ADAMA SCIENCE AND TECHNOLOGY UNIVERSITY
SCHOOL OF ELECTRICAL ENGINEERING AND COMPUTING

4G LTE Radio Network Dimensioning in Case of Adama City

By

Girma Abebe

Advisor

Dr. Feyisa Debo

A Thesis Submitted to the Adama Science and Technology University, School of Electrical Engineering and Computing, in Partial Fulfillment of the Requirements for the Degree of Masters of Science in Electrical Communication Engineering

March, 2019
Adama, Ethiopia

4G LTE Radio Access Network Dimensioning in Case of Adama City | 2019

4G LTE Radio Network Dimensioning in Case of Adama City

Submitted by

Girma Abebe Student	Signature	21/03/2019 Date

Approved by

1. Dr. Feyisa Debo Advisor	Signature	22/03/2018 Date
2. Dr. Sotyasto Mishra Internal Examiner	Signature	23/3/2019 Date
3. Dr. Eristu Yiggaw External Examiner	Signature	Mar. 21/2019 Date
4. Hinsermu Alemayehu Garbaba, Electrical Power and Control Engineering Department Head Head of Department	Signature	22/3/2019 Date
5. Dereje Tekilu Aseffa (PhD), Dean, School of Electrical Engineering & Computing Dean of SoEEC	Signature	22/03/2019 Date
6. ________ Dean of Post Graduate Studies	Signature	Date

Declaration

I hereby declare that the work which is being presented in the thesis entitled, 4G LTE Radio Network Dimensioning in Case of Adama City submitted to Adama Science and Technology University (ASTU) in partial fulfillment of the requirements for the degree Master of Science in Communication Engineering, is the result of my own research carried out under the supervision of Dr. Feyisa and all sources of materials used for the thesis have been fully acknowledged.

Girma Abebe ________________

Name Signature

Date of Submission: _________________

This thesis has been submitted for examination with my approval as a university advisor.

Dr. Feyisa Debo _______________

Advisor Signature

Acknowledgments

First let me grateful to almighty God for his blessings in my life. I would like to thanks ASTU for giving me chance and time to finish this work. I would like to express my sincere appreciation and gratitude to Dr. Feyisa Debo for being my advisor and for his valuable guidance and help during the process of this thesis. His continuous interest was a constant source of motivation for me throughout the work.

It is a pleasure to pay tribute to Ethio telecom staffs for providing me with important data that are relevant to this study. I am also so grateful to my families, friends and classmates, who always motivate and support me to complete this thesis. I am thankful for those who stood with me throughout my work, giving me encouragements as well as valuable helps all the way through.

Abstract

The recent increase of mobile data usage and emergence of new applications such as Online Gaming, mobile TV, Live Streaming Contents have greatly motivated the 3rd Generation Partnership Project (3GPP) to work on the Long Term Evolution (LTE). The LTE is the latest standard in the mobile network technology tree. It inherits and develops the GSM/EDGE and UMTS/HSPA network technologies and is a step toward the 4th generation (4G) of radio technologies designed to optimize the capacity and speed of 3G mobile communication networks. In this thesis, the LTE system capacity and coverage are investigated and a model is proposed on the base of the Release 8 of 3GPP LTE standards. After that, the frequency planning of LTE is also studied. The results cover the interference limited coverage calculation, the traffic capacity calculation and radio frequency assignment. The implementation is achieved on the ATOLL software platform for the LTE Radio Planning.

Keywords: 3GPP, Capacity, Coverage, Frequency Planning, LTE

List of Abbreviations

3GPP	3rd Generation Partnership Project
4G	4th Generation
AMC	Adaptive Modulation and Coding
BH	Busy Hour
BLER	Block Error Rate
CCU	Cell Center User
CEU	Cell Edge User
CP	Cyclic Prefix
CQI	Channel Quality Indicator
DFT	Discrete Fourier Transform
EDGE	Enhanced Data Rates for GSM Evolution
EUTRA	Evolved UMTS Terrestrial Radio Access
E-UTRAN	Evolved UMTS Terrestrial Radio Access Network
FDD	Frequency Division Duplex
FDMA	Frequency Division Multiple Access
FFT	Fast Fourier Transform
FRF	Frequency Reuse Factor
GSM	Global System for Mobile Communication
HSPA	High Speed Packet Access
LTE	Long Term Evolution
MCS	Modulation and Coding Scheme
MIMO	Multiple Input Multiple Output
MU-MIMO	Multi User MIMO
OFDM	Orthogonal Frequency-Division Multiplexing
OFDMA	Orthogonal Frequency-Division Multiple Access
PAPR	Peak-to-Average Power Ratio
PBCH	Physical Broadcast Channel
PL	Path Loss
PRACH	Physical Random Access Channel
PSS	Primary Synchronization Signal
PUCCH	Physical Uplink Control Channel
PUSCH	Physical Uplink Shared Channel
QAM	Quadrature Amplitude Modulation
QPSK	Quadrature Phase Shift Keying
RB	Resource Block
REFSENS	Reference Sensitivity
RF	Radio Frequency
SC-FDMA	Single-Carrier Frequency-Division Multiple Access
SFR	Soft Frequency Reuse

SINR	Signal to Interference and Noise Ratio
SNR	Signal to Noise Ratio
SSS	Secondary Synchronization Signal
SU-MIMO	Single User MIMO
TDD	Time Division Duplex
TDMA	Time Division Multiple Access
TTI	Transmission Time Interval
UE	User Equipment
UMTS	Universal Mobile Telecommunications System
WCDMA	Wideband Code Division Multiple Access

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER ONE

Introduction

These days, the rapid growth of mobile communication and technologies made an outstanding development not only to ease our daily lives but also to make an important contribution to the persistent computing environments. Starting from the first Generation of cellular network, which is analog communication to the ones that are being developed now like LTE, LTE advance and WIMAX 802.16m, the technology is expanding in higher quality and accessibility [1]. Besides the end user expectations have grown from conventional mobile voice traffic to additional simple text communication and even to live streaming services and internet access which greatly affecting the traffic demands. All these requirements motivated the need for new emerging system architectures and management with issues related to quality of service, capacity and coverage. For this reason, the 3rd Generation Partnership Project (3GPP), which is currently the dominant specifications development group for mobile radio systems in the world, started to work on the upcoming new standard called, the Long-Term Evolution (LTE).

LTE is the evolution of the Third-generation of mobile communications to the Fourth-generation technology that is essentially an all IP broadband Internet system with voice and other services built to ensure 3GPP's competitive edge over other cellular technologies. On the contrary to the circuit-switched 3GPP technologies like GSM and WCDMA, which are currently serving nearly 85% of the global mobile subscribers, LTE has been designed to be a high data rate and low latency system supporting only packet switched services. It aims to provide seamless connectivity between two end user equipment (UE) without any disruption to the services in use during mobility. Based on the LTE Rel.‟8 standardization document of 3GPP, the technology enables flexible transmission bandwidth selection between 1.4 MHz and 20 MHz depending on the available spectrum which significantly enhances the service capacity compared to previous cellular technologies [2].

These and other significant performance achievements rely on recently introduced physical layer technologies, such as Orthogonal Frequency Division Multiplexing (OFDM), Multiple-Input Multiple-Output (MIMO) systems and Smart Antennas. Furthermore, as a result of these technologies minimization to the system and UE complexities; its co-existence with other 3GPP and non- 3GPP Radio Access Technologies (RATs) and straightforward planning and deployment approaches were basically achieved [3], [4].

Thus, books, literatures and documentation are available describing the technological advancement, technical standardizations and basic planning and deployment specifications. The planning approach of LTE is divided depending upon the system architecture of LTE as Radio access network and core network planning. LTE Radio access network planning refers to analytical approach which is based on algorithmic formulation and focuses on the radio engineering aspect of the planning process, i.e., on determining the locations, estimated capacity and size of the cell sites (coverage and capacity planning), and assigning frequencies to them by examining the radio-wave propagation environment and interferences among the cells.

Background

LTE is launched 2014 in Addis Ababa with improved performance in service delivery and system simplicity. Ethio telecom recent telecom expansion project (TEP) has a vision in deploying LTE in rest of Ethiopia and our government also signed contract agreement with Huawei, ZTE and Ericsson and upgrade cellular network to 3G, which gives an easy and smooth transition to 4G network.

However mobile customers are dissatisfied by the existing network quality of service (QoS). The main reason behind this is that, proper radio network planning in Ethiopia as a whole and Adama in particular, is not taken in to account during the radio access network planning phase of the existing network deployment.

Even though there is a responsible department for radio network planning in ethio telecom, the trend in this regard is not satisfactory. Ethio telecom has licensed Mentum Planet planning software for radio network planning, however; in practical speaking, ethio telecom's participation is limited on providing initial input about customers from the existing VLR. Vendor's are using a customized radio link budget software which doesn't show whether necessary system, transmitter and receiver parameters are considered or not per 3GPP standards. And when we see the result of the path loss compared with standards it is too small so that the area to be covered by a single base station is small which requires more sites per the entire area this may be vendor's strategy to sell more telecom equipment's for their clients.

Whoever did the planning in our country, the radio network planning problem is clearly seen by the congestion happened immediately after deployment in Addis Ababa and other cities, and customers are dissatisfied by the coverage, capacity and quality of service here in Adama city. Even after the planned network deployed, the regional project office is requested to choose areas to build additional new sites without conducting scientific planning procedures.

Hence this is the background information that motivates me to do proper LTE radio network dimensioning for Adama city.

Thesis Layout

The thesis work is done in such a way that it gives a clear flow and understanding regarding LTE coverage and capacity dimensioning. Chapter one presents a short introduction with problem explanation, the objectives, methodology and scope. Chapter two presents literature review and theoretical background of LTE for the study. Chapter three focuses on LTE Radio Network dimensioning Process starting from site survey to site count. Chapter four is all about Analysis and Results. Chapter five covers the Simulation result and analysis. Finally, conclusions are given followed by points of future work in Chapter six.

1.1. Statement of the Problem

In cellular network, there are sequential steps for radio network planning. These steps start from simple analysis to computer aided mathematical computation; i.e., from nominal planning state to detail planning and then optimization. The system to be deployed is a new technology, the first step in RAN planning, i.e., the nominal planning, is considered as critical point since it gives the first rough estimation to coverage and capacity.

In recent years the government of Ethiopia made telecom infrastructures expansion projects throughout the country. And Ethio telecom is the only service provider and responsible for every telecom services in Ethiopia. By this time the company has both fixed and radio access networks widely. One thing that has been clearly seen during the problem identification is that, the continuous demand on high data rate and multimedia services here in Adama is growing however; the service quality is far from being perfect. This is due to the coverage and capacity limitation in the existing network.

The problem being addressed in my study is regardless of the cellular network infrastructures built in Adama, the existing cellular network coverage and its capacity is limited to fulfill advanced customer service requirements. Hence the study will address the problem of Adama city cellular network on the basis of coverage, capacity and QoS. Hence proper LTE radio network planning can solve the problem.

LTE nominal radio network planning is done basically using link budget calculation to estimate the cell size and theoretical traffic and throughput calculation for capacity estimation. Thus, the major problem in the obtained result is that this result don't represent the real values but In order to make this RAN planning stage more accurate, the inclusion of the terrain model has to be considered in simple manners, so that improvement in the result is obtained while the simplicity of the process is still maintained.

To properly resolve this problem and perform the LTE radio network planning, a consideration of certain site is important where in this project Adama City is considered. In the other hand, the city is widely populated with GSM base station antennas and repeaters of (2G and 3G) company and at the same time the service quality is far from being perfect. This might be because of improper radio network planning or optimization done.

1.2. Objective

1.2.1. General Objective

The main aim of this work is to study and describe the nominal radio access network planning in LTE. It is the intension of the work to understand the different inputs and outputs parameters in LTE dimensioning.

1.2.2. Specific Objective

Specifically

- ✓ Coverage dimensioning
- ✓ Capacity dimensioning
- ✓ Site Count
- ✓ Simulating the model with ATOLL planning software

1.3. Literature Review

There have been several works done on the area of GSM, UMTS and LTE dimensioning and planning. Some of the recently published articles related to this work are reviewed as follows:

Yiming Sun, 2004 [5]: Radio Network Planning for 2G and 3G. He deals with the procedure of how to carry out the radio network planning for 2G and 3G systems. The general steps and methods for wireless radio network planning are first addressed. Then the issue of radio network planning is discussed with special focus on the 2G and 3G networks, as well as a comparison between 2G and 3G radio network planning processes which is summarized at the end.

Reshma Begum Shaik, T.Krishna Chaitanya, 2012 [6]: Simulation of GSM Mobile Networks Planning Using ATOLL Planning Tool, International Journal of Engineering and Innovative Technology (IJEIT). They showed that planning of GSM networks with ATOLL.

Anteneh Temesgen, 2015 [7]: WCDMA Radio Network Dimensioning and Planning for the case of Bahir Dar City. He covers WCDMA radio coverage and capacity dimensioning and planning. He took demographic data for capacity estimation and he considered cell load and calculated throughput in detail for capacity dimensioning.

A. Benjamin Paul & Sk.M. Subani, 2012 [8]: Code Planning of 3G UMTS Mobile Networks using ATOLL Planning Tool", International Journal of Engineering Research & Technology (IJERT). This paper involves on simulation exercise on planning of 3G UMTS network with the help of Atoll planning software tool. It involves planning of coverage, quality& capacity of UMTS Network which uses WCDMA in radio interface between 3G base station and the User equipment. It also involves planning of scrambling codes for 3G WCDMA Network.

Abdul Basit, Syed, 2009 [9]: Dimensioning of LTE Network Description of Models and Tool, Coverage and Capacity Estimation of 3GPP Long Term Evolution radio interface. This thesis covers coverage and capacity estimation in radio network dimensioning. Radio link budget is used to investigate coverage planning. He used excel based dimensioning vendor tool which is designed for the usage of vendor. This can't assure weather the important parameters are considered.

Liang Zhang, 2010 [10]: Network Capacity, Coverage Estimation and Frequency Planning of 3GPP Long Term Evolution, Linköping University Master Thesis. In this thesis, the capacity of the LTE network is depicted with the indicators of average transmission data rate, peak transmission data rate and the subscriber's numbers supported by the system. The coverage of the LTE system is also calculated on the base of base station parameters and different propagation models. The theoretical work of this thesis was implemented in WRAP software and by using WRAP‟s capacity calculation and evaluation tools, estimation and optimization of an LTE network was performed.

Bethelhem Seifu, 2012 [11]: LTE Radio Network Planning: Modeling Approaches for the Case of Addis Ababa. This thesis covers coverage and capacity dimensioning and RAN nominal planning of LTE networks. She used Matlab 2008b as a simulation environment for analysis. The planning didn't use the digital map of the area and she specifies as a limitation about the number of user in that area are not known and here is the main drawback of her thesis.

Marwa Elbagir Mohammed & Khalid Hamid Bilal, 2012 [12]: LTE Radio Planning Using Atoll Radio Planning and Optimization Software", International Journal of Science and Research (IJSR). They carried out coverage and capacity estimation in radio network dimensioning. Radio link budget is investigated for coverage planning.

