ISLAMIC UNIVERSITY OF TECHNOLOGY

DHAKA, BANGLADESH

ORGANISATION OF ISLAMIC COOPERATION

LTE RADIO PARAMETERS AND NETWORK PLANNING

A Thesis Presented to

The Academic Faculty

by

Mugumya Twarik Harouna	Student No. 092303
Rammah Muhammed	Student No. 092304
Nafiu Salele	Student No. 092307

In partial fulfillment

of the requirements for the award of the Higher Diploma

in

Electrical and Electronic Engineering

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LTE RADIO PARAMETERS AND NETWORK PLANNING

Approved by

....

Mr. Nafiz Imtiaz Bin Hamid, Supervisor

Assistant Professor

Department of Electrical and Electronic Engineering,

Islamic University of Technology(IUT), Bangladesh

Organisation of Islamic Cooperation(OIC)

Date Approved:__________________

DECLARATION

This is to declare that the work presented in this thesis is the result of our own investigation carried out under the supervision of Mr. Nafiz Imtiaz Bin Hamid, in the Department Of Electrical And Electronic Engineering.
It has not already been accepted for any degree or diploma, and is also not being concurrently submitted for any other degree or diploma.

Authors:

....	....	....
Mugumya Twarik Harouna	Rammah Muhammed	Nafiu Salele
Student No. 092303	Student No. 092304	Student No. 092307

Date:__________________

Supervisor:

....

Mr. Nafiz Imtiaz Bin Hamid

Assistant Professor

Department of EEE

Signature of Head of the Department

....

Prof. Dr. Md. Shahid Ullah

Head

Department of Electrical and Electronic Engineering,IUT

Date:__________________

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All praise and thanks are due to Allah who has enabled us to accomplish this piece of work and may his Peace and blessings be upon the last prophet Muhammad (SAW).

This thesis is a result of research of four months and this is by far the most significant scientific accomplishment in our lives. It would be impossible without support and appreciation of those who mattered most.

First and foremost, We would like to acknowledge with gratitude the continuous support and guidance rendered to us by our supervisor Mr. Nafiz Imtiaz Bin Hamid, Assistant Professor, Department of Electrical and Electronic Engineering, IUT . Without his scholarly guidance, timely supervision, constructive criticism and valuable advices, We would not have been able to complete this thesis with such level of professionalism.

We wish to take this opportunity to express our sincerest gratitude and heartiest thanks to our dear parents and family members for being such delightful people and the inspiration for our effort. Without their prayers, continued encouragement, moral and financial support, it would not have been easy for us to accomplish this work, indeed their reward is with the Almighty Allah.

We also thank all our friends and colleagues and whoever helped us in the course of our work and our write-up.

DEDICATION

We dedicate this piece of work to our families

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LIST OF ABBREVIATIONS

Abbreviation	**Meaning**
3GPP	Third Generation Partnership Project
4G	Fourth Generation
CDMA	Code Division Multiple Access
DL	Downlink
EDGE	Enhanced Data rates for GSM Environment.
eNodeB	Evolved Node B
FDD	Frequency Division Duplex
GPRS	General Packet Radio Service
GSM	Global System for Mobile Communications
HSPA	High-Speed Packet Access
LTE	Long Term Evolution
LOS	Line of Sight
Mbps	megabits per second
MIMO	Multiple-Input and Multiple-Output
OFDM	Orthogonal Frequency-Division Multiplexing
OFDMA	Orthogonal Frequency-Division Multiple Access
QAM	Quadrature Amplitude modulation
SUI	Stanford University Interim
SISO	Single Input Single Output
SC-FDMA	Single Carrier Frequency-Division Multiple Access
TDD	Time Division Duplex
UE	User Equipment
UL	Uplink
UMTS	Universal Mobile Telecommunications System
W-CDMA	Wideband Code Division Multiple Access

Abstract

The ever growing need for data transmission capacity drives the network service providers to build Mobile LTE networks in the urban areas. The 3GPP LTE is the evolution of the UMTS in response to ever-increasing demands for high quality multimedia services according to users' expectations. LTE promises to deliver an unrivalled user experience with ultra-fast broadband and very low latency and at the same time, a very compelling business proposition for operators with flexible spectrum bandwidth, smooth migration and the ability to deliver low cost per bit voice and data services. LTE is designed to have wider channels up to 20MHz, with low latency and packet optimized radio access technology. The peak data rate envisaged for LTE is 100 Mbps in downlink and 50 Mbps in the uplink. LTE has very promising features, like bandwidth scalability and both FDD and TDD duplexing methods. This thesis introduces the radio parameters required for efficient LTE radio network planning through numerous simulations, and then after we establish a radio network using Dhaka as a case study

Chapter 1

Introduction

1.1 Background

LTE (Long term evolution) is a 4G technology, it's the latest standard and the next step in wireless technology and it's expected to be the mobile broadband platform for services in innovation for the foreseeable future. LTE is a 3GPP standard that provides for an uplink speed of up to 50 megabits per second (Mbps) and a downlink speed of up to 100 Mbps. LTE may also be referred more formally as Evolved UMTS Terrestrial Radio Access (E-UTRA) and Evolved UMTS Terrestrial Radio Access Network (E-UTRAN).

The 3GPP body began its initial investigation of the LTE standard as a viable technology in 2004. In March 2005, 3GPP began a feasibility study whose key goals were to agree on network architecture and a multiple access method, in terms of the functional split between the radio access and the core network. The study concluded in September 2006 when 3GPP finalized selection of the multiple access and basic radio access network architecture. 3GPP decided to use OFDMA in the downlink direction and use SC-FDMA in the uplink direction. The specifications for the LTE standard were approved by 3GPP in January 2007. The specifications are now under change control, leading to their inclusion in 3GPP Release 8. While the LTE requirements are finalized, the standard is not fully completed. LTE Release 8 was completed by late 2008.

1.2 Problem Statement

LTE introduces new opportunities as well as challenges. Great spectrum flexibility and spectrum allocation alternatives contribute to the complexity and the Radio Networks become more complex as well. The radio network planning process and design criteria vary from region to region depending upon the dominating factor, which could be capacity or coverage. The design process itself is not the only process in the whole network design, and has to work in close coordination with the planning processes of the core and especially the transmission network. Dhaka city being a highly populated city with its population increasing daily, in order to carter for the ever increasing population, there is a need to carry out proper radio planning using a high spectral efficient standard.

1.3 Objectives

The objectives of this Thesis were:

1.3.1 General Objective

To find out the radio parameters required for efficient radio planning through numerous simulations. Using Dhaka city for case study.

1.3.2 Specific Objectives

- Understand basic radio network planning process for LTE
- Explore specific radio features through link and system level simulations.
- To establish an LTE radio network in Dhaka City
- To analyze the performance of the wireless network

1.4 Scope of the Study

The scope of our study will focus its discussion around the radio parameters upon which the coverage and capacity analysis is based-on for efficient network planning of LTE technology, and also we have chosen Dhaka city as our case study of radio network planning.

1.5 Significance of the study

Dhaka city is a highly populated city with a population of over 15 million people, this thesis will help to determine the radio parameters that will help to carry out efficient radio network planning thus making a tremendous prediction on how well we can provide Dhaka city with best signal using the latest technology.

Chapter 2

Overview of LTE

2.1 Introduction to LTE

LTE (Long Term Evolution) is a wireless broadband technology designed to support roaming Internet access via cell phones and handheld devices.
LTE as a 4G technology,it offers significant improvements over older cellular communication standards. The E-UTRAN (Evolved Universal Terrestrial Access Network) is the access part of the Evolved Packet System (EPS). The main requirements for the new access network are high spectral efficiency, high peak data rates, short round trip time and frequency flexibility.

2.2 Motivation for LTE

- User demand for higher data rates and quality of service
- Packet Switch optimized system
- Continued demand for cost reduction (CAPEX and OPEX)
- Low complexity
- Avoid unnecessary fragmentation of technologies for paired and unpaired band operation

2.3 Features of LTE

3GPP Release 8/9/10 E-UTRA physical layer implementation conforming to TS36.211, TS36.212 and TS36.213 LTE has the following features.

- FDD and TDD duplexing mode
- Downlink and uplink support
- Complete support for 1, 2, 4 and 8 antenna transmissions including all MIMO layering and precoding options, and any number of antennas for UE-specific beamforming
- Full control of all parameters via MATLAB
- DCI message creation and control region building and decoding
- All physical layer steps available as individual functions/blocks:
  - Transport channel coding/ decoding
  - Scrambling/ descrambling
  - Symbol Modulation/ demapping
  - Resource element mapping
  - OFDM and SC-FDM

2.4 Objectives of LTE

The objective of LTE was to increase the capacity and speed of wireless data networks using new DSP (digital signal processing) techniques and modulations that were developed around the turn of the millennium.

2.5 Benefits of LTE

LTE provides among others the following benefits:-

- Provides a global ecosystem with inherent mobility .
- Offers easier access and use with greater security and privacy.
- Dramatically improves speed and latency.
- Delivers enhanced real-time video and multimedia for a better overall experience.
- Enables high-performance mobile computing.
- Supports real-time applications due to its low latency.
- Creates a platform upon which to build and deploy the products and services of today and those of tomorrow.
- Reduces cost per bit through improved spectral efficiency.

2.6 LTE Supporting Technologies

LTE aims at better spectral flexibility, higher data rates, low latency, improved coverage and better battery lifetime. To achieve the targets, LTE employs the enabling technologies: Orthogonal Frequency Division Multiple Access (OFDMA), Single Carrier Frequency Division Multiple Access (SC-FDMA) [3][8] and Multiple Input Multiple Output (MIMO). LTE employs OFDMA for downlink and SC-FDMA for uplink data transmissions.

2.6.1 MIMO

Multiple-input and multiple-output (MIMO) employs multiple transmit and receive antennas to substantially enhance the air interface. It uses space-time coding

of the same data stream mapped onto multiple transmit antennas. This offers a substantial improvement over traditional reception diversity schemes where only a single transmit antenna is deployed to extend the coverage of the cell.
MIMO processing also uses spatial multiplexing , allowing different data streams to be transmitted simultaneously from different transmitter antennae. see Figure 2.1.
Spatial multiplexing increases the end-user data rate and cell capacity. In addition, when knowledge of the radio channel is available at the transmitter, such as through feedback information from the receiver, MIMO can implement beamforming to further increase available data rates and spectrum efficiency. Multiple antennas are also used to transmit the same data stream, thus providing redundancy and improved coverage, especially close to cell edge.

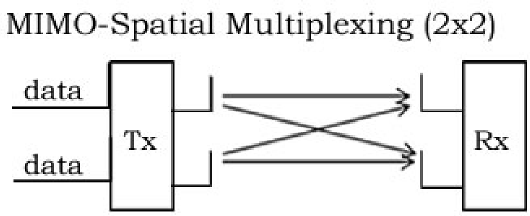


Figure 2.1: Simplified illustration of 2x2 MIMO (Spatial Multiplexing)

2.6.2 OFDM and OFDMA

Orthogonal Frequency Division Multiple Access (OFDMA) is a variant of Orthogonal Frequency Division Multiplexing (OFDM), which is a digital multi-carrier modulation (MCM) scheme widely used in wireless systems. In general, MCM is a parallel transmission method that divides a radio frequency channel into several, more narrow-bandwidth subcarriers and transmits data simultaneously on each subcarrier. OFDM is well suited for high data rate systems that operate in multipath environments because of its robustness to delay spread. The cyclic extension enables an OFDM system to operate in multipath channels without the need for a complex Decision Feedback Equalizer (DFE) or Maximum Likelihood Sequence

Estimation (MLSE) equalizer. As such, it is straightforward to exploit frequency selectivity of the multipath channel with low-complexity receivers. This allows frequency-selective scheduling, as well as frequency-diverse scheduling and frequency reuse one-deployments. Furthermore, due to its frequency domain nature, OFDM enables flexible bandwidth operation with low complexity. Smart antenna technologies are also easier to support with OFDM, because each subcarrier becomes fl at faded and the antenna weights can be optimized on a per-subcarrier or block of subcarriers basis. In addition, OFDM enables broadcast services on a synchronized single frequency network (SFN) with appropriate cyclic prefix design. This allows broadcast signals from different cells to combine over the air, thus significantly increasing the received signal power and supportable data rates for broadcast services.

2.6.3 SC-FDMA

Single-carrier Frequency Division Multiple Access(SC-FDMA) also known as DFT (Discrete Fourier Transform) spread OFDMA was chosen to reduce Peak to Average Ratio (PAR), which has been identified as a critical issue for use of OFDMA in the uplink where power-efficient amplifiers are required in mobile devices. Another important requirement was to maximize the coverage. For each time interval, the base station scheduler assigns a unique time-frequency interval to a terminal for the transmission of user data, thereby ensuring intracell orthogonality. Slow power control, for compensating path loss and shadow fading, is sufficient as no near-far problem is present due to the orthogonal uplink transmissions. Transmission parameters, coding, and modulation are similar to the downlink transmission. The chosen SC-FDMA solution is based on using a cyclic prefix to allow high-performance and low-complexity receiver implementation in the eNodeB. As such, the receiver requirements are more complex than in the case of OFDMA for similar link performance, but this is not considered to be a problem in the base station. The terminal is only assigned with contiguous spectrum blocks in the frequency domain to maintain the single-carrier properties and thereby ensure power-efficient transmission. This approach is often referred to as blocked or localized SC-FDMA.

