due to the nature of Ramallah city and the limitations that limits the optimization process. Data rate values ranges from 50000 kbps to almost 20000 kbps in few regions. As shown in the figure the worst result is in the middle of the city this is due to the over population and the crowded buildings in this region. This affected on the most results as will be shown later. Here the data rate value in the middle region is almost. Appendix A shows the levels we passed through to get the optimized data rate result.

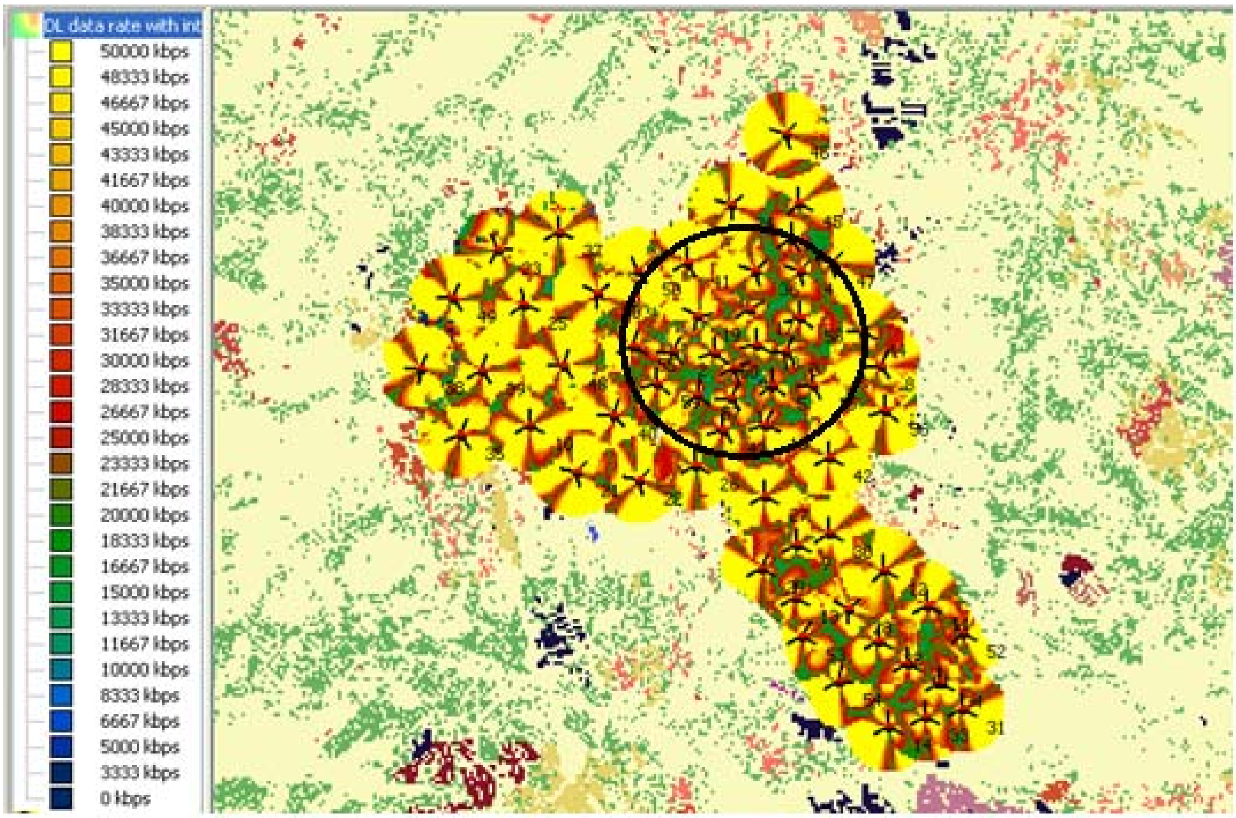


Figure 4.27 Ramallah DL data rate

2) UL Data Rate

Figure (4.28) shows that the most regions in Ramallah have high UL data rate values reach to 25000 kbps. Also there are few regions especially the middle of the city have lower data rate ranges from almost 17500 kbps to 7500 kbps .

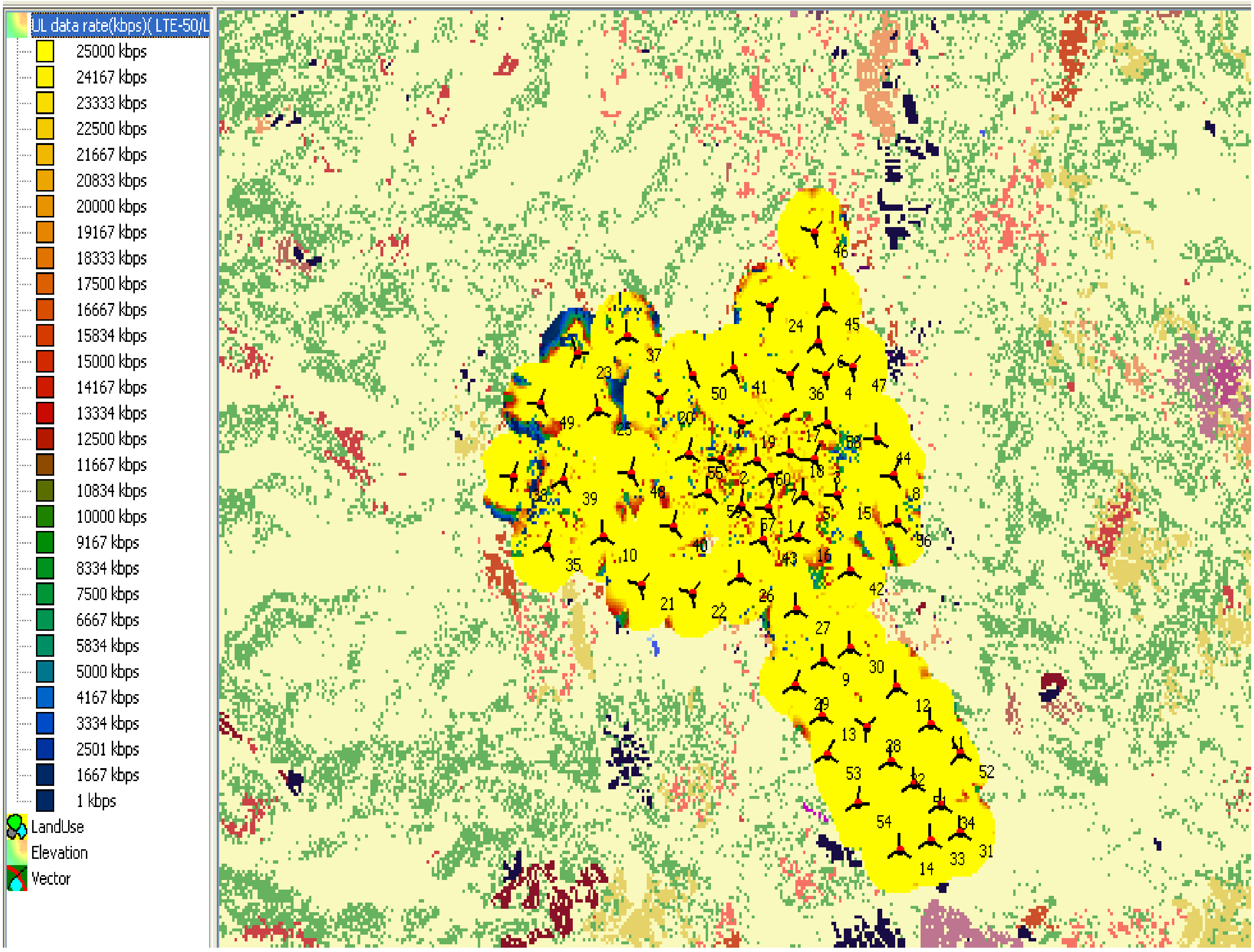


Figure 4.28 Ramallah UL data rate.

3) DL C/(I+N)

Figure 4.29 shows the DL signal to interference ratio C/(I+N). The values range from 47 dB to almost 10 dB. As shown in the figure the worst result is in the middle of the city as expected , this is due to the short distances between sites in this region.

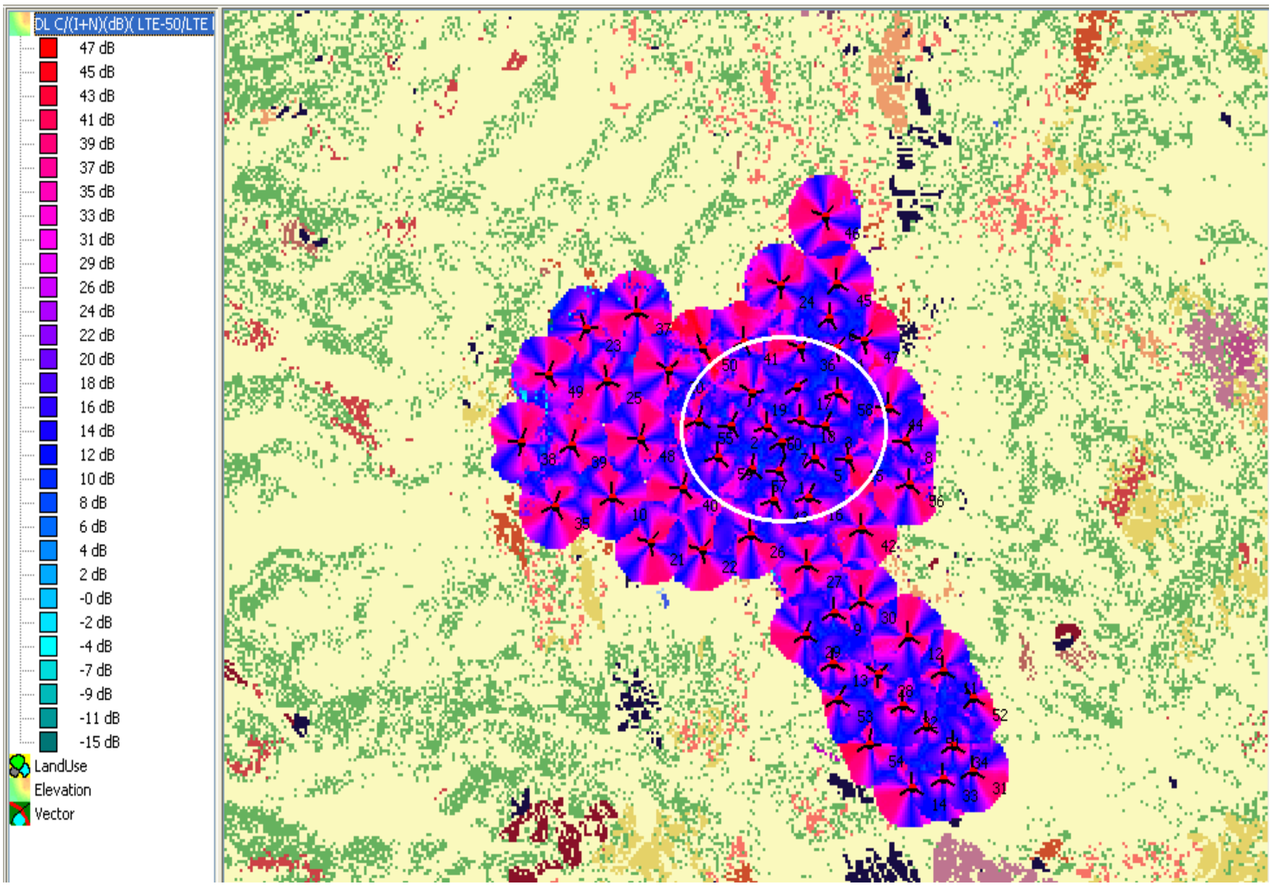


Figure 4.29 Ramallah DL signal to interference ratio C/(I+N)

4) UL C/(I+N)

Figure (4.30) shows the UL signal to interference ratio C/(I+N). The values in most regions range from 20 dB to almost 15 dB, but there are some regions have lower values range from 7dB to almost 2 dB .

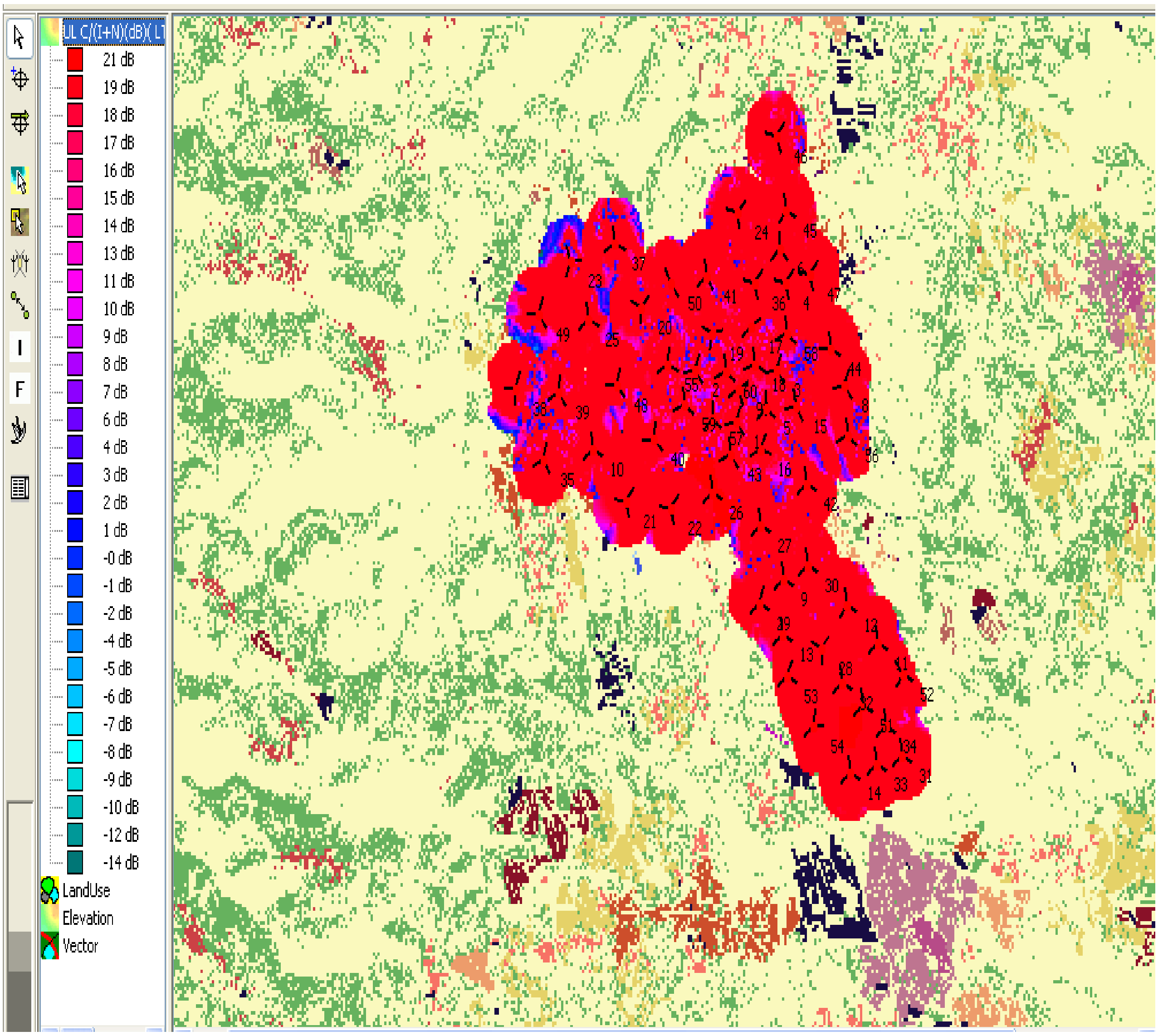


Figure 4.30 Ramallah UL Signal to interference ratio C/(I+N)

5) Signal Strength

Figure 4.31 shows the Ramallah signal strength plot. As shown in the figure the signal strength values range from almost -24.8 dBm to -99.4 dBm. Here also the lower values are in the middle region for the same reasons mentioned before. Appendix A shows the levels we passed through to get the optimized signal strength result.

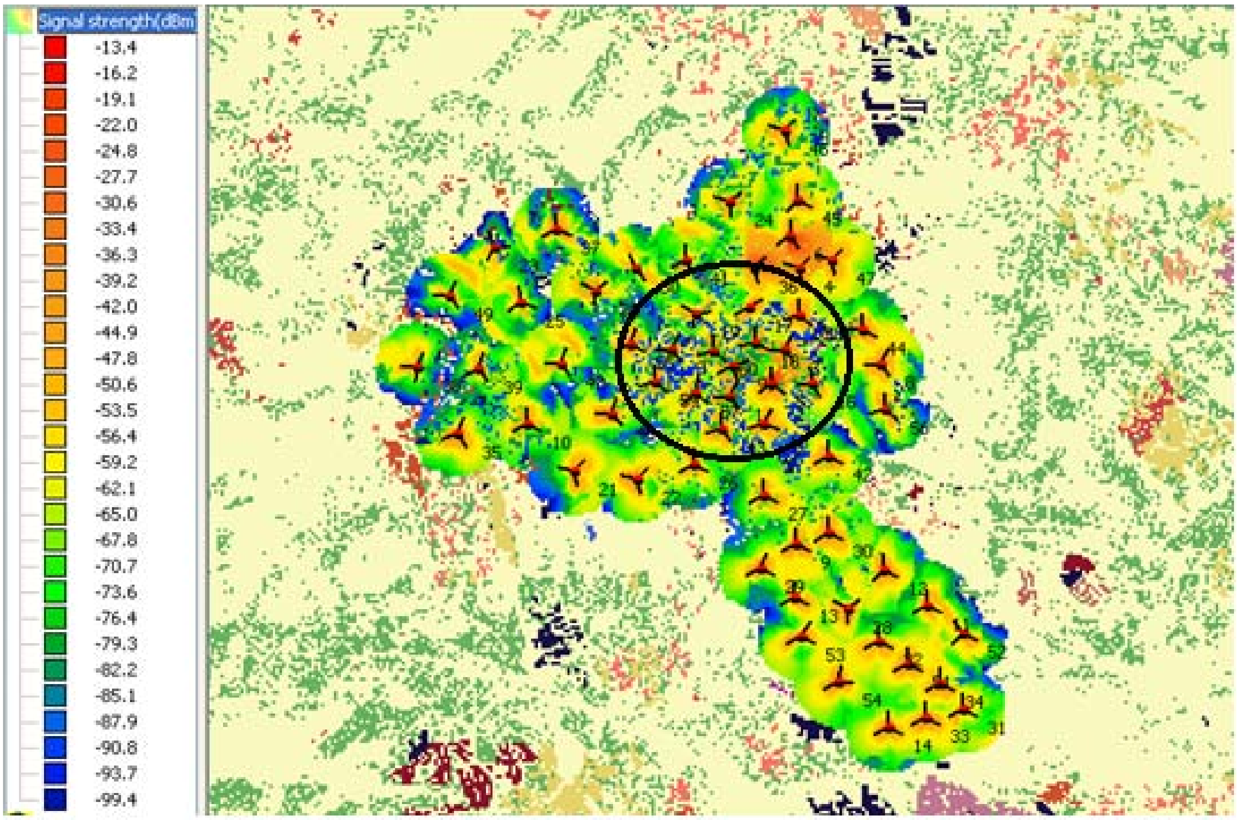
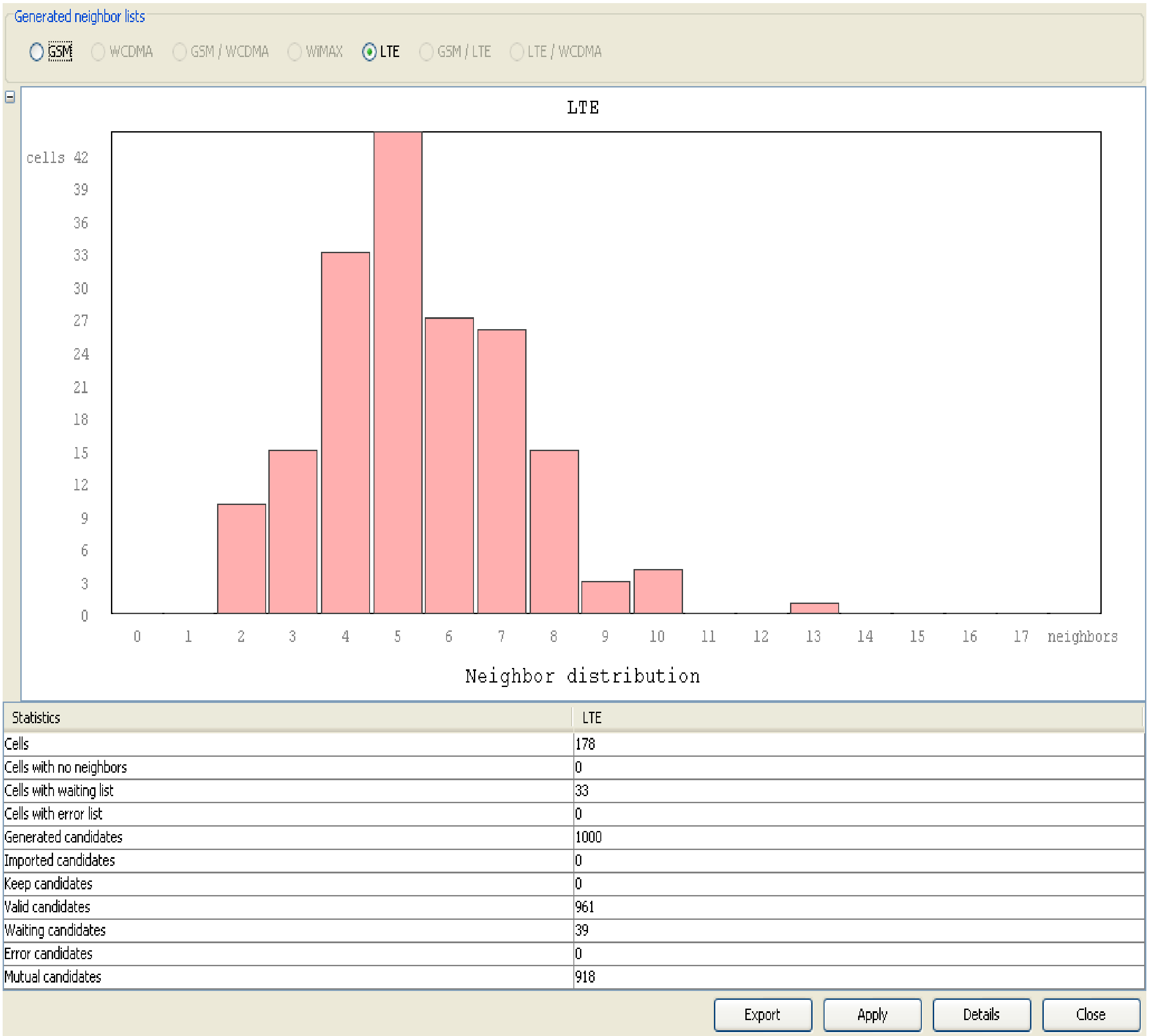


Figure 4.31 Ramallah signal strength

6) Ramallah neighbour list

Figure 4.32 shows a summary of generated neighbor list for Ramallah city.



Statistics	LTE
Cells	178
Cells with no neighbors	0
Cells with waiting list	33
Cells with error list	0
Generated candidates	1000
Imported candidates	0
Keep candidates	0
Valid candidates	961
Waiting candidates	39
Error candidates	0
Mutual candidates	918

Figure 4.32 Ramallah neighbour list

4.5.2 Survey Results

In Ramallah city we took site 99 as a case study to show the weakness in its coverage and signal strength results. We took the coordinates of the site from Google Earth to know its real location . Then we visited the place it were put in and took many photos clarify the exact location of it.

Figure 4.33 shows site 99 location on Google Earth. It shows the real location of the site.

Figure 4.33 Site 99 location on Google Earth

Figure 4.34 shows the real location of site 99. We located it through the tool on a building in Rokab street which known with its crowded buildings and people. This influenced on its coverage and data rate.

Figure 4.34 Real location of site 99

Figure 4.35 shows the high building that locates on front of the site which affects on its converge and signal quality. We may increase the height of the site to 20m or change the antenna up tilt in order to improve the results. Another solution is to move the site on the front building and changing the antenna azimuth and tilt.