There are also technical literature and periodic reviews that deal heavily with future coexistence of 2G, 3G and 4G. Especially Wireless World research Coexistence of GSM, HSPA/WCDMA and LTE, 4G Americas and 3GPP standards are the literatures that helps me in planning LTE.

1.4. Methodology

This project is entirely based on books on LTE, 3GPP standardization documents, different IEEE articles, journals, previous studies on this subject and known simulators and documents and Tools. The work started with preliminary study on LTE and the general radio network planning. On the process of reviewing related works the statement of the problem had been clearly specified. Data collections regarding the working area and the expected traffic demand and long-term telecom forecast have been done. After that, data analyses have been done to identify the area of work, Based on that, theoretical dimensioning processes starting from coverage dimensioning, capacity dimensioning are carried out.

1.5. Scope and Limitation

1.5.1. Scope of the project

This project is a case study and is expected to address features that are necessary for proper implementation of LTE technology in Adama City. In depth,

- ✓ It should estimate the calculation of capacity and coverage and positioning sites process in the area of study.
- ✓ From the technical point of view, it should point out the relation between coverage and capacity when planning is performed.

1.5.2. Limitations of the project

The main limitation was the traffic information which was built according to the information from Adama Information Center and it may be different from real information.

Adama City is considered as only urban population.

CHAPTER TWO

LTE Architecture

LTE is the evolution of the radio access Universal Mobile Telecommunications System (UMTS) known as Evolved UTRAN (E-UTRAN), whereas the evolution of the non-radio part including the Evolved Packet Core (EPC) network is referred to as the System Architecture Evolution (SAE). Both the LTE and SAE form what we call the Evolved Packet System (EPS). Figure 1 shows the overall network architecture [13] with the different types of interfaces and the type of traffic carried on each link.

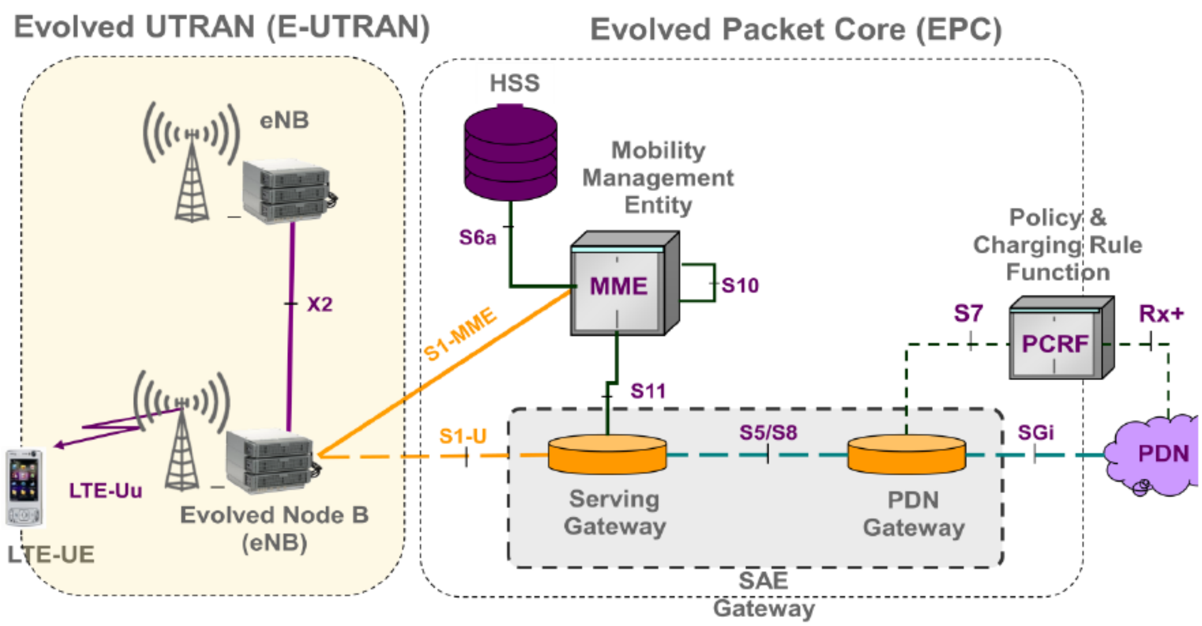


Figure 1: Typical architecture for LTE networks

The architecture of the access network is pretty simple as it is composed o f a single type of node called enhanced NodeB (eNodeB or eNB). These advanced base stations are used to connect the User Equipment (UE) to the network. The E-UTRAN is considered a flat architecture because it has no centralized controllers. As shown in Figure 2, the E-UTRAN architecture consists of a network of eNodeBs that are interconnected with each other by X2 interfaces that allow communication between the different eNBs and connected to the EPC by S1 interfaces; Sl-U user plane interface used between the eNB and the S-GW and S1-C (S1-MME) interface which allows communication between the eNB and the MME.

All the following active UE radio functions are run by the E-UTRAN: (1) IP packet header compression; (2) Security and data encryption; (3) Connecting to the EPC which includes selecting and sending signals to MME as well as creating bearer path and routing data to S-GW; and (4) Radio Resource Management (RRM) which covers all radio bearers functions such as admission control, mobility control, dynamic allocation of resources to UE, scheduling, and radio bearer control. On the other hand, the main task of the core network is to control the UE and establish the bearers. It also provides the idle and active terminals with QoS, security, mobility and management and finally allows connectivity with external IP packet networks. The architecture of the core network is a little bit more complex as is it composed of different pieces of equipment. As shown in Figure 1, the EPC is composed of five main nodes which are as follows [14], [15], [16].

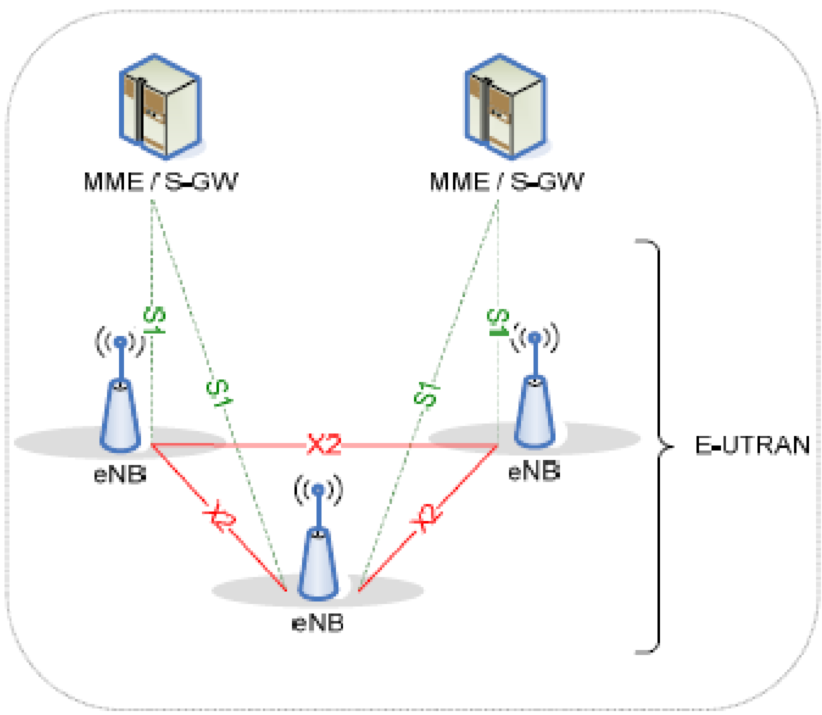


Figure 2: Overall E-UTRAN Architecture

• **Serving Gateway (S-GW):** It is the local mobility anchor that holds data when the UE are moving between eNodeBs during handover, and it deals with the user plane. S-GW is the connection between the radio part and the EPC. It is the hub on which all IP packets are transferred through; it transports the IP data traffic between UE and the external networks. Moreover, it keeps information about the bearers when the UE is idle and it works as a buffer for downlink data when the MME is initiating paging of the UE for bearers' reestablishment. S-GW has different administrative tasks in the network; it gathers data for charging such as the traffic on the link whether sent or received by a user. In addition, it works as mobility anchor for internetworking with other 3GPP technologies like UMTS and GPRS. Logically, this gateway is connected to the PDN gateway.

• **Packet Data Network (PDN) Gateway (P-GW):** It is the interconnection point between the EPC and the external IP networks and it is mainly in charge of assigning and distributing the IP addresses for the UE, besides enforcing the QoS and flow based charging that is based on PCRF rules. The PDN gateway has the responsibility to distribute and sort out the IP packets in the downstream into different QoS based channels and bearers based on the Traffic Flow Templates (TFTs). It also has the ability to work as a mobility anchor for internetworking with non 3GPP technologies like High Rate Packet Data (HRPD) , (1xEV-DO) and Wi-Fi. P-GW is considered the default gateway as well; it performs packet filtering and lawful interception which includes analyzing the signaling data in addition to the network management information.

• **Mobility Management Entity (MME):** It is the control node that is responsible for the signaling between the UE and the core network. It deals with the control plane, and it is considered the termination point of the Non Access Stratum (NAS) which plays a key role in initiating and maintaining the EPS bearers. It has a major role in registering UE in a network, handling mobility functions between UE and core network, and creating and keeping IP connectivity. NAS is carried over LTE-Uu which is the air interface between UE and eNB and the SI-MME interfaces between the eNB and the MME. On the other hand, Access Stratum (AS) protocols are those that run between eNodeBs and UE.

In conclusion, NAS functions between a core network and the user equipment; whereas, AS functions between the radio network and the user equipment. There are two classifications for the main functions supported by the MME: (1) bearer management, and (2) connection management. The former is handled by the session management layer in the NAS protocol and is related to the establishing, maintaining and releasing bearers; but the latter is handled by the connection or mobility management layer in the NAS protocol and is related to establishing connection between the network and the UE along with providing security. In fact, the MME is responsible for : (1) distributing the paging messages to the eNBs, (2) security, (3) mobility control for users in idle state, (4) control of bearers, and (5) protecting NAS signaling integrity and ciphering.

• **Home Subscriber Server (HSS)**: It holds dynamic information to keep track of the MME identities to which users are connected. HSS also includes data for the user's System Architecture Evolution (SAE) subscription such as the QoS profile and any roaming access restrictions. Moreover, it has the Packet Data Network (PDNs) information that allows users to connect to the PDN (e.g., Internet, IMS). It also plays a role in authentication and security due to its ability to integrate the Authentication Center (AuC) which formulates security keys and authentication vectors.

• **Policy Control and Charging Rules Function (PCRF):** One of its tasks is to control the Policy Control and Charging Enforcement Function (PCEF) functionalities that are flow based and residing in the P-GW. The QoS authorization, which is consisting of the QoS Class Identifiers (QCI) and bit rates, defines the PCEF treatment for certain data flows in harmony and agreement with the user's subscription profile.

As shown in Figure 1.1, the names of the interfaces are standardized. The Sl-U interface connects the eNB and the S-GW for user plane traffic (i.e. bearers' tunneling, inter-eNB handover), also the Sl-C (currently referred to as SI-MME) connects the eNB with the MME for control processes and signaling messages between the eNB and the MME. Sll connects the MME to the S-GW, S6 (currently referred to as S6a) connects the MME and the HSS, and S5 connects the S-GW to the P-GW. In addition to that, the S7 (currently referred to as G_x) connects the P-GW (PCEF) to the PCRF, and the SGi is the interface between the P-GW and the packet data network such as Internet or IMS (IP Multimedia Subsystem).

2.1 LTE Physical Layer

The design of the LTE physical layer is heavily influenced by requirements for high peak transmission rate (100 Mbps DL or 50 Mbps UL), spectral efficiency, and multiple channel bandwidths (1.25-20MHz). To fulfill these requirements, orthogonal frequency division multiplex (OFDM) was selected as the basis for the physical layer.

OFDMA and SC-FDMA

LTE has selected Orthogonal Frequency Division Multiple Access (OFDMA) in the downlink and Single-Carrier Frequency Division Multiple Access (SC-FDMA) in the uplink [17], [18], [19]. For the downlink, OFDMA is unanimously considered as the most appropriate technique for achieving high spectral efficiency. For the uplink, the LTE of 3GPP employs SC-FDMA because of its low Peak-To-Average Power Ratio (PAPR) properties compared to OFDMA.

OFDMA is a multiple access scheme on the base of the Orthogonal Frequency-Division Multiplexing (OFDM) modulation technique. The OFDM signal can be generated by using the Fast Fourier Transform (FFT). In an OFDM system, the available spectrum is divided into multiple, mutually orthogonal subcarriers. Each of these subcarriers is independently modulated by a low rate data stream and can carry independent information streams. Figure 3 shows how the OFDM technique is applied for a signal with 5 MHz bandwidth.

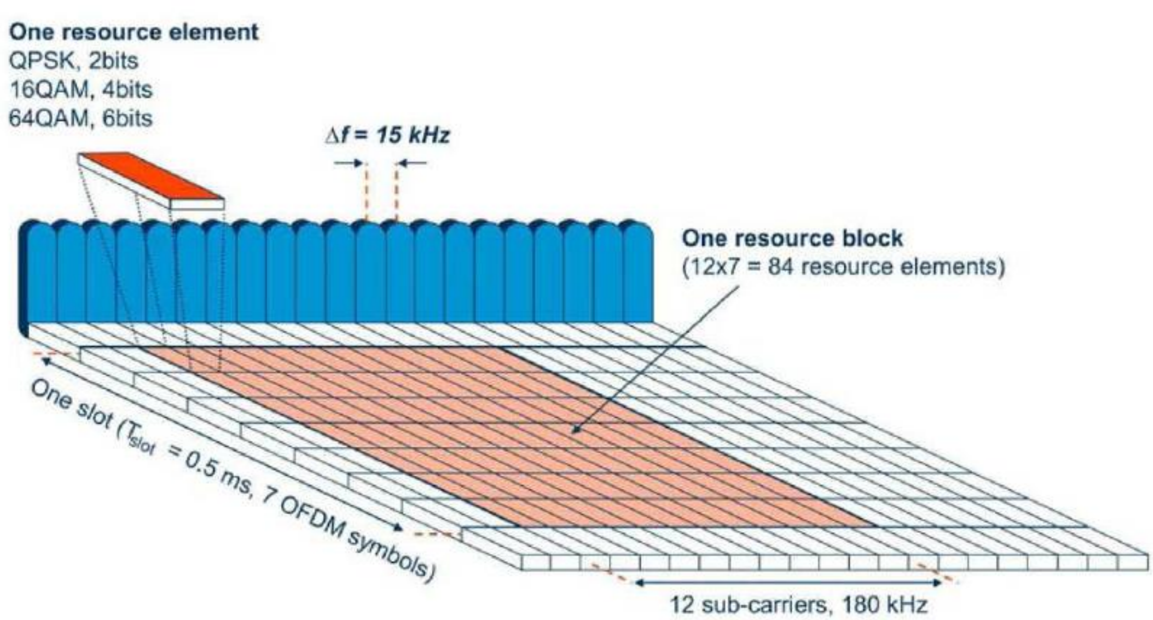


Figure 3: Frequency-time representation of an OFDM Signal

In the frequency domain, the 5 MHz bandwidth is divided into a high number of closely spaced orthogonal subcarriers. The subcarriers in LTE have a constant spacing of 15 kHz. In E-UTRA, the downlink modulation schemes can be QPSK, 16QAM and 64QAM. In the time domain, a guard interval is added to each symbol to combat inter OFDM symbol interference due to channel delay spread. In E-UTRA, the guard interval is a cyclic prefix (CP) which is inserted prior to each OFDM symbol. A group of subcarriers is called a sub-channel.