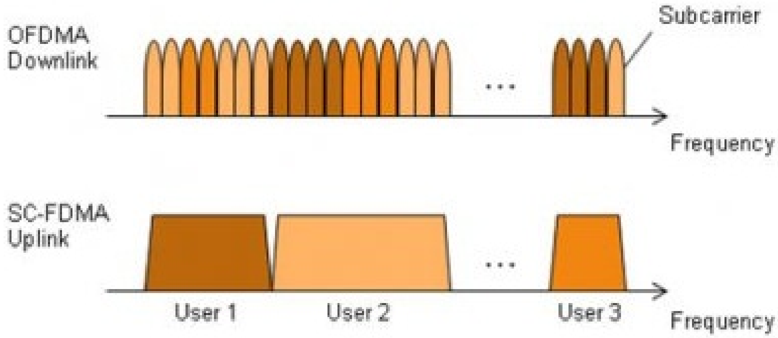


Figure 2.2: OFDMA and SC-FDMA

Chapter 3

Propagation Models

Propagation models

These are mathematical formulations used to characterize the behavior of the radio waves as a function of frequency, surrounding environment and distance.

Propagation models are main tools for path loss prediction in wireless systems which are daily in use for designing, planning and analyzing wireless communication networks.

Although there are lots of different kinds of propagation models that exist, none of them can be applied as the universal solution for all kinds of propagation conditions.

It is important to point out that there is no general method or algorithm that is universally accepted as the best propagation model. Each model can be useful for some specific environment and the accuracy of any particular technique or algorithm depends on the fit between the parameters available for the area concerned and the parameters required by the model.depends on system and terrain parameters

3.1 Path Loss Models

Path loss is the difference (in dB) between the transmitted power and the received power. Path loss is necessary to calculate link budget, is predicted using the radio propagation models, they are also referred to as path loss models.
Propagation models can be divided into three main groups: deterministic, statistical and empirical models. Deterministic models make use of the physical laws which determine radio wave propagation mechanisms for a particular location. These models require a 3-D data of the propagation environment. Accuracy of deterministic models is usually very high but on the expense of high computing complexity. Stochastic models, on the other hand, require the least information about the environment but provide the least accuracy. They model the environment as a series of random variables. Empirical models are based on extensive measurements and mainly give prediction of path loss. They are more often used in practice than statistical and deterministic propagation models, because of low cost and model simplicity with acceptable accuracy. The empirical propagation models which are suggested as good solutions, and we have also decided to use the the radio propagation models for our work. A comparison is made between different proposed radio propagation models that would be used for LTE, like Stanford University Interim (SUI) model, Okumura model, COST 231 Hata model, COST Walfisch-Ikegami & Ericsson 9999 model. The comparison is made using different system parameters (e.g. frequency, antenna height, etc.) and terrain parameters (e.g. urban area, suburban area, rural area).

3.1.1 SUI Model

Stanford University Interim (SUI) model is developed for IEEE 802.16 by Stanford University. It is used for frequencies above 1900 MHz. In this propagation model, three different types of terrains or areas are considered. These are called as terrain A, B and C. Terrain A represents an area with highest path loss, it can be a very dense populated region while terrain B represents an area with moderate path loss, a suburban environment. Terrain C has the least path loss which describes a rural or flat area. In Table 3.1, these different terrains and different factors used in SUI model are described.

parameter	Terrain A	Terrain B	Terrain C
a	4.6	4	3.6
b(1/m)	0.0075	0.0065	0.005
c(m)	12.6	17.1	20

Table 3.1: Different terrains and their parameters

The Path loss in SUI can be described as

$$PL = A + 10\gamma log(\frac{d}{d_o}) + X_f + X_h + S$$

where PL represents Path Loss in dBs, d is the distance between the transmitter and receiver, do is the reference distance (Here its value is 100), X_f is the frequency correction factor, X_h is the Correction factor for BS height, S is shadowing & γ is the path loss component and it is described as

$$\gamma = a - bh_b + (\frac{c}{h_b})$$

Where h_b is the height of the base station and a, b and c represent the terrain for which the values are selected from the above table.

$$A = 20log(\frac{4\pi d_o}{\lambda})$$

Where A is free space path loss while d_o is the distance between Tx and Rx and λ is the wavelength. The correction factor for frequency & base station height are as follows:

$$X_f = 6\log(\frac{f}{2000})$$

$$X_h = -10.8\log(\frac{h_r}{2000})$$

Where f is the frequency in MHz, and h_r is the height of the receiver antenna. This expression is used for terrain type A and B. For terrain C, the below expression is used.

$$X_h = -20\log(\frac{h_r}{2000})$$

$$S = 0.65(\log f)^2 - 1.3\log(f) + \alpha$$

Here,α = 5.2 dB for rural and suburban environments (Terrain A & B) and 6.6 dB for urban environment (Terrain C).

3.1.2 Okumura Model

Okumura model is one of the most commonly used models. Almost all the propagation models are enhanced form of Okumura model. It can be used for frequencies up to 3000 MHz. The distance between transmitter and receiver can be around 100 km while the receiver height can be 3 m to 10 m. The path loss in Okumura model can be calculated as

$$PL(dB) = L_f + A_{mm}(f,d) - G(h_t) - G(h_r) - G_{AREA}$$

Here L_F the free space path loss and it is calculated by the following expression:

$$L_f = -20\log\frac{\lambda}{4\pi d_o}$$

While $G(h_t)$ and $G(h_r)$ are the BS antenna gain factor and receiver gain factors respectively. Their formulas are as follows:

$$G(h_b) = 20\log(\frac{h_b}{200})$$

$$G(h_r) = 10\log(\frac{h_r}{3})$$

Where h_b and h_r are the heights of base station and receiver receptively. $A_{mm}(f,d)$ is called as median attenuation factor. Different curves for median attenuation factor are used depending on the frequency and the distance between the transmitter and receiver. The area gain G_{AREA} depends on the area being used and its graph along with median attenuation factor is depicted in Figure1.

3.1.3 Cost-231 Hata Model

COST-231 Hata model is also known as COST Hata model. It is the extension of Hata model and it can be used for the frequencies up to 2000 MHz. The expression for median path loss,
PLU, in urban areas is given by

$$PL(dB) = 46.3 + 33.9\log(f) - 13.82\log(h_b) - a(h_r) + [44.9 - 6.55\log(h_b)]\log(d) + c$$

Here, f represents the frequency in MHz, d denotes the distance between the transmitter & receiver, h_b & h_r the correction factors for base station height and receiver height respectively. The parameter c is zero for suburban & rural environments while it has a value of 3 for urban area. The function $a(h_r)$ for urban area is defined as:

$$a(h_r) = 3.2(\log(11.75h_r))^2 - 4.97$$

And rural & Surburban areas it is as follows

$$a(h_r) = (1.1\log(f) - 0.7)h_r - (1.58f - 0.8))$$

3.1.4 Cost-231 Walfisch-Ikegami Model

COST-231 Walfisch-Ikegami model is an extension of COST Hata model . It can be used for frequencies above 2000 MHz. When there is Line of Site (LOS) between the transmitter & receiver the path loss is given by the following formula:

$$PL = 42.64 + 26\log(d) + 20\log(f)$$

While in Non-Line of Sight (NLOS) conditions, path loss is given as:

$$PL = L_O + L_{RTS} + L_{MSD}$$

Where L_O is the attenuation in free-space and is described as:

$$L_O = 32.45 + 20\log(d) + 20\log(f)$$

L_{RTS} represents diffraction from rooftop to street, and is defined as:

$$L_{RTS} = -16.9 - 10\log(W) + 10\log(f) + 20\log(h_b - h_r) + L_{ori}$$

Here L_{ORI} is a function of the orientation of the antenna relative to the street a (in degrees) and is defined as:

$$L_{ori} = \begin{cases} -10 + .35a & \text{for } 0 < a < 35 \\ 2.5 + 0.075(a-35) & \text{for } 35 < a < 55 \\ 4 - 0.114(a-55) & \text{for } 55 < a < 90 \end{cases}$$

L_{MSD} represents diffraction loss due to multiple obstacles and is specified as:

$$L_{MSD} = L_{BSH} + K_A + k_D\log(d) + K_F\log(f) - 9\log(S_b)$$

Where

$$L_{BSH} = \begin{cases} -18\log(1 + h_t - h_b) & \text{for } h_t > h_b \\ 54 + 0.8(h_t - h_b)2d & \text{for } h_t \leq\leq h_b \\ & andd < o.5km \end{cases}$$

$$K_A = \begin{cases} 54 & \text{for } h_t > h_b \\ 54 + 0.8(h_t - h_b) & \text{for } h_t \leq h_b \\ & \text{and } d > 0.5km \end{cases}$$

$$K_D - \begin{cases} 18 + (\frac{h_t - h_b}{h_b}) & \text{for } h_t > h_b \\ 18 & \text{for } h_t \leq h_b \\ & \text{and } d > 0.5m \end{cases}$$

$$K_F = -4 + k(\frac{f}{924})$$

Here, $k = 0.7$ for suburban centers and 1.5 for metropolitan centers.

3.1.5 Ericsson 9999 Model

This model is implemented by Ericsson as an extension of the Hata model. Hata model is used for frequencies up to 1900 MHz. In this model, we can adjust the parameters according to the given scenario. The path loss as evaluated by this model is described as:

$$PL = a_0 + a_1 \log(d) + a_2 \log(h_b) + a_3 \log(h_b) log(d)$$

$$-3.2(\log(11.75))^2 + g(f)$$

Where

$$g(f) = 11.19 log(f) - 1.78(\log(f))^2$$

The values of a_0, a_1, a_2 and a_3 are constant but they can be changed according to the scenario (environment). The defaults values given by the Ericsson model are $a_0 = 36.2$, $a_1 = 30.2$, $a_2 = 12.0$ and $a_3 = 0.1$. The parameter f represents the frequency.

3.2 Comparison of propagation models

Model	Freq (MHz)	Dist (Km)	Height of BS(m)	Receiver height(m)	Urban P_L(dB)	Suburban P_L(dB)	Rural P_L(dB)
SUI	1900	5	30	3	72.17	59.83	38.20
SUI	1900	5	80	3	72.17	59.83	38.24
Okumura	1900	5	30	3	126.99	116.99	96.99
Okumura	1900	5	80	3	107.37	97.37	77.37
Ericsson	1900	5	30	3	144.31	178.38	203.26
Ericsson	1900	5	80	3	140.36	174.43	199.31
Cost 231	1900	5	30	3	194.03	189.32	189.32
Cost 231	1900	5	80	3	183.66	178.94	178.94
Walfish-Ikegami	1900	5	30	3	150.20	147.51	126.35
Walfish-Ikegami	1900	5	80	3	150.20	147.51	126.35

Table 3.2: Comparison of propagation models

Summary

The accumulated path losses for all the three urban, suburban and rural terrains are shown in Table 3.2. It can be seen from the table that SUI model has the lowest path loss prediction (72.17 dB) in urban environment for. While, COST 231 Hata model has the highest path loss (194.03 dB) in urban environment. In suburban environment, the results are the same. SUI model shows the lowest path loss of 59.83 dB & COST 231 Hata model has the highest path loss. In the Rural environment, the results show some difference, SUI still has the lowest path loss but for the rural case, Ericsson has the highest path loss.

Although SUI gave the best result, a disadvantage of this model is that it does not classify terrain type according to mostly used category , but it has its own classification (terrain types: A, B and C) as seen in table 3.1 this is because SUI model is developed for IEEE 802.16.

Chapter 4

Simulations and Analyses

In the deployment process of LTE, simulations are necessary to test and optimize algorithms and procedures. This has to be carried out on both the physical layer and in the network context. Simulation of the physical layer is done using a link level simulator and in the network context done using a system level simulator.
A MATLAB-based down-link physical-layer simulator for LTE [1] and a MATLAB computationally efficient LTE system level simulator [1] both from Vienna University of Technology, Austria were used for the Capacity and coverage Analysis.
Link level simulations allow for the investigation of channel estimation, tracking, and prediction algorithms, synchronization algorithms, Multiple-Input Multiple-Output (MIMO) gains, Adaptive Modulation and Coding (AMC) and feedback. Furthermore, receiver structures, modeling of channel encoding and decoding, physical layer modeling crucial for system level simulations and alike are typically analyzed on link level [4].
System level simulations analyze the performance of a whole network, It focus more on network-related issues, such as resource allocation and scheduling, multiuser handling, mobility management, admission control, interference management, and network planning optimization [5].