Figure 4.35 Site 99 location

Site 99 data rate before and after simulation

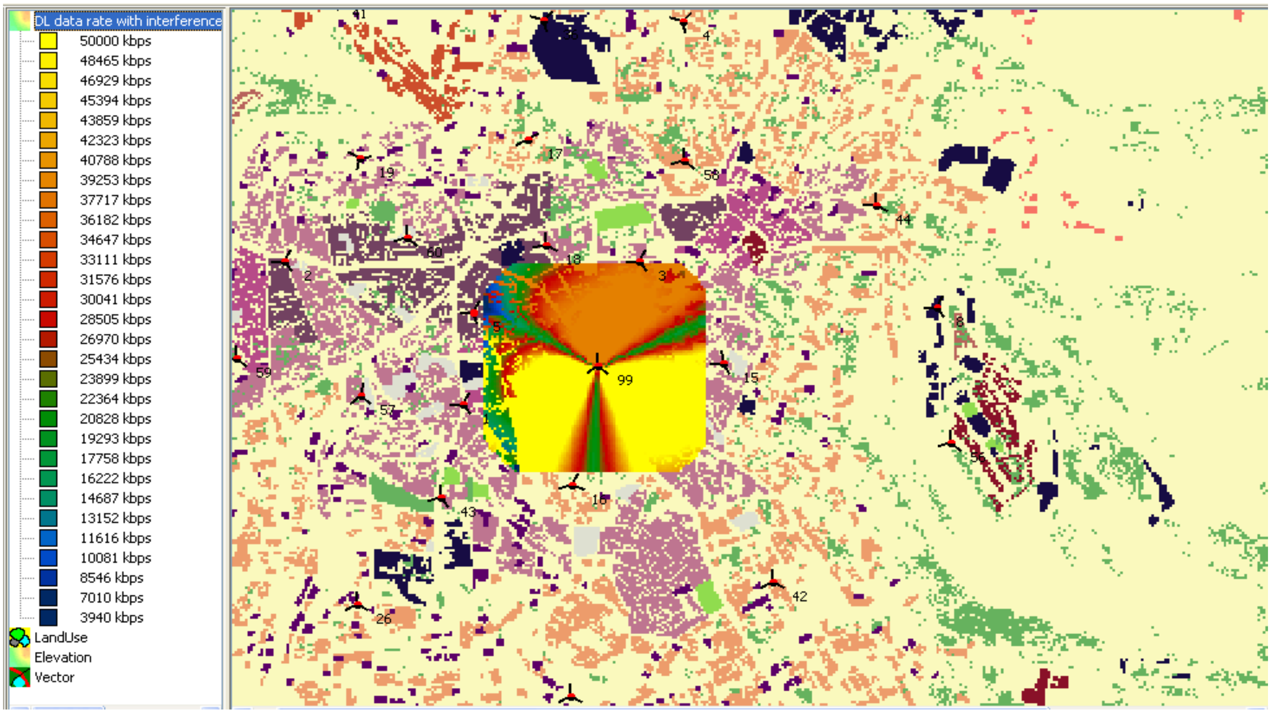


Figure 4.36 site 99 data rate before optimization

Figure 4.37 site 99 data rate after optimization.

Site 99 signal strength before and after optimization

Figure 4.38 shows signal strength before optimization. There are uncovered areas due to the mountain.

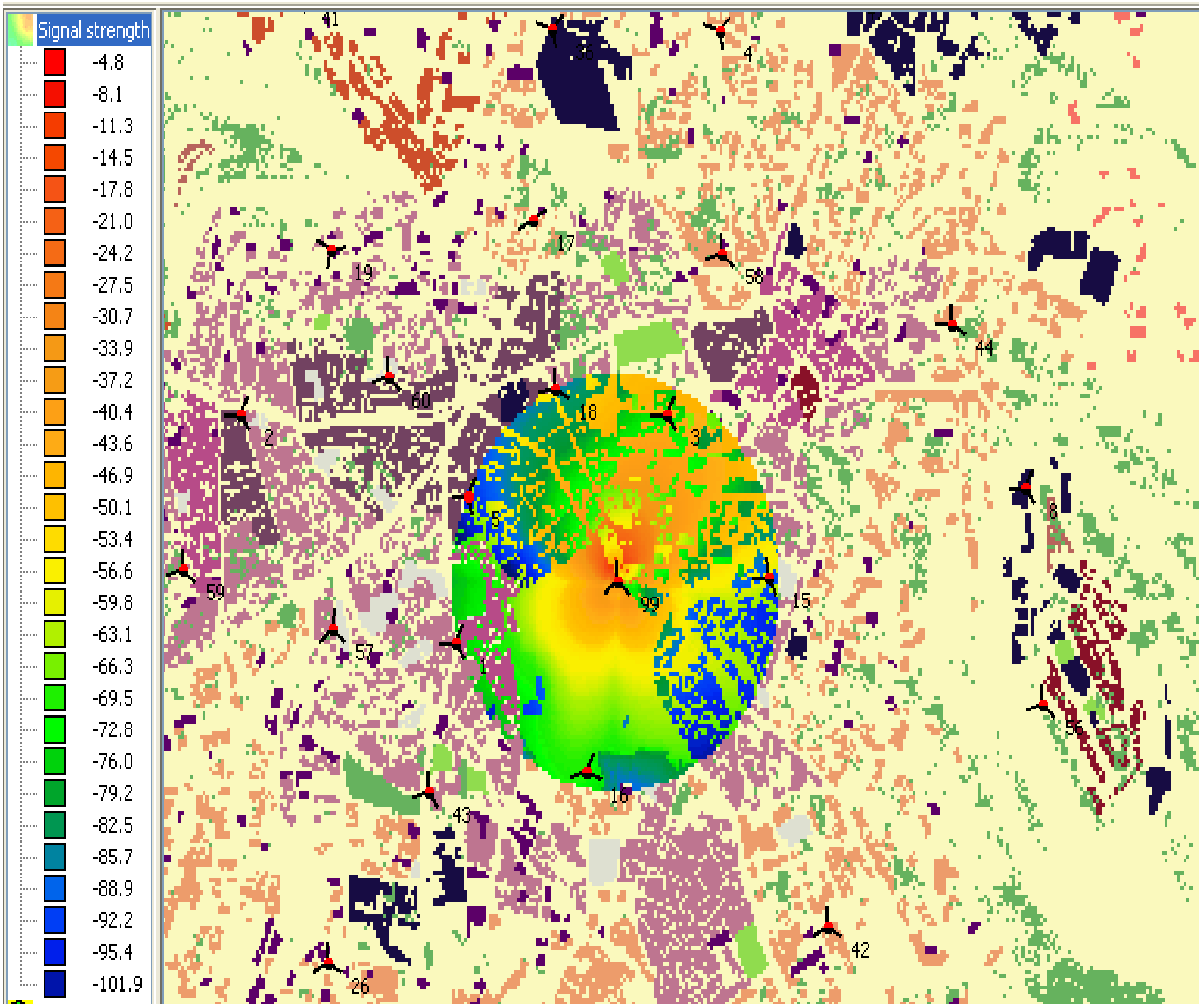


Figure 4.38 Signal strength before optimization

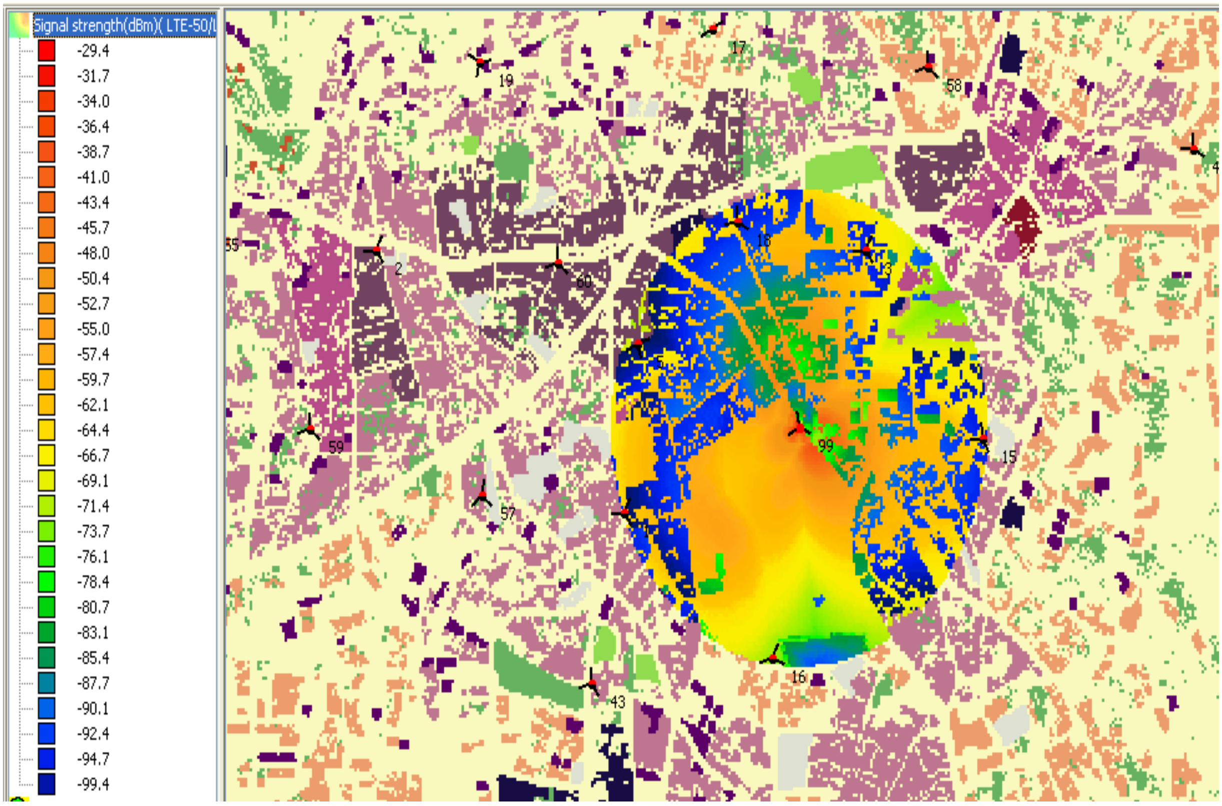


Figure 4.39 signal strength after optimization.

After we changed the site tilt to -10 at cell C and -4 at cell A the data rate and signal strength results are optimized as shown in the previous figures. Appendix A shows the characteristics of site 99 after optimization.

4.6 Nablus

Nablus governorate is located to the north of the West Bank and has a total area of 613.5 Km^2. It is situated between and on the slopes of two mountains: Ebal (940 m.), and Jerzim (881 m) above sea level, it is distinguished by its location in a narrow valley between these two mountains.

Population density is concentrated in the area between the two mountains. Recently, people have started to spread to the mountains, so we use special distribution of sites in this city according to its nature and Population density distribution. In this city we distributed 60 sites with radius 500 m , antenna height (15-20) m, transmitted power 43dBm, and antenna gain as 12dB on the centre of the city and 15 dB in the edges. Engineers faced several problems when they planned to cover Nablus because of its geographical nature, so several solutions will be introduced. In our project we used two sector sites between the two mountains and used mechanical up tilt .

Figure 4.40 Nablus city

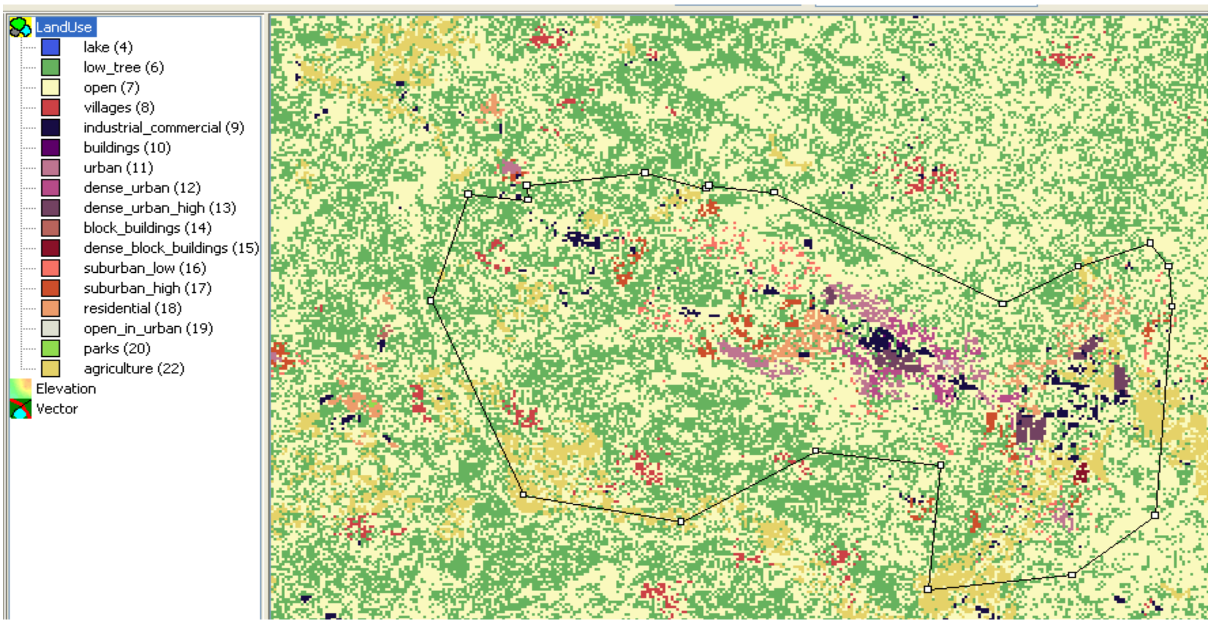


Figure 4.41 the resident distribution in Nablus city

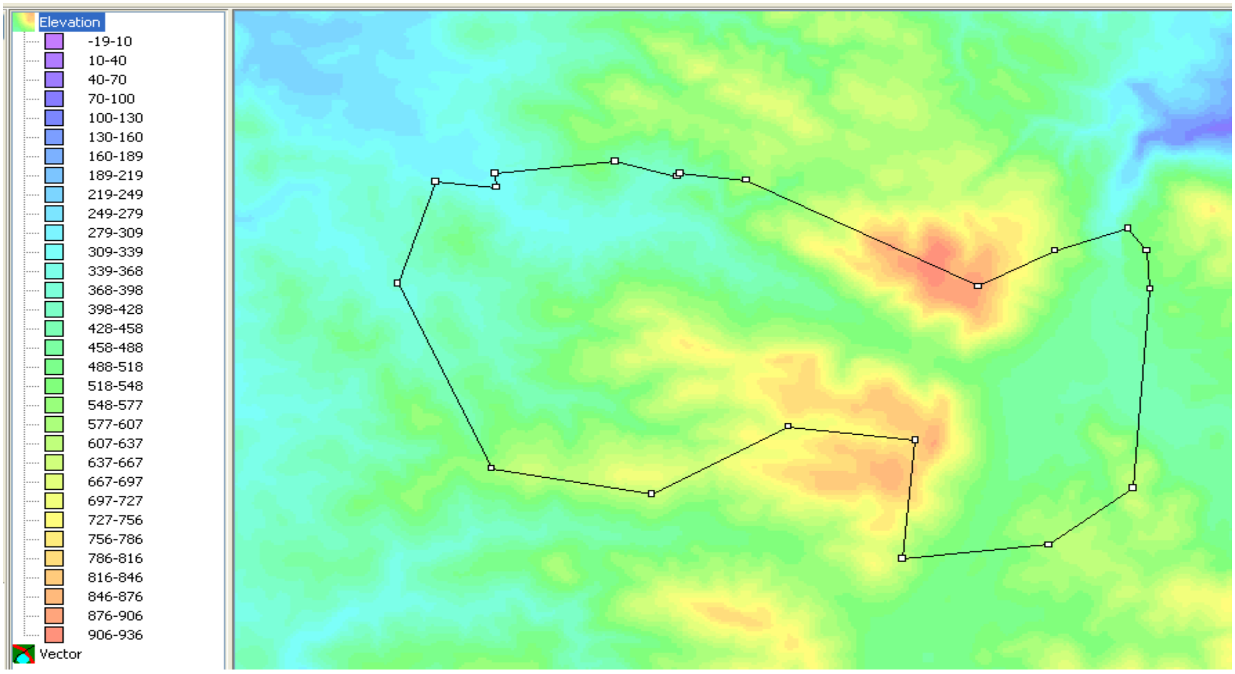


Figure 4.42 the elevations of Nablus city .

4.6.1 Nablus results

The final fine tuned and optimized results of Nablus city are shown in the following plots :

1) **DL Data Rate** :

Figure 4.43 shows DL data rate which looks high in most regions and looks low in others which is predictable due to the mountainous nature of Nablus city and the limitations that limit the optimizing process possibilities. Data rate values ranges from 50000 kbps to almost 20000 kbps in some regions. As shown in the figure the lowest data rate values are almost in the middle of the city; this is due to the over population and crowded buildings located in the region between Jarzeem and Ebal mountains. Appendix A shows the levels we passed through to get the optimized data rate result.

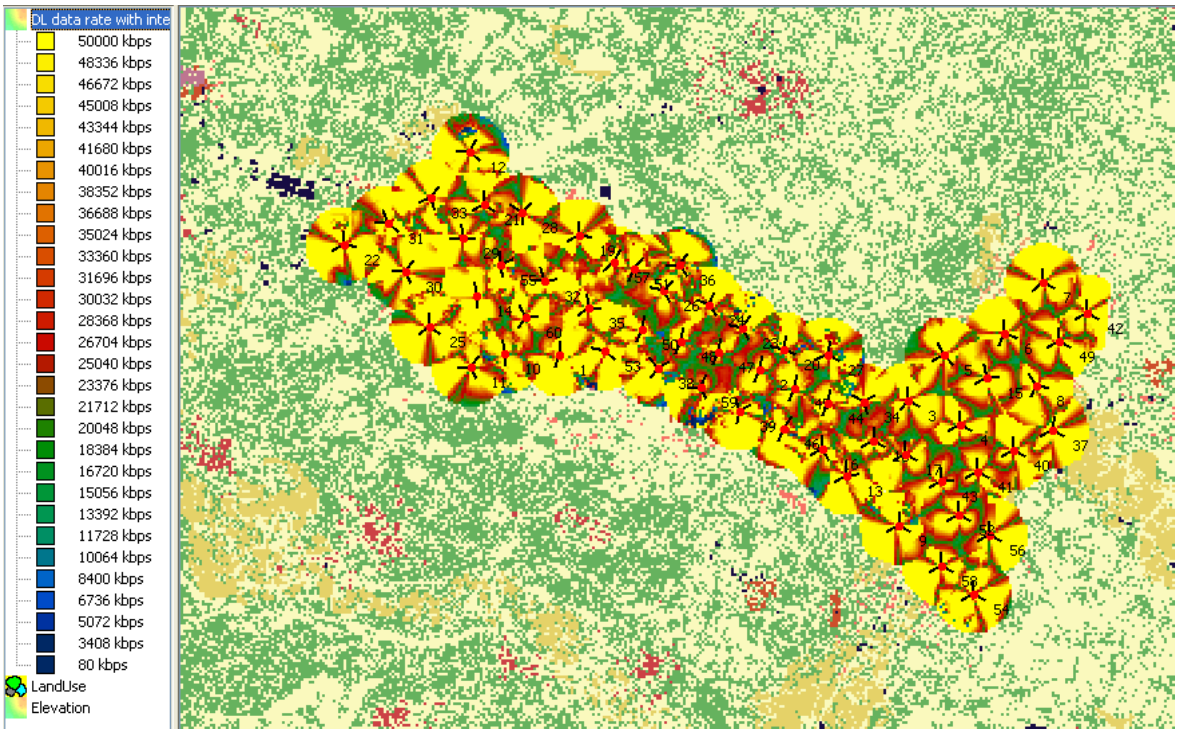


Figure 4.43 Nablus DL data rate

2) UL Data Rate

As shown in figure 4.45 the most regions in Nablus have high UL data rate values reach to 25000 kbps. However, there are some regions in the middle of the city and its edges have lower data rates reach 2512 kbps.

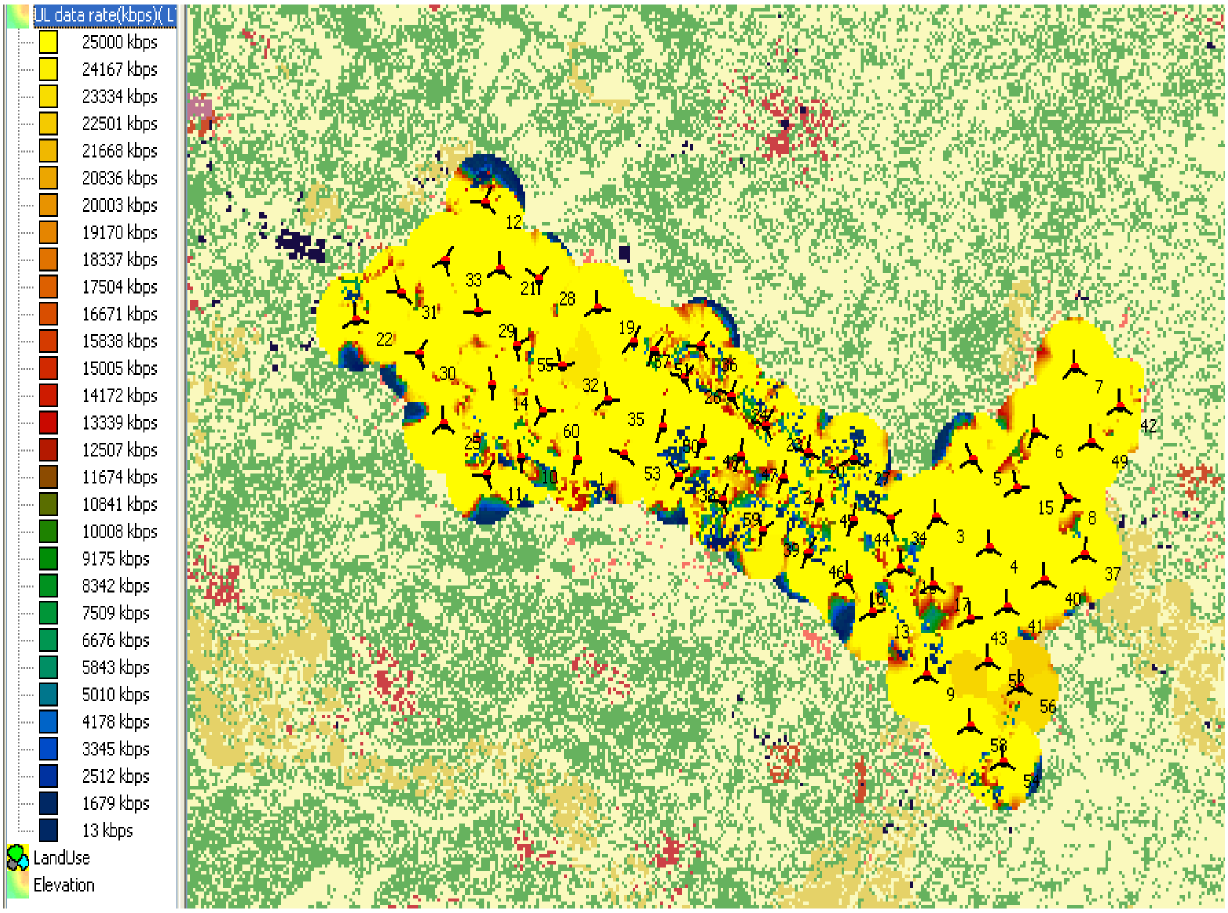


Figure 4.45 Nablus UL data rate

3) DL C/(I+N)

Figure 4.46 shows the DL signal to interference ratio C/(I+N). The values range from 50 dB to almost 10 dB . From the figure the lower values shown are expected ; due to the short distances between the site and the other in the most regions in the city which make the interference value higher than the signal power .