Each of the 15 kHz LTE air interface subcarriers are 'Orthogonal' to each other giving rise to the name 'Orthogonal Frequency Division Multiplexing' (OFDM) which is employed in the downlink. The process of modulating data symbols and combining them is equivalent to an Inverse Fourier Transform operation (IFFT). The reverse operation is applied to the OFDM symbol to retrieve the data stream which is equivalent to a Fast Fourier Transform operation (FFT). There are many advantages of using OFDM in a mobile access system, namely:

1. Long symbol time and guard interval increases robustness to multipath and limits inter symbol interference.
2. Eliminates the need for intra-cell interference cancellation.
3. Allows flexible utilization of frequency spectrum.
4. Increases spectral efficiency due to orthogonality between sub-carriers.
5. Allows optimization of data rates for all users in a cell by transmitting on the best (i.e.nonfaded) sub-carriers for each user.

The downlink physical layer of LTE is based on OFDMA. However, despite its many advantages, OFDMA has certain drawbacks such as high sensitivity to frequency offset resulting from instability of electronics and Doppler spread due to mobility) and high peak-to-average power ratio (PAPR). PAPR occurs due to random constructive addition of sub-carriers and results in spectral spreading of the signal leading to adjacent channel interference. It is a problem that can be overcome with high compression point power amplifiers and amplifier linearization techniques. While these methods can be used on the base station, they become expensive on the User Equipment (UE). Hence, LTE uses Single Carrier FDMA (SC-FDMA) with cyclic prefix on the uplink, which reduces PAPR.

2.2 Adaptive Modulation and Coding (AMC)

In cellular communication systems, the quality of the signal received by a UE depends on the channel quality from the serving cell, the level of interference from other cells, and the noise level. To optimize system capacity and coverage for a given transmission power, the transmitter should try to match the information data rate for each user to the variations in the received signal.

This is commonly referred to as link adaptation and is typically based on Adaptive Modulation and Coding (AMC). The AMC consists of the modulation Scheme and code rate.

Modulation Scheme: Low-order modulation (i.e. few data bits per modulated symbol, e.g. QPSK) is more robust and can tolerate higher levels of interference but provides a lower transmission bit rate. High-order modulation (i.e. more bits per modulated symbol, e.g. 64QAM) offers a higher bit rate but is more prone to errors due to its higher sensitivity to interference, noise and channel estimation errors; it is therefore useful only when the Signal to Interference and Noise Ratio (SINR) is sufficiently high.

Code rate: For a given modulation, the code rate can be chosen depending on the radio link conditions: a lower code rate can be used in poor channel conditions and a higher code rate in the case of high SINR. The type of modulation used in LTE depends on the radio environment. The UE estimates the quality in the downlink and signals it back to the eNodeB in the Channel Quality Indicator (CQI). The uplink reference signals that are embedded into the uplink transmission are used by the eNodeB to estimate the quality in the uplink. The eNodeB decides which modulation technique should be used based on the quality of the downlink and uplink radio environment. LTE supports the following modulation techniques in the downlink and uplink:

- ✓ 64 Quadrature Amplitude Modulation (64 QAM) which uses 64 different quadrature and amplitude combinations to carry 6 bits per symbol
- ✓ 16 Quadrature Amplitude Modulation (16 QAM) which uses 16 different quadrature and amplitude combinations to carry 4 bits per symbol
- ✓ Quadrature Phase Shift Keying (QPSK) which used 4 different quadrature's to send 2 bits per symbol

In LTE and WiMAX, each subcarrier is modulated with a conventional modulation scheme depending on the channel condition. LTE uses QPSK, 16QAM, or 64QAM. The FFT sizes of 128, 256, 512, 1024 and 2048, corresponding to WiMAX and LTE channel bandwidth of 1.25, 2.5, 5, 10 and 20MHz are used. In time domain, guard intervals known as cyclic prefix (CP) are inserted between each of the symbols to prevent inter-symbol interference at the receiver caused by multipath delay spread in the radio channel.

Spectrum Flexibility: FDD and TDD

Depending on regulatory aspects in different geographical areas, radio spectrum for mobile communication is available in different frequency bands in different bandwidths. Spectrum flexibility, which enables operation under all these conditions, is one of the key features of LTE radio access. Besides being able to operate in different frequency bands, LTE can be deployed with different bandwidths ranging from approximately 1.25MHz up to approximately 20MHz.

Furthermore, LTE can operate in both paired and unpaired spectrum by providing a single radio access technology that supports frequency-division duplex (FDD) as well as time division duplex (TDD) operation.

2.3 LTE FDD Frame Structure

In this section, we summarize the basic concepts of the LTE system that form the foundation for the LTE network planning [20], [21], [22]. The LTE FDD frame structure is demonstrated in Figure 4 for normal cyclic prefix (CP). Each LTE FDD radio frame is $T_f = 307200 \times T_s = 10$ ms long and consists of 20 slots of length T_s lot = $15360 \times T_s = 0.5$ms, numbered from 0 to 19. For LTE FDD, 10 sub-frames are available for downlink transmission and 10 for uplink transmissions in each 10 ms interval. UL and DL transmissions are separated in the frequency domain.

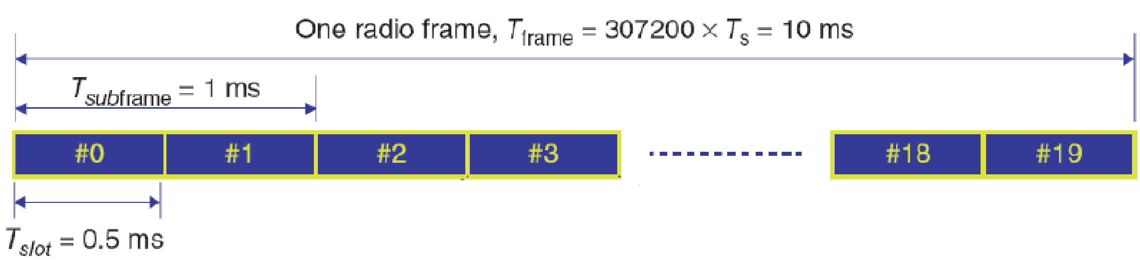


Figure 4: LTE FDD frame and slot structure

Resource Blocks (RB)

A physical resource block (PRB) is used in LTE to describe the physical resource in the time/frequency grid. Figure 5 illustrates the LTE time/frequency grid definitions. A PRB consists of 12 consecutive subcarriers and lasts for one slot, 0.5ms. Each subcarrier is spaced by 15 kHz. The NRB DL parameter is used to define the number of RB (resource blocks) used in the downlink. This is dependent on the channel bandwidth. In contrast, NRB UL is used to identify the number of resource blocks in the uplink. Each resource block consists of NSCRB subcarriers, which for standard operation is set to 12 or a total of 180 kHz lasting in a 0.5ms slot.

The resource element (RE) is the smallest defined unit, which consists of one OFDM subcarrier during one OFDM symbol interval [23]. Each RB consists of 12 × 7 = 84 REs in the case of normal CP and 72 REs for extended CP. The maximum RB is 100. The 100 RB corresponds to the transmission bandwidth while 20MHz is the channel bandwidth.

The number of subcarriers depends on the system BW (i.e., 1.4→72, 3→180, 5→300, 10→600, 15→900, 20→1200). Within the LTE carrier bandwidth of up to 20MHz there are some subcarriers that are faded and other that are not faded. Transmission is done using those frequencies that are not faded. The transmission can be scheduled by RB, each of which consists of 12 consecutive subcarriers, or 180 kHz, for the duration of one slot (0.5 ms).

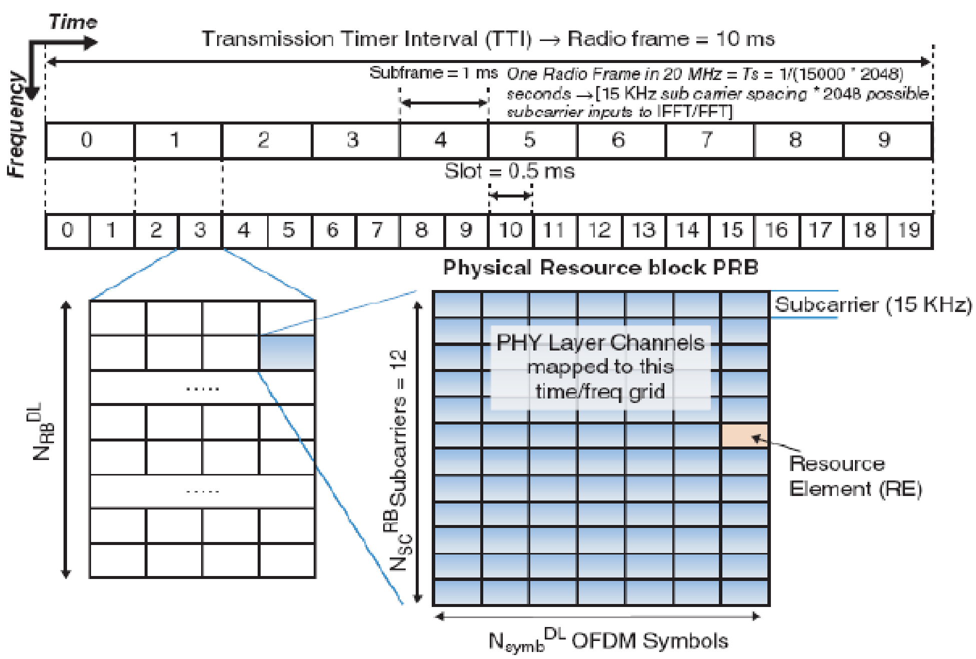


Figure 5: Physical resource block and resource element

2.4 LTE Multiple Antenna Technology

Multiple Input Multiple Output (MIMO) systems form an essential part of LTE in order to achieve the ambitious requirements for throughput and spectral efficiency [10]. MIMO refers to the use of multiple antennas at the transmitter and receiver side. There are two functionality modes of MIMO. Different gains can be achieved depending on which MIMO mode is used. Two methodologies are used to provide improvements in the signal to noise ratio and they are characterized by improving the reliability of the system with respect to the various forms of fading.

The Spatial Multiplexing mode: allows transmitting different streams of data simultaneously on the same resource blocks by exploiting the spatial dimension of the radio channel so that the data rate or capacity is increased.

Spatial Diversity mode: spatial diversity used in this narrower sense often refers to transmit and receive diversity, used to exploit diversity and increase the robustness of data transmission. Each transmit antenna transmits essentially the same stream of data, so the receiver gets replicas of the same signal. This increases the signal to noise ratio at the receiver side and thus the robustness of data transmission especially in fading scenarios.

Only the spatial multiplexing mode is concerned in this thesis while calculating the LTE capacity and data rate. Take a 4 x 4 antenna configuration (4 transmit antenna and 4 receiver antenna) as an instance, as Figure 6 shows, where each receiver antenna may receive the data streams from all transmit antennas.

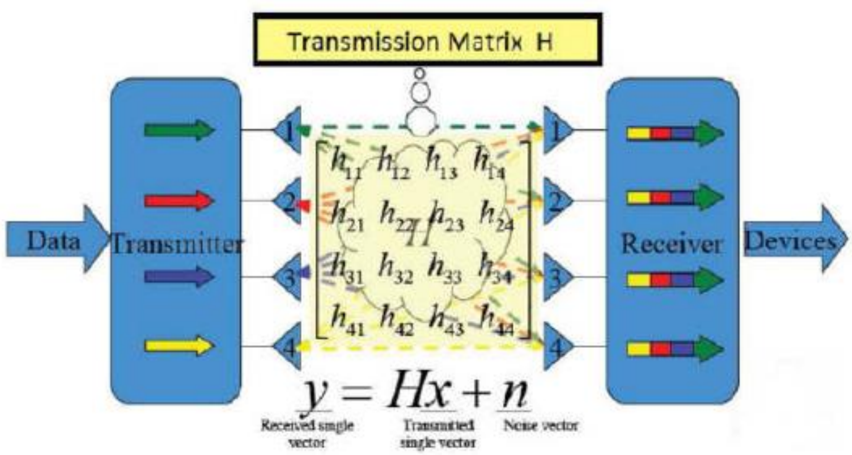


Figure 6: MIMO Transmission

The transmission relationship can be described with a Transmission Channel Matrix H. The coefficients h_{ij} stands for transmit antenna j to receive antenna i, thus describing all possible paths between transmitter and receiver sides.

Suppose receive vector is y, transmit vector is x, the noise vector is n and H is the transmission channel matrix. Then the MIMO transmission can be described with the formula:

$$y = H_x + n \qquad 2.1$$

In an M_xN antenna configuration, the number of data streams which can be transmitted in parallel over the MIMO channel is given by the minimum value of M and N and is limited by the rank of the transmission matrix H. For example, a 4 x 4 MIMO system could be used to transmit four or fewer data streams.

In the spatial multiplexing mode, the data streams transmitted can belong to one single user (single user MIMO/SU-MIMO) or to different users (multi user MIMO/MU-MIMO). While SU-MIMO increases the data rate of one user, MU-MIMO allows increasing the overall capacity.

In Spatial Multiplexing mode the data rate (in the case of SU-MIMO) or capacity (in the case of MU-MIMO) is increased; see **Figure 7**.

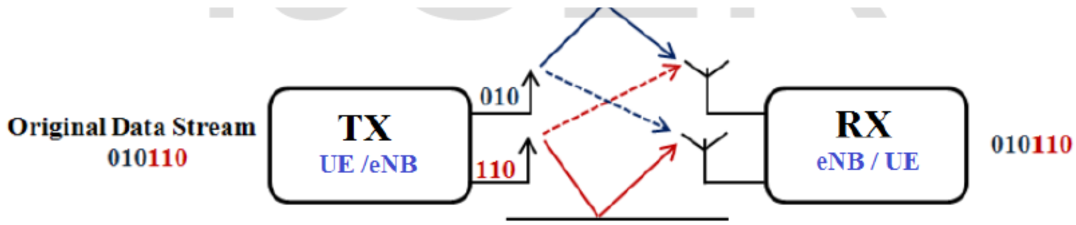


Figure 7: Spatial Multiplexing

Only the MU-MIMO is concerned in the thesis when calculating the system capacity. As the MIMO for the uplink is considered in 3GPP LTE advanced standards phase, the MIMO is not applied in Uplink in this thesis. As a result of the use multiple antennas, MIMO wireless technology is able to considerably increase the capacity of a given channel while still obeying Shannon's law.

2.5 Physical Signals and channels

The LTE air interface consists of physical signals and physical channels, which are defined in 36.211. Physical signals are generated in Layer 1 and used for system synchronization, cell identification, and radio channel estimation. Physical channels carry data from higher layers including control, scheduling, and user payload. Physical signals are summarized in Table 2.1.