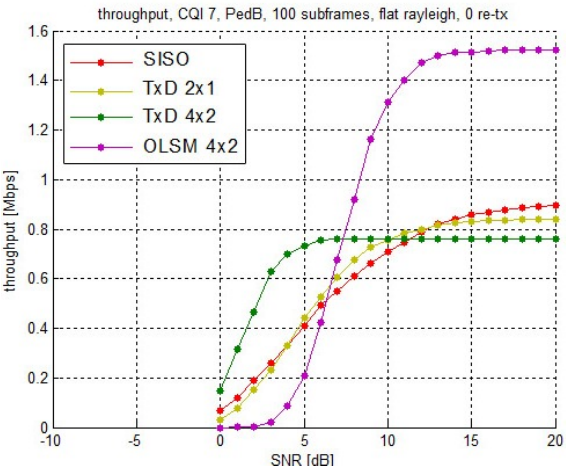
4.1 Link level Simulation

The coverage analysis was done using a Matlab based link level simulator for LTE. The link level simulations were carried out with the parameters stated below in Table 4.1 set for the simulator. We focused on the various changes in the various parameters as we change the criteria. The criterion we set was the number of subframes to simulate.

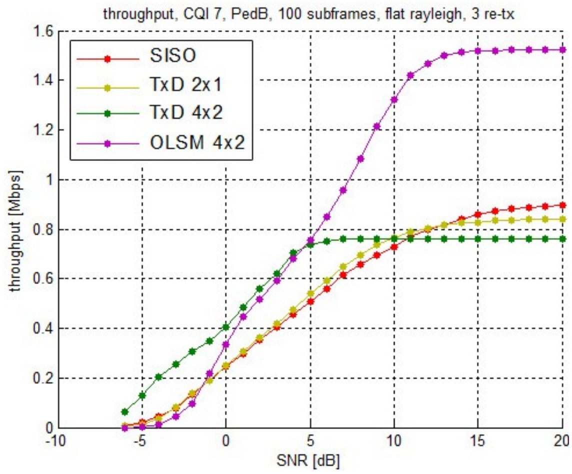
We obtained the results of the throughput vs SNR for the simulation with 100 subframes and 1000 subframes as shown in the Figures 4.1 and 4.2 respectively. Both simulations were done using flat rayleigh and Pedestrian B (PedB)channel, with zero and 3 retransmissions.

Parameter	Value
Number of User Equipments	1
Bandwidth	1.4MHz
Retransmissions	0 and 3
Channel type	Flat Rayleigh, PedB uncorrelated
Filtering	Block Fading
Receiver	Soft Sphere Decoder
Simulation length	100,1000 subframes
Transmit modes	SISO, TxD (2x1 and 4x2) and OLSM (4x2)

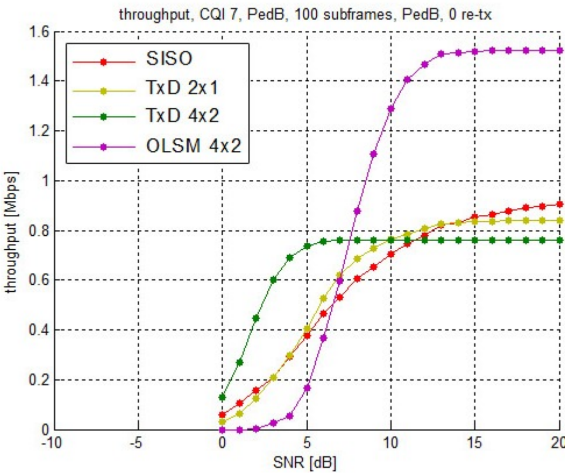
Table 4.1: Basic settings used for link level simulator



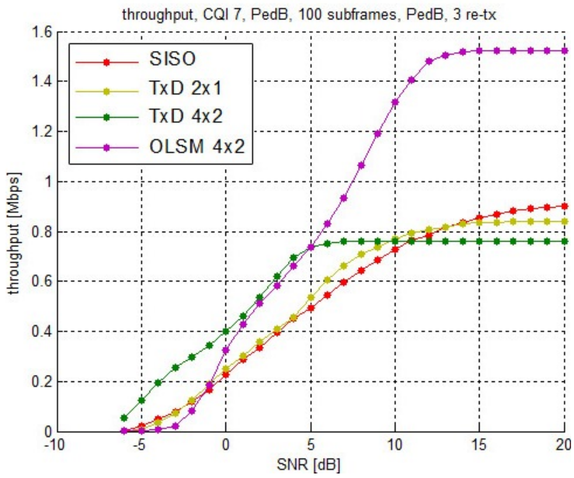
(a) Flat Rayleigh channel, no HARQ



(b) FlatRayleigh, 3 retransmissions



(c) PedB channel, no HARQ



(d) PedB channel, 3 retransmissions

Figure 4.1: Throughput Results For 100 Subframes

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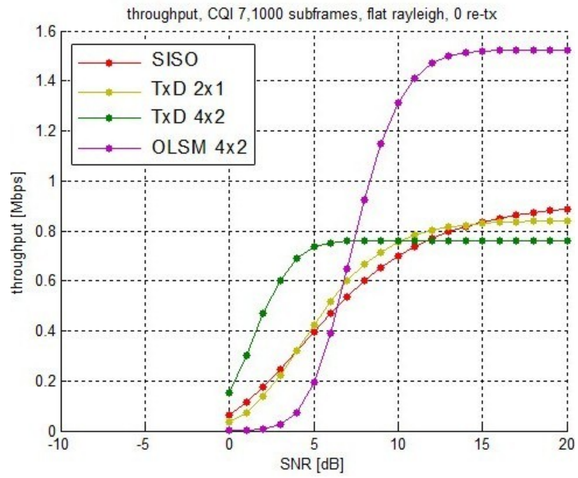
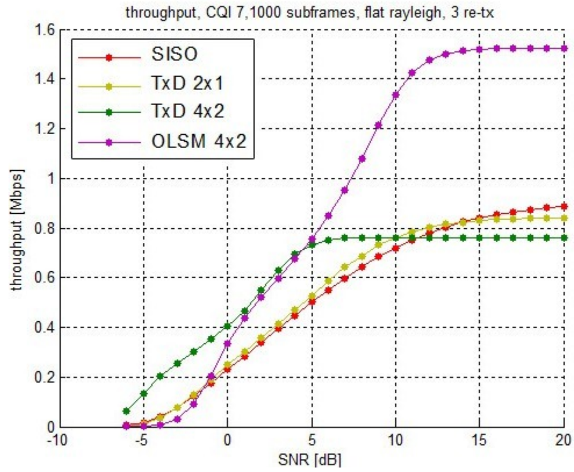
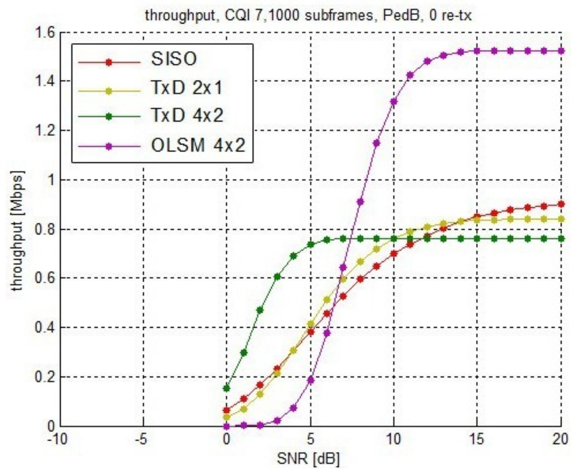


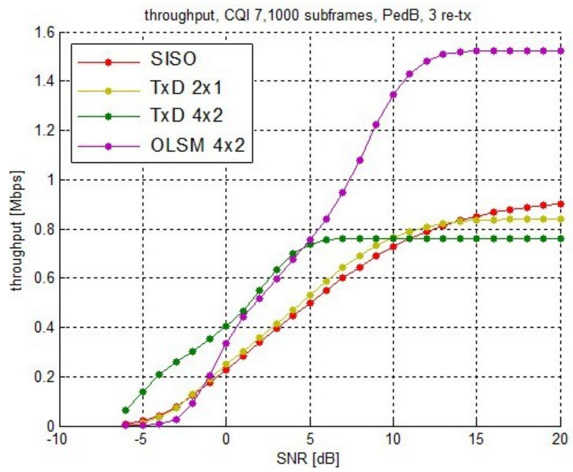
(a) Flat Rayleigh channel, no HARQ



(b) FlatRayleigh, 3 retransmissions



(c) PedB channel, no HARQ



(d) PedB channel, 3 retransmissions

Figure 4.2: Throughput Results For 1000 Subframes

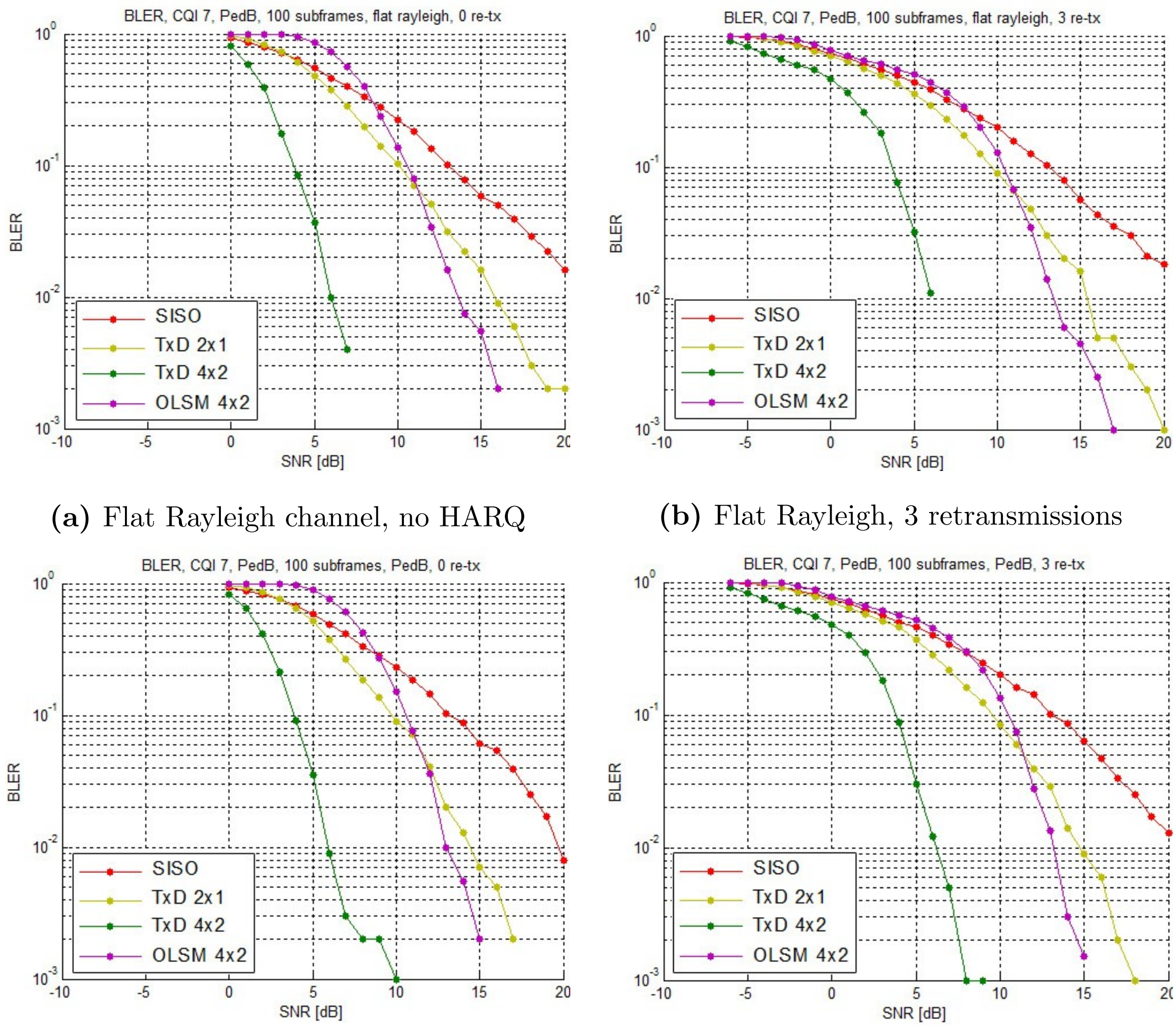
We observed the change in the results of throughput with the increase in the number of the subframes. It can be clearly observed that as we increases the number of subframes, the plots obtained are more smooth and realistic.

The result of the plots got with Flat Rayleigh channel are slightly similar to those got with PedB channel.

Considering the case of 1000 subframes, if we fix our SNR requirement to be at 15dB, we observe that the highest throughput (about 1.52Mbps) is achieved with MIMO scheme: Open Loop Spatial Multiplexing (OLSM) 4x2 mode and the least throughput (about 0.78Mbps) is got with Transmit diversity (TxD) 4x2 Mode.

Block Error Ratio(BLER) Result

The results of the Block Error Rate(BLER) were also got using both 100 subframes and 1000 subframes the plots can be seen in the Figure 4.3 and 4.1 respectively. Both simulations were done using Flat Rayleigh and Pedestrian B (PedB) channel with zero and 3 retransmissions.