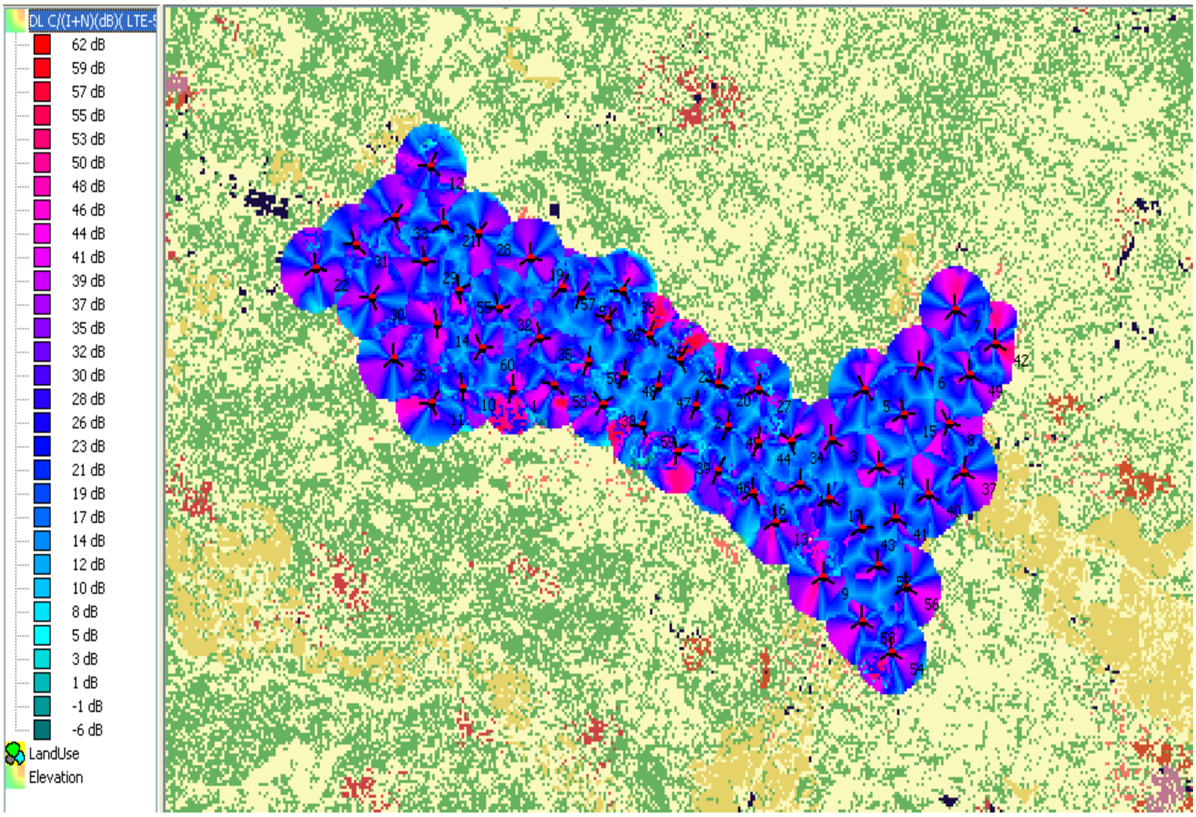


Figure 4.46 Nablus DL signal to interference ratio C/(I+N).

4) UL C/(I+N)

Figure 4.47 shows UL signal to interference ratio C/(I+N). The values vary from region to region to range between 14dB to almost 1dB in the middle of the city and some of its edges , and reach its maximum (20dB) in most regions around.

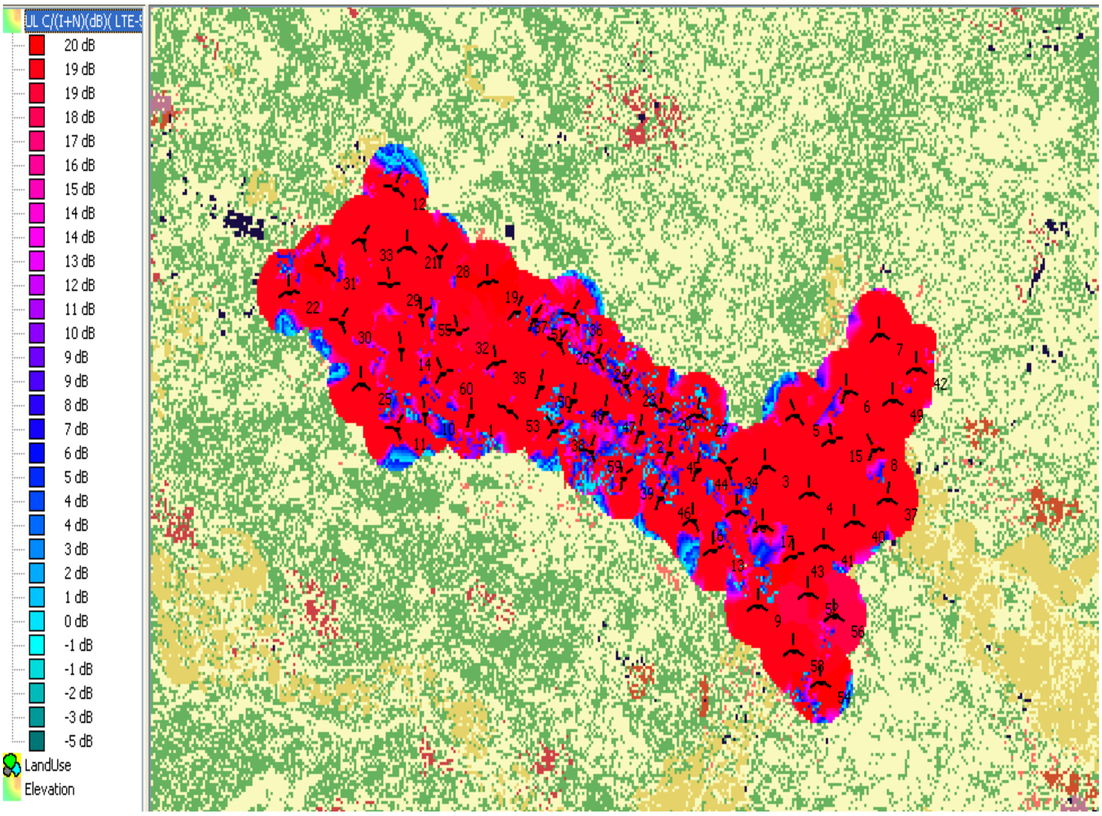


Figure 4.47 Nablus UL signal to interference ratio C/(I+N)

5) **Signal Strength**

We faced some difficulties in optimizing the signal strength especially in the middle region of the city. There were many uncovered areas ; due to the two mountains. After long fine tuning and optimizing, the results have improved and all the areas became covered .As shown in figure 4.48 the values range from almost -32.8 dBm to -90.7 dBm .The lower values here are in the middle region for the same reasons we've mentioned before. However these results could be improved more and more by the planner since the optimization process is endless. Appendix A shows the levels we passed through to get the optimized signal strength result.

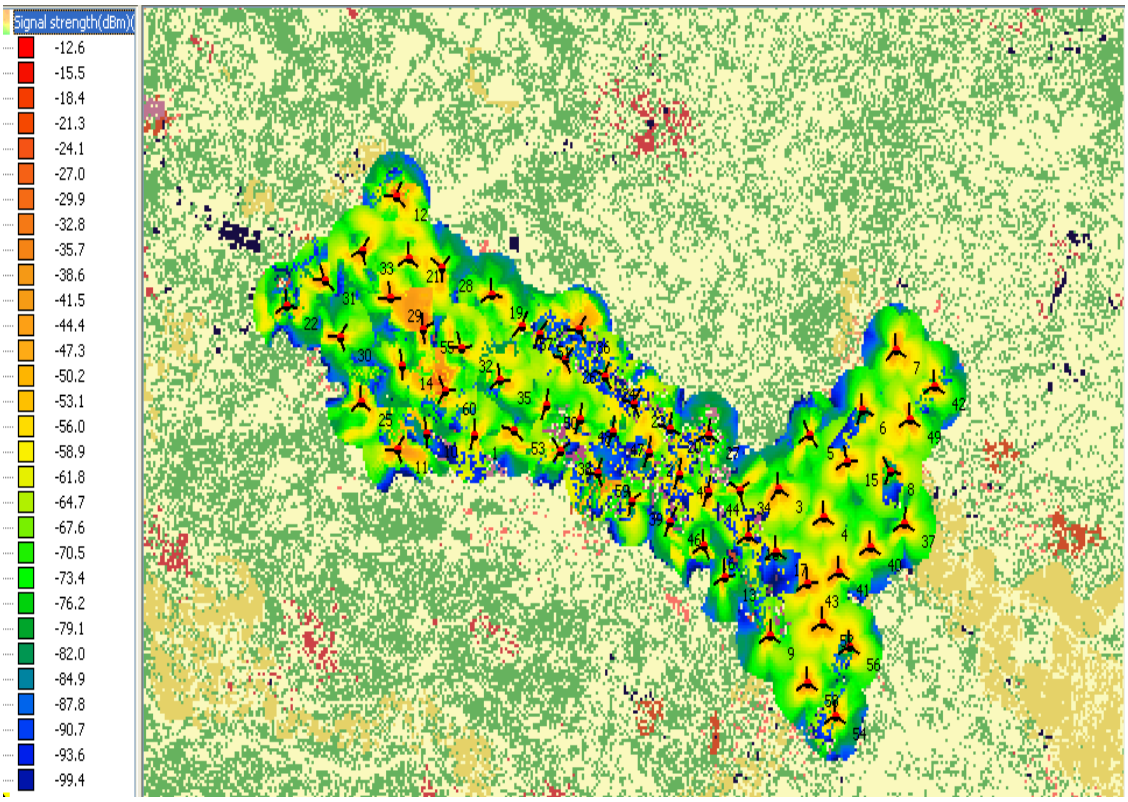
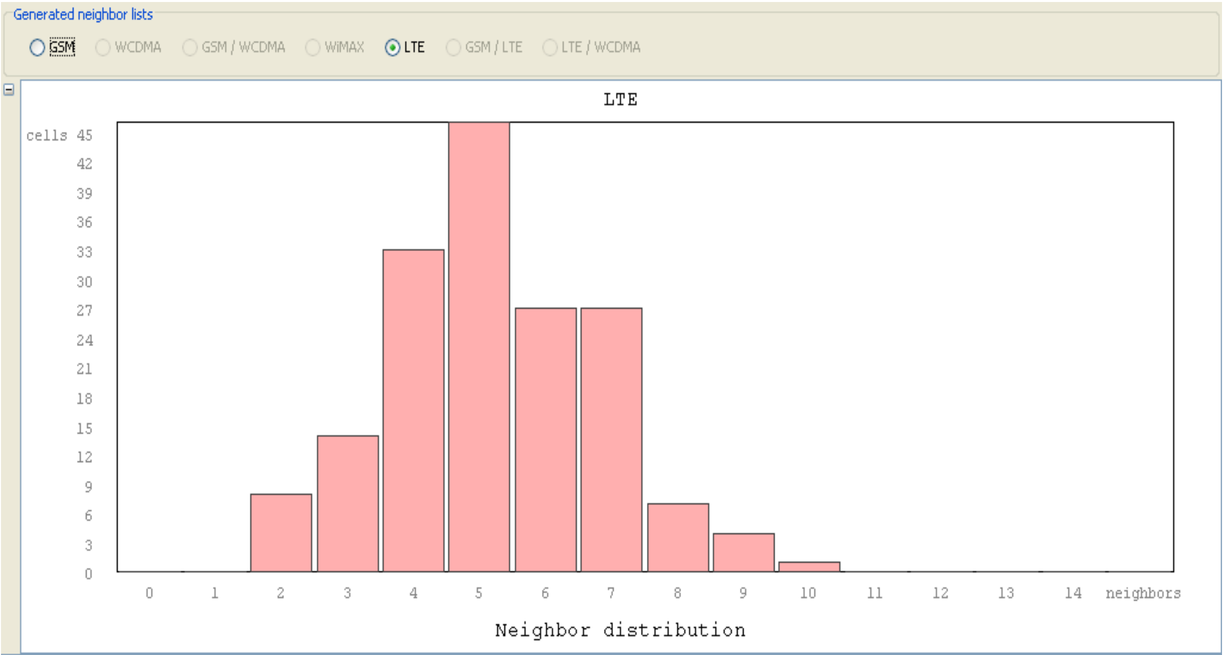


Figure 4.48 Nablus signal strength

6) Nablus neighbour list

Figure 4.49 shows a summary of generated neighbour list for Nablus city.



Statistics	LTE
Cells	167
Cells with no neighbors	0
Cells with waiting list	17
Cells with error list	0
Generated candidates	893
Imported candidates	0
Keep candidates	0
Valid candidates	873
Waiting candidates	20
Error candidates	0
Mutual candidates	840

Figure 4.49 Nablus neighbour list

4.7 Conclusion

This chapter showed the optimization results of LTE networks in three cities (Hebron, Ramallah, Nablus). To fully specify the results we've achieved in planning and optimization processes, we included several plots for down link data rate , signal strength , C/I+N and many others . In these plots we showed the points of weakness in the network coverage , capacity and quality planning and put suggestions for these sites with bad planning results that were embedded in case studies . We could do site survey for some sites in the two cities Ramallah and Hebron to see what was the reason of getting bad results for these sites specially.

Chapter 5

Self Organized network
Neural Network Matlab code

Contents

5.1 Overview

During the optimization process we faced some challenges and difficulties made us think in some solutions and strategies that ease from these difficulties in this process; by giving the network the ability to take the decision of tuning and optimizing by itself which is more faster than the manual tuning and more efficient from two aspects of saving the effort and time to give faster decision in the required fine tune. Two case studies are embedded here which clarify how the network takes its own decision of the required change automatically.

5.2 Self Optimizing Network (SON)

Self Organizing Network introduced as A part of 3GPP Long Term Evolution (LTE) and it is a good solution for improving O&M, it aims to reduce the cost of installation and management by reducing the amount of manual processes involved in the planning, integration and configuration of new eNBs. This leads to a faster network deployment and cost reduction for the operators, in addition leads to a great system management which is less affected by human errors, that improves the network performance and flexibility.(6)

3GPP initiated the work towards standardizing self-organizing capabilities for LTE, in Release 8 and Release 9, in order to automate the configuration and optimization of wireless networks to adapt to varying radio channel conditions by providing network intelligence.(7

An additional enhancements in coverage and capacity optimization, energy efficiency and minimization of operational expenses through minimization of drive tests has added in Release 10 .(2)

Recently, there are two fundamental operational issues that service providers must take into consideration, some processes are repetitive, while others are too fast or complex or difficult to be performed manually. Automating this processes clearly saves time, reduces effort, and provides accurate real time data ,thus providing performance, quality, and operational benefits.

This research discusses Self-Organizing Network (SON) techniques, and explains how these capabilities will positively affect the network operations in LTE network using neural networks.

5.3 Neural Network (NN)

Neural Network consists of some elements operate in parallel. It's taken from the nature of the biological nervous system. These networks can be trained to perform a function or a particular task, by adjusting the values of the connections (weights) between elements.[3]

Each input to NN leads to a certain target (the desired output). It is trained and adjusted until the output (the response) matches the target by making a comparison between them and calculating the error . As shown in figure 5.1.[9]

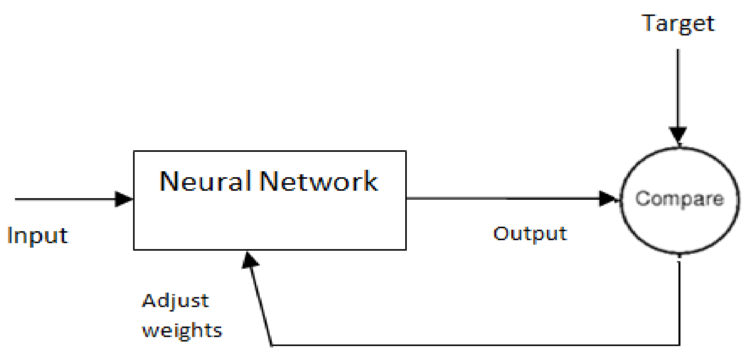


Figure 5.1 Neural Network.[9]

There are many reasons and benefits for using NN, mainly its ability to learn and generalize. Generalization means that the network can produce outputs for inputs not included in training ,which gives it the capability to solve complex problems in various fields, such as: pattern recognition, identification, classification, clustering, speech, vision and control systems.[8]

5.3.1 Network Architectures

The NN can be constructed from number of information –processing units called neurons. Two or more neurons can be combined in a layer, and the network could contain more than one layer.[9]

5.3.1.1 Layer of Neurons:

As shown in the figure 5.2 each element of the input vector **p** is connected to each neuron. Each branch or connection has its own weight or strength, where each input element is multiplied by a weight. The weighted input **wp** is then summed with a bias **b** to form the net input **n=wp+b** to a transfer function. Then the transfer function takes the net input and produces the output **a=f(wp+b).** The transfer function is used to limit the amplitude of the output . There are many functions that can be used in NN, such as: hard-limit ,linear and sigmoid transfer function.[9]

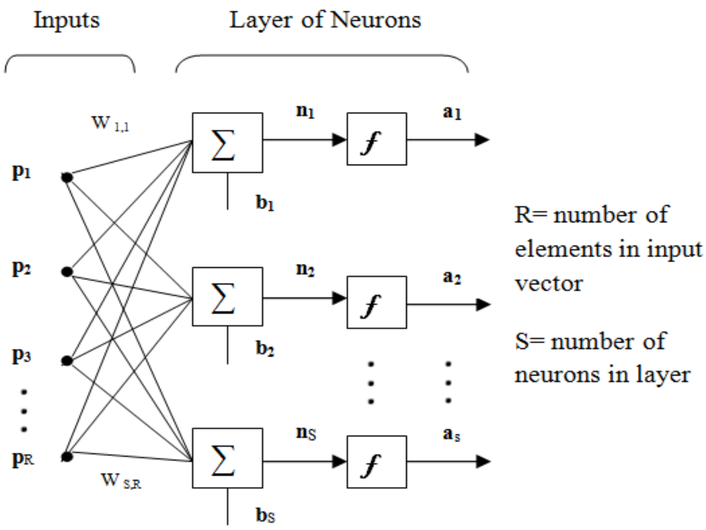


Figure 5.2 Layer of Neurons

The input vector elements enter the network through the weight matrix **W** :

$$\mathbf{W} = \begin{bmatrix} w_{1,1} & w_{1,2} & \cdots & w_{1,R} \\ w_{2,1} & w_{2,2} & \cdots & w_{2,R} \\ \\ w_{S,1} & w_{S,2} & \cdots & w_{S,R} \end{bmatrix}$$

Figure 5.3 Weight Matrix

5.3.1.2 Learning (training) Process

As mentioned before, NN has the ability to ***learn*** from its environment and it can improve its performance through learning . Training process can be defined as a process of simulation to adjust the weights and biases in order for NN to do a task. The weights and biases are adjusted to minimize the error **e=T-a** ;which is the difference between the response **a** and the target output **T**. The training process is repeated until the network reaches the steady state, where there are no more significant changes in the weights.[8],[9]

There are two types of the NN, Perceptron and Linear Network. Perceptron is the simplest form of the NN. It is used in classification problems, and it uses the hard-limit transfer function, which has only two values of output 0 and 1 . Linear Neural Network uses linear transfer function ,where the output is not limited between just two values like the output in perceptron , but it can take any value. Linear network also uses Least Mean-Square (LMS) procedure. It can only solve linearly separable problems.[9]

The following sections discuss another new case study and shows the alternative solutions we've put to optimize the network faster , efficiently and automatically depending on the intelligence of NN; since the cellular radio networks' optimization relays heavily on performing extensive drive testes, computer simulations, collecting statistics and network reports. Accordingly, optimization professionals tend to manually tune the network parameters as well as applying some other physical modifications on the base station antennas, such as setting antennas' gain, azimuth directions, or down tilt angels.[6].

5.4 Neural Networks for Self-Organizing the Down-Tilt angles

We introduced a new intelligent way for determining the most appropriate antenna down tilt using Neural Network (NN). To judge on the final outcome, we used the patterns of a planner array antenna and made a comparison between its manually tilted patterns and the artificially tilted patterns after injecting the NN behind the antenna. A plot of the antenna beam pattern for each down tilt angle using the two ways were presented.

Carefully optimizing the down tilt angels produces enhanced signal strength levels at the targeted areas, thus reducing the interference levels from other covering cells. However, excessive down tilt angle may lead to dramatic coverage shortages, specifically at the edges of the main loop direction.

To better optimize the antenna down tilt angles the linear NN on the back processing plan of the base station's antenna system. As a new innovative self down tilting antenna system, the linear NN will be able to optimize the antenna tilt resulting on better managing the real time behaviour of the base station. The neural network is going to be trained to intelligently choose the most appropriate down tilt angle producing the most suitable vertical beam pattern gain for the used antenna.

5.4.1 System design

We introduced a new innovative technique granting the antenna systems of the cellular base stations to behave as self-organizing antennas; while manoeuvring and controlling the down tilt angles. Instead of the classical and manual down tilt optimization technique, a direct linear NN was trained to estimate the tilt angle of the vertical radiation pattern of the antenna system. To achieve that a Matlab code was developed, which includes two parts:

Part 1:

Formulating the desired down tilt patterns: A [40X3] matrix representing the gain values of the vertical radiation patterns (the desired output) corresponding to the tilt angles (0^o, 6^o, and 12^o). they are used as the required input to train the neural network shown in figure (1).

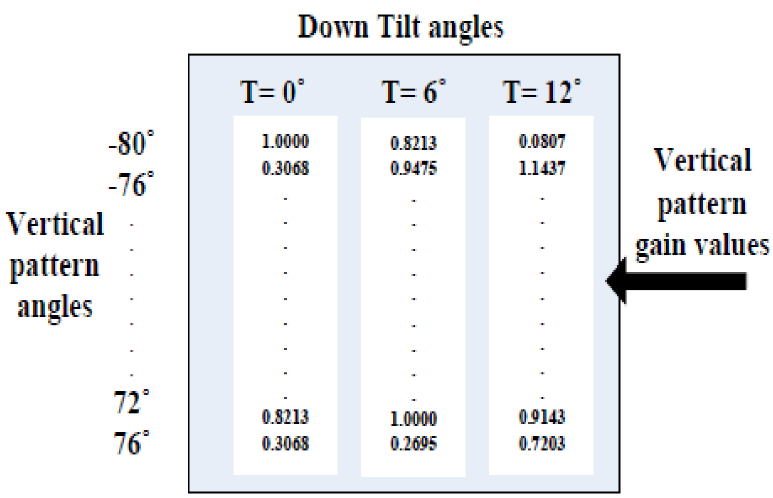


Figure 5.4 Down Tilt values used

To train the NN : Gain values in the desired matrix were taken from the array pattern for rectangular Planar Array equation (5):

$$G(\cos\beta) = |E(\cos\beta)|^2 = \left(\frac{\sin((Nkd\cos(\beta+i))/2)}{\sin((kd\cos(\beta+i))/2)}\right)^2. \quad (1)$$

Where:

G(cos β) : Radiation pattern.

N: number of the array elements, which equals 9.

k=2π/λ.

d:distance between array elements.

i: antenna down tilt.

Part 2:

Training the NN: these tilt vectors will be fed and an input to train the NN system as shown in figure 5.5. The desired tilt vectors will be multiplied by a suitably adapted weighted matrix chosen by the trained neural network itself and then will be added to the bias. Weight and bias values will be adjusted until the response (the actual output) of the network is matched to the target (the desired output) or until getting the minimum error, which is the difference between the actual output and the target. This process is called training (learning), where the NN has the ability to learn from its environment and it can improve its performance through learning.

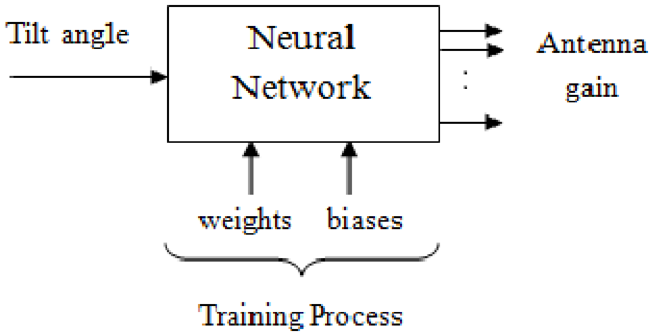


Figure 5.5 Self-organizing NN system

As shown in figure 5.6, this process is repeated until the NN network system reaches the steady state, where there are no more significant changes in the weights .[(3)(4)] The linear NN's specific settings: number of trainings sessions, error goal, and the maximum learning rate were set as follows: 5000, 10-5, and 0.1 respectively.