In the downlink, primary and secondary synchronization signals encode the cell identification, allowing the UE to identify and synchronize with the network. In both the downlink and the uplink there are reference signals (RS), known as pilot signals in other standards, which are used by the receiver to estimate the amplitude and phase flatness of the received signal. The flatness is a combination of errors in the transmitted signal and additional imperfections that are due to the radio channel. Without the use of the RS, phase and amplitude shifts in the received signal would make demodulation unreliable, particularly at high modulation depths such as 16QAM or 64QAM. In these high modulation cases, even a small error in the received signal amplitude or phase can cause demodulation errors.

Table 2.1: LTE Physical Signals

Downlink Physical Signals	**Purpose**
Primary Synchronization Signal, PSS	Used for cell search and identification by the UE. Carries part of the cell ID (one of three orthogonal sequences)
Secondary Synchronization Signal, SSS	Used for cell search and identification by the UE. Carries the reminder of the cell ID (one of 168 binary sequences)
Reference Signal, RS	Used for downlink channel estimation. Exact sequence derived from cell ID (one of 3×168=504 pseudo random sequences)
Uplink Physical Signals	**Purpose**
Reference Signals (Demodulation and Sounding)	Used for Synchronization to the UE and for UL channel estimation

Reference Signals

To carry out coherent demodulation of different physical channels at both the downlink and uplink, the transmitters and receivers need to perform channel estimation. A straightforward way to enable channel estimation in LTE is to insert known reference symbols into the OFDM/SC-FDM time frequency grid. In the downlink direction, an example of reference symbols for 1 antenna transmission is illustrated in Figure 8.

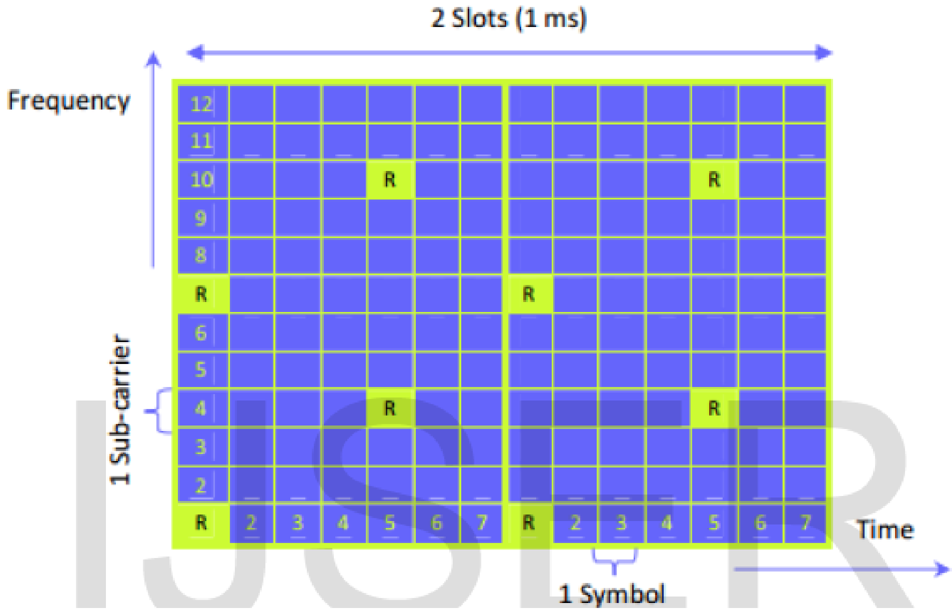


Figure 8: LTE downlink reference signals

The RS is similar to the "UMTS pilot" and it is used by the UE to predict the channel characteristics. As LTE is a MIMO based technology, it can have more than two transmit antennas and in order to avoid RSs from the same cell interfering with each other, different antennas will be transmitting RS at different times and frequencies.

Synchronization Signals

A UE wishing to access the LTE system follows a cell search procedure which includes a series of synchronization stages by which the UE determines time and frequency parameters that are necessary to demodulate DL signals, to transmit with correct timing and to acquire some critical system parameters. There are two cell search procedures in LTE: one for initial synchronization and another for detecting neighbor cells in preparation for handover. In both cases, the UE uses two special signals broadcast on each cell: primary synchronization sequence (PSS) and secondary synchronization sequence (SSS).

CHAPTER THREE

Coverage and Capacity Dimensioning

Dimensioning is the initial phase of network planning. It provides the first estimate of the network element count as well as the capacity of those elements. The purpose of dimensioning is to estimate the required number of radio base stations needed to support a specified traffic load in an area and the specific service to the cell edge users .Dimensioning is an important part of the whole planning process, which also includes, detailed planning and optimization of the wireless cellular network. As a whole, planning is an iterative process covering design, synthesis and realization. The aim of this whole exercise is to provide a method to design the wireless cellular network such that it meets the requirements set forth by the customers. This process can be modified to fit the needs of any wireless cellular network. This is a very important process in network deployment.

Dimensioning is based on a set of input parameters and the provided results are relevant for that set of input parameters only. These parameters include area under consideration, expected traffic and required QoS. Dimensioning provides the evaluation of the requirements for network infrastructure and computation of number of sites required to serve certain area while fulfilling the coverage capacity requirements. This is done with the help of dimensioning tool for both access and core networks. Dimensioning uses relatively simpler models for modeling of the actual conditions as compared to the detailed planning. Simpler models and methods reduce the time required for dimensioning. On the other hand, dimensioning tool should be accurate enough to provide results with an acceptable level of accuracy, when loaded with expected traffic profile and subscriber base.

3.1. LTE Coverage Dimensioning Process

Coverage estimation is used to determine the required base station must be used to fulfill coverage of area under study. Coverage estimation calculates the area where base station can be heard by the users (receivers). It gives the maximum area that can be covered by a base station. Coverage planning includes radio link budget and coverage analysis. Based on the calculation of RLB, maximum allowed propagation loss is obtained. Maximum allowed propagation loss gives the attenuation of the signal as it travels from transmitter to the receiver. Path loss is converted into distance by using appropriate propagation models. This is the distance from the base station where the transmitter signals can be received by the users (receiver). This distance or the radius of the cell is used to calculate the number of sites required to cover the whole area with respect to coverage estimation [25].

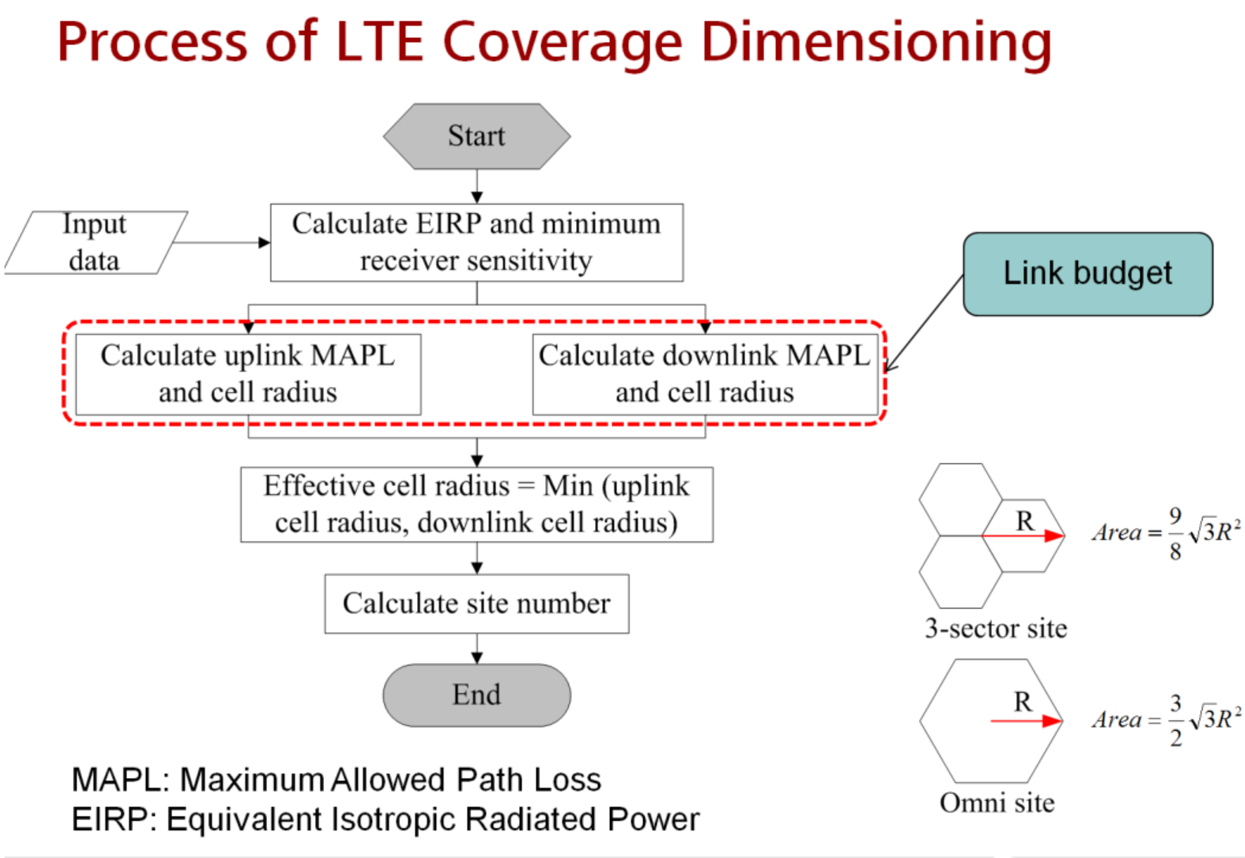


Figure 9: LTE Coverage Dimensioning Flow

Let us start with Radio link budget calculation

3.1.1. Radio Link Budget

Coverage planning consists of evaluation of DL and UL radio link budgets. The maximum path loss is calculated based on service throughput defined by the cell edge user that required SINR level at the receiver. The minimum of the maximum path losses in UL and DL directions is converted into cell radius, by using a propagation model appropriate to the deployment area. Calculating the link budget, one can determine the coverage area and radius of the cell, allowing estimation of the number of base stations needed to cover the area where you intend to offer the service. It is noteworthy that the characteristics of the environment (dense urban, urban, suburban, etc.) in which the network is installed, are determinant for the results of Link Budget, due to propagation loss the signal will suffer. The link budget gives the path loss estimate both for the uplink and the downlink which gives to deliver specific throughput to the cell edge user.

Maximum allowable attenuation of the radio wave traversing the air interface excludes clutter data (e.g. penetration losses, propagation data) is expresses as:

$MAPL = EIRP - Minimum\ Signal\ Receiption\ Strengt - Penetration\ loss - shadow\ fading\ margin$---3.1a

Maximum Allowed Path Loss (MAPL) has different values for dense urban, urban and suburban (UL & DL).

The receiver sensitivity: indicates the minimum signal strength required to enable decoding by the eNodeB or UE receiver if there is no interference and formulated as:

$Receiver\ Sensitivity = Noise\ figure + SINR + Thermal\ Noise$.......................................3.1b

Minimum signal reception strength: It used to formulate the receiver side losses and margin such as body loss, cable loss and marginal gain to receiver sensitivity and calculated as:
$Minimum\ Signal\ Receiption\ Strength = RS + IM + LR - RAG$………..……………………3.1c

Where RS is receiver sensitivity, IM is interference Marginal; LR is receiver body loss + Cable loss, RAG is receiver antenna gain.

So the calculation must be done to every condition. From the equation (3.1) we can find the cell radii from the propagation model cost-231 hata.

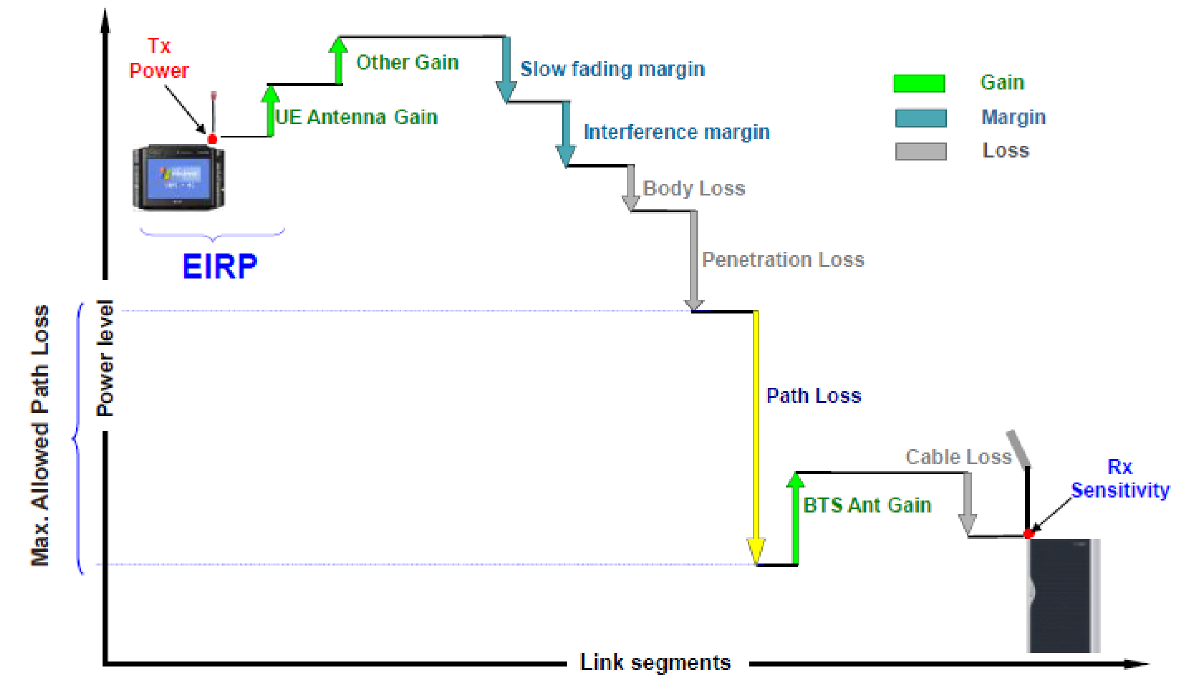


Figure 10: LTE Link Budget Procedure – Uplink

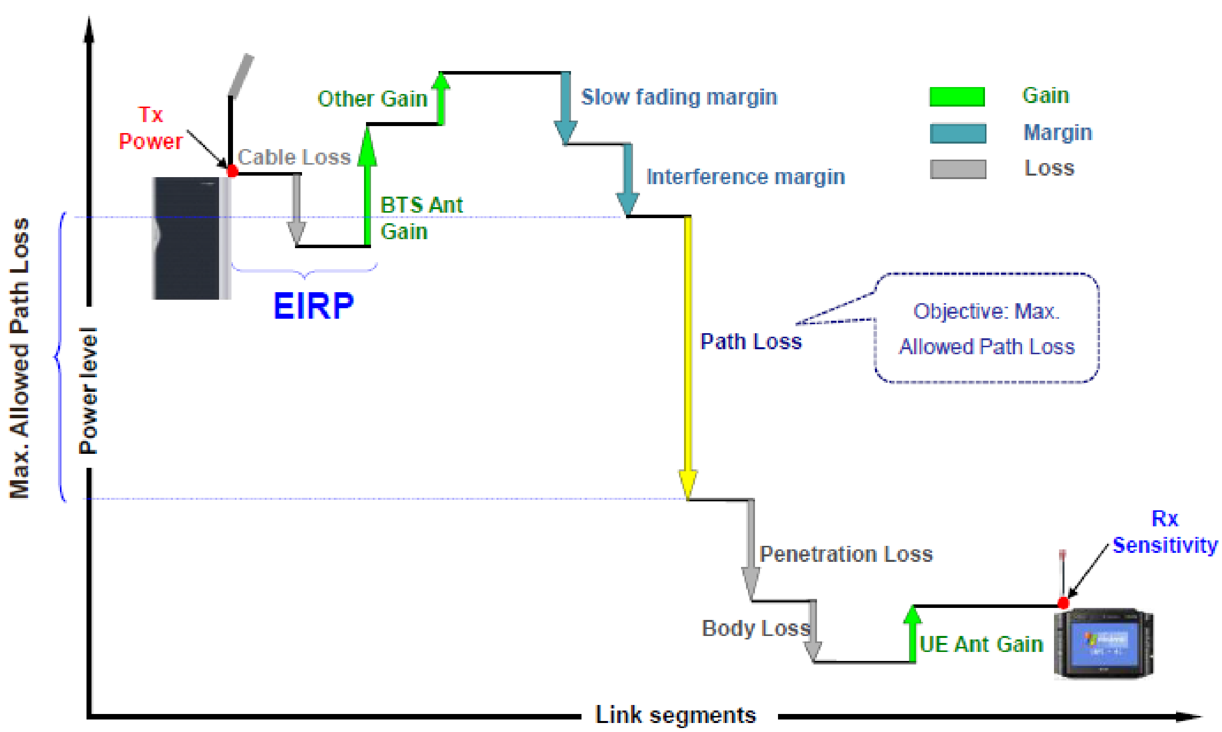


Figure 11: LTE Link Budget Estimation – Downlink [20]

Penetration loss: Penetration loss indicates the fading of radio signals from an indoor terminal to a base station due to obstruction by a building.