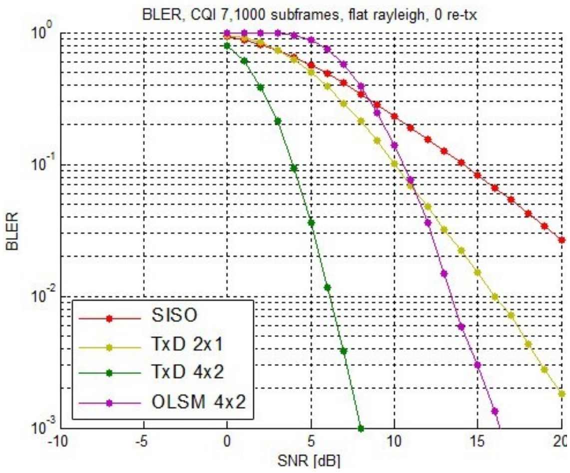
(a) Flat Rayleigh channel, no HARQ

(b) Flat Rayleigh, 3 retransmissions

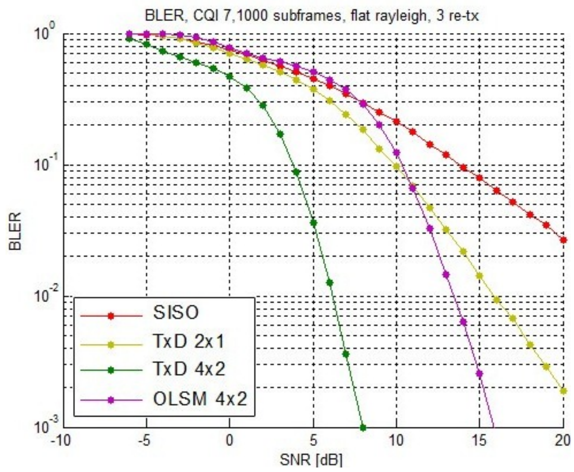
(c) PedB channel, no HARQ

(d) PedB channel, 3 retransmissions

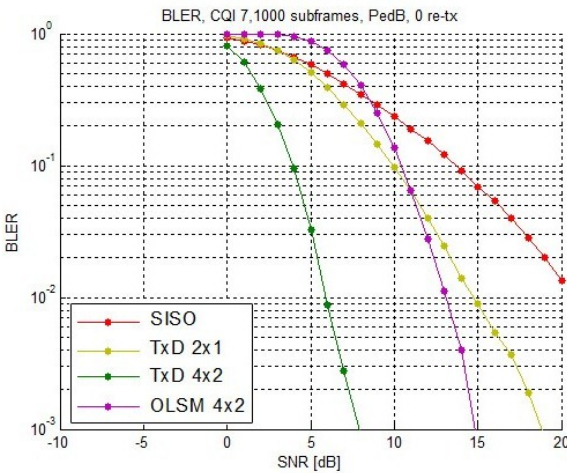
Figure 4.3: BLER result for 100 subframes



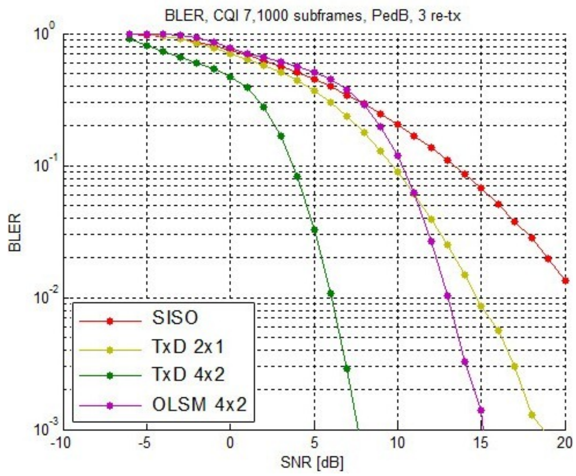
(a) Flat Rayleigh channel, no HARQ



(b) Flat Rayleigh, 3 retransmissions



(c) PedB channel, no HARQ



(d) PedB channel, 3 retransmissions

Figure 4.4: BLER results for 1000 subframes

In the case of the BLER, if we also consider the case of 1000 subframes as seen in Figure , if we fix our BLER to be at maximum at 10^{-1}, to achieve this target we need a least SNR of about 4dB which is achieved with TxD 4x2, this means less signal power is needed, the same BLER can also be achieved with a maximum SNR of 14dB given by SISO and this implies that more signal power has to be given.

Summary

From the simulation, we can observe that the highest throughput is achieved with MIMO scheme: Open Loop Spatial Multiplexing (OLSM) 4x2 mode, while the suitable BLER is achieved also with the MIMO scheme but with the transmit diversity (TxD) 4x2 Mode. The more the number of the subframes the more realistic the result is.

4.2 System level simulation

To determine the level at which predicted link level gains impact network performance, the capacity analysis was done using a MATLAB computationally efficient LTE system level simulator, the parameters set for the simulator were 21 cells which forms the region of interest, a simulation length of 50TTIs was used, Scheduler: Proportional fair, 2 transmitting and 2 receiving antennas, and MIMO Transmit mode: Closed loop spatial multiplexing. Case studies were carried out, simulation were attempted for 10, 15, 20 and 25 and 30 user equipments per cell. For every case study three user equipments at close, intermediate and far region were taken, summary of the obtained throughput (Mb/s) of the individual UE at different positions and the overall throughput are given in the Tables 4.2, 4.3, 4.4, 4.5, and 4.6.