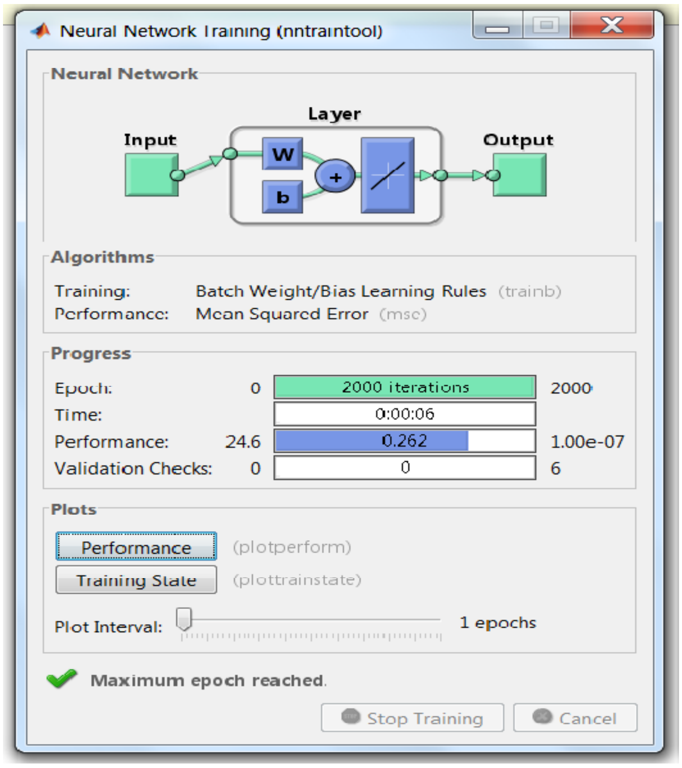


Figure 5.6 Linear NN training process

5.4.2 Simulation Results

The simulation results of the trained NN on a sample of three down tilt angles (0^o, 6^o, and 12^o) are presented in figure 5.7. The linear array vertical radiation patterns where drawn in polar coordinates, given that the number of antenna elements is 9, with a spacing distances equals to λ/2 between each of them. The results for the three down tilt angles when using the trained NN are almost similar to those without NN. However, the results of the simulations for the 6^o down tilt angle when using the NN are slightly reduced in comparison to the tilt without the NN. In such cases the neural network was trained on certain tilt angles where it estimates the gain values with a small error, given that the NN has the ability to learn and generalize. Generalization means that the network can produce outputs for inputs not included in training. This means that more NN training is required.

It is important to notice that the side lobes of the antenna are not affected when applying tilt through the NN, they maintaining similar behaviour without NN in the antenna system.

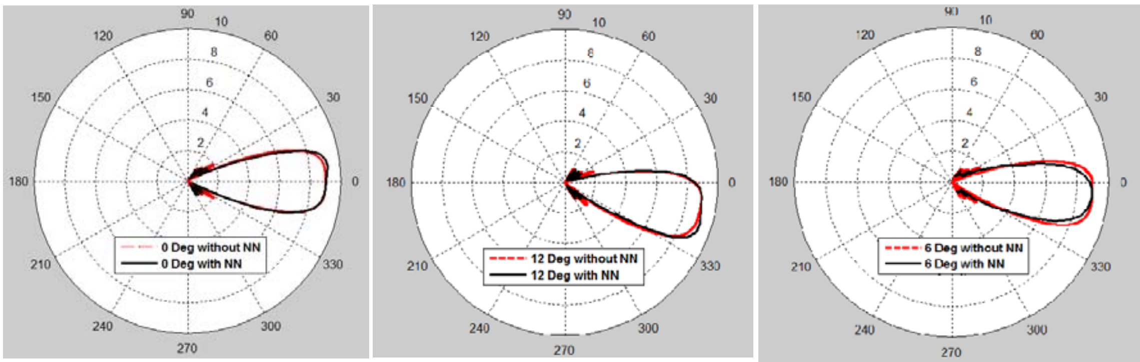


Figure 5.7 NN plots for linear array radiation pattern, in polar coordinates for

Input down tilt angles: 0˚, 6˚, 12˚ to NN.

Figure 5.8 shows The neural network plots for linear array radiation pattern, in polar coordinates for untrained input down tilt angles: 4˚,8˚,10˚.

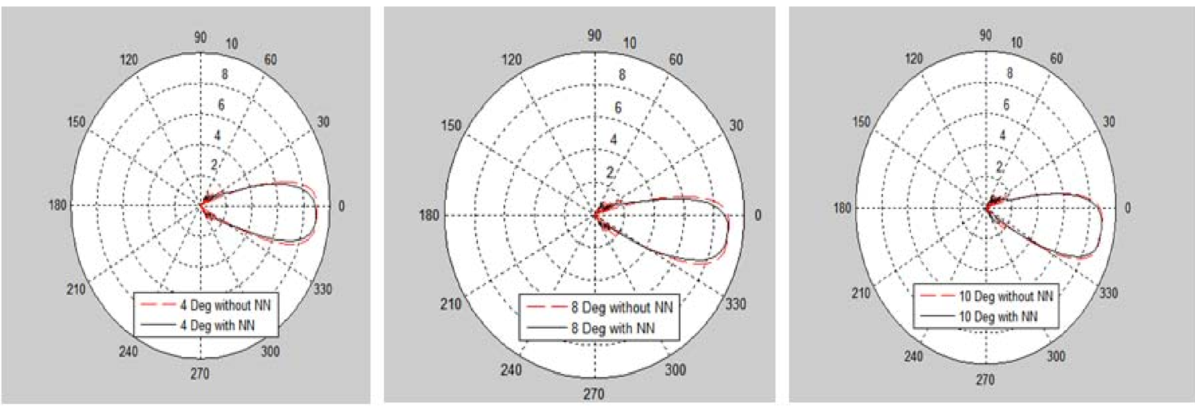


Figure 5.8 NN plots for linear array radiation pattern, in polar coordinates for untrained input down tilt angles: 4˚,8˚,10˚.

The presented results using the NN are almost similar to the antenna system without the NN, but with slight error deviations depending on quality of training and learning the NN on the desired output values. [52]

5.5 Conclusion

In this chapter we introduced a new mechanism to self optimize the network called Neural Network (NN) . We showed the effectiveness of using the NN in making estimation for the radiation patterns corresponding to certain down tilt angles with minimum error percentage in comparison to the antenna systems without the NN . and also to estimate the desired capacity with a certain level of SNR with minimum error .

Chapter 6
Future ideas

Although LTE planners use the planning tools in planning the networks which depend on entries from the planner itself and is totally done manually , there's no doubt that planning the network in such attitude consumes the planner time , effort and money which made the searching for other alternatives very necessary !

One of the alternatives we thought in is to utilize the smartness of the nural network to make it perform the planning process automatically . Depending on the neural network principles and matlab codes we could create a code that intelligently determine the most suitable antenna down tilt using Neural Network (NN). To judge on the final obtained result , we made a comparison between the manually tilted patterns by a planner and the artificial tilted patterns after injecting the NN behind the antenna. The plot of the antenna beam pattern for each down tilt angle using the classical and artificial methods were mentioned in ch 5 .

As another enhancement in performing the planning process we designed a code using the NN that determines the antenna configurations that matched with any incoming SNR value . To judge on the final out coming we hold a comparison between the classical relation output and the artificial NN result the error was very small to be noticed . The plot combines both the classical and artificial results were mention in ch 5 .

In our project the future vision is to complete the planning process for the other cities of Palestine .

More future ideas can be thought in to enhance the performance of the planning process is to trains NN to choose the suitable antenna configuration which matched with other incoming parameters in addition to capacity such as: price, bandwidth, frequency and BER .

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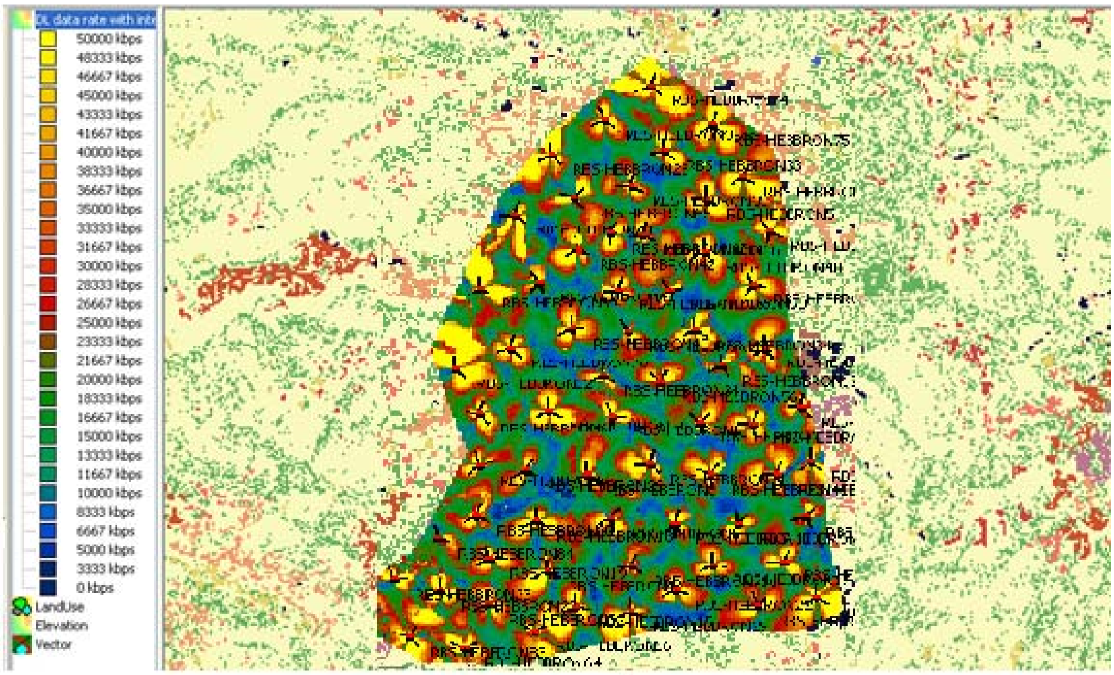
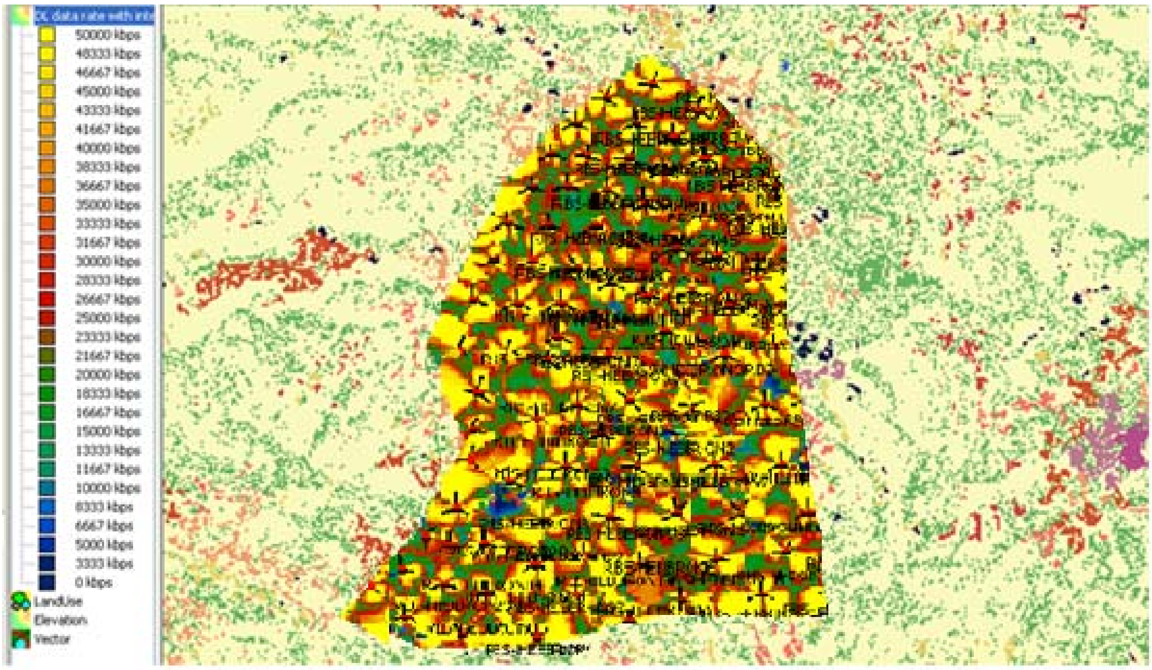
Appendix A

Hebron optimization levels

Data rate optimization levels: The following figures show the data rate optimization levels of Hebron city, it show the data rate before and after tuning the parameters and optimizing process.



1


50000 kbps
48333 kbps
46667 kbps
45000 kbps
43333 kbps
41667 kbps
40000 kbps
38333 kbps
36667 kbps
35000 kbps
33333 kbps
31667 kbps
30000 kbps
28333 kbps
26667 kbps
25000 kbps
23333 kbps
21667 kbps
20000 kbps
18333 kbps
16667 kbps
15000 kbps
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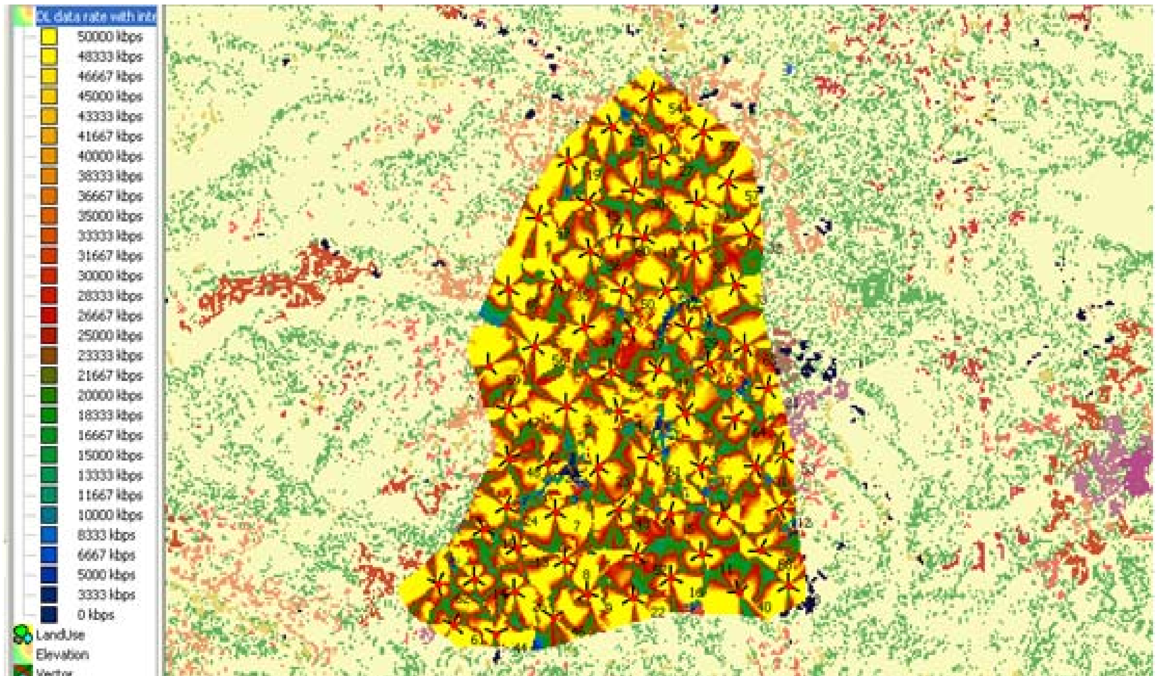
0 kbps
LandUse
Elevation
Vector

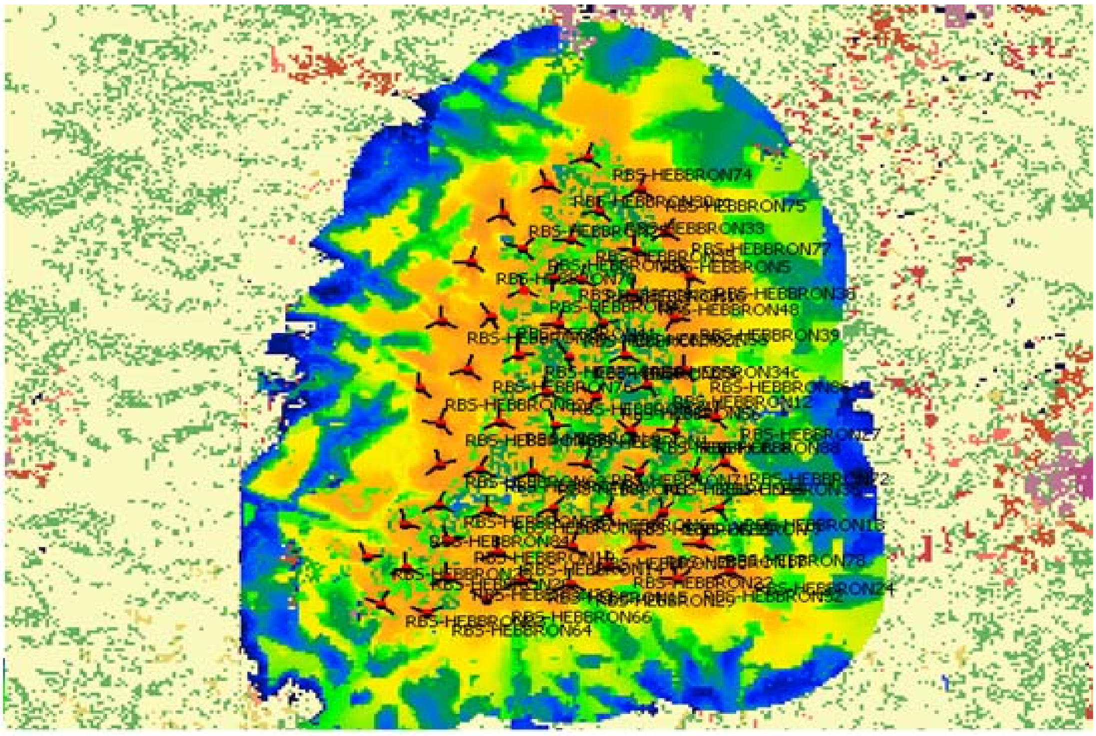
2


50000 kbps
48333 kbps
46667 kbps
45000 kbps
43333 kbps
41667 kbps
40000 kbps
38333 kbps
36667 kbps
35000 kbps
33333 kbps
31667 kbps
30000 kbps
28333 kbps
26667 kbps
25000 kbps
23333 kbps
21667 kbps
20000 kbps
18333 kbps
16667 kbps
15000 kbps
13333 kbps
11667 kbps
10000 kbps
8333 kbps
6667 kbps
5000 kbps
3333 kbps
0 kbps
LandUse
Elevation
Vector

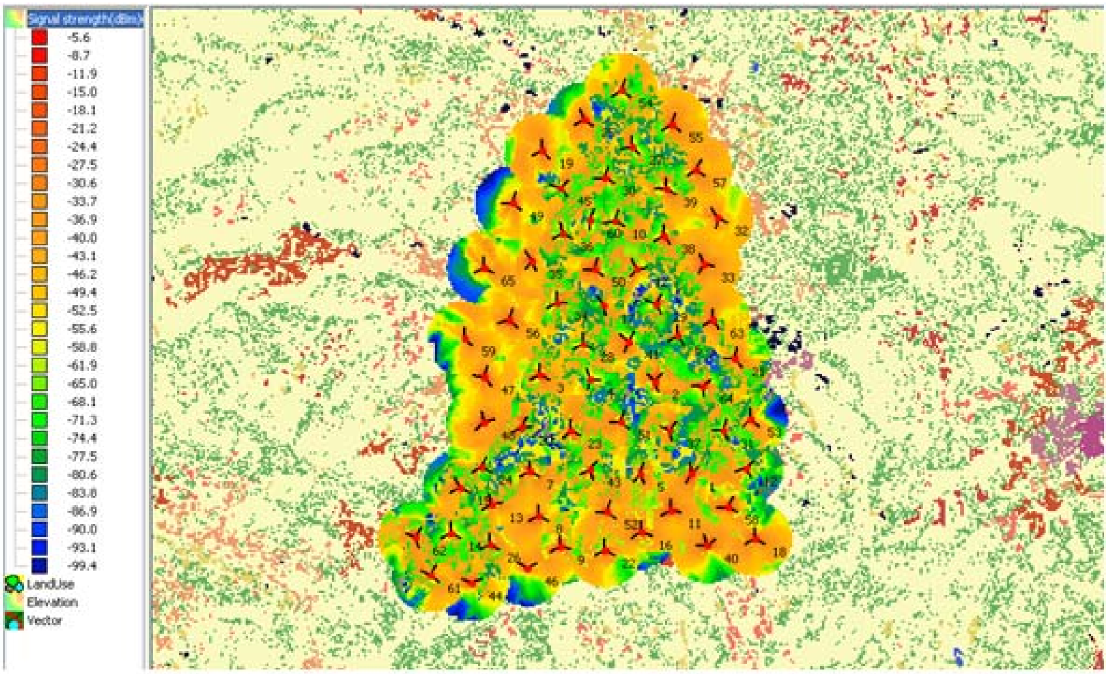
3

Signal strength optimization levels:

The following figures show the signal strength of Hebron city before (with default parameters) and after tuning the parameters and optimization process.