Body loss: Body loss indicates the loss generated due to signal blocking and absorption when a terminal antenna is close to the body.

Feeder Loss: Feeder loss indicates the signal loss caused by various devices that are located on the path of the antenna to the receiver. Any device using an external antenna for service provision at either the base station side or terminal side must consider feeder loss.

Transmitter Power: It includes the base station affecting downlink budget and terminal sides which affects the uplink budget.

Antenna Gain: indicates the degree to which an antenna transmits input power in concentration and can be increase by reduce the lobe width of the radiation at the vertical plan and maintain the Omni-directional radiation performance at the horizontal plane.

Interference Margin Interference margin accounts for the increase in the terminal noise level caused by the interference from other users and it indicates the degradation of system receive performance caused by internal interference in the system due to system traffic. In fact, due to the frequency division nature of LTE, there is also a close correlation between actual traffic load and interference margin experienced by the network.

Slow Fading Margin Shadow fading indicates the fading brought by obstruction due to a building or a natural feature. Shadow fading changes slowly, and is thus called "slow fading". Statistics repeatedly show that the median levels of received signals follow log-normal distribution with the time and location at a certain distance. Fading caused by location mainly from obstruction far exceeds fading caused by time. Therefore, the major concern for shadow fading is those caused by location changes.

Required SINR is the main performance indicator for LTE. Cell edge is defined according to the required SINR for a given cell throughput. Therefore, the accurate knowledge of required SINR is central to the authenticity of the RLB and thus the process of dimensioning. Required SINR depends up on the factors like Modulation and Coding Schemes (MCS) and Propagation Channel Model. Higher the MCS used, higher the required SINR and vice versa.

Parameters in Downlink MAPL Calculation

Subcarrier Power (dBm) = Max Total Tx Power (dBm) - 10*log(The Number of Subcarriers to Distribute Power)

For eNodeB Max Total Power (dBm) is 46dBm (40W)

The Number of Subcarriers to Distribute Power is related to the system bandwidth. For example For 20MHz bandwidth, ***Subcarrier Power (dBm)*** **=** 46 – 10log(12*100) = 15.2dBm For 10MHz bandwidth, ***Subcarrier Power (dBm)*** **=** 46 – 10log(12*50) = 18.2dBm

Table 3.1: Downlink MAPL Calculation [20]

Tx		**Formula**
	Max Total Tx Power (dBm)	A=46
	RB to Distribute Power	C= 100
	Subcarriers to Distribute Power	D=12*C=1200
	Subcarrier Power (dBm)	E =A-10*Log10(D)=15.21
	Tx Antenna Gain (dBi)	G=18
	Tx Cable Loss (dB)	H=0.5
	EIRP per Subcarrier dBm	J = E+G-H=32.71
Rx		**Formula**
	SINR (dB)	K=-1.84
	Rx Noise Figure (dB)	L=7
	Receiver Sensitivity_(dBm)	M = K+L-174+10*Log10(15000)=-127.08
	Rx Body Loss(dB)	P=-0.5
	Interference Margin (dB)	Q=-5.99
	Min Signal Reception Strength (dBm)	R= M+P+Q
	Path Loss & Shadow Fading Margin	**Formula**
	Penetration Loss (dB)	S=15
	Shadow Fading Margin (dB)	T=8
	Path Loss (dB)	U =J -R -S –T

Table 3.2: Uplink MAPL Calculation [20]

Tx		Formula
	Max Total Tx Power (dBm)	A=23
	RB to Distribute Power	C=4
	Subcarriers to Distribute Power	D=12*C=48
	Subcarrier Power (dBm)	E =A-10*Log_{10}(D)=6.19
	Tx Body Loss (dB)	I=0
	EIRP per Subcarrier (dBm)	J = E-I=6.19
Rx		**Formula**
	SINR (dB)	K=0.47
	Rx Noise Figure (dB)	L=2.5
	Receiver Sensitivity_(dBm)	M = K+L-174+10*Log_{10}(15000)= -129.27
	Rx Antenna Gain (dBi)	N=18
	Rx Cable Loss(dB)	O=-0.5
	Interference Margin (dB)	Q=-1.97
	Min Signal Reception Strength (dBm)	R= M-N+O+Q
	Path Loss & Shadow Fading Margin	**Formula**
	Penetration Loss (dB)	S=15
	Shadow Fading Margin (dB)	T=8
	Path Loss (dB)	U =J -R -S –T

Propagation models

The radio propagation model plays a key role in the link budget. The maximum path loss allows the maximum cell range to be estimated with a suitable propagation model, such as Cost231–Hata model. The cell range gives the number of base station sites required to cover the target geographical area. The cell has different range according to the carrier frequency that used. The cell range increase with low carrier frequency for that the low carrier frequency used to coverage the rural area.

Radio propagation models are classified into outdoor and indoor propagation models. These two types of propagation models involve different factors. In an outdoor environment, landforms and obstructions on the propagation path, such as buildings and trees, must be considered. Signals fade at varying rates in different environments. Propagation in free space gives the lowest fade rate. The fading of signals is larger than free space when radio waves propagate in open areas/suburban areas and fading rate is the largest in urban/dense urban areas. Indoor propagation model features low RF transmits power, a short coverage distance and complicated environmental changes. The Propagation models are based on the frequency band, type of deployment area (urban, rural, suburban, etc.), and type of application. Table 3.3 lists the most widely used propagation models in current cellular systems.

Table 3.3 lists of propagation models

Model	Frequency MHZ	Recommended use
Cost-231 Hata	150—2000	$0.02 < d < 5$ km, UMTS, GSM1800, LTE
Erceg-Greenstein	1900—6000	$0.1 < d < 8$ km, Fixed WiMAX
IMT	800-2800	Indoor office, vehicular, outdoor to indoor
ITU-526	30—1000	Fixed receivers
ITU-529	300-1500	$1 < d < 100$ km, GSM900, CDMA2000, LTE
Okumura-Hata	150—2200	$1 < d < 20$ km, GSM900, CDMA2000, LTE
WLL	30—10000	Fixed receivers, Microwave Links, WiMAX

One of the listed propagation models that will be used in this project is Cost-231 Hata because it has the highest path loss compared with other propagation models [24].

Cost231-Hata Model

Path loss estimation is performed by empirical models if land cover is known only roughly, and the parameters required for semi-deterministic models cannot be determined. Four parameters are used for estimation of the propagation loss by Hata's well-known model: frequency f, distance d, base station antenna height and the height of the mobile antenna .Cost231-Hata model can be used in macro cells as the propagation model.

The application range is as follows:

- ✓ Frequency band: 1500 MHz to 2000 MHz

- ✓ Base station height: 30 meters to 200 meters.
- ✓ Terminal antenna height: 1 meter to 10 meters
- ✓ Distance between the transmitter and receiver: 1 km to 20 km

The Path loss prediction for COST231 – Hata model is given by the following formula [14]:

$PL\ (dB) = 46.3 + 33.9 * \log (f) - 13.82 * \log (h_b) - \alpha (h_r) - [44.9 - 6.55 \log(h_b] \log d + c$ ……...3.2

Here, f represents the frequency in MHz; d denotes the distance between the transmitter & receiver, h_b & h_r the 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 $\alpha(h_r)$ for urban area is defined as:

$\alpha\ (h_r) = 3.2\ (\log\ (11.75 h_r)\ {}^2 h - 4.97$………….……………………………………….....3.3

For rural & suburban areas, it is as follows:

$\alpha\ (h_r) = [1.1 * \log\ (f) - 0.7] * h_r - (1.58 \log\ (f) - 0.8)$ ……………………………..…………..3.4

After determining the appropriate cell radius, sites number and sites coverage areas are calculated by the equations below:

Site coverage Area for Omni Site:

$$A = \frac{3\sqrt{3} * R^2}{2}$$

Site coverage Area for two sector Site:

$$A = \sqrt{3} * R^2$$

……………………..……………….……….......3.5

Site coverage Area for three sector Site:

$$A = \frac{9\sqrt{3} * R^2}{8}$$

Finally, the site count based on coverage is calculated as follows:

Total number of site = $\frac{Target\ Area\ to\ be\ covered}{Site\ area}$ ……….…………………………..…...…3.6

3.2. LTE Capacity Dimensioning Process

Capacity planning deals with the ability of the network to provide services to the users with a desired level of quality. After the site coverage area is calculated using coverage estimation, capacity related issues are analyzed. This involves selection of site and system configuration, e.g. channels used, channel elements and sectors. These elements are different for each system. Configuration is selected such that it fulfills the traffic requirements. In some wireless cellular systems, coverage and capacity are interrelated, e.g. in WCDMA. In this case, data pertaining to user distribution and forecast of subscriber's growth is of utmost importance .Dimensioning team must consider these values as they have direct impact on coverage and capacity. Capacity evaluation gives an estimate of the number of sites required to carry the anticipated traffic over the coverage area.

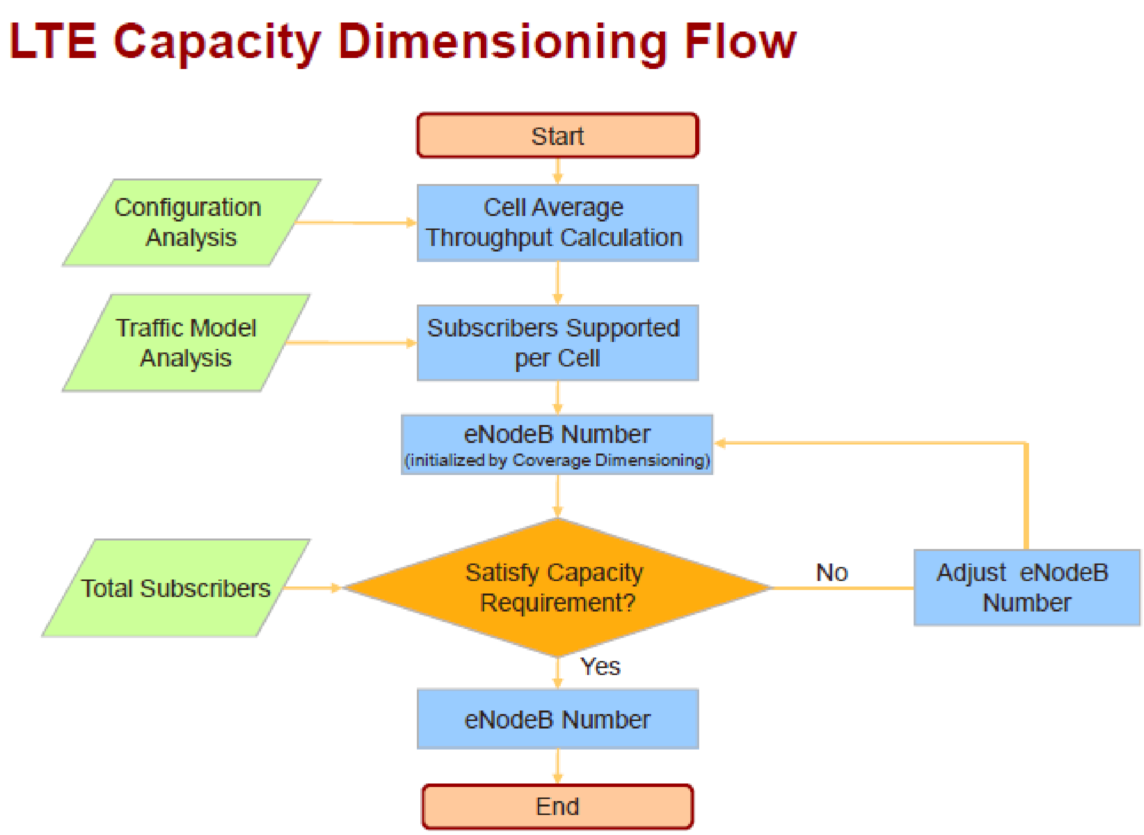


Figure 12: LTE Capacity Dimensioning Flow

LTE dimensioning process starts with the Radio Link Budget Calculations, used to determine the maximum path loss. The result of this step depends upon the propagation models used. The estimated cell size, obtained in this step, leads to the maximum allowed size of the cells. This parameter is used to calculate the number of cells in the area of interest. Thus, a rough estimate of the required number of cell site is obtained. Capacity calculations follow the above process for coverage estimation. If the coverage estimates for the given configuration, fulfills the capacity requirements, then there is no addition to the previous plan. On the other hand, suitable number of cell sites is added to achieve the capacity targets.

After the estimation of the cell size and sites count from the coverage prediction, the capacity estimation is carried out to verify whether the given sites count can carry the estimated users capacity.

It is verified whether with the given sites density, the system can carry the specified load or new sites have to be added. Theoretical capacity of the network is limited by the number of eNBs installed in the network. Cell capacity in LTE is impacted by several factors, which includes interference level, packet scheduler implementation and supported. In LTE, the main indicator of capacity is the SINR distribution in the cell. The SINR distribution can be directly mapped to the system capacity (data rate). The capacity based on the number of sites is compared with the result of the coverage and the larger of the two numbers is selected as the number of end sites. The subscriber density and subscriber traffic profile are the main requirements for capacity dimensioning.

The aim of LTE capacity dimensioning is to obtain the packet switch throughput supported by the network based on the available bandwidth and channel condition of each user.

The LTE Cell Capacity (Throughput) depends on:

1. Cell Range (Path loss): the cell range considered a variation of the Inter Site Distance (ISD), the larger ISD the less cell capacity because the SINR distribution is bad in larger cells which become more & more noise limited.