Simulation for Fifteen UEs

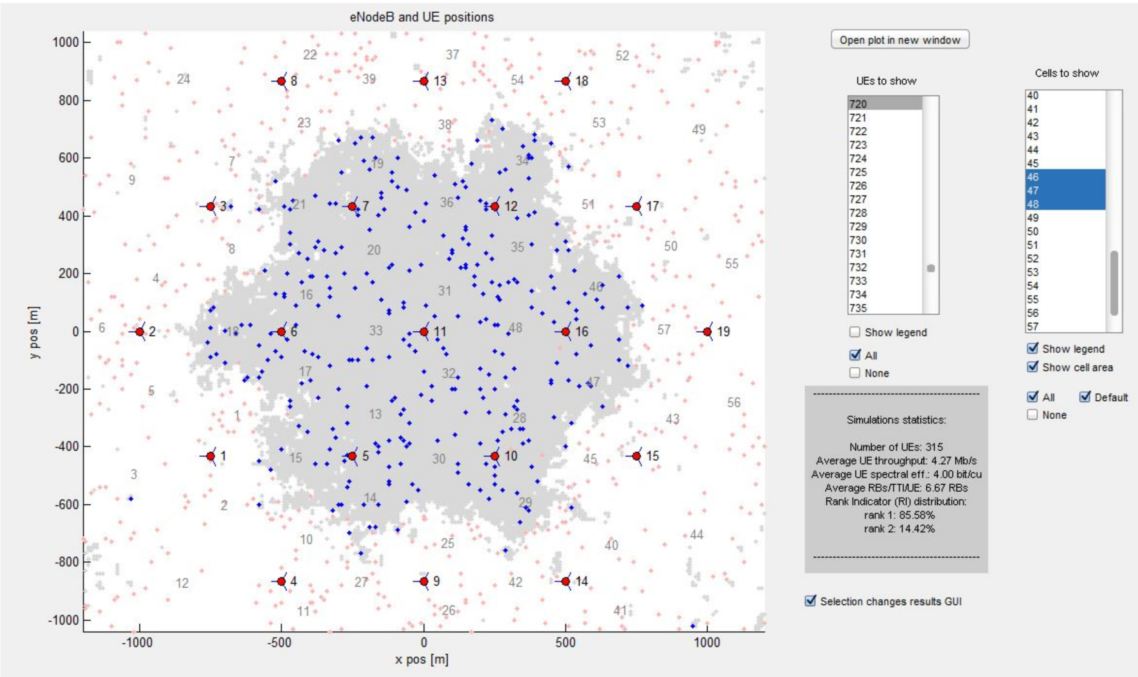


Figure 4.5: Region of Interest, eNodBs and UEs Distribution for 15 UEs per cell

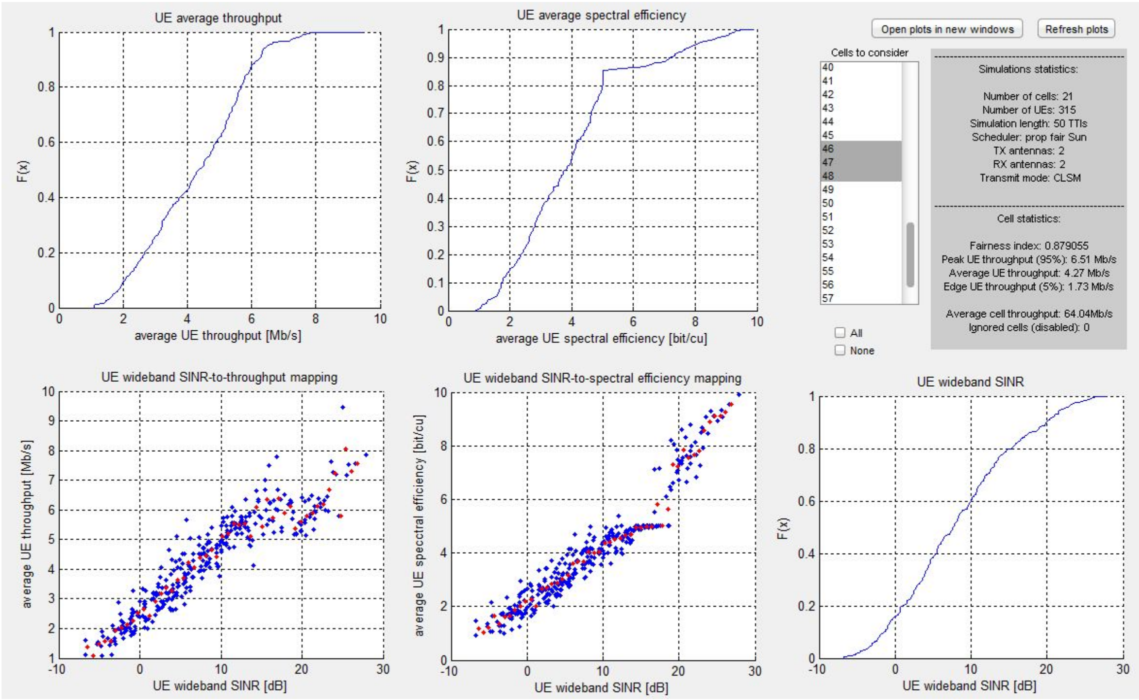


Figure 4.6: Throughput and aggregate results

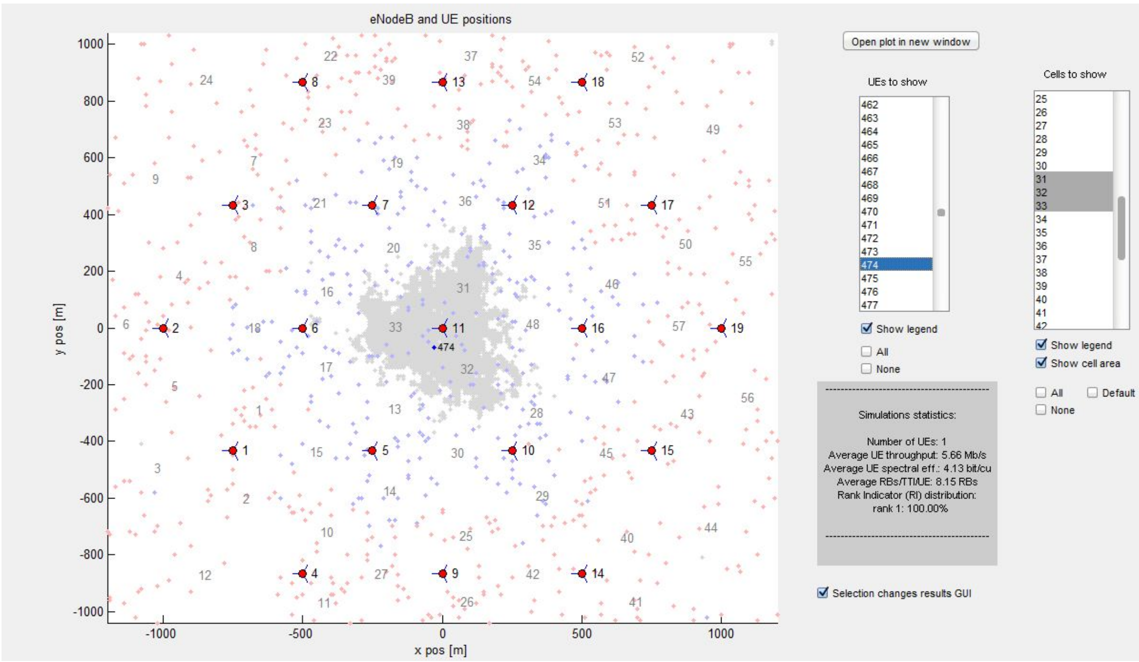


Figure 4.7: UE 474 at Close Region

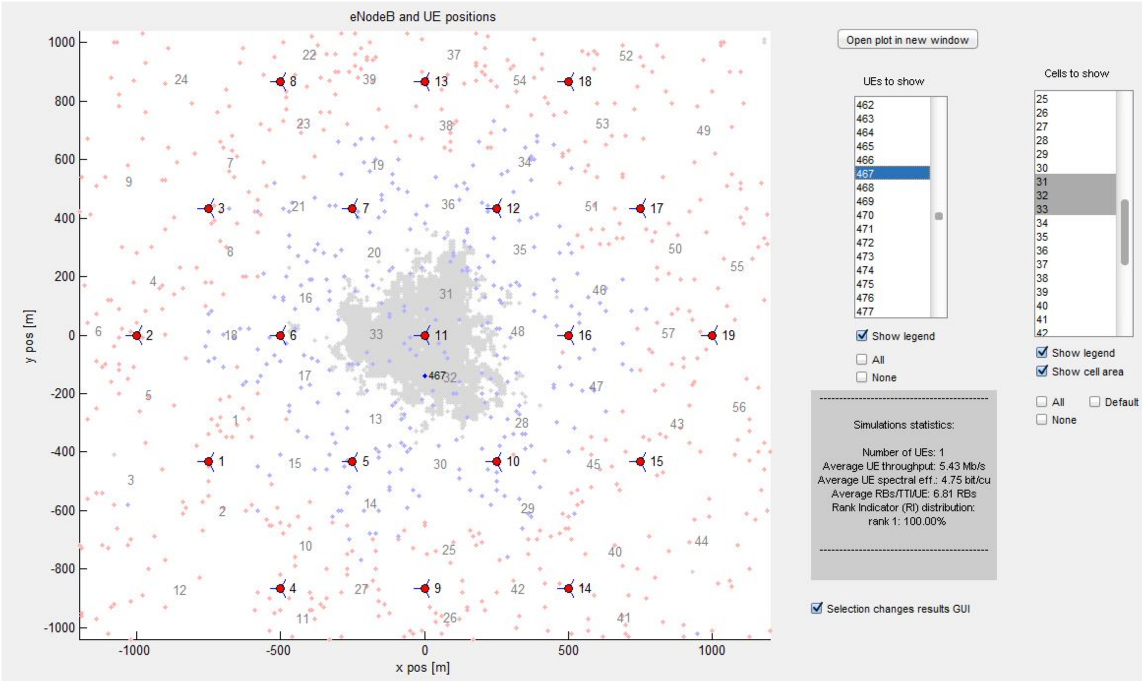


Figure 4.8: UE 467 at Intermediate Region

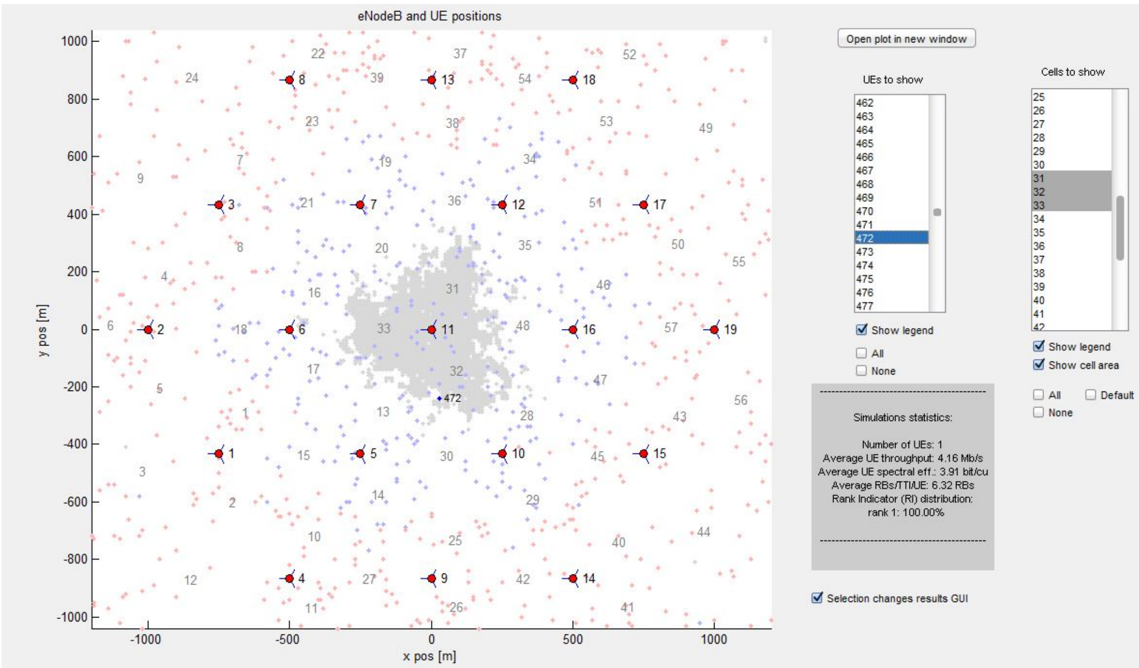


Figure 4.9: UE 472 at far Region

Simulation for Fifteen UEs

Case study for 15UE per cell with Average Throughput of 4.27Mb/s

User Equipments	Region	Average Throughput(Mb/s)
UE 474	Close	5.66
UE 467	Intermediate	5.43
UE 472	Far	4.16

Table 4.2: Case study with 15UEs per cell

Simulation for Ten UEs

Case study for 10UE per cell with average throughput of 5.87Mb/s

User Equipments	Region	Average throughput(Mb/s)
UE 311	Close	7.17
UE 315	Intermediate	7.83
UE 320	Far	5.68

Table 4.3: Case study with 10UEs per cell

Simulation for Twenty UEs

Case study for 20UE per cell with Average Throughput of 3.00Mb/s

User Equipments	Region	Average Throughput(Mb/s)
UE 631	Close	3.61
UE 656	Intermediate	2.12
UE 651	Far	1.38

Table 4.4: Case study with 20UEs per cell

Simulation for Twenty Five UEs

Case study for 25UE per cell with Average Throughput of 2.245Mb/s

User Equipments	Region	Average Throughput(Mb/s)
UE 790	Close	3.70
UE 792	Intermediate	3.23
UE 795	Far	2.33

Table 4.5: Case study with 25UEs per cell

Simulation for Thirty UEs

Case study for 30UE per cell with Average Throughput of 2.05Mb/s

User Equipments	Region	Average Throughput (Mb/s)
UE 978	Close	0.84
UE 973	Intermediate	2.79
UE 988	Far	2.33

Table 4.6: Case study with 30UEs per cell

Figure 4.6 shows the aggregate UE results, as well as some cell-related statistics. For the UE-related results, the active UEs from the selected cells are used to obtain the results, deactivated UEs are ignored.
Results of the Empirical Cumulative Distribution Function (ECDF) of the UE average throughput, ECDF of the UE average spectral efficiency and ECDF of the UE wideband SINR were obtained.
In the case of 15 UEs per cell, the average throughput is 4.27Mb/s, its corresponding CDF is 0.48 as seen in Figure 4.6, this same average throughput has a wideband signal to noise ratio (SINR) of about 8.0 and average spectral efficiency of 3.7 obtained at the same CDF.

4.3 Atoll Simulations

The capacity and coverage values were attempted in the simulations performed in Atoll together with help of other published data.

Throughput analysis

From system level simulation, assuming that the satisfactory throughput was achieved for 15 UE/cell.

Capacity calculation

Taking the population of Dhaka to 15.4 million people
Overbooking factor to be 50
Let 0.8% of the total population be covered
i.e. $0.8\% * 15400000 = 1,23,200$
Users to be supported simultaneously
$123200/50 = 2464$
No. of eNodeB for capacity $= 2464/(3 * 15) = 54.74556 \approx 55$