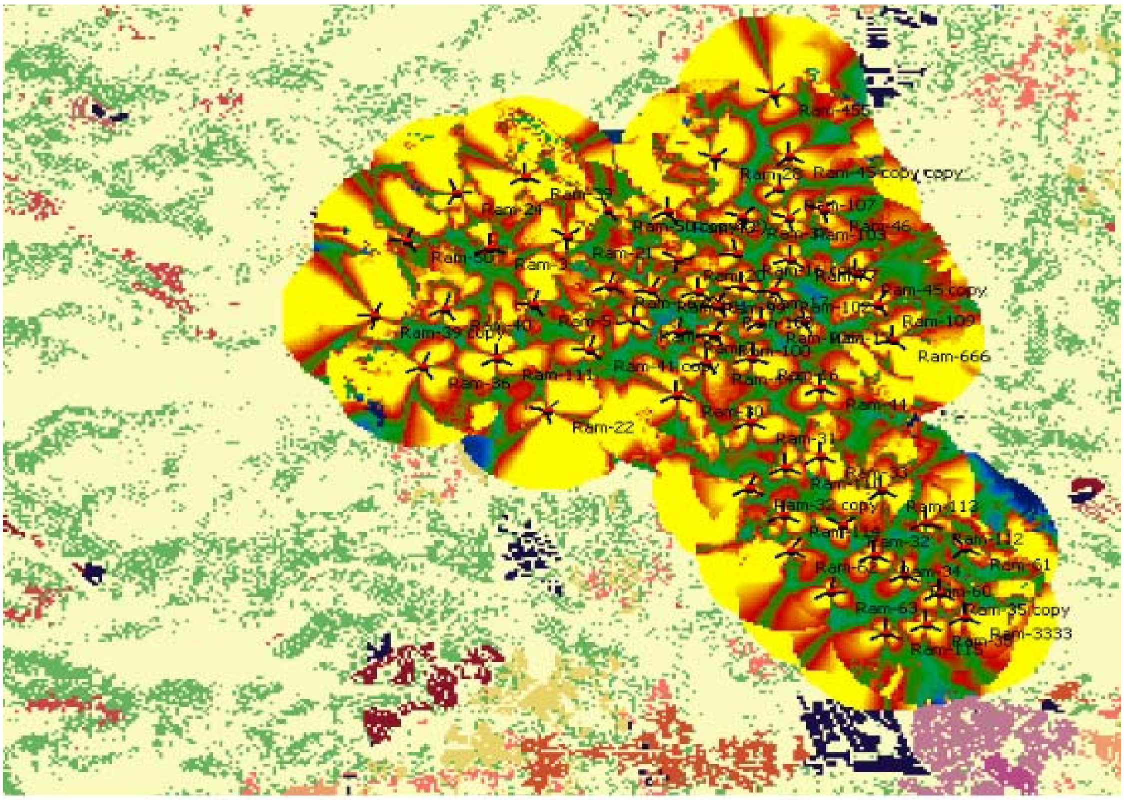
1



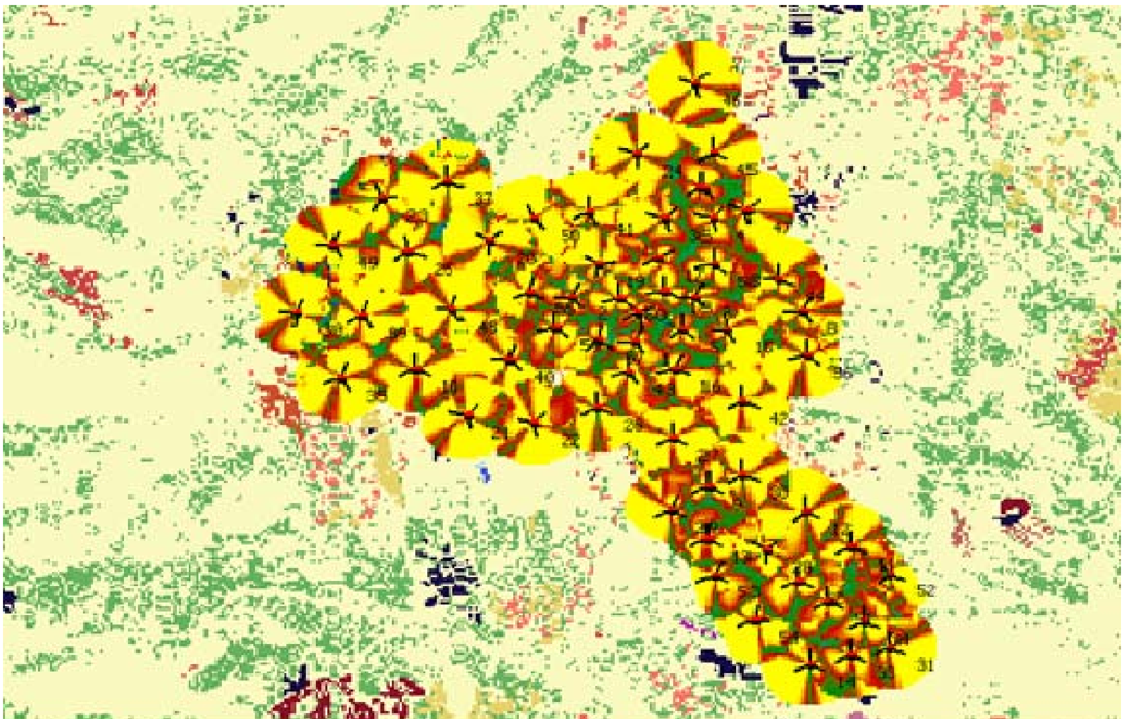
2

Ramallah optimization levels

Data rate optimization levels : The following figures show the data rate optimization levels of Nablus city, it shows the data rate before and after tuning the parameters and optimizing process.

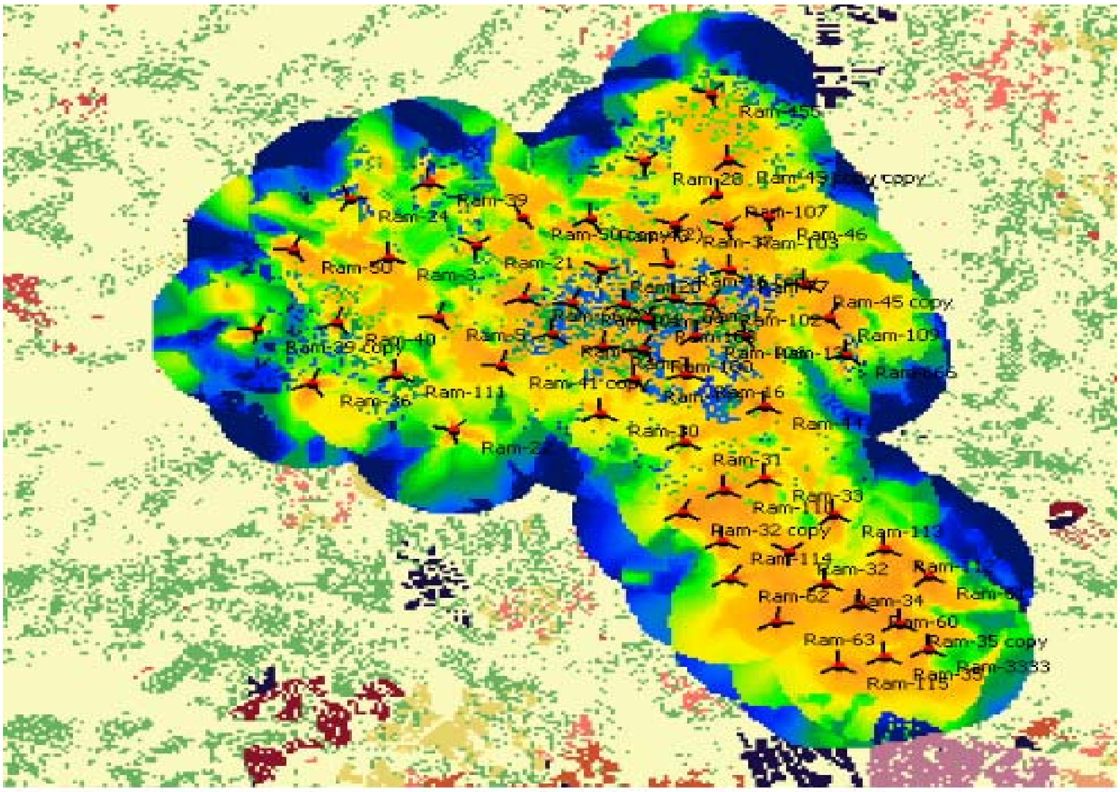


1

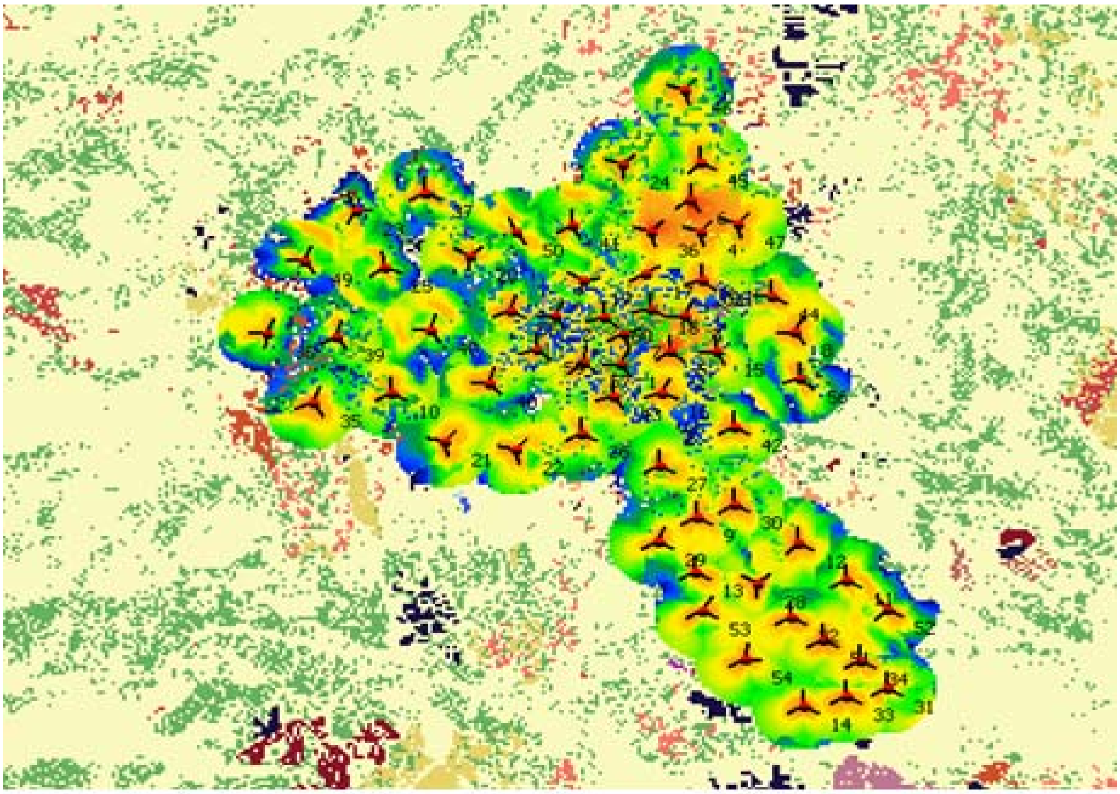


2

Signal strength optimization levels: These figures show the signal strength of Ramallah city before and after tuning the parameters and optimization process.



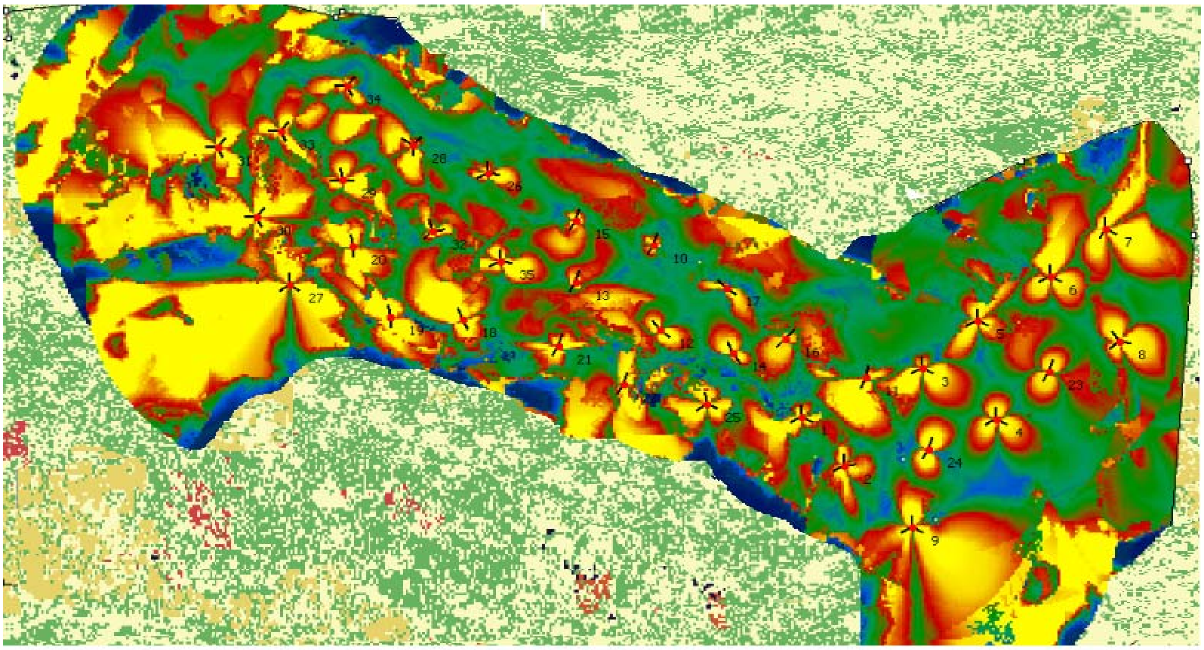
1



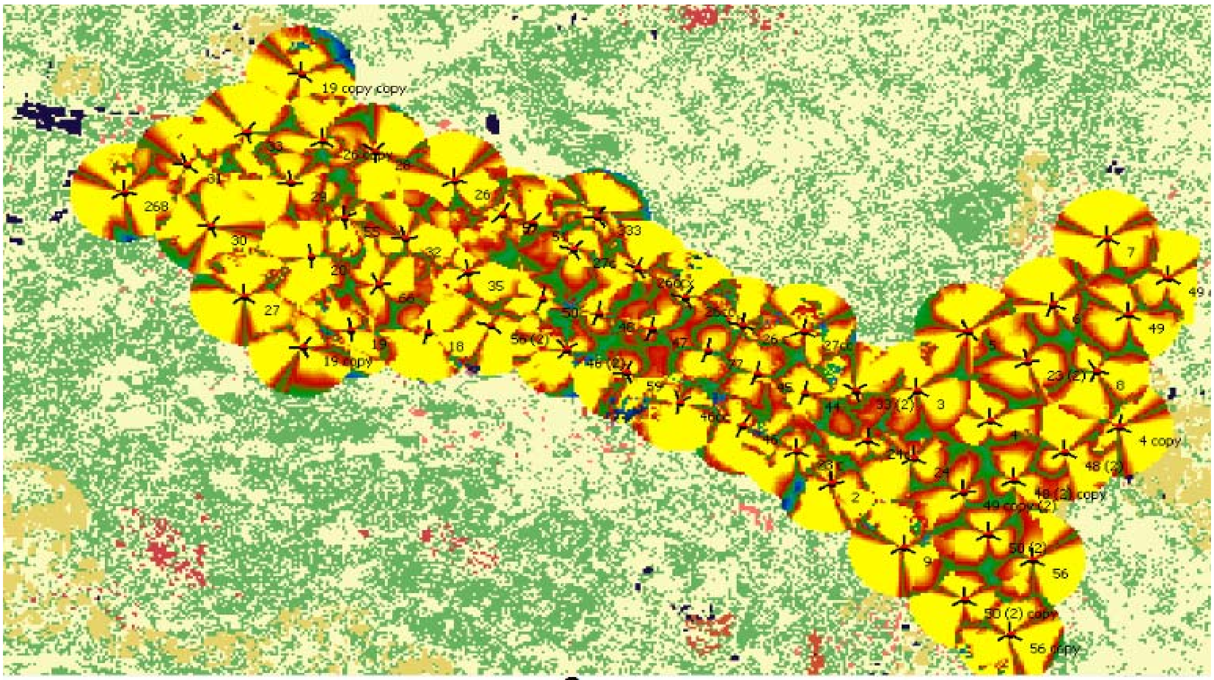
2

Nablus optimization levels

Data rate optimization levels The following figures show the data rate optimization levels of Nablus city, it shows the data rate before and after tuning the parameters and optimizing process.

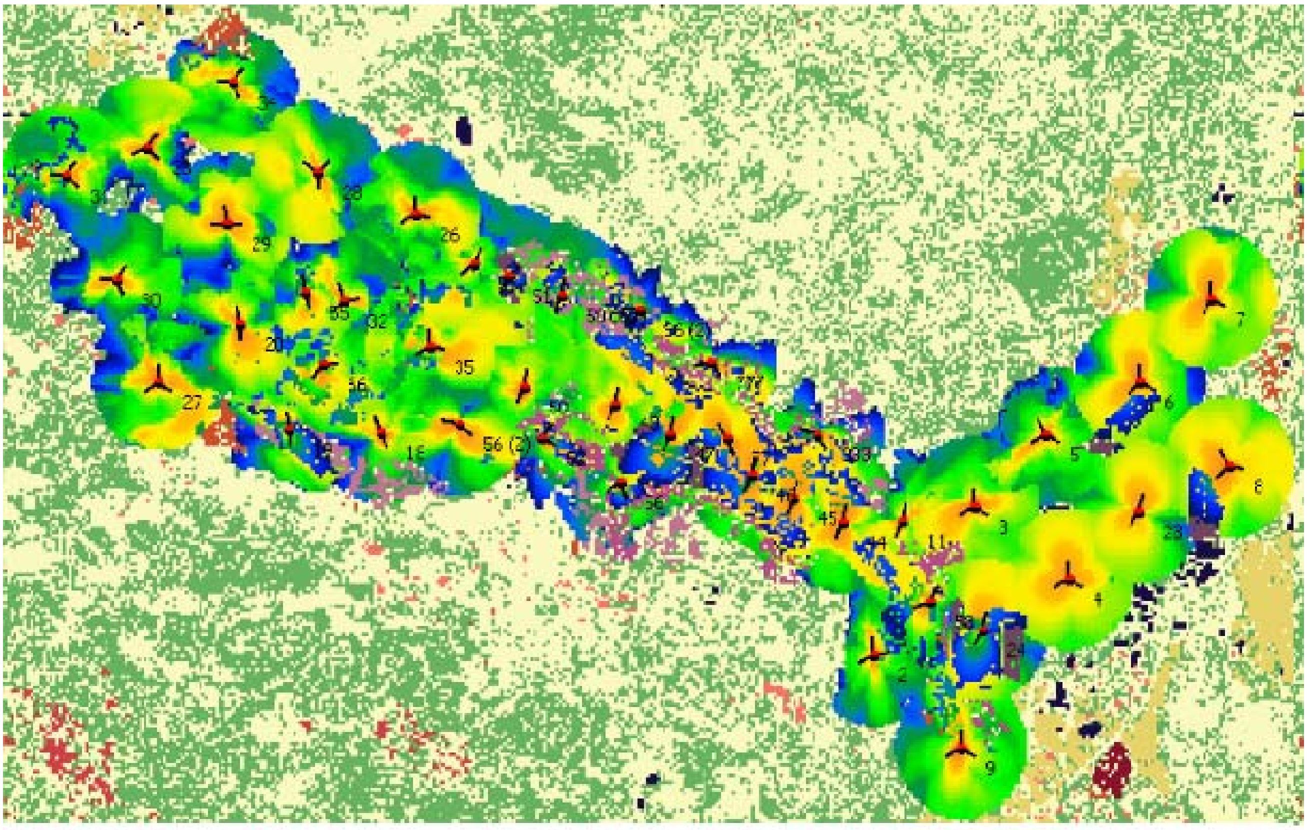


1

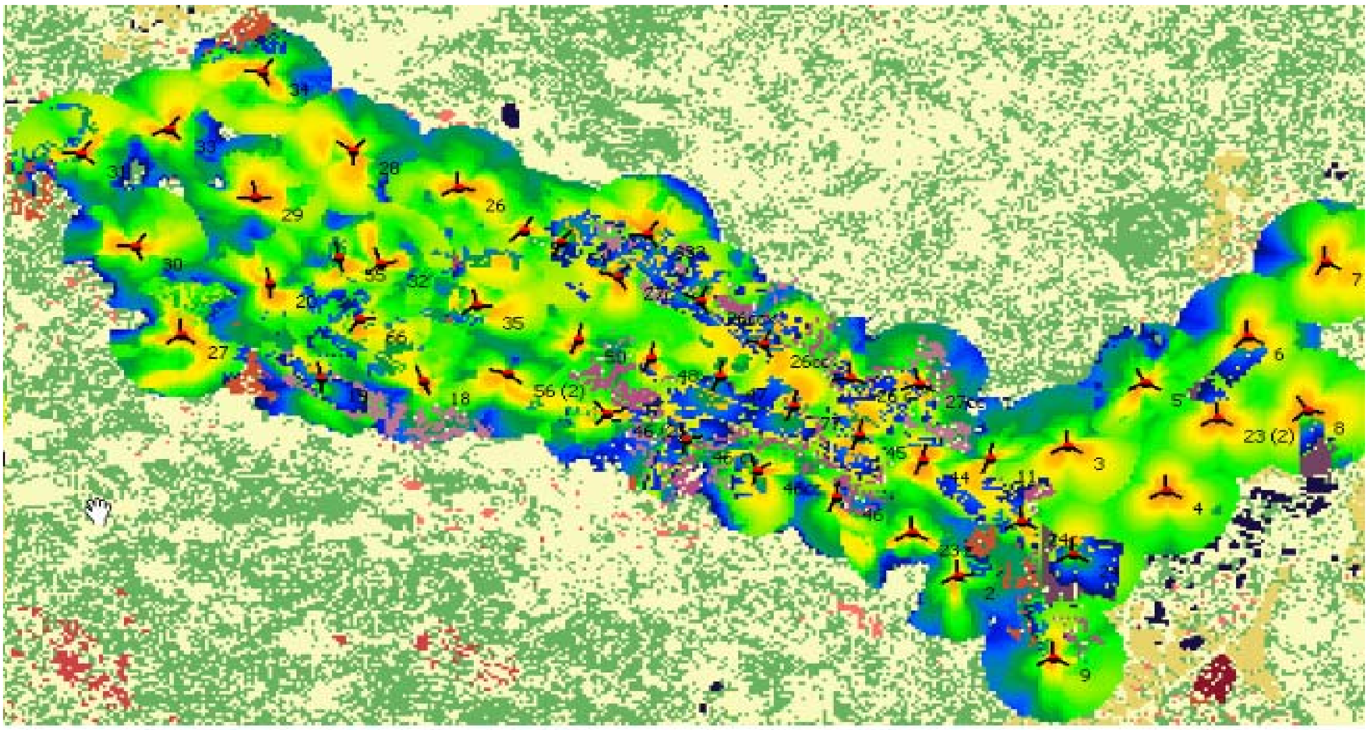


2

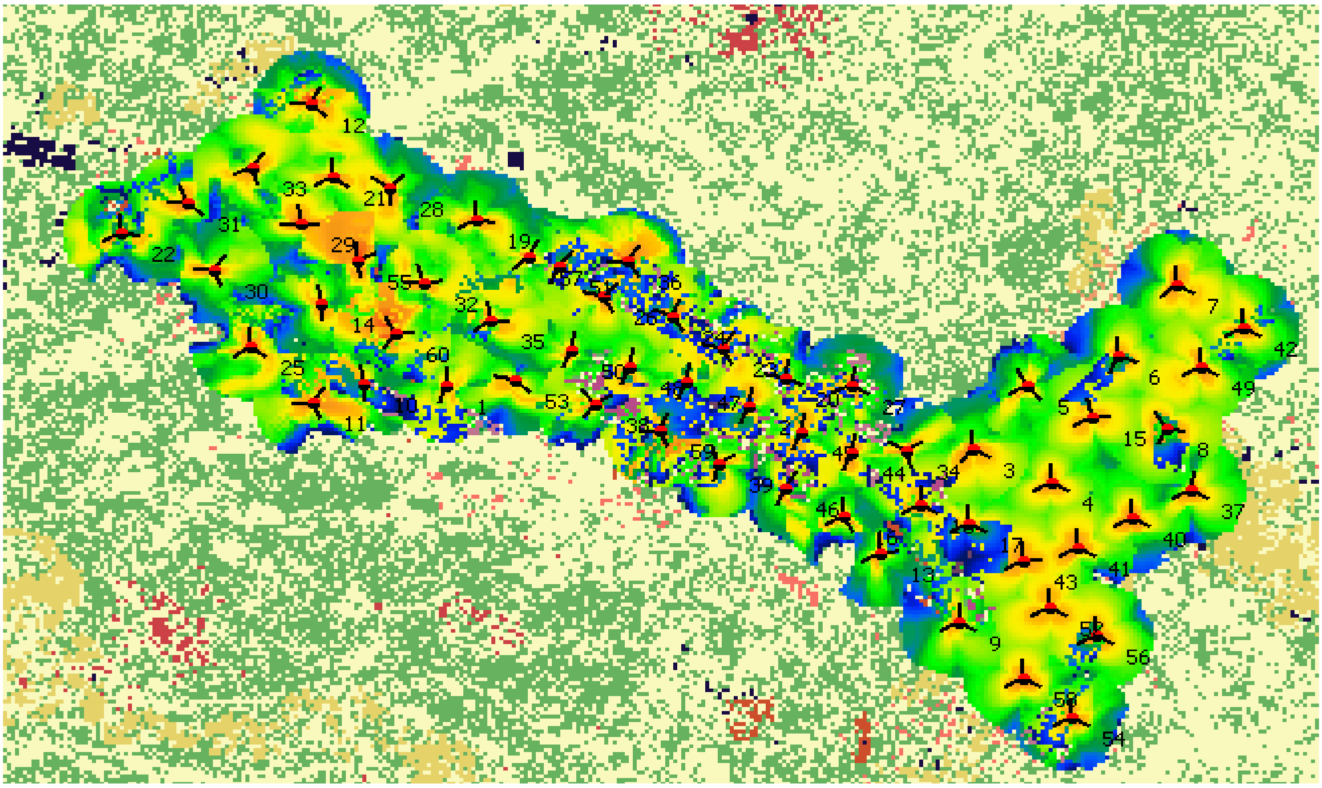
Signal strength optimization levels : These figures show the signal strength of Nablus city before and after tuning the parameters and optimization process.