2. Channel Bandwidth (1.4 MHz - 20 MHz): The best capacity performance can be achieved with wide channel bandwidth due to the maximum frequency diversity gain And Small Bandwidth configurations are characterized by high system overhead.

3. LTE Features:

- ✓ **MIMO (Multiple Input Multiple Output):**
  - **Transmit diversity (Tx diversity)** it results in coverage improvement therefore, it is more suitable to be used at the cell edge.
  - **Open / Closed Loop Spatial Multiplexing** Spatial multiplexing on the other hand doubles the subscriber data rate
- ✓ **Scheduling: Proportional Fair** or **Round Robin**: From the average cell throughput point of view there is some gain when Proportional Fair (PF) is used, the main reason for the gain is coming from the fact that the SINR distribution in the cell is improved when proportional fair is used. The gain is dependent on the number of users that are scheduled together in the same TTI (1ms): the higher the number of scheduled users per TTI the higher the average cell throughput gain when proportional fair is in use

4. Cell Load: It has to be noticed that when the neighbor cell load is decreasing the cell throughput is increasing as expected.

3.2.1. Traffic volume based approach:

The traffic volume based approach estimates the maximum traffic volume in gigabytes that can be carried by LTE sites. Network dimensioning in the busy hour needs to be reserved in order to guarantee low delays and reasonably good data rates. The traffic model defines an application services such as VoIP, Video, Streaming, Web browsing & FTP provided by network based on the service providers. The main purpose of traffic model is to describe the average subscriber behavior during the most loaded day period (the Busy Hour) and the capacity of site should be based on busy hour as the traffic is not equality distributed during 24 hour.

The average throughput per subscriber based on traffic usage in the month ρ (Gigabytes) is calculated using:

$$\Omega(\text{Kbps}) = \rho * \left(\frac{\left(\frac{8\text{bit}}{\text{byte}} * \text{BH ratio}\right)}{30 \text{ days x time in second}}\right) \quad \ldots\ldots\ldots 3.7$$

Where

- ✓ Ω(Kbps) is average throughput per subscriber in busy hour (UL + DL)
- ✓ ρ is the Traffic Usage in Month/User
- ✓ BH is busy hour

After manipulating the average throughput per subscriber for each service type defined by operator, the total average throughput per subscriber in busy hour is given by:

$$\Phi\ (\text{Kbps}) = \sum(\Omega(\text{Kbps}) * Usage\ ratio\ of\ the\ service) \ldots\ldots\ldots 3.8$$

Where

- ✓ $\Phi\ (Kbps)$ is the total throughput per subscriber in busy hour (UL + DL)

Finally based on the traffic of services, the average throughput per subscriber for uplink and downlink written as

$$\Gamma\ (\text{Kbps}) = \Phi\ (\text{Kbps}) * \text{ UL traffic ratio}$$

$$\eta\ (\text{Kbps}) = \Phi\ (\text{Kbps}) * \text{ DL traffic ratio} \quad \ldots\ldots\ldots 3.9$$

Where

- ✓ $\Gamma\ (Kbps)$ is the average throughput for uplink
- ✓ $\eta\ (Kbps)$ is the average throughput for downlink

As per 3GPP release 10, LTE support modulation QPSK, 16QAM and 64QAM for downlink and QPSK and 16QAM for uplink. Each of Modulation has its bits carrying capacity per symbol. One QPSK symbol can carry 2bits, one 16QAM symbol can carry 4bits and 64 QAM symbol can carry 6 bits.

$$\delta\ (Mbps) = (data\ RE/sec * bits\ \text{per}\ RE * MIMO\ effect * coding\ rate) \ldots\ldots\ldots 3.10$$

Where:

- ✓ $\delta\ (Mbps)$ is the peak throughput per site per modulation
- ✓ The data RE/s is the data in resource element per second
- ✓ Coding rate indicates the volume coding rate of the channel code. For example, the volume coding rate of QPSK1/2 is 1/2, and the volume coding rate of 16QAM3/4 is 3/4.

The average throughput per site for uplink and downlink formulated as:

$\lambda\ (Mbps) = \sum(Mbps) * Trafic\ ratio\ of\ UL$ ………..…………………………………..……...3.11

$\mu\ (Mbps) = \sum(Mbps) * Trafic\ ratio\ of\ DL$ ………………………………....………………...3.12

Where

$(Mbps)$ is the average throughput per site for uplink

- ✓ $\mu(Mbps)$ is the average throughput per site for downlink

The number maximum subscriber number per site is calculated for both uplink and downlink from eqs.3.9 to 3.12 as follow:

$Max\ Sub\ No.per\ site\ UL = \lambda\ (Mbps)/\Gamma\ (Kbps)$………….…………………………………....3.13

$Max\ Sub\ No.per\ site\ DL = \mu\ (Mbps)/\eta\ (Kbps)$……………...……….………………………....3.14

Finally the total site based on the capacity required, taking the minimum number of subscriber from uplink and downlink or from equation 3.13 and equation 3.14 is calculated as:

$Total\ site\ number = \frac{Total\ sub.of\ the\ area}{Max.Sub.per\ site}$………………………………………………………………...…3.15

Site Count

In the LTE network dimension the required sites number for a specific area should be chosen to be the maximum number of sites obtained from coverage and capacity dimensioning calculations to satisfy the demand traffic requirements.

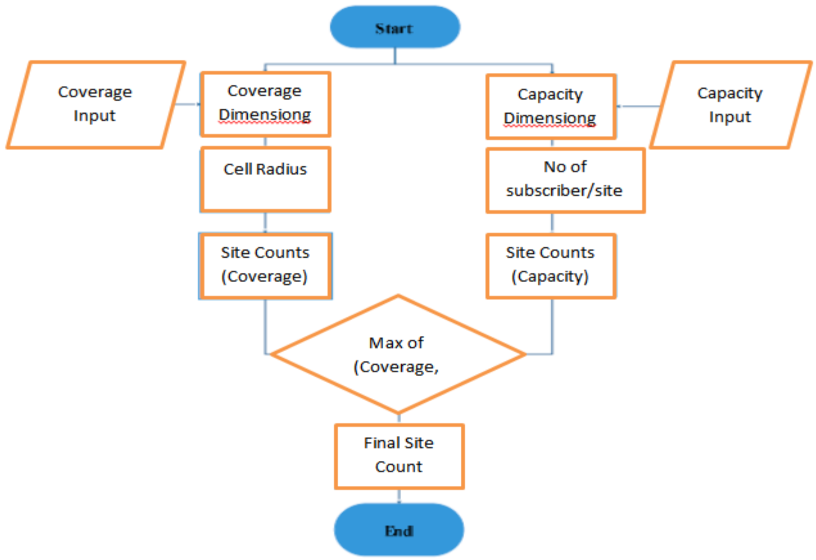


Figure 13 Site count selection

3.3 Frequency planning

LTE is designed to operate in wide range of different frequency bands depending on the duplex mode of operation. Table 3-3 lists the currently defined LTE frequency bands, together with the corresponding duplex mode (FDD or TDD). There are currently 17 bands defined for FDD and 8 bands for TDD. Whenever possible, the RF requirements for FDD and TDD have been kept identical to maximize the commonality between the duplex modes between the duplex modes. All of these bands are available in each of the world's regions and all bands are Release-independent and can be implemented by UEs conforming to any Release. One point worth mentioning is proper frequency band selection. A typical UE would support a certain subset of these bands depending on the desired market, since supporting all would be challenging for the transceiver, in particular for the front-end components such as Power Amplifiers (PAs), filters and duplexers. The set of frequency bands chosen defines the capability of the UE to switch bands, roam between national operators and roam internationally; thus it has to be based on the regulation standard set by the country. Similarly, frequency selection has to be area dependent. For instance, for urban areas that are highly populated, high frequency bands such as LTE 2600MHz and LTE 1800MHzare used for capacity enhancement. Whereas, rural areas with dispersed population frequency bands such as LTE 900 MHz are used for wider coverage.

Table 3.4: LTE Frequency Band

LTE Band	Uplink(MHz)		Downlink (MHz)		Duplex mode
1	1920	1980	2110	2170	FDD
2	1850	1910	1930	2170	FDD
3	1710	1785	1805	1880	FDD
4	1710	1755	2110	2155	FDD
5	824	849	869	894	FDD
6	830	840	875	885	FDD
7	2500	2570	2620	2690	FDD
8	880	915	925	960	FDD
9	1749.9	1784.9	1844.9	1879.9	FDD
10	1710	1770	2110	2170	FDD
11	1427.9	1447.9	1475.9	1495.9	FDD
12	698	716	728	746	FDD
13	777	787	746	756	FDD
14	788	798	758	768	FDD
17	704	716	734	746	FDD
18	815	830	860	875	FDD
19	830	845	875	890	FDD
…….					

33	1900	1920	1900	1920	TDD
34	2010	2025	2010	2025	TDD
35	1850	1910	1850	1910	TDD
36	1930	1990	1930	1990	TDD
37	1910	1930	1910	1930	TDD
38	2570	2620	2570	2620	TDD
39	1880	1920	1880	1920	TDD
40	2300	2400	2300	2400	TDD

In case of this work band 3 is used with for uplink from1727.5MHz to 1747.5MHz and for downlink from 1822.5MHz to 1842.5MHz.

Table 3.5: 1800 MHz bandwidth

Operator	Bandwidth	1800M			
		Uplink		Downlink	
Ethio telecom	1800 Bandwidth	1710-1747.5		1805-1842.5	
	GSM	1710-1727.5		1805-1822.5	
	LTE		1727.5-1747.5		1822.5-1842.5

Note that, band 6 was defined in the context of Rel.‟8; it is replaced by Band 19 for later Releases of LTE (Rel.‟9 and 10) thus only legacy terminals (UE) would use band 6.

To achieve effective performance, high mobility and other advanced futures that LTE presents, careful frequency planning is needed to be performed. The starting point for „how much spectrum‟ and „in which frequency band‟ must be used to determine how far is the area required to be covered and what data rate would be required on a cell for an acceptable and competitive mobile broadband service in perhaps five to ten years‟ time. In any case, the rate achievable in a cell is shared through weighted scheduling between all the users in the cell area. Thus an average user rate will be much lower than the maximum data rate offered when a cell is highly occupied. In most cases, the transmitter must not only generate a clear signal within the assigned spectrum, but also keep the interference within the acceptable level so that the receiver can demodulate the wanted signal reliably and reject the interference from neighboring carriers. Thus, to obtain the intended signal quality using the limited frequency spectrum there has to be a way of properly using the spectrum.

3.3.1 Frequency Reuse scheme in LTE

In order to fully utilize the spectrum and greatly enhance the system capacity with minimum interference, it is known that effective reuse of resources is very important. The LTE RAN can be constructed in the same frequency band-(intra-frequency planning) i.e., the frequency reuse pattern size of 1 can be used. The benefit of this solution is that the users can take full advantage of the high bandwidth with respective peck data rates. However the interference in here is remarkably high.

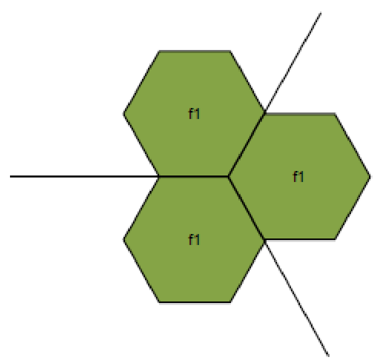


Figure 14: Frequency reuse factor 1

Another solution is to divide the available LTE frequency band into smaller blocks in order to create higher reuse pattern sizes; i.e., inter-frequency planning. For instance, if the LTE system has been granted a total of 15 MHz of bandwidth, it can be used completely for all the sites. This option, as it has been shown above in Figure 5-2, provides with the highest possible data rate, although the average data rate suffers at some extend due to the inter-cell interfaces when other users are present. However, if the 15 MHz block is divided into 5 MHz slices, it makes it possible to use three different frequencies per sector. This means that the frequency reuse size 3 can be applied. In such cases, the interference can be reduced, and thus the total number of users will increase. Nevertheless, the peak data rate per user is now only one third compared to the services offered via the full frequency band of 15 MHZ.

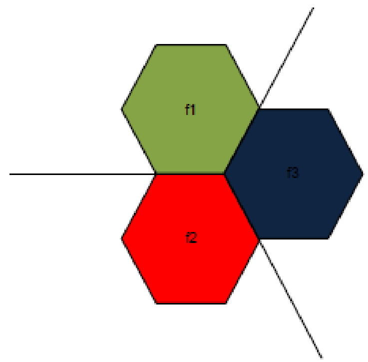


Figure 15: Frequency reuse 3

To mitigate these inter-dependent factors, the concept of ICIC (Inter Cell Interference Coordination) is implemented in LTE. Such a technique enables the eNBs, via the X2 interface, to pass overload and high interference information, this in turn may be used by the eNB to dynamically adjust the power and the number of RB allocated in it.

The ICIC method describes the basic rules on how a system performance boost can be achieved by managing the system bandwidth and transmits power. This is a hybrid frequency partitioning, combining the concepts of the two previous schemes. It consists of dividing the spectrum into two parts which will have different frequency reuse. One section of the system spectrum is used in all cells, while the other part of the spectrum is divided among different eNBs as in inter-frequency planning. The idea is that the eNB would assign the fully-reused frequency portions to center-cell UEs and the other portions to the cell edge UEs. In real LTE networks, cell edge frequency reuse can be 3 while cell center frequency reuse is 1 as it can be seen in figure below.

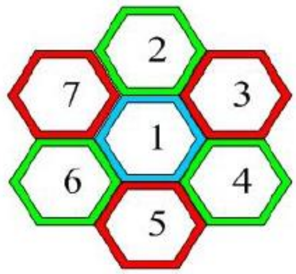


Figure 16: Cell edge frequency reuses 3 and cell center frequency reuses 1

CHAPTER FOUR

Results and Analysis

Coverage Analysis

From **equation (3.2)**, the COST-231 HATA model for path loss prediction is given by:

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

- $33.9*\log(f) = 33.9*\log(1800)$
  $= 33.9*3.255$
  $= 110.35$
- $13.82*\log(h_b) = 13.82*\log(30)$
  $= 13.82*1.48$
  $= 20.45$
- $\alpha\ (h_r) = 3.2*(\log(\ 11.75h_r))\ ^2 h_r - 4.97$
  $= 3.2*(\log(11.75*1.5))^2*1.5 - 4.97$
  $= 3.2*1.55*1.5 - 4.97$
  $= 2.47$
- $[44.9 - 6.55\log(\ h_b)\ ]\log\ d = [44.9 - 6.55\log(1.5)]\log\ d$
  $= 35.21\log\ d$

» PL(dB) = 46.3+110.35-20.45-2.47-35.21log d+3

=136.73+35.21log d

» log d = (PL-136.73)/35.21

» $d = 10^{(PL-136.73)/35.21}$

Link budget and coverage planning is calculated, for both cases UL and DL as following the procedure steps are:

Step 1: Calculate the Max Allowed Path Loss (MAPL) for DL and UL.