Atoll Predictions

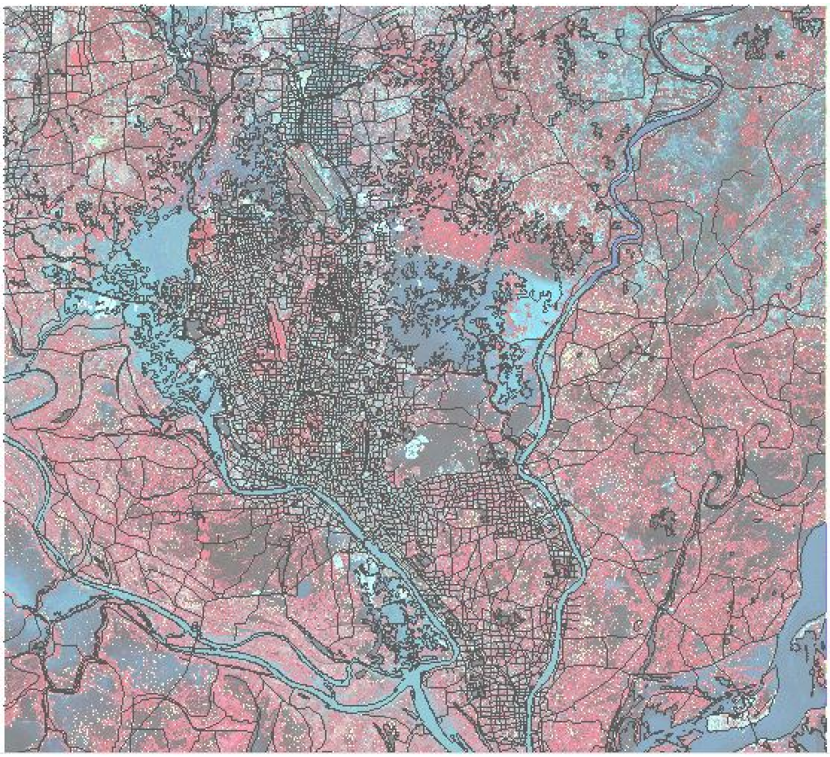


Figure 4.10: Dhaka Digital Map

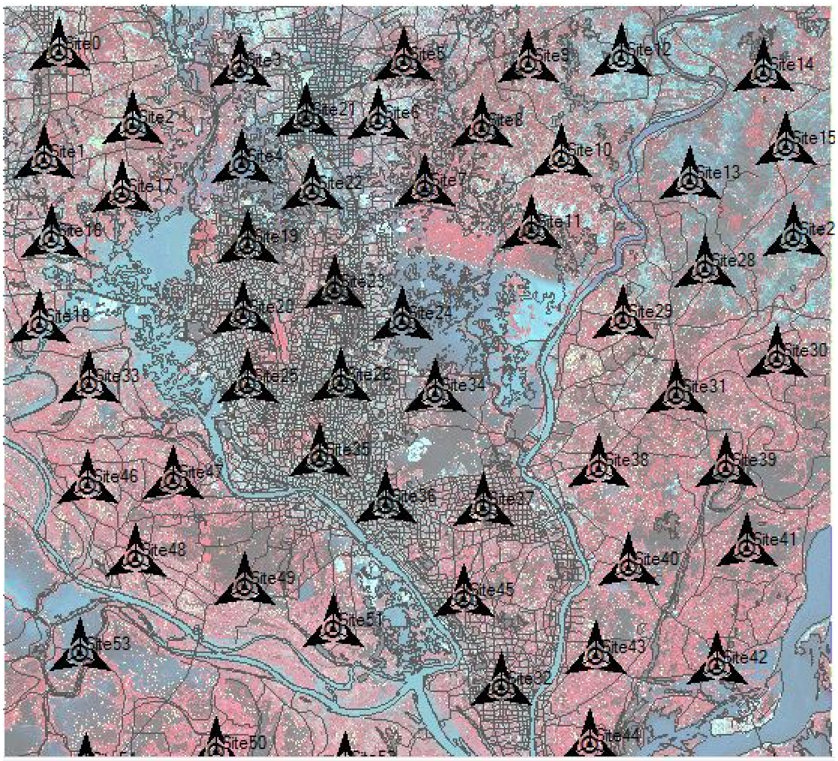


Figure 4.11: Transmitters placed on the Map

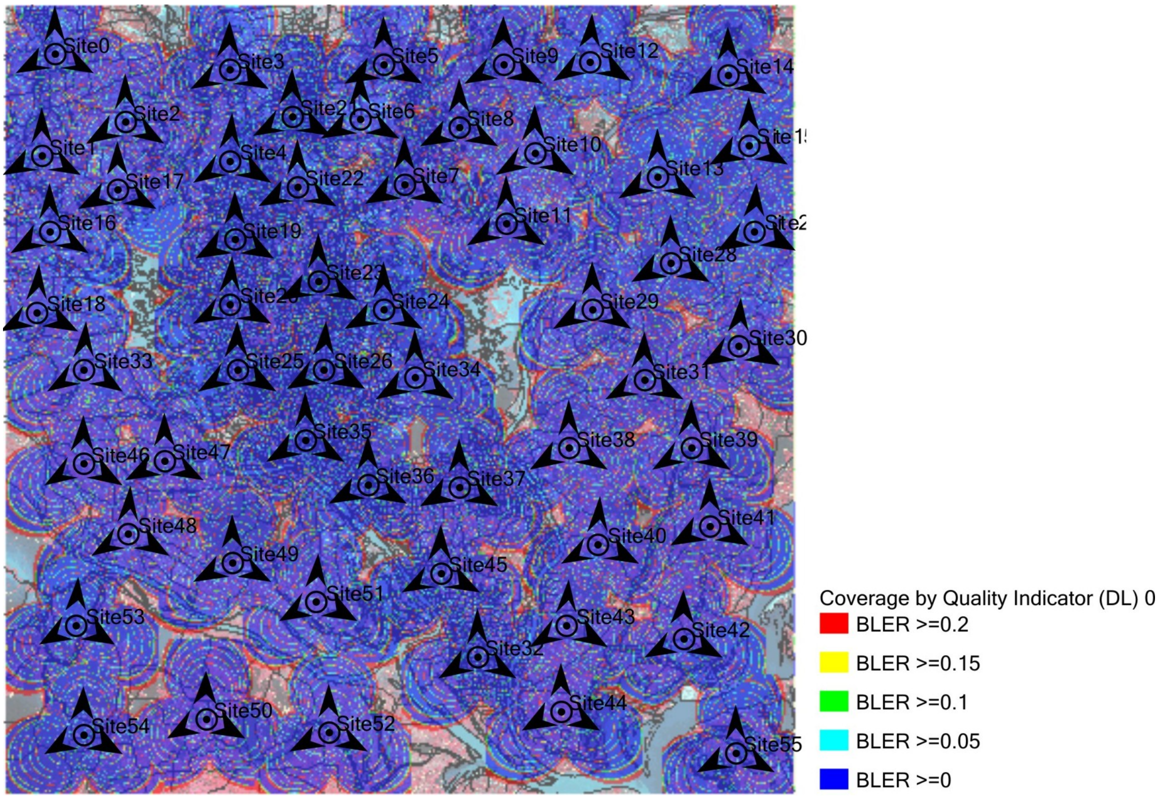


Figure 4.12: Coverage by Quality Indicator DL

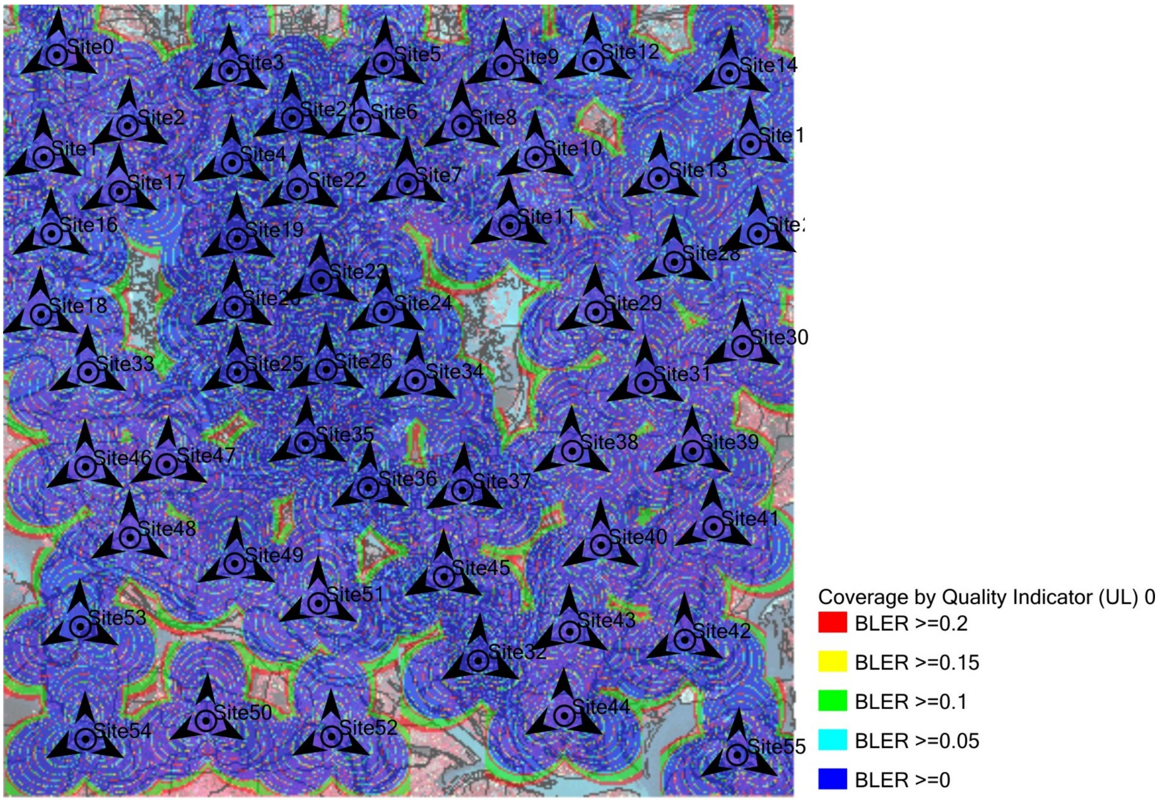


Figure 4.13: Coverage by Quality Indicator UL

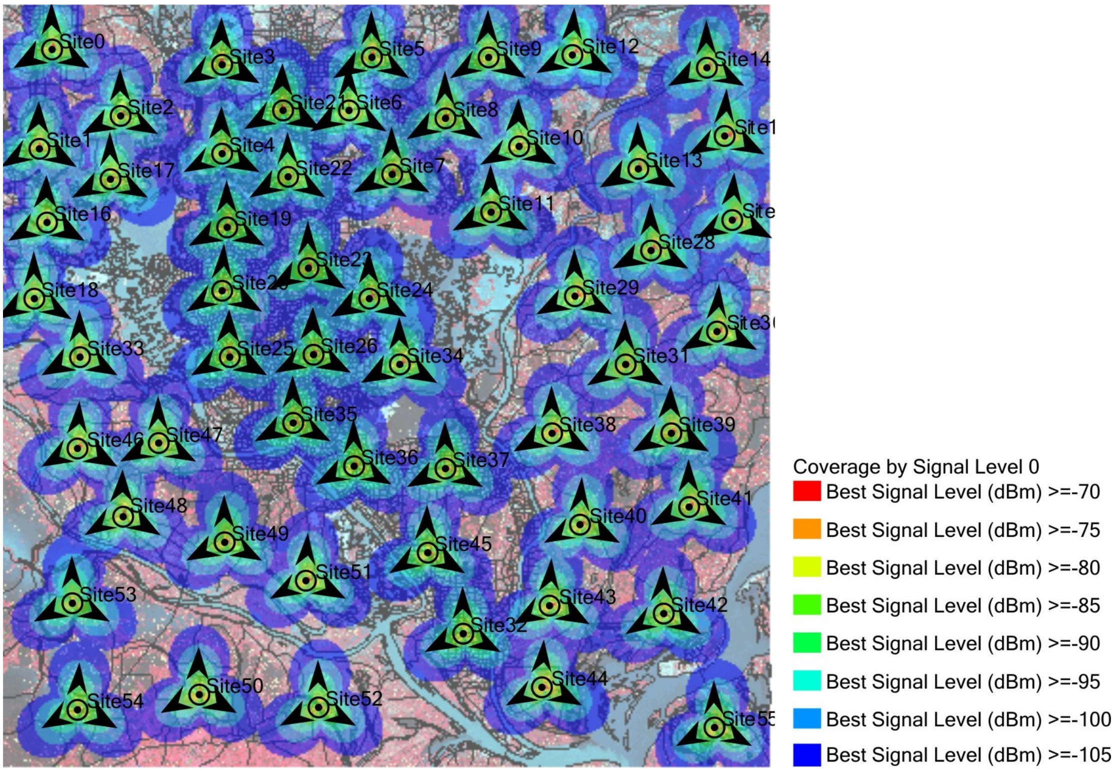


Figure 4.14: Coverage by Signal Level

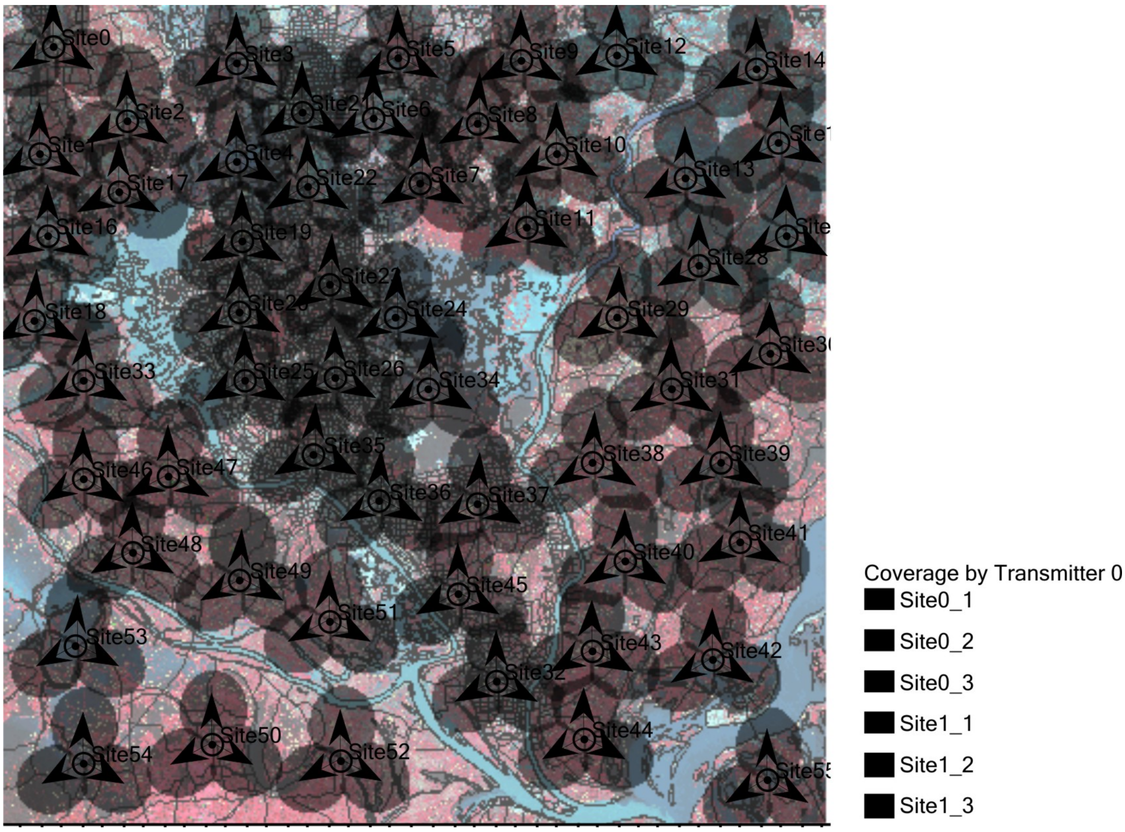


Figure 4.15: Coverage by Transmitter

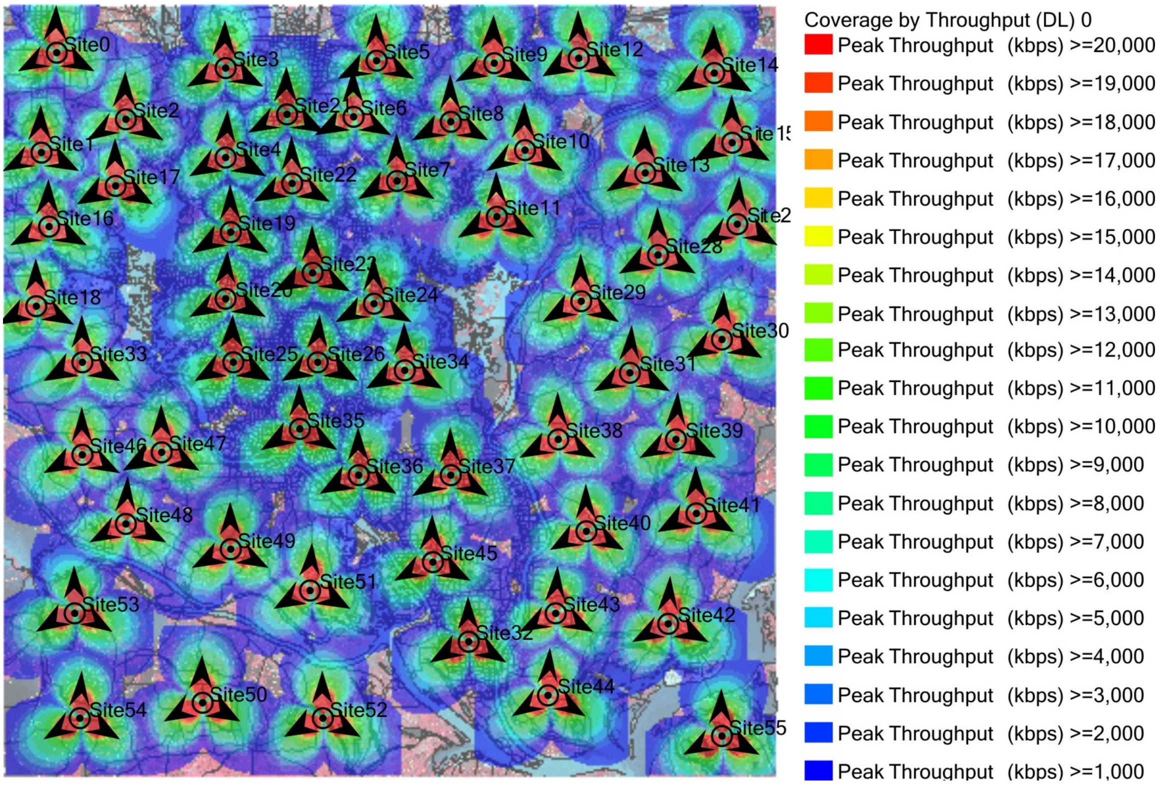


Figure 4.16: Coverage by Throughput DL

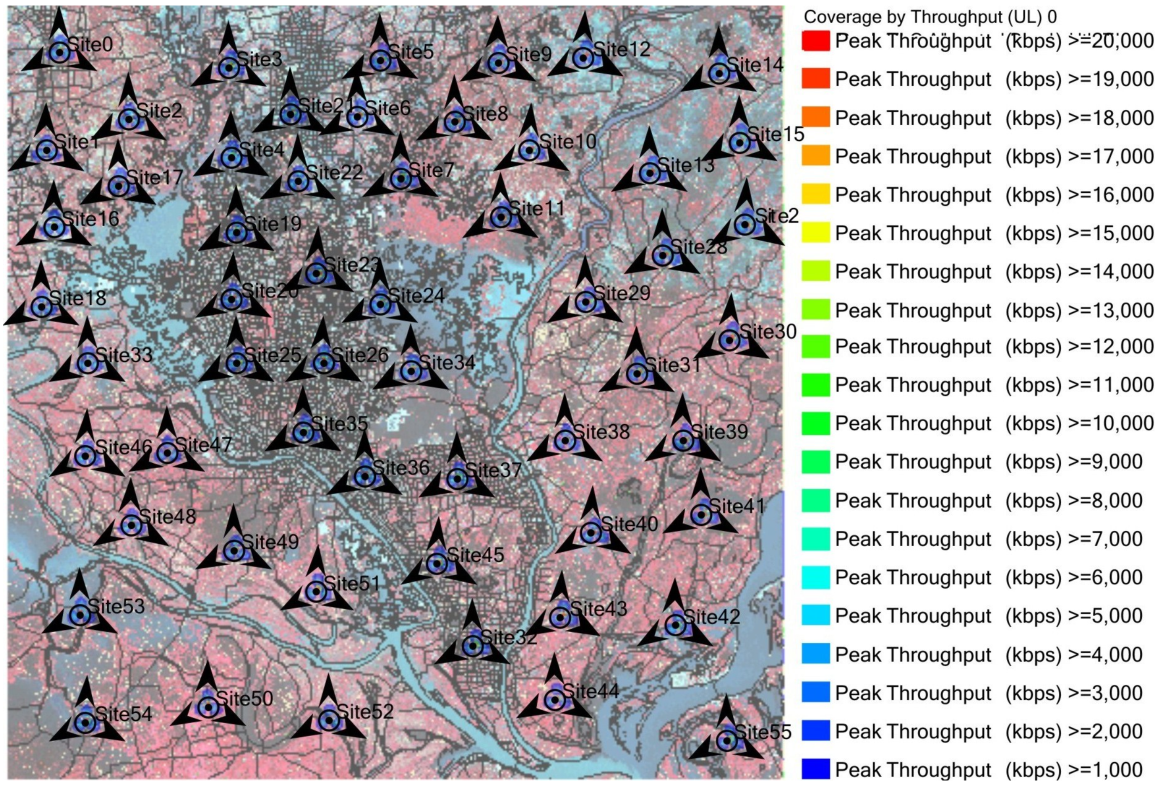


Figure 4.17: Coverage by Throughput UL

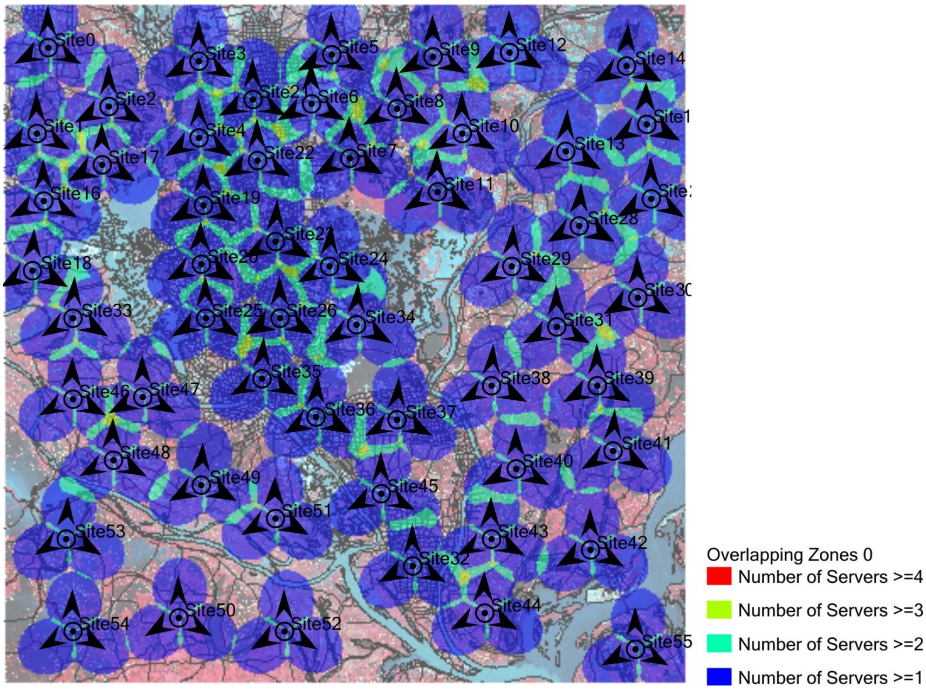


Figure 4.18: Overlapping Zones

Dhaka Traffic Map Simulations

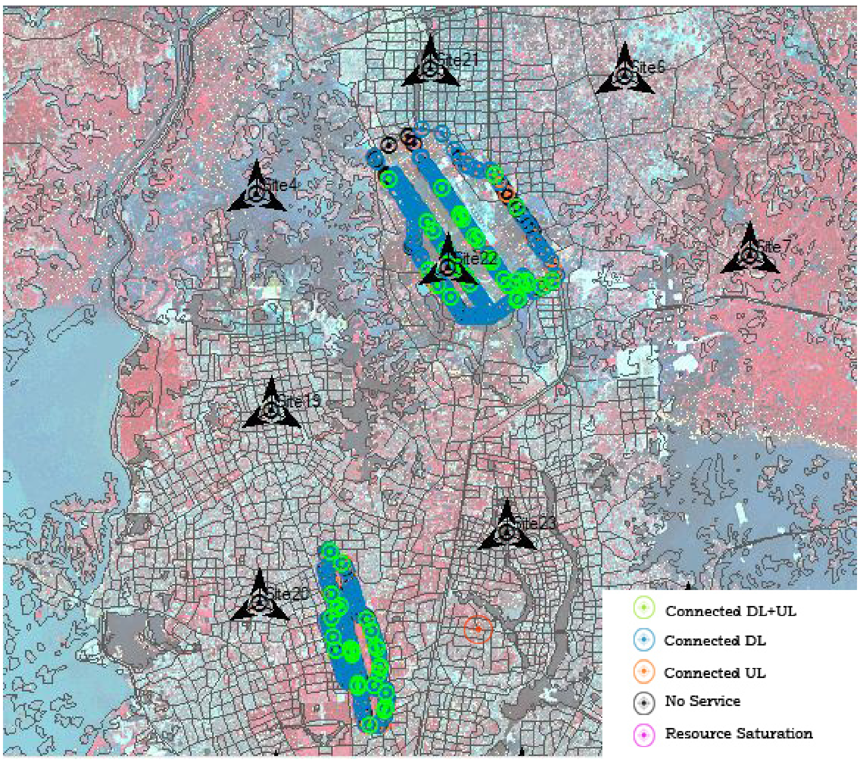


Figure 4.19: Dhaka Airport traffic Map after simulation

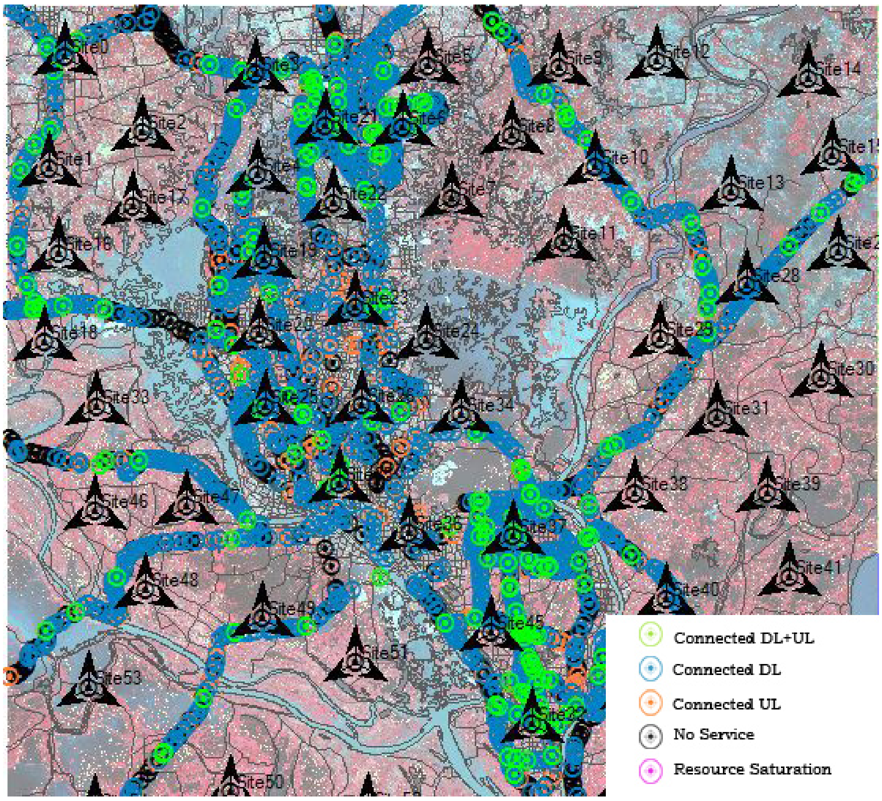


Figure 4.20: Dhaka Main road traffic Map after simulation

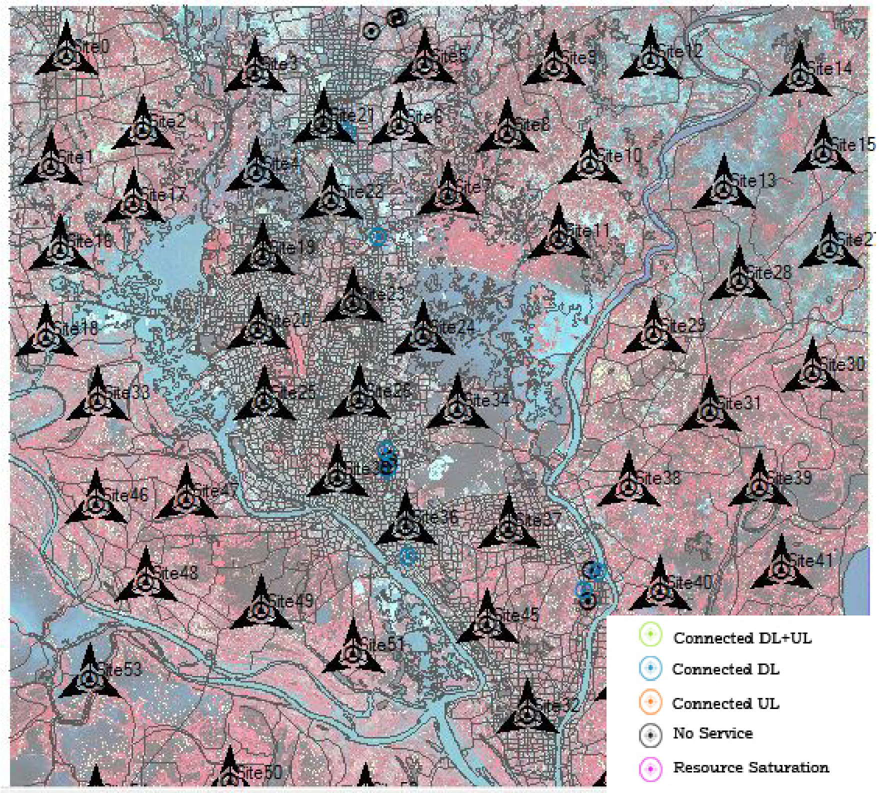


Figure 4.21: Dhaka Railway traffic Map after simulation

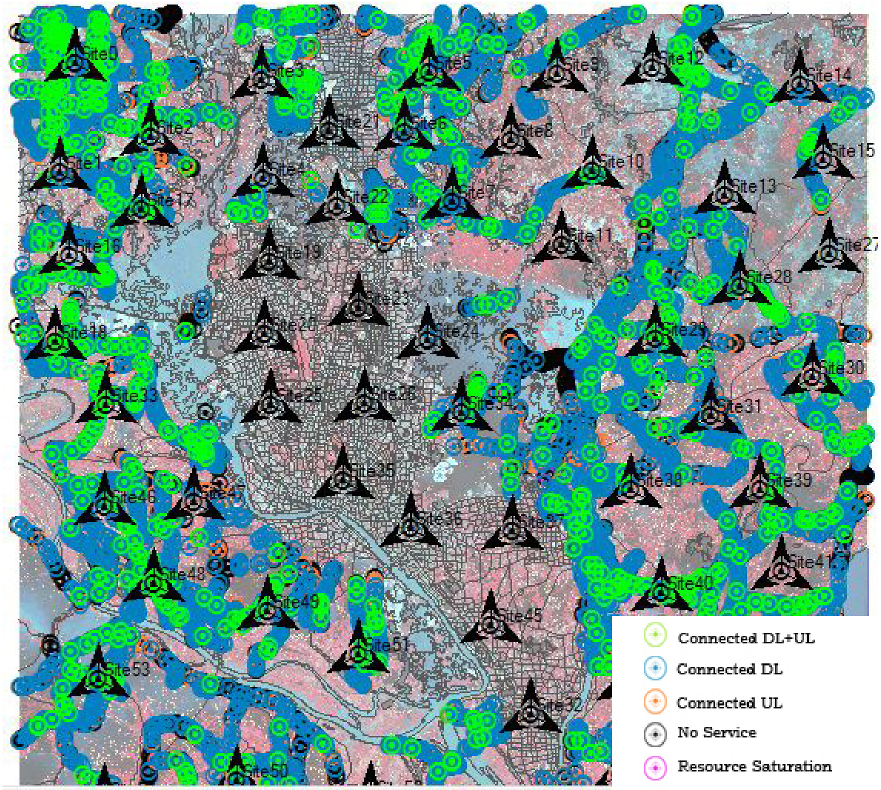


Figure 4.22: Dhaka Secondary road traffic Map after simulation

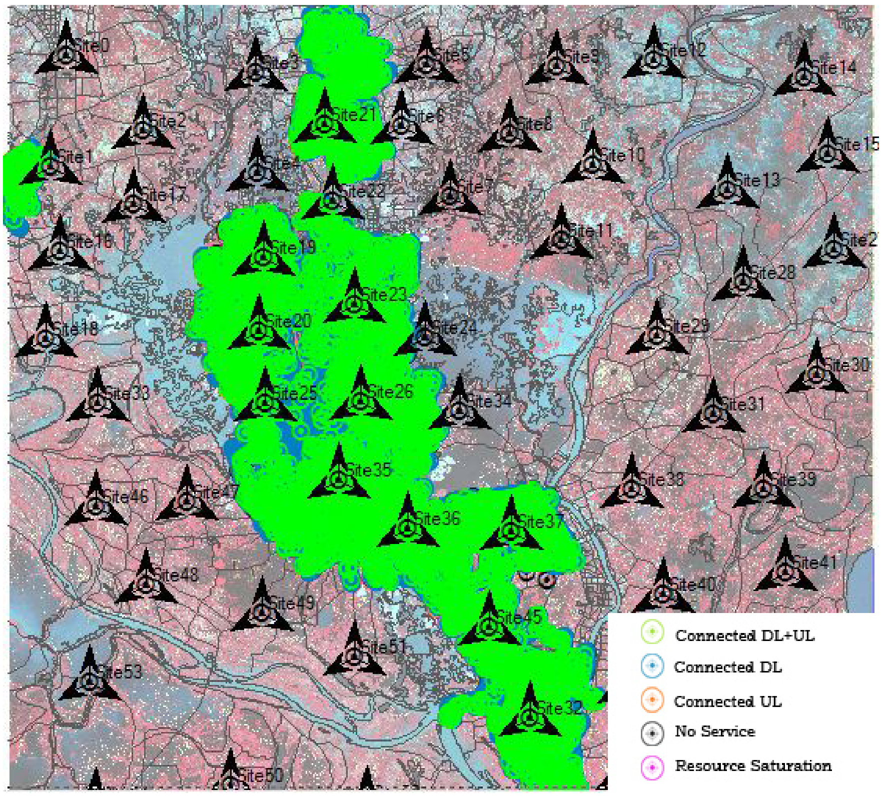


Figure 4.23: Dhaka Street traffic Map after simulation

Point Analysis Tool

The Point Analysis Tool is Used to Find The signal received by a User Equipment at some position from the Different Base station surrounding it.

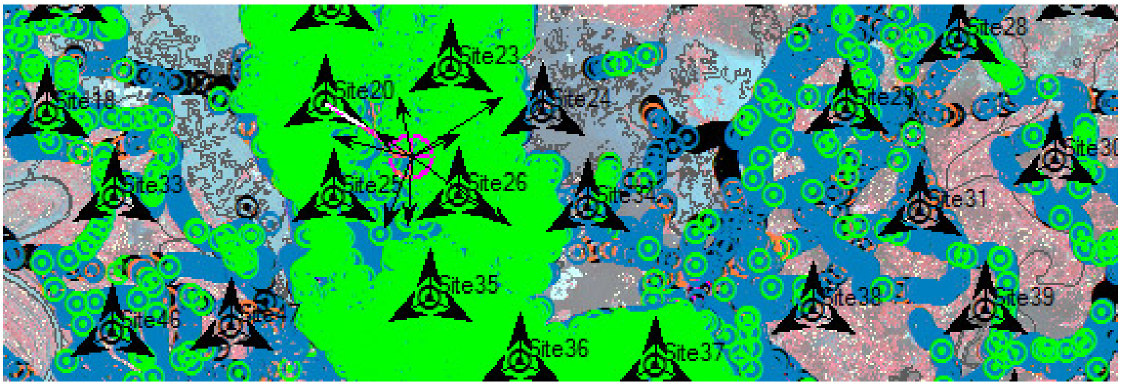


Figure 4.24: Point Analysis Tool Position

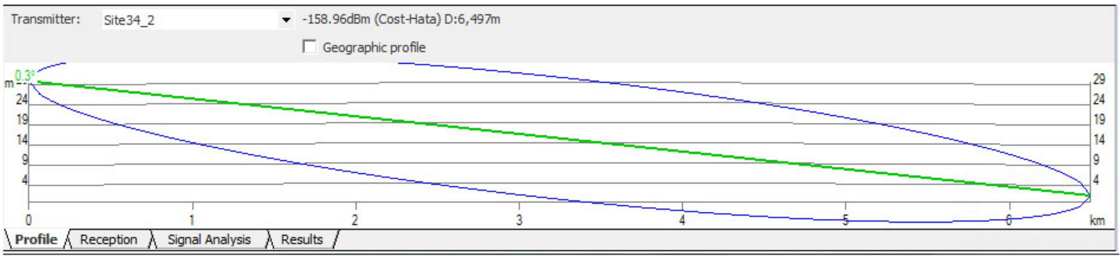