1



2


12
33
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30
32
14
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60
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10
1
11
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50
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47
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20
27
7
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6
49
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34
44
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41
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54
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39

3

Sites Survey

Site 20

The following figures show the site explorer for site 20 in Hebron, which contain all the parameters related to antenna branch, power, transmission scheme , the azimuth, downtilt, antenna height, etc .

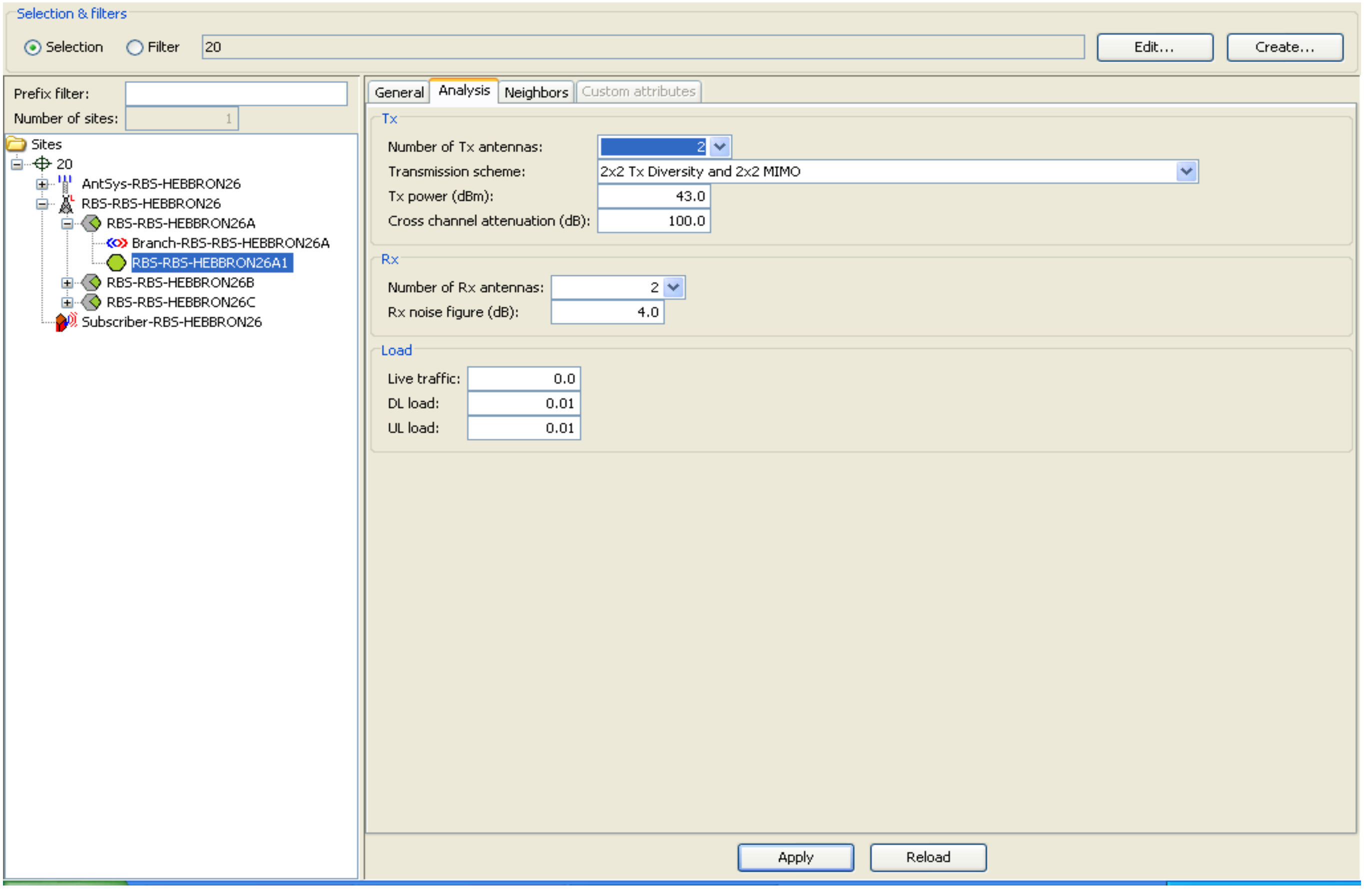


Fig ():site20 Transmission scheme

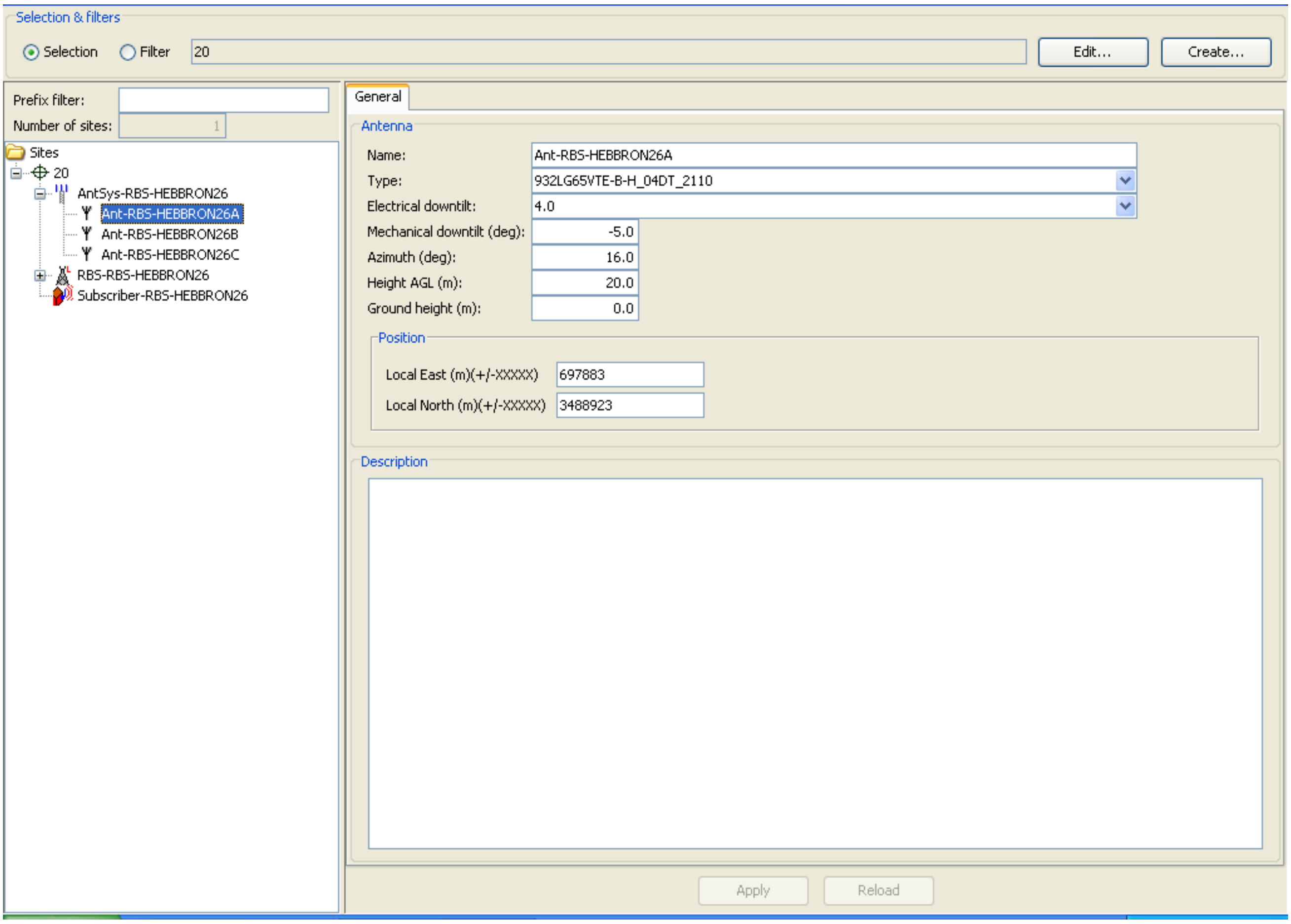


Fig ():site20 sector A antenna branch parameters.

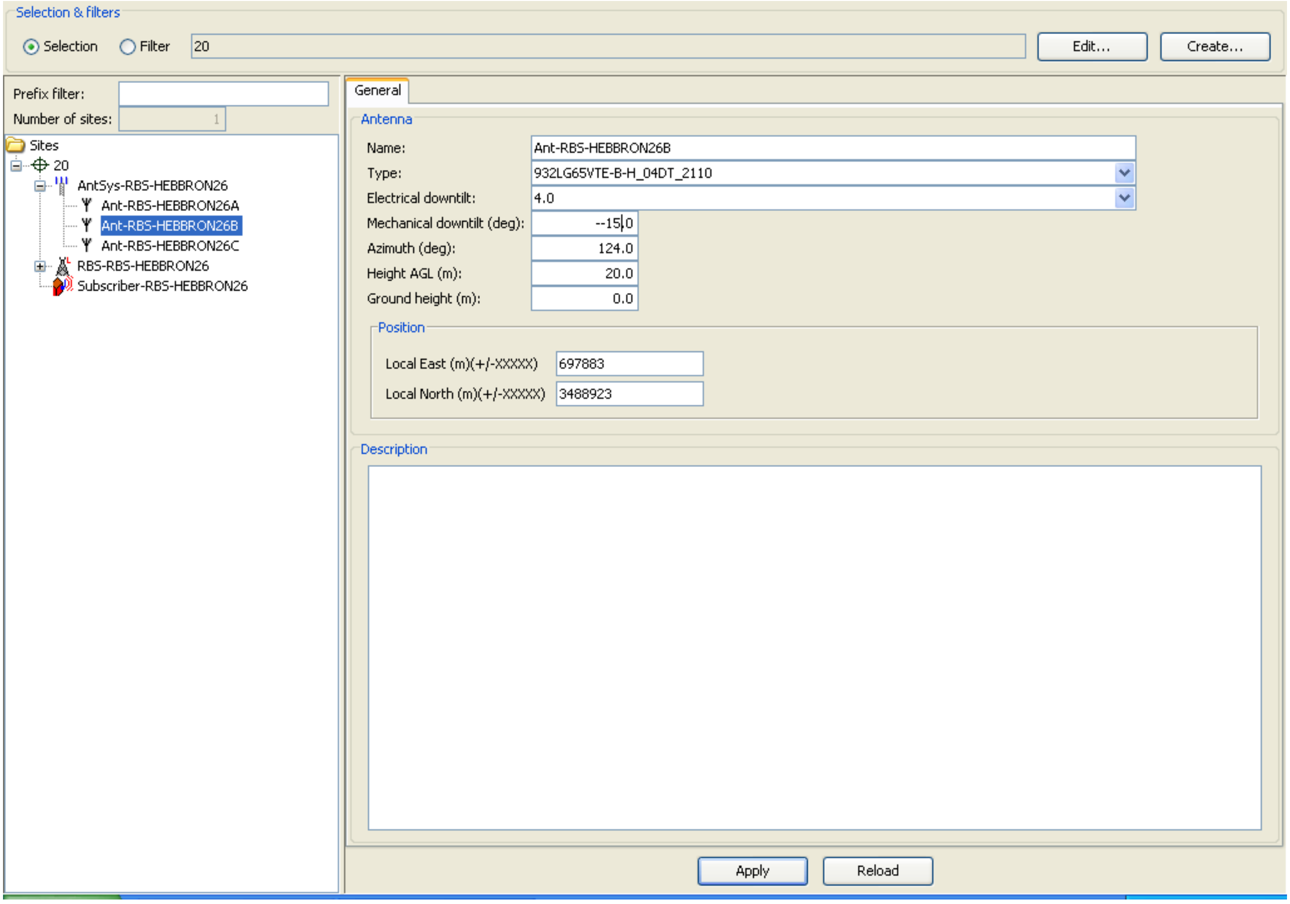


Fig ():site20 sector B antenna branch parameters

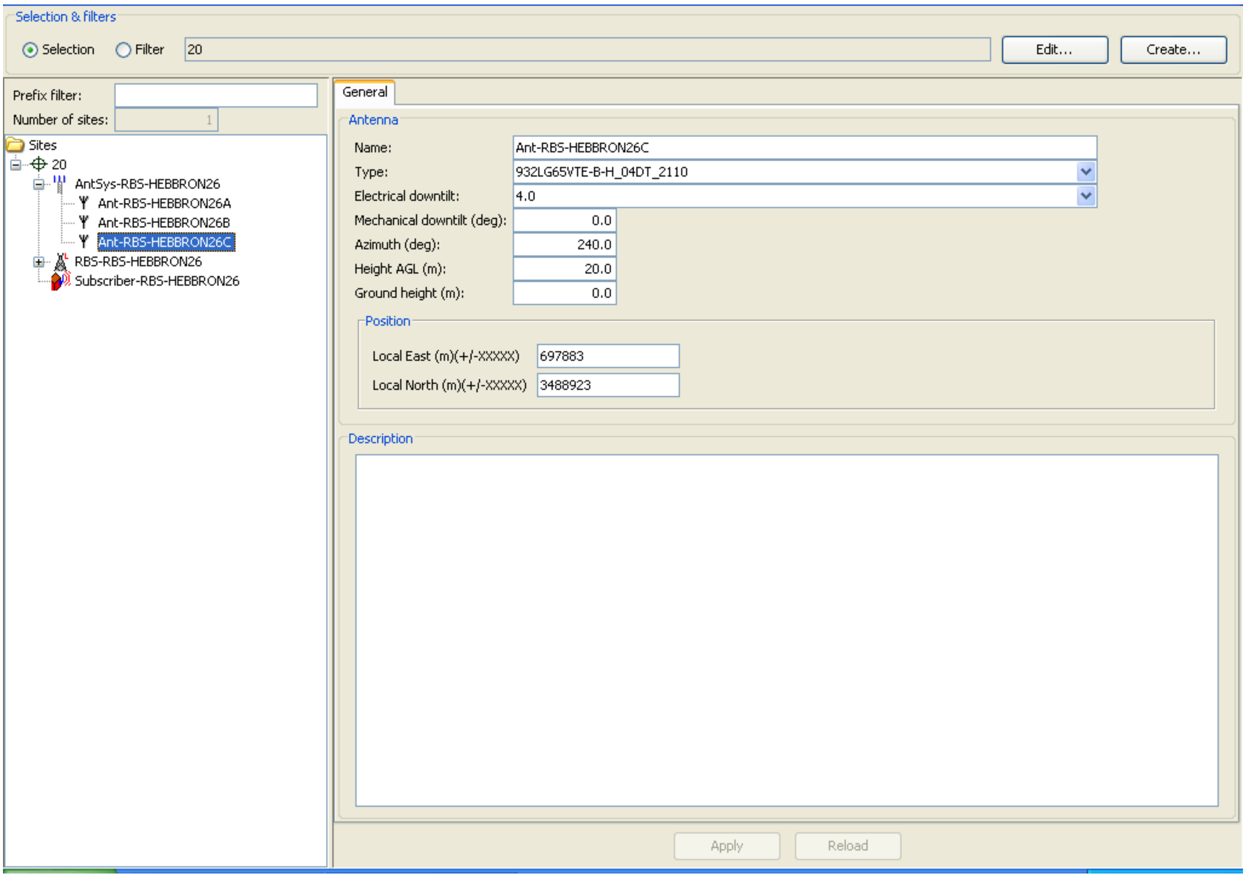


Fig () Site 20 sector C antenna branch parameters

Site 42

The following figures show the site explorer for site 42 in Hebron, which contain all the parameters related to antenna branch, power, transmission scheme , the azimuth, downtilt, antenna height, etc .

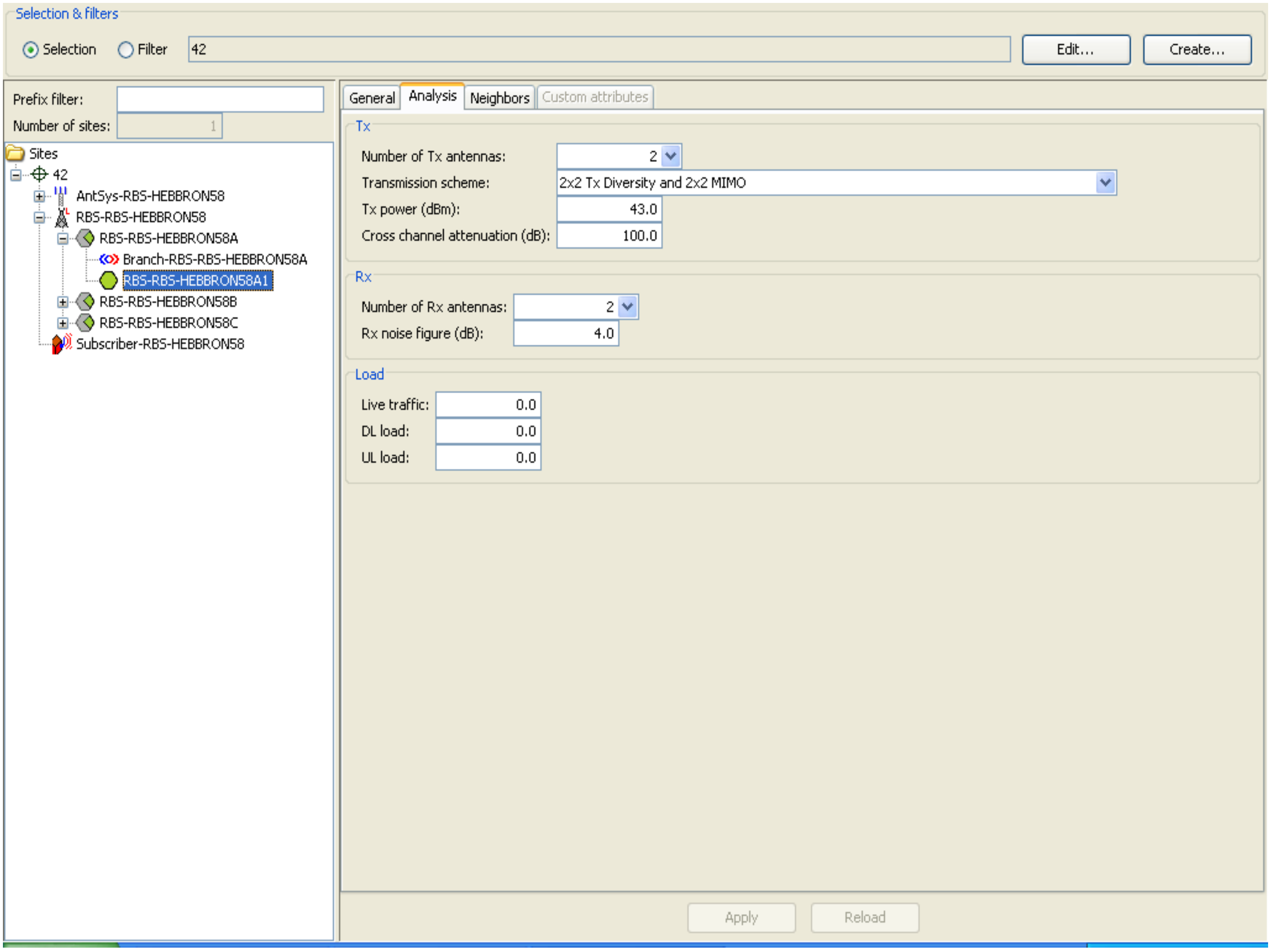


Fig (): Site42 Transmission scheme.

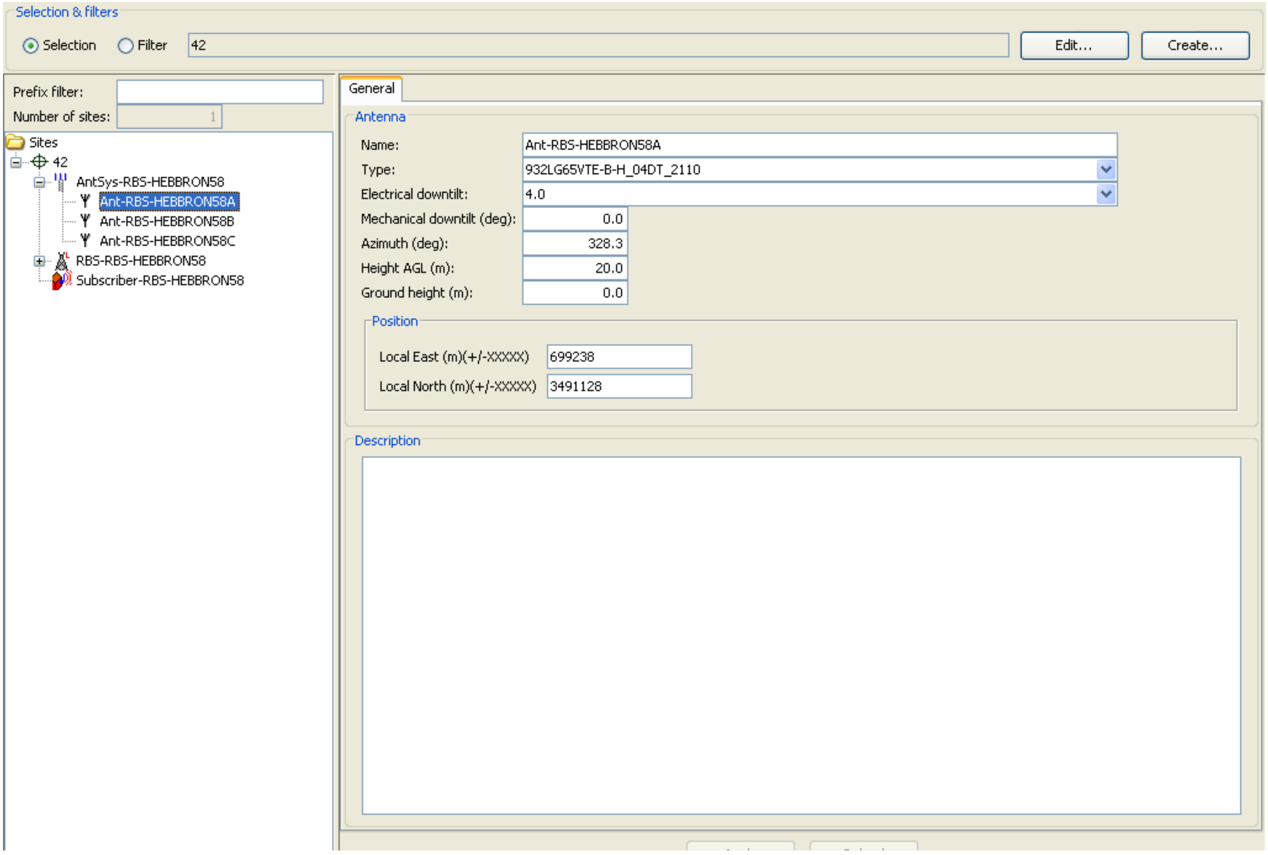


Fig (): Site 42 sector A antenna branch parameters.