Table 4.1: Summary of Downlink MAPL Calculation

Tx		**Formula**
	Max Total Tx Power (dBm)	A=46
	RB to Distribute Power	C= 100
	Subcarriers to Distribute Power	D=12*C=1200
	Subcarrier Power (dBm)	E =A-10*Log10(D)=15.21
	Tx Antenna Gain (dBi)	G=18
	Tx Cable Loss (dB)	H=0.5
	EIRP per Subcarrier dBm	J = E+G-H=32.71
Rx		**Formula**
	SINR (dB)	K=-1.84
	Rx Noise Figure (dB)	L=7
	Receiver Sensitivity_(dBm)	M = K+L-174+10*Log10(15000)=-127.08
	Rx Body Loss(dB)	P=-0.5
	Interference Margin (dB)	Q=-5.99
	Min Signal Reception Strength (dBm)	R= M+P+Q=-133.57
	Path Loss & Shadow Fading Margin	**Formula**
	Penetration Loss (dB)	S=15
	Shadow Fading Margin (dB)	T=8
	Path Loss (dB)	U =J -R -S –T=32.71+133.57-15-8=143.28

Table 4.2 Summary of Uplink MAPL Calculation

Tx		**Formula**
	Max Total Tx Power (dBm)	A=23
	RB to Distribute Power	C=4
	Subcarriers to Distribute Power	D=12*C=48
	Subcarrier Power (dBm)	E =A-10*Log_{10}(D)=6.19
	Tx Body Loss (dB)	I=0
	EIRP per Subcarrier (dBm)	J = E-I=6.19
Rx		**Formula**
	SINR (dB)	K=0.47
	Rx Noise Figure (dB)	L=2.5
	Receiver Sensitivity_(dBm)	M = K+L-174+10*Log_{10}(15000)= -129.27
	Rx Antenna Gain (dBi)	N=18
	Rx Cable Loss(dB)	O=-0.5
	Interference Margin (dB)	Q=-1.97
	Min Signal Reception Strength (dBm)	R= M-N+O+Q= -149.74
	Path Loss & Shadow Fading Margin	**Formula**
	Penetration Loss (dB)	S=15
	Shadow Fading Margin (dB)	T=8
	Path Loss (dB)	U =J -R -S -T= 132.93

Step 2: Calculate the DL and UL cell radiuses by the propagation model equation (3.1)

Cell radius is $d_{UL} = 10^{(PL-136.73)/35.21}$

$=10^{(132.93-136.73)/35.21}$

$=10^{-3.8/35.21}$

$=0.78km$

$d_{DL} = 10^{(PL-136.73)/35.21} = 10^{(143.28-136.73)/35.21}$

$= 10^{0.186}$

$= 1.53km$

Step 3: Determine the appropriate cell radius by balancing the DL and UL radiuses. Normally the minimum of the maximum path losses in UL and DL directions is converted into cell radius i.e. minimum of the radii is used as cell radius

Since the cell with minimum radius is chosen, the cell radius will be 0.78km

Step 4: Calculate the site coverage area and the required sites number.

So Site Area = $\frac{9}{8}\sqrt{3}[R]^2$

$= \frac{9}{8}\sqrt{3}[0.78]^2$

$= 1.19km^2$

Finally, the site count based on coverage is calculated as follows:

Total number of site = $\frac{Target\ Area\ to\ be\ covered}{Site\ area}$

Considering coverage of densely populated area around centre of Adama city 70km^2

The Total number of site to cover this area is

$\# \text{ of site} = \frac{Area\ to\ be\ covered}{Site\ area}$

$= \frac{70}{1.19}$

=59 sites are required

Analysis on capacity

The daily traffic can be estimated as a percentage of the busy hour traffic. In this thesis, we assume that the busy hour assumed to be in different three time segment within the 24 hours of a day. The first segment is from 8:00 AM to 8:30 AM in the morning, the second segment is from 12:30 AM to 1:30 PM in the afternoon and the third segment is assumed to be from 8:00 PM to 9:00 PM in the evening. Thus, a total of 3 hours are consider to be the busy hours within 24 hours of a day, which makes the busy hour traffic to be 12.5% of the daily traffic. Assume the traffic model of table below as input parameter based on the current usage of Ethio Telecom data usage.

Table 4.3 Ethio Telecom data usage

Types of customer	Traffic Usage in GB/Month/User	Busy hour convergence ratio	Usage ratio of the services	Traffic ratio	
				DL	UL
Type 1	20	12.5	10%	80%	20%
Type 2	15	12.5	40%	80%	20%
Type 3	10	12.5	50%	80%	20%

The average throughput per subscriber based on traffic usage in the month ρ (Gigabytes) is calculated as

$$\Omega(\text{Kbps}) = \rho * \left(\frac{\left(\frac{8\text{bit}}{\text{byte}} * \text{BH ratio}\right)}{30 \text{ days x time in second}}\right)$$

For type 1: $=20x10^9 * \left(\frac{\left(\frac{8\text{bit}}{\text{byte}} * 12.5\%\right)}{30*60*60}\right)$ *= 185.185*

For type 2: $=15x10^9 * \left(\frac{\left(\frac{8\text{bit}}{\text{byte}} * 12.5\%\right)}{30*60*60}\right)$ *= 138.889*

For type 3: $=10x10^9 * \left(\frac{\left(\frac{8\text{bit}}{\text{byte}} * 12.5\%\right)}{30*60*60}\right)$ *=92.593*

Types of customer	Average throughput /user in BH (Kbps)(DL+UL)
Type 1	185.185
Type 2	138.889
Type 3	92.593

Total Avg. throughput per sub @BH (Kbps)= Σ *Avg. throughput per sub x packet percentage*

$$= 185.185 \times 10\% + 138.889 \times 40\% + 92.593 \times 50\%$$
$$= 18.518 + 55.556 + 46.296$$
$$= 120.370$$

Downlink and uplink throughput per subscriber

Total avg. throughput per sub in BH (Kbps)	UL	24.074
	DL	96.296

Calculate average throughput per site for uplink and downlink using equations 3.10,3.11,3.12

Description	Value	Assigned	Remark
Used bandwidth (MHz)	20	a	-
Assumed 10% of bandwidth used for guard (CP) (MHz)	2	b	10% *a
Effective bandwidth (MHz)	18	c	a-b
Bandwidth of one subscriber (KHz)	15	d	-
Total subcarrier	1200	e	c/d
Symbols per 1ms for resource block	16800		12*7*2
Symbols per 1ms for resource block (Mbps)	16.8		16800/1000

MIMO	2Tx2R for downlink		
Bits capacity per symbol (bit)	2		QPSK
	4		16QAM
	6		64QAM
Coding rate	0.667		QPSK
	0.793		16QAM
	0.8		64QAM

Input parameters for average throughput per site manipulation

Modulation	Data rate	Code Rate	MIMO effect	Data resource/sec (Mbps)
QPSK	2	0.3	2	16.8
16QAM	4	0.38	2	16.8
64QAM	6	0.45	2	16.8

Total Peak Throughput per site (Mbps)	162
Average throughput per site for downlink (Mbps)	129.6
Average throughput per site for uplink (Mbps)	32.4

The number maximum subscriber number per site is calculated for both uplink and downlink

Downlink: maximum number of subscriber =**1346 sub/site**

Uplink: maximum number of subscriber =**1346 sub/site**

Finally the total site based on the capacity required, taking the minimum number of subscriber per site from uplink and downlink for Adama City. Ethiotelecom has plan of deploying LTE network that support an LTE subscribers of 100000 in Adama City.

$$Total\ site\ number = \frac{Total\ sub.of\ the\ area}{Max.Sub.per\ site}$$

$$= \frac{100000}{1346}$$

=75 sites

Hence comparing the number of sites from capacity and coverage planning and choosing the maximum we obtain 75 sites to satisfy both coverage and capacity.

CHAPTER FIVE

Simulation Results and Discussion

5.1 Simulation

Simulation is a practical and scientific approach to analyze a complex system. In this project, simulation is used to investigate the RAN nominal planning of LTE networks as it is done using Atoll simulation environment. The LTE radio network planning simulation is intended to carry out the link budget calculation, propagation modeling using the terrain model, coverage estimation and capacity evaluation.

Site Survey

The process of site survey is to identify the different environmental factors that directly or indirectly affect the radio network planning process and as well to list out them as planning parameters. For this project the Adama City was considered as the area of planning. Adama city is one of the fast growing cities in Oromia region both in population and area. Adama is the city in which different conference was held. In this project I choose Adama City which has area of about 70 km^2 with an assumption of 100,000 LTE subscribers distributed in it.

ATOLL Overview

ATOLL is a multi-technology wireless network design and optimization platform that supports wireless operators throughout the network lifecycle, from initial design to optimization. ATOLL's integration and automation features help operators smoothly automate planning and optimization processes through flexible scripting and SOA-based mechanisms. ATOLL supports a wide range of implementation scenarios, from standalone to enterprise-wide server-based configurations. ATOLL has become the industry standard for radio network planning and optimization. Before running the predictions, it is important to create the zones. Below is a description of these zones base on the ATOLL User Manual.

Filtering Zone: The filtering zone is a graphical filter that restricts the objects displayed on the map and on the Data tab of the Explorer window to the objects inside the filtering zone. It also restricts which objects are used in calculations such as coverage predictions, etc.

Computation Zone: The computation zone is used to define which base stations are to be taken into consideration in calculations and the area where ATOLL calculates path loss matrices, coverage studies, etc.

Focus Zone: With the focus zone, you can select the areas of coverage predictions or other calculations on which you want to generate reports and results.

The first input is a digital map, which is used to setup working environments on the ATOLL tool. In this study digital map of Adama city is used to perform the simulation and the selected area is shown in Figure 16. A digital map is an electronic database containing geographical information such as land usage

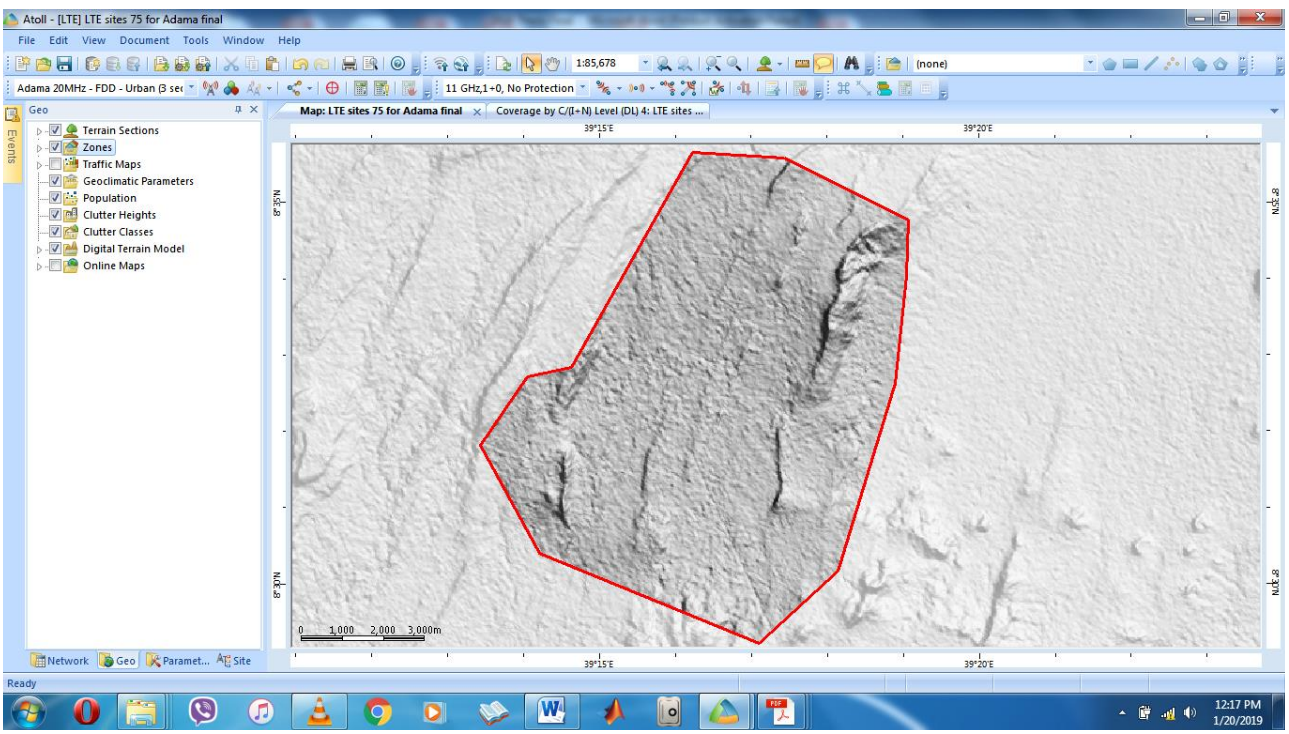


Figure 17: Digital map of Adama

The second inputs are the parameters used to configure network parameters such as site parameters, transmitter & cell parameters and global parameters. Table below shows some of the main parameters used to configure the target network in the ATOLL.

Table 5.1 Network configuration sample parameters

Parameters	**DL**	**UL**
Frequency	1800 MHz	
Bandwidth	20 MHz	
Duplex Mode	FDD	
Propagation Model	Cost-Hata	
Frequency Reuse	1	
Scheduling	Proportional Fair	
MIMO Configuration	2x2	1x2
Transmit Power	46 dBm	23 dBm

Once the network parameters configurations completed, the sites placement will be performed to know the geographical location of each sites. In practical case, a site survey will be performed to study the feasibility of the location in terms of land acquisition and facilities such as road access and availability of power supply.

After the sites placement step is completed, target network prediction and capacity evaluation will be done. The target network prediction result will be evaluated to validate the target network requirement. From the previous chapter results, the received signal level (RSL) is Maximum transmitted signal minus path loss.

So RSL =Pt-PL…………………………………………………………...…..5.1

The LTE Network design targets requirement is shown in the table below.

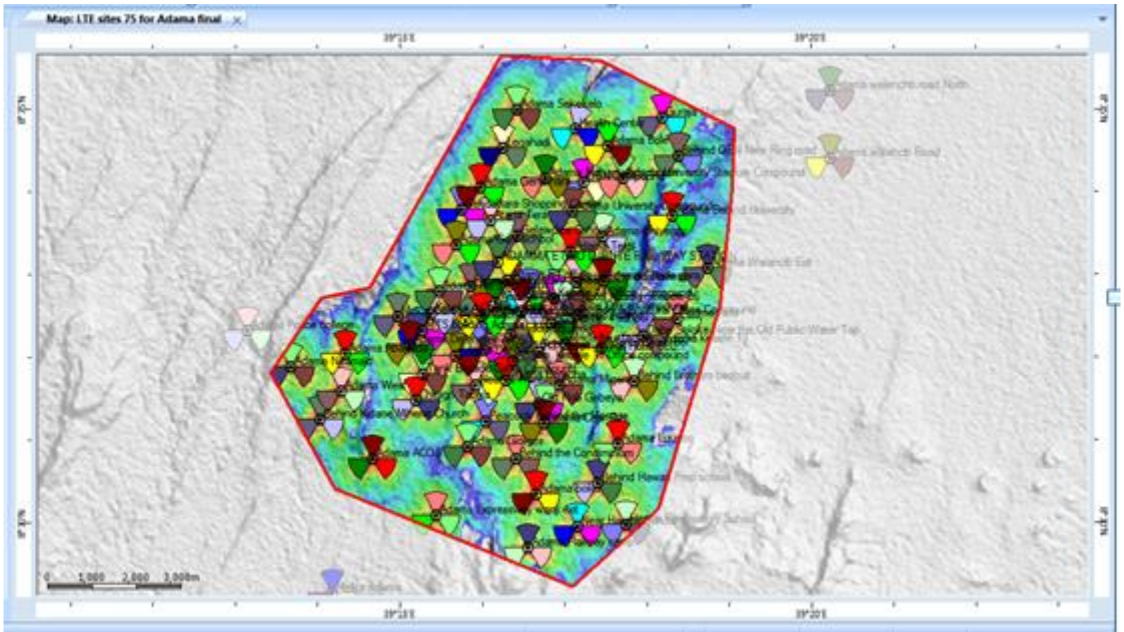
Table 5.2: The design targets requirement for the LTE Network

Criteria		Target downlink	Target uplink
Best Signal Level	Good	> -97.28dBm	>-109.93dBm
	Medium	-97.28 to -133.57dBm	-109.93dBm to -149.74dBm
	Loss	< -133.57 dBm	<-149.74dBm
Area coverage probability		90%	
Overlapping Zones	Area with > 2 servers	Below 35%	
	Area with > 4 servers	Below or 2%	

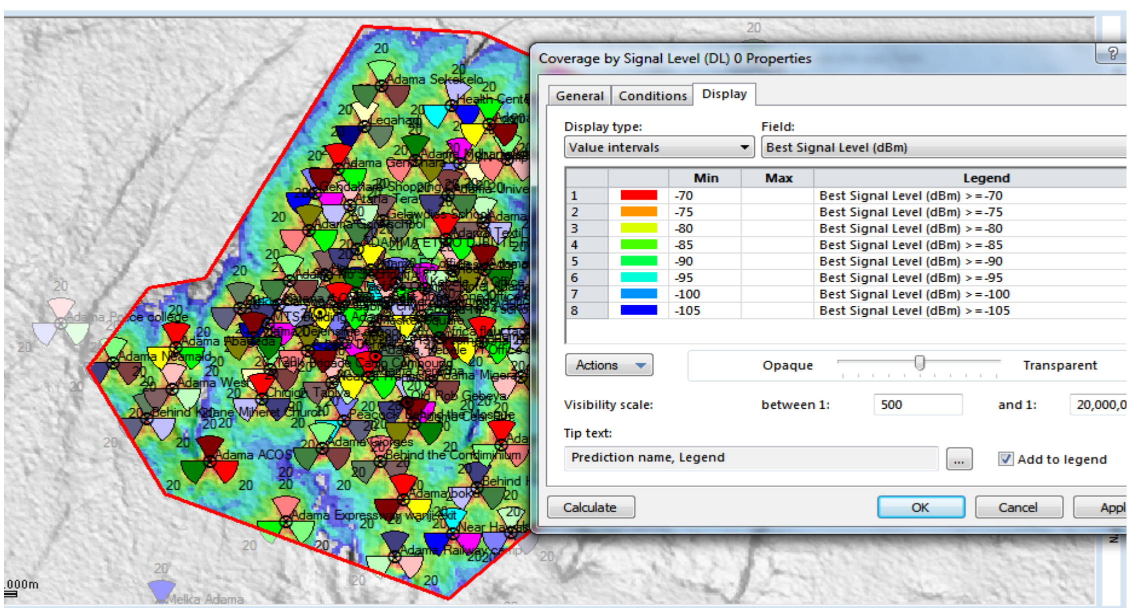
Coverage predictions have been performed by: transmitter, signal level, downlink throughput and Channel to Interference plus Noise Ratio (CINR). Corresponding coverage prediction results have been shown with respective coverage prediction properties.

Coverage by Signal Level*:*

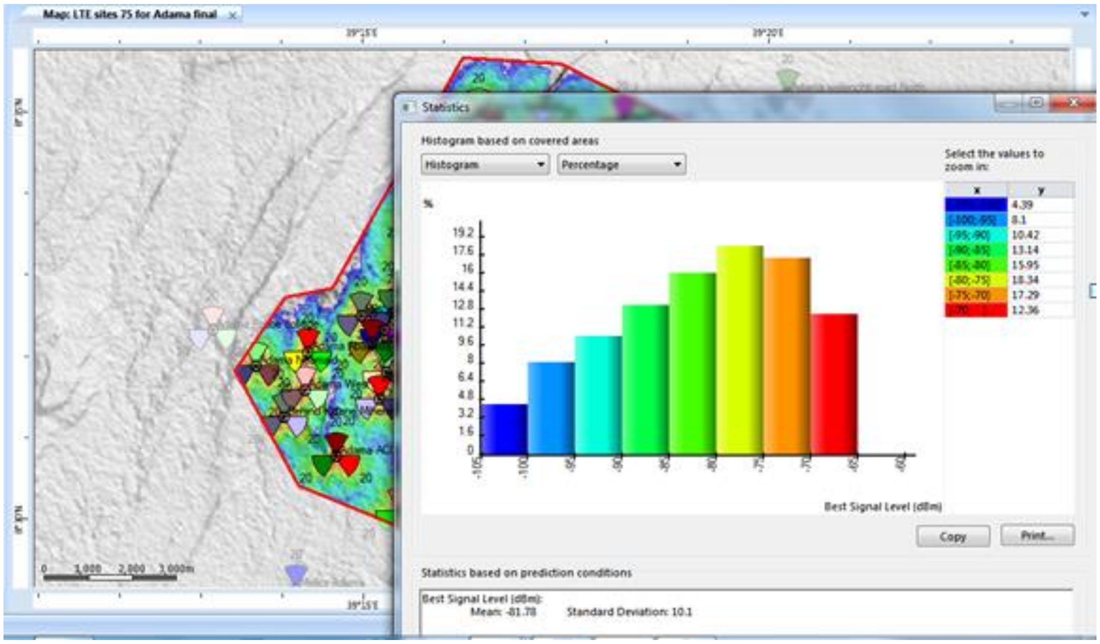
Coverage is defined as the possibility to get a service with a defined network requirement in terms of signal quality. A coverage prediction by signal level allows us to predict coverage zones by the transmitter signal strength within the computation zone. Signal level in a cell addresses the highest signal strength of the best server of the studied area. A signal level coverage prediction displays the signal of the best server for each pixel of the area studied. For a transmitter with more than one cell, the signal level is calculated for the cell with the highest power. As show on figure 18 more than 88.75% of the target area/Adama city area is covered by strong signal i.e. -97.28dBm.



a) Coverage by Signal Level



b) Coverage Signal Level



c) Histogram of Signal Level

Figure 18: Coverage by Signal Level

Coverage Prediction by Transmitter:

A coverage prediction by transmitter allows predicting coverage zones by transmitter at each pixel. You can base the coverage on the signal level, path loss, or total losses within a defined range. It predicts the maximum area that can be covered by a base station. How far the placed transmitters have covered is shown in coverage by transmitter map in figure 19. For a transmitter with more than one cell, the coverage is calculated for the cell with the highest power.

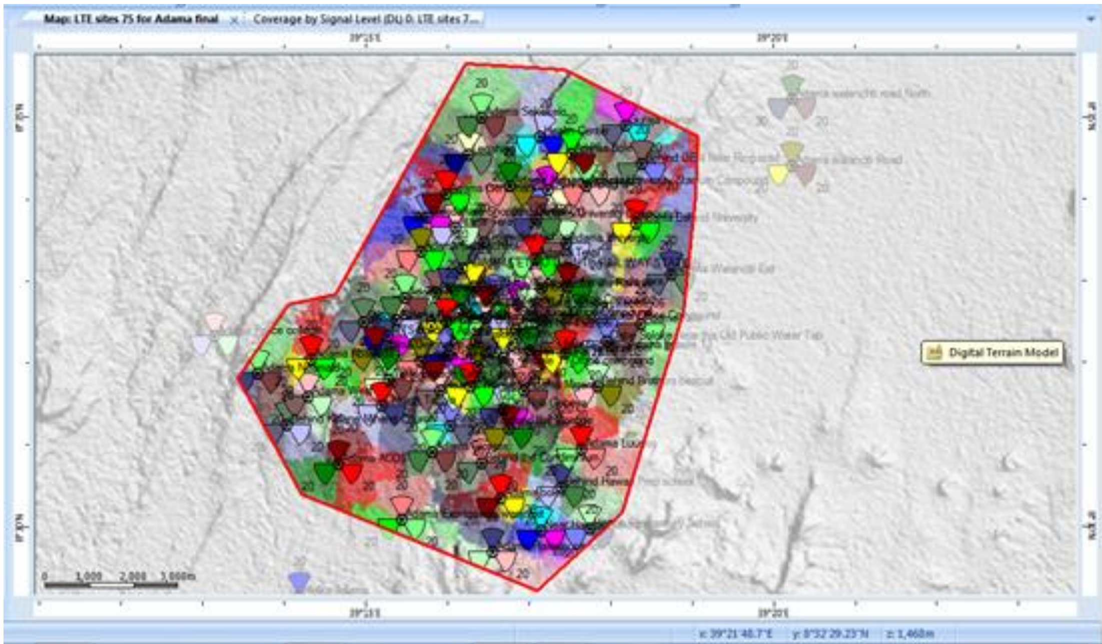


Figure 19: Coverage Prediction by Transmitter

Coverage Prediction on Overlapping Zones:

The other coverage prediction that has been done on the selected area is by the overlapping zones meanwhile cells are considered to overlap. The overlapping zone occurs very often in mobile networks and can reduce the quality of a network, in particular the area where it occurs. The overlapping zone is the existence of several zones in which a cell is dominant (best server), but that is outside the normal coverage area. It is mainly caused by antennas located at higher and lower areas, but also due to reflections in the environment. Hence large areas overlapping reduce the performance. The best server predictions of LTE are shown in Figure 19. The overlapping area percentage of 4 or more servers must be less than 2%, and the area with 2 or more servers must be less than 35% [27]. As requirement for this indicator of Figure 20, it was determined that the area percentage of 4 or more servers must be less than 2% which is 1.48%, and the area with 2 or more servers must be less than 35% which is 30.6%. Overlapping zones as shown on figure 20 are composed of pixels that are, for a defined condition, covered by the signal of at least two transmitters. You can base a coverage prediction on overlapping zones on the signal level, path loss, or total losses within a defined range. For a transmitter with more than one cell, the coverage is calculated for the cell with the highest power.

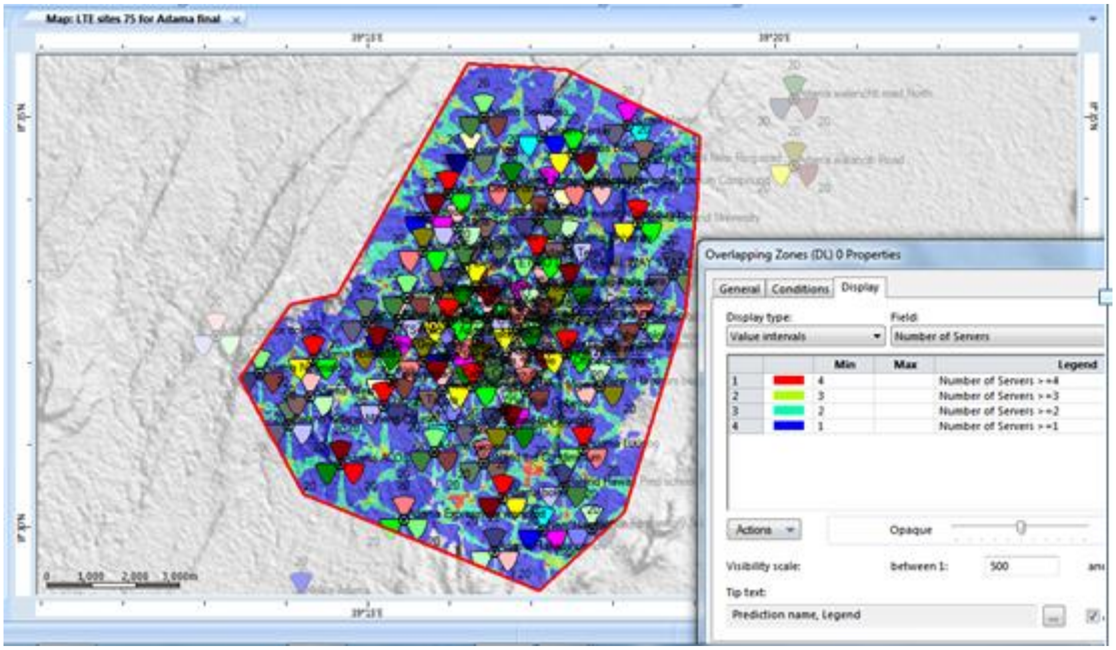


Figure 20: Coverage Prediction on Overlapping Zones

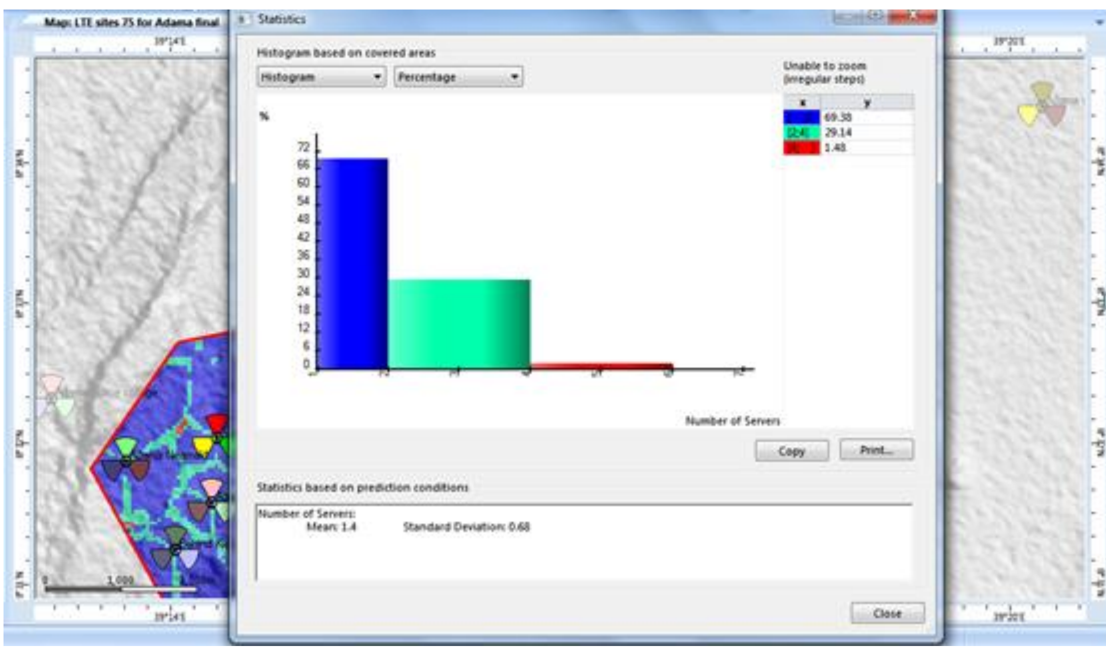