Figure 4.25: Point Analysis Tool Profile

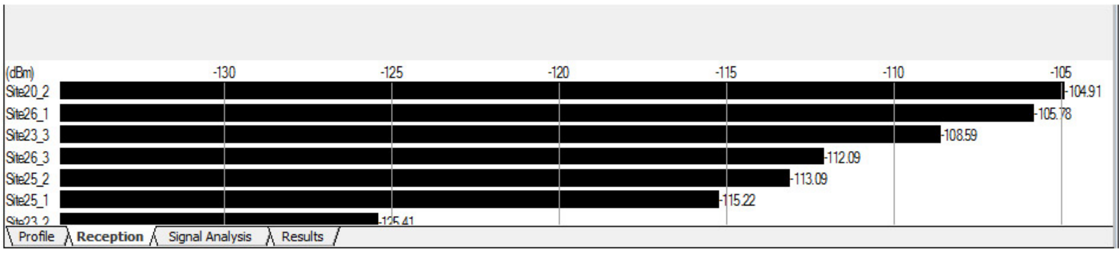


Figure 4.26: Point Analysis Tool Reception

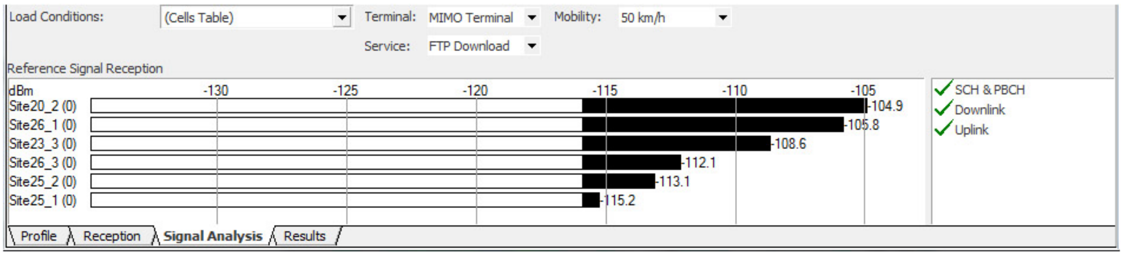


Figure 4.27: Point Analysis Tool Signal Analysis

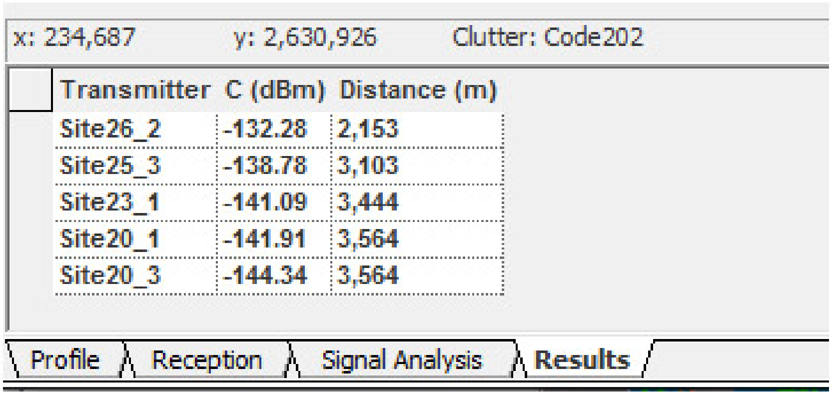


Figure 4.28: Point Analysis Tool Result

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Chapter 5

Conclusions and Future Work

The main objective of this investigation was to find out the radio parameters required for efficient radio planning through numerous simulations. The target capacity and coverage values obtained in Link level and system level simulations were attempted in the simulations performed in the Atoll planning tool using Dhaka city as a case study for the LTE radio network planning.

Some limitations were faced during the simulations as stated below:-

The current version of the link level simulator (LTE_Link_Level_1.7_r1089 September 2012) was only implemented for MIMIO modes: Transmit diversity, OLSM (Open loop spartial multiplexing) only and CLSM (Closed Loop Spartial Multiplexing) was not yet implemented,It could only support only one user equipment per eNodeB, multiple UEs could not be simulated.

The current version of the system level simulator (LTE_System_Level_1.6_r885 September 2012) also had a limitation of user equipments, in that it could only simulate to upto a maximum 30 user equipments.

Future Work

In the future, our work will be focusing on optimizing the LTE radio network plan we established so that it can perform up to the users' expectations.

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Appendix A

LTE data rate calculation

From the 3GPP specification:

1 Radio Frame = 10 Sub-frames

1 Sub-frame = 2 Time-slots

1 Time-slot = 0.5 ms (i.e1 Sub-frame = 1 ms)

1 Time-slot = 7 Modulation Symbols (when normal CP length is used)

1 Modulation Symbols = 6 bits; if 64 QAM is used as modulation scheme

Radio resource is managed in LTE as resource grid....

1 Resource Block (RB) = 12 Sub-carriers

Assume 20 MHz channel bandwidth (100 RBs), normal CP
Therefore, number of bits in a sub-frame
= 100RBs x 12 sub-carriers x 2 slots x 7 modulation symbols x 6 bits
= 100800 bits
Hence, data rate = 100800 bits / 1 ms = 100.8 Mbps
If 4x4 MIMO is used, then the peak data rate would be 4 x 100.8 Mbps = 403 Mbps.
If 3/4 coding is used to protect the data, we still get 0.75 x 403 Mbps = 302 Mbps as data rate.

Appendix B

Atoll

Atoll is an open, scalable, and flexible multi-technology network design and optimization platform that supports.
wireless operators throughout the network lifecycle, from initial design to densification and optimization.
Atoll supports the following technologies:
GSM/GPRS/EDGE

- UMTS/HSPA
- CDMA2000 1xRTT/EV-DO
- LTE
- TD-SCDMA
- WiMAX 802.16d
- WiMAX 802.16e
- Microwave Radio links

ATOLL GENERAL FEATURES

- MULTI TECHNOLOGY TOOL

  - Dedicated Project Templates & Propagation Models for all supported technology

- USER FRIENDLY GUI
  - Windows based tools
  - Easy to export/ import all required data
  - Simply support copy/paste all data
- FLEXIBILITY IN DATA MANAGEMENT
  - Display, Sorts & Filter
- WORKING SYSTEMS
  - Stand Alone .atl documents