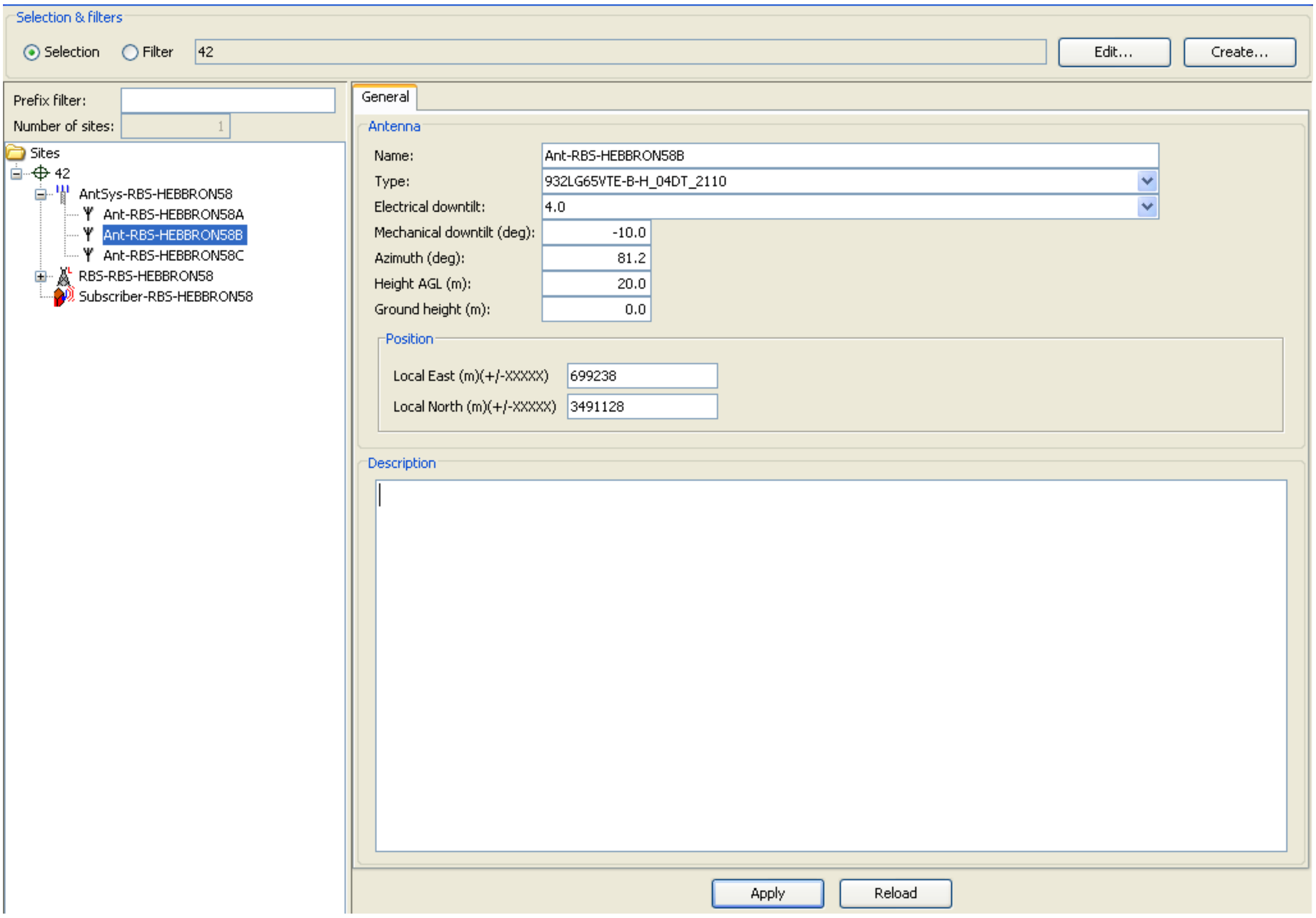


Fig (): Site 42 sector B antenna branch parameters.

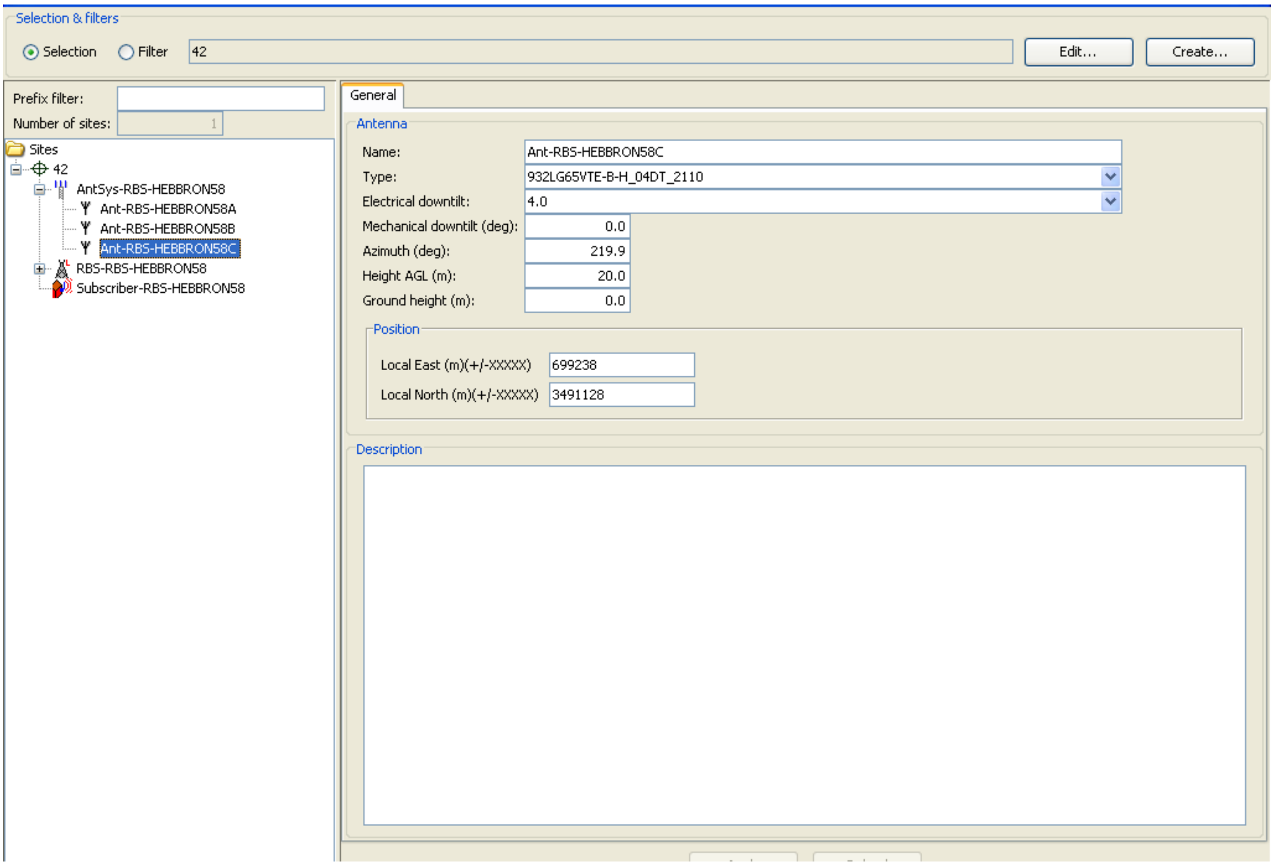


Fig (): Site 42 sector C antenna branch parameters.

Site 99

The following figures show the site explorer for site 99 in Hebron, which contain all the parameters related to antenna branch, power, transmission scheme , the azimuth, downtilt, antenna height, etc .

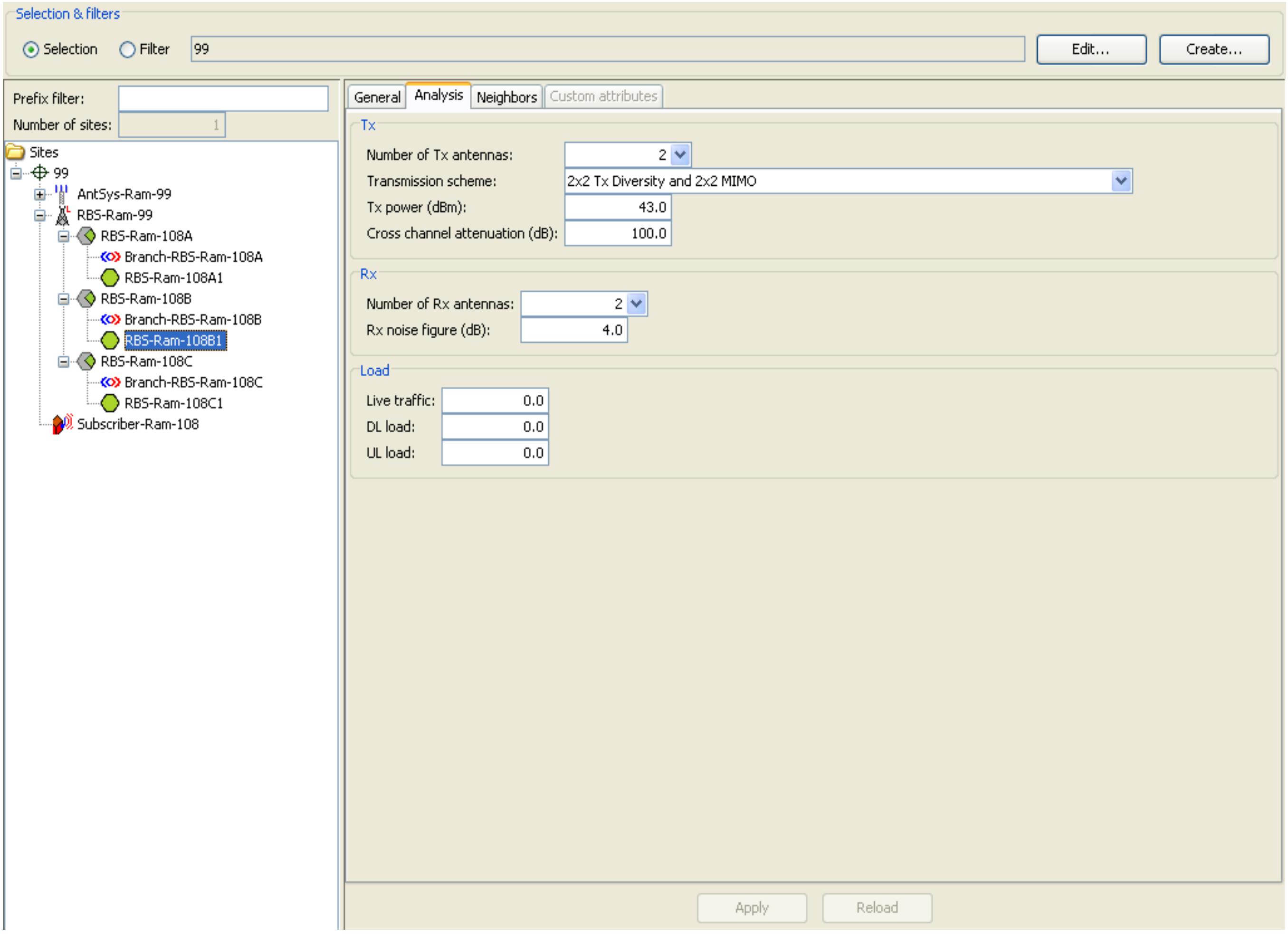


Fig (): site 99 transmission scheme

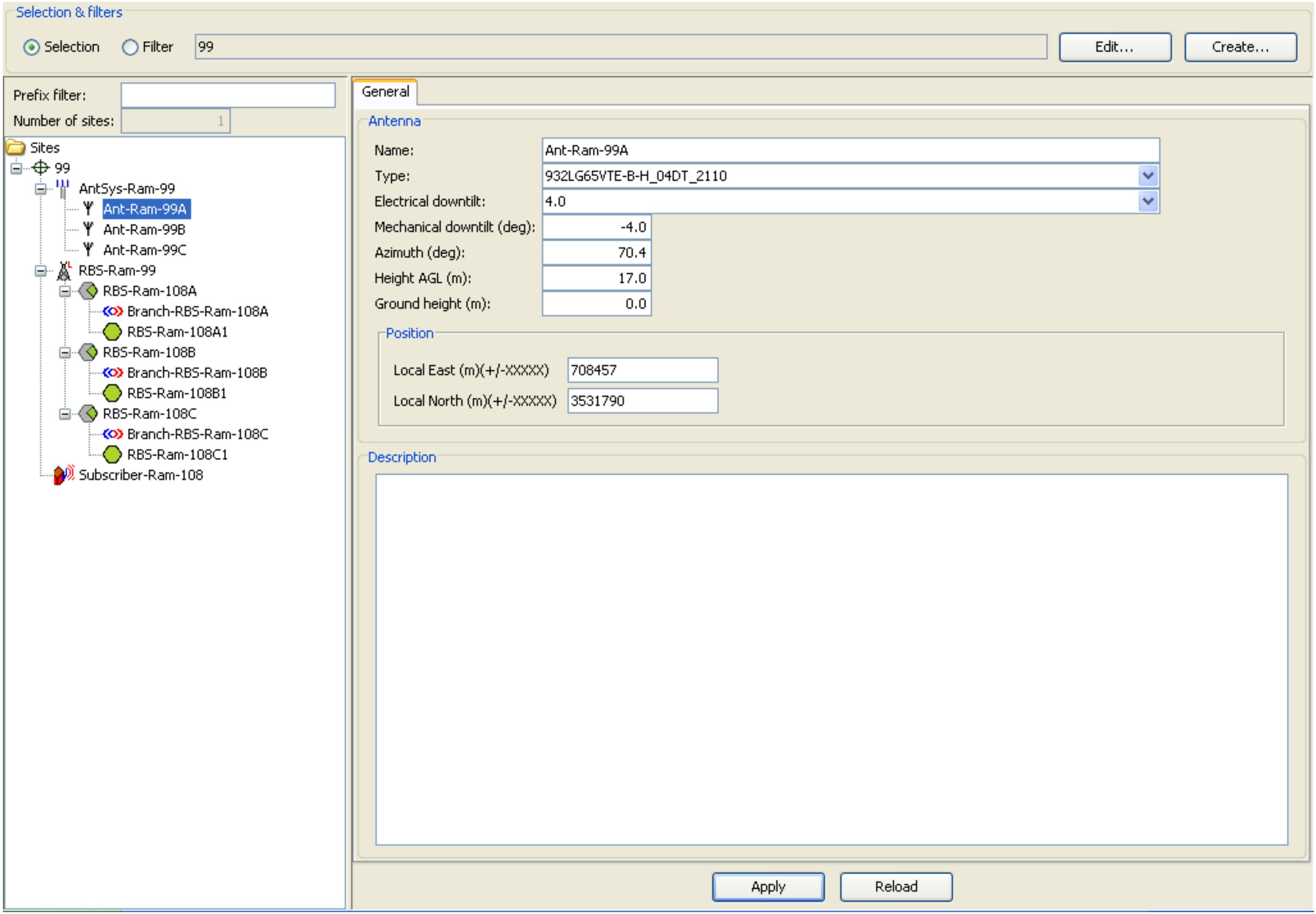


Fig (): Site99 sector A antenna branch parameters.

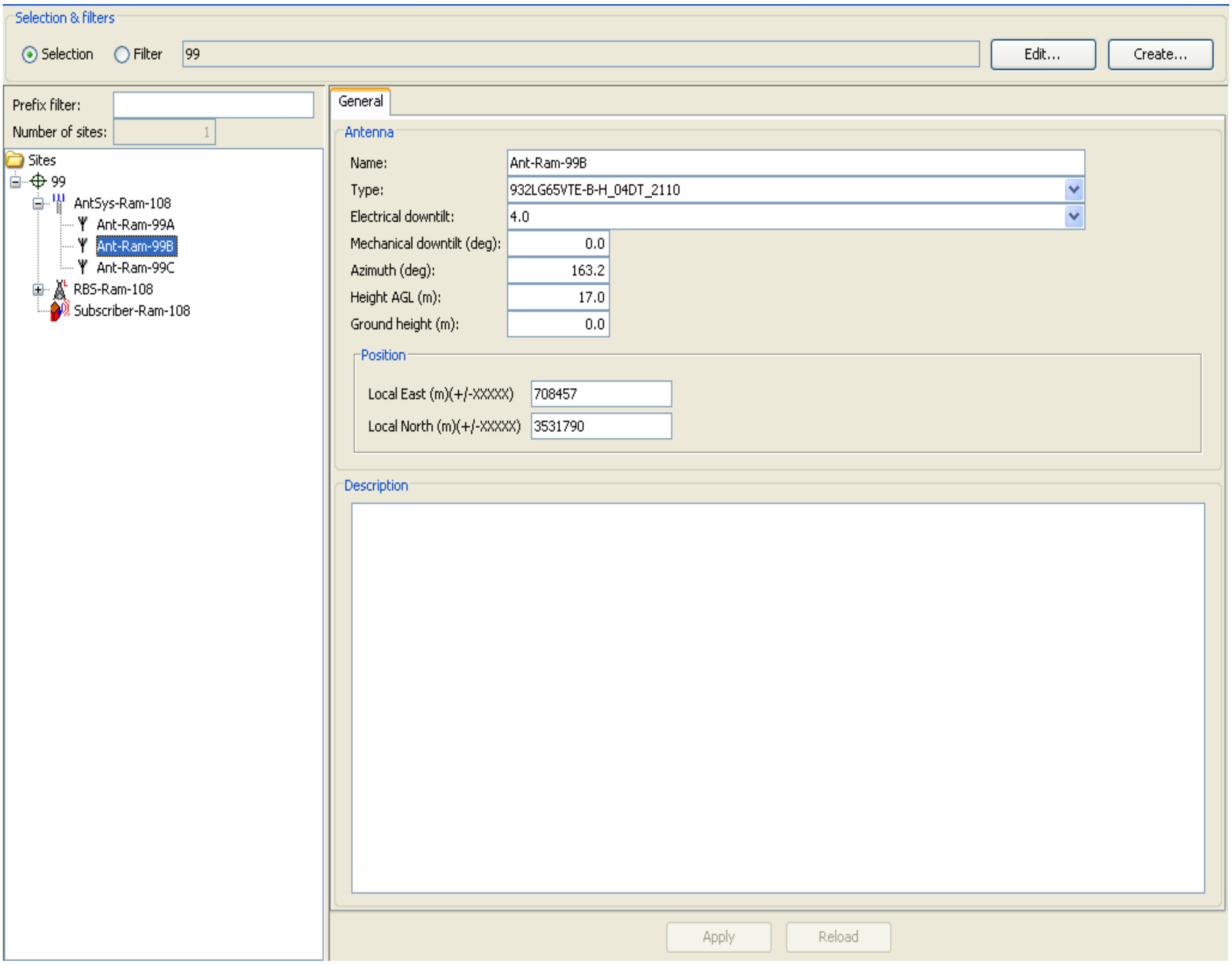


Fig (): Site99 sector B antenna branch parameters.

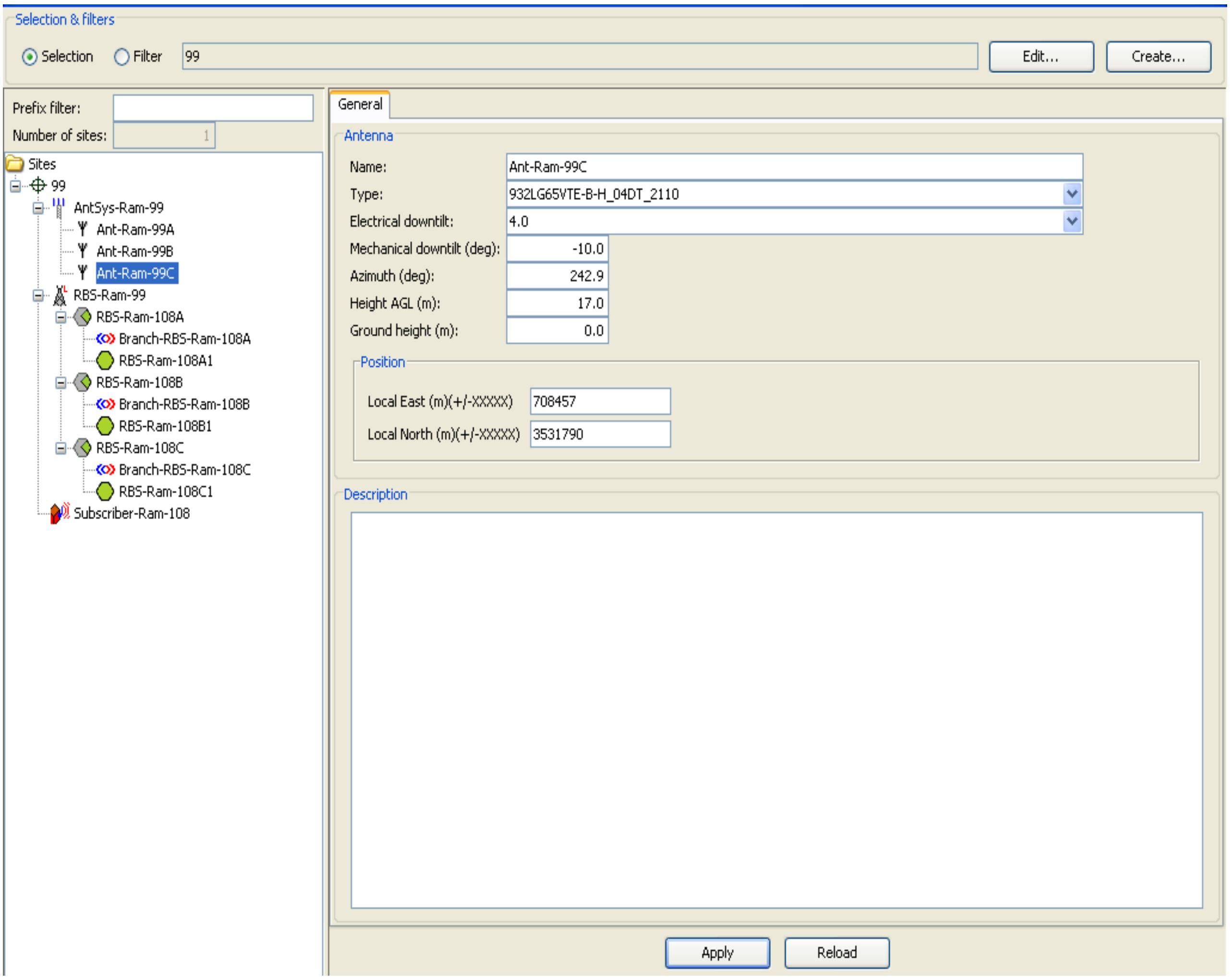
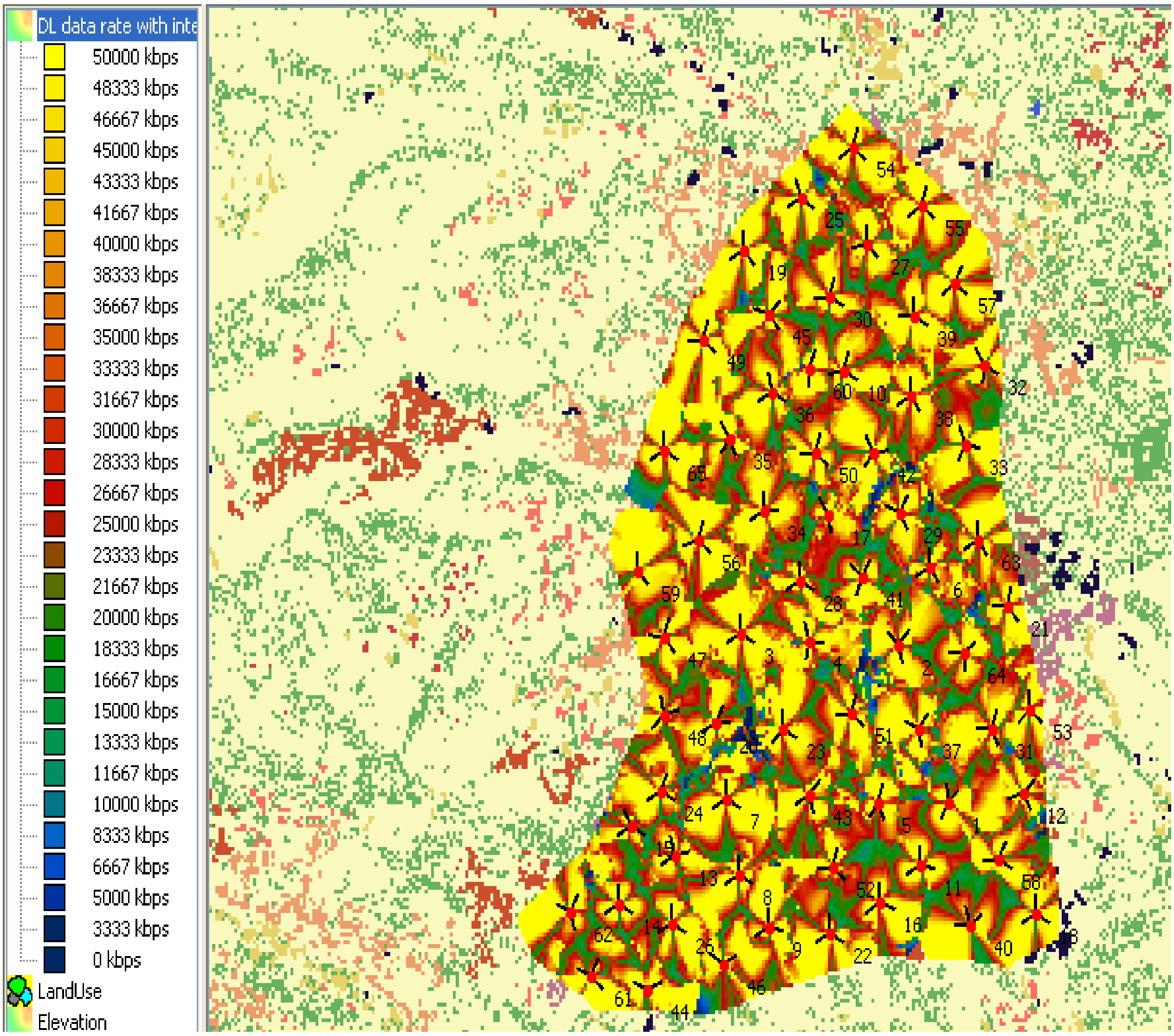


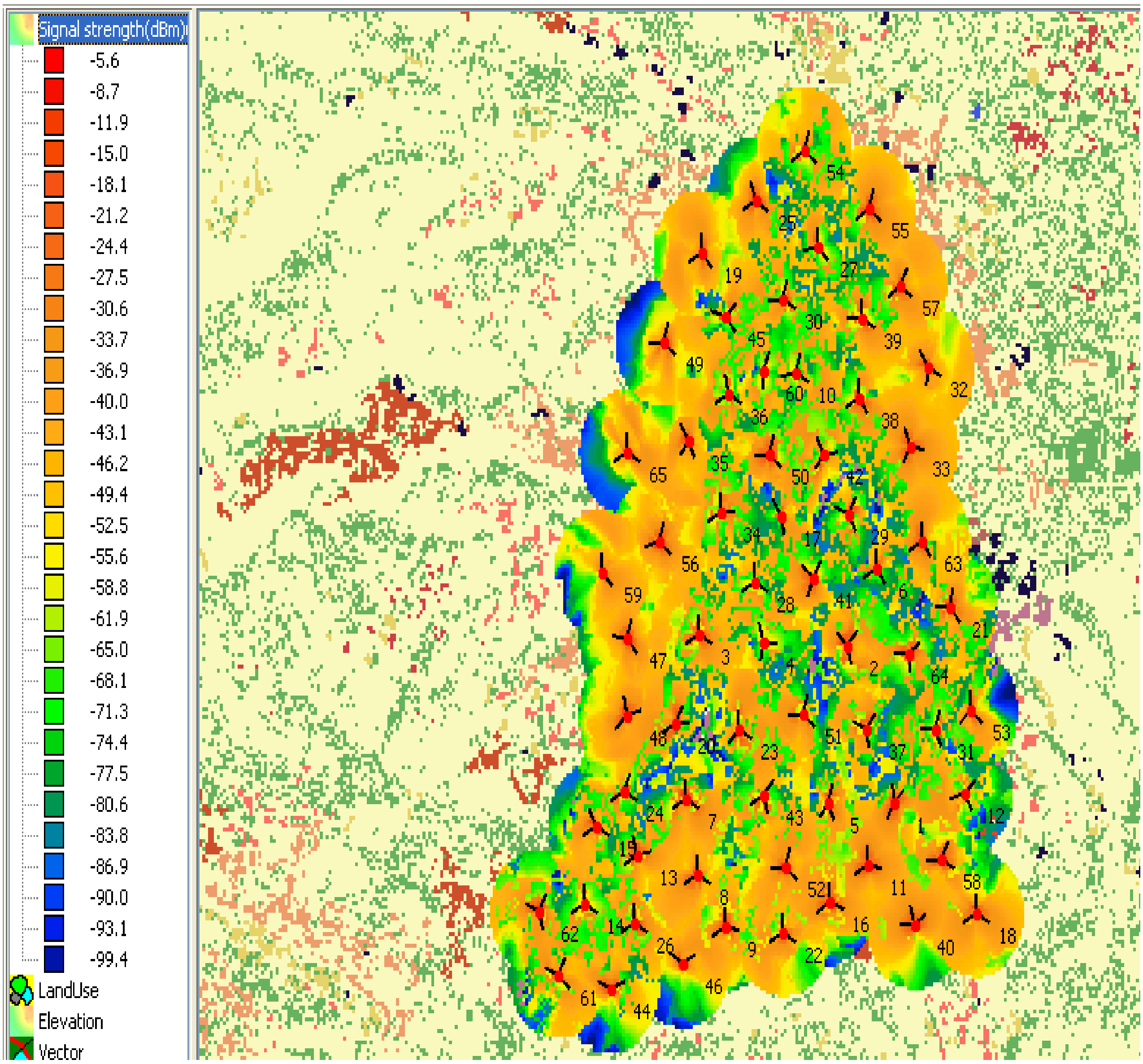
Fig (): Site 99 sector C antenna branch parameters.

More clear figures for Hebron

Data rate:

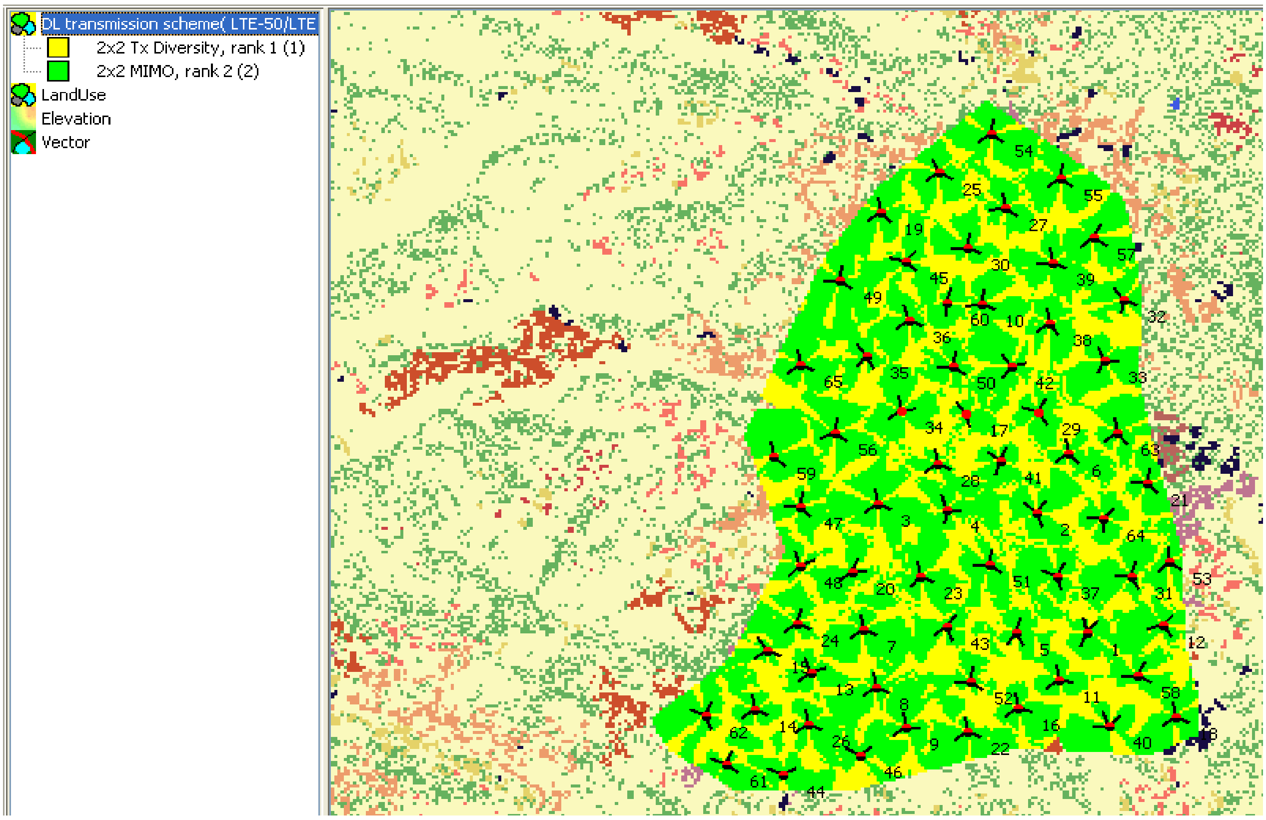


Signal strength:

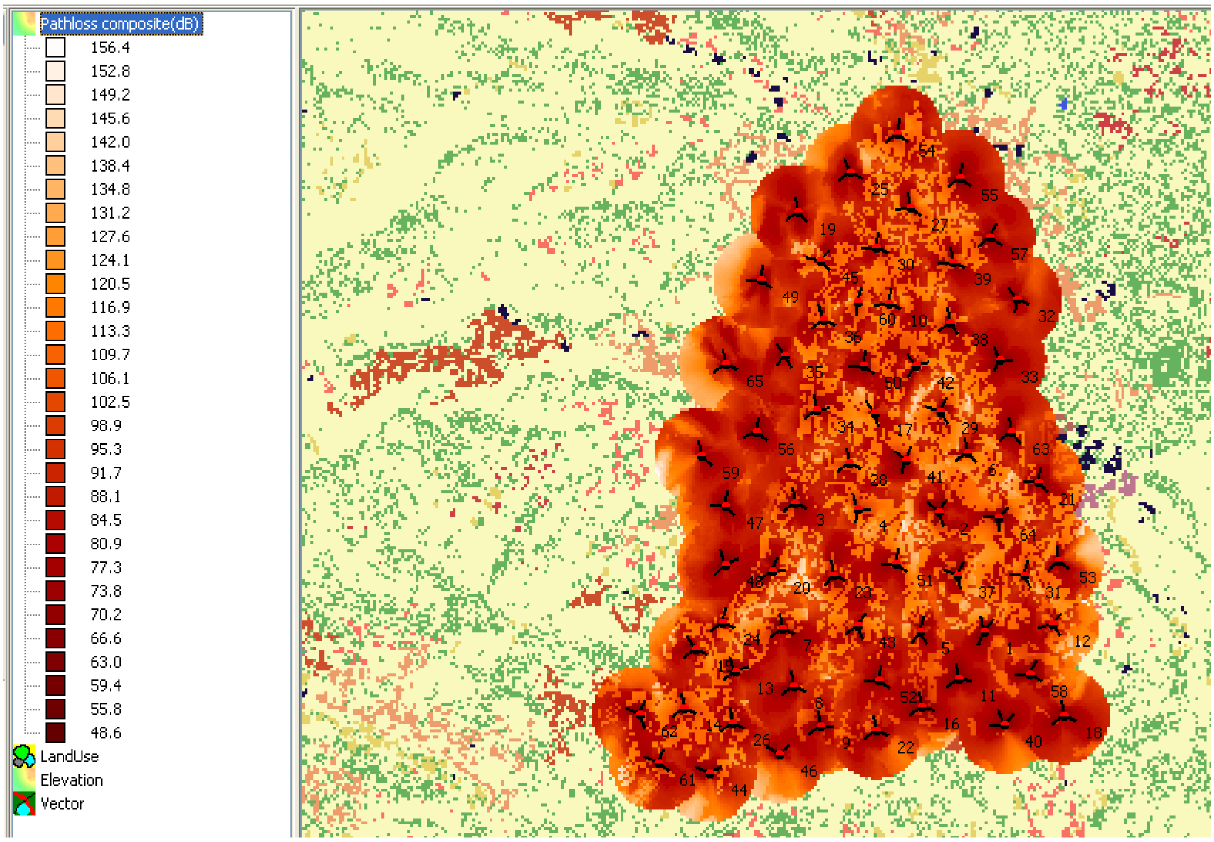


Additional figures for Hebron city analysis:

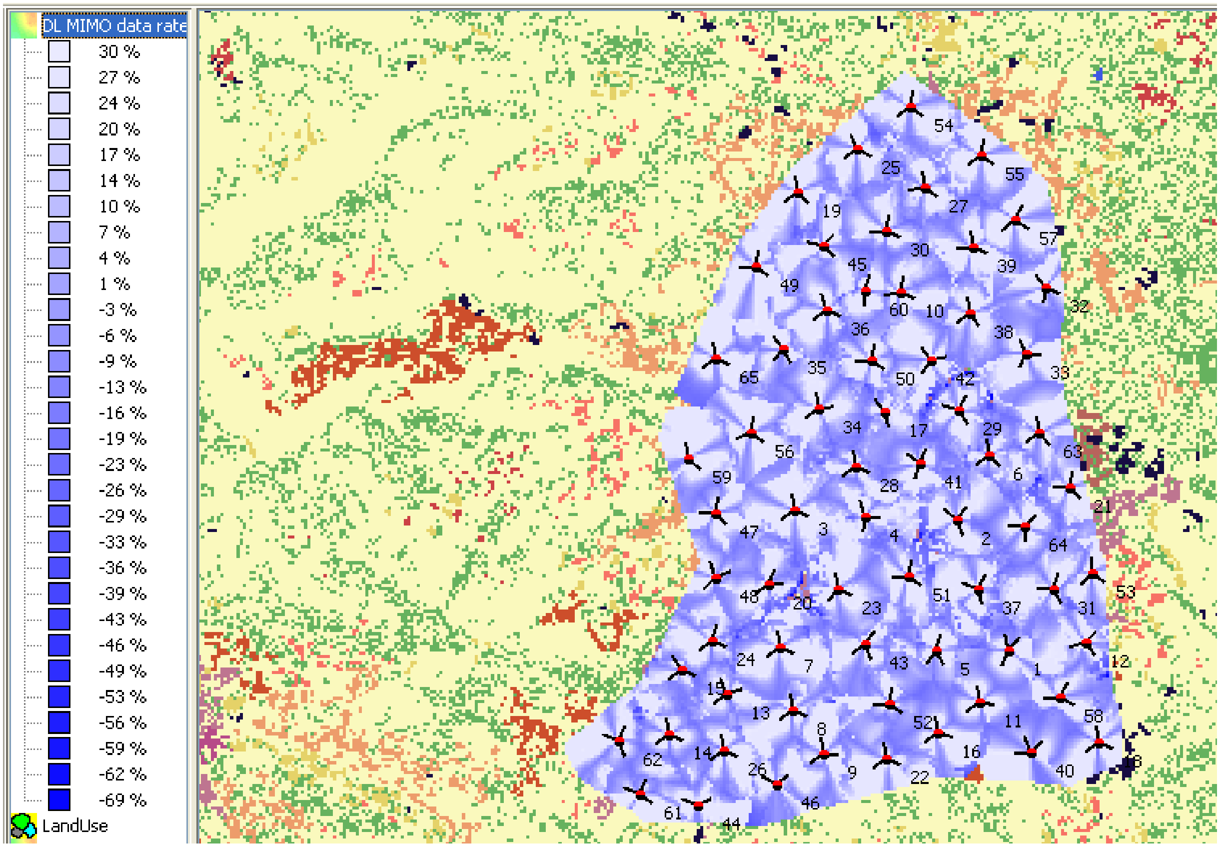
DL transmission scheme:



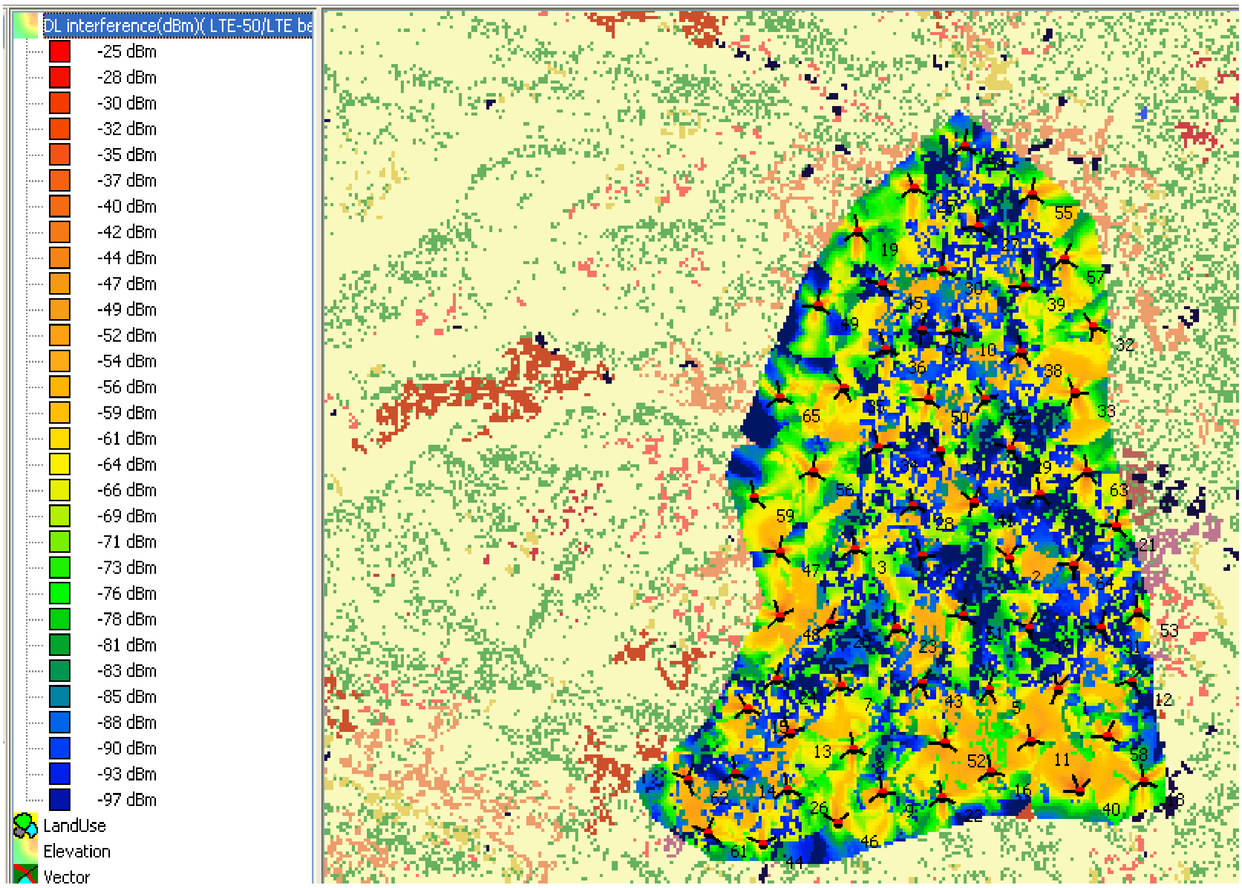
Pathloss composite(dB):



DL MIMO data rate:



DL interference (dBm):



Appendix B

THE MATLAB CODE

Neural Networks for Self-Organizing the Down-Tilt angles of Cellular Base Station Antennas Codes

```
% this code generates the two beam patterns together (with and
without NN)
clear all
close all
clc
color1 = ['G';'G';'G';'G';'G';'G';'G';'G';'G';'G';'G';'G'];

color = ['B';'B';'B';'B';'B';'B';'B';'B';'B';'B';'B';'B'];
tilt=4  % incoming tilt

theta = -60*pi/180 :3*pi/180 / 10791 :57* pi/180;

var = cos(theta+(tilt)*(pi/180));

num = sin((9. * 2. * pi * 0.5) .* var);

den = sin((2. * pi * 0.5) .* var);

pattern = num ./ den; % beam pattern

maxval = max(abs(pattern));

pattern = abs(pattern );

figure(1)
polar(theta ,abs(pattern),color1(tilt,:));
hold on
grid on


p=[0 6 12]; % i/p for Neural Network

t=[
    1.0000        0.8213       0.0807;
    0.3068        0.9475       1.1437;
    0.8213        0.0807       1.1494;
    0.9475        1.1437       0.0277;
    0.0807        1.1494       1.3687;
    1.1437        0.0277       2.0367;
    1.1494        1.3687       1.4743;
    0.0277        2.0367       0.1782;
    1.3687        1.4743       2.3932;
    2.0367        0.1782       4.6014;
    1.4743        2.3932       6.4155;
    0.1782        4.6014       7.6856;
    2.3932        6.4155       8.4448;
    4.6014        7.6856       8.8215;
    6.4155        8.4448       8.9645;
```

```
    7.6856        8.8215       8.9978;
    8.4448        8.9645       9.0000;
    8.8215        8.9978       8.9978;
    8.9645        9.0000       8.9645;
    8.9978        8.9978       8.8215;
    9.0000        8.9645       8.4448;
    8.9978        8.8215       7.6856;
    8.9645        8.4448       6.4155;
    8.8215        7.6856       4.6014;
    8.4448        6.4155       2.3932;
    7.6856        4.6014       0.1782;
    6.4155        2.3932       1.4743;
    4.6014        0.1782       2.0367;
    2.3932        1.4743       1.3687;
    0.1782        2.0367       0.0277;
    1.4743        1.3687       1.1494;
    2.0367        0.0277       1.1437;
    1.3687        1.1494       0.0807;
    0.0277        1.1437       0.9475;
    1.1494        0.0807       0.8213;
    1.1437        0.9475       0.3068;
    0.0807        0.8213       1.0000;
    0.9475        0.3068       0.2695;
    0.8213        1.0000       0.9143
    0.3068        0.2695       0.7203]; % Neural Network target

maxlr = 0.40*maxlinlr (p,'bias');

net = newlin([0 12],40,[0],maxlr);

net.trainParam.lr=0.1;% larning rate

net.trainParam.goal=0.0000001; % error rate

net.trainParam.epochs=2000; % # of epochs

net= train(net,p,t); % training process

a=sim(net,p); % output
e=t-a; % error between target matrix and the output


beta=-60*pi/180:3*pi/180:57*pi/180; % the angles on the beam (-60,-
57,......,0,3.....,57)



b=sim(net,tilt);

polar(beta',b,color(1,:))

hold on

legend_str1 = [];

legend_str1 =[ legend_str1 ;...
{[ num2str(tilt), ' Deg without NN']}];

legend_str = legend_str1;
for n = 1 :13
legend_str =[ legend_str ;...
{[ num2str(tilt), ' Deg with NN']}];
end
legend(legend_str)
```

```
% capacity code

clear all
close all
clc

SNR=1:1:45;
SNR=SNR';
p=[ 1 15 30 45]; % trained input

t=[2.3 2.6 2.7 2.75 ;6.5 8.5 9.4 9.8;11.5 17.5 18.8 19.25; 16.5 27.1
28.6 29.5]; % target matrix

t=t';

maxlr = 0.40*maxlinlr(p,'bias');

net = newlin([1 45],4,[0],maxlr);

net.trainParam.lr=0.1;        % larning rate

net.trainParam.goal=0.0000001; % error

net.trainParam.epochs=30000; % # of epochs

net= train(net,p,t); % training process

a=sim(net,p); % output

for i=1:45
b=sim(net,i);
```

```
x(i,:)=b;
end
Capacity=x

Iteration = 1e3;
SNR_V_db = linspace(1,45,45);

SNR_V = 10.^(SNR_V_db/10);

nt =[1:4] % # of transmission antennas

nr =[2]; % # of received anttenas

for i=1:4
    for s=1:1:45
       for(j=1:Iteration)

           H=(random('rayleigh',1,2,i)); % channel matrix

Ergodic_Capacity(s,j)=sum((log2(1+((eig(full(H*H'))*(10^(SNR_V_db(s)/
10))/i))))); % Capacity
           set (gca, 'XTick',1:1:45)
           set (gca, 'YTick',1:0.5:40)
       end
    end
color = ['b';'r';'g';'k'];
f1 = figure(1);
hold on
h= plot(SNR_V_db, mean(Ergodic_Capacity'),'color',color(i,:));
set(h,'LineWidth',1.45);
xlabel('SNR dB')
ylabel('Capacity bits/s/Hz')
end

legend_str = [];
for n = 1 : length(nt)
legend_str =[ legend_str ;...
{['nt = ',num2str(nt(n)), ' , nr = ',num2str(nr(1))]}];
end
legend(legend_str)

for q=1:4
H=plot (SNR,x(:,q),':','color',color(q,:));
set(H,'LineWidth',1.45);
end
grid on
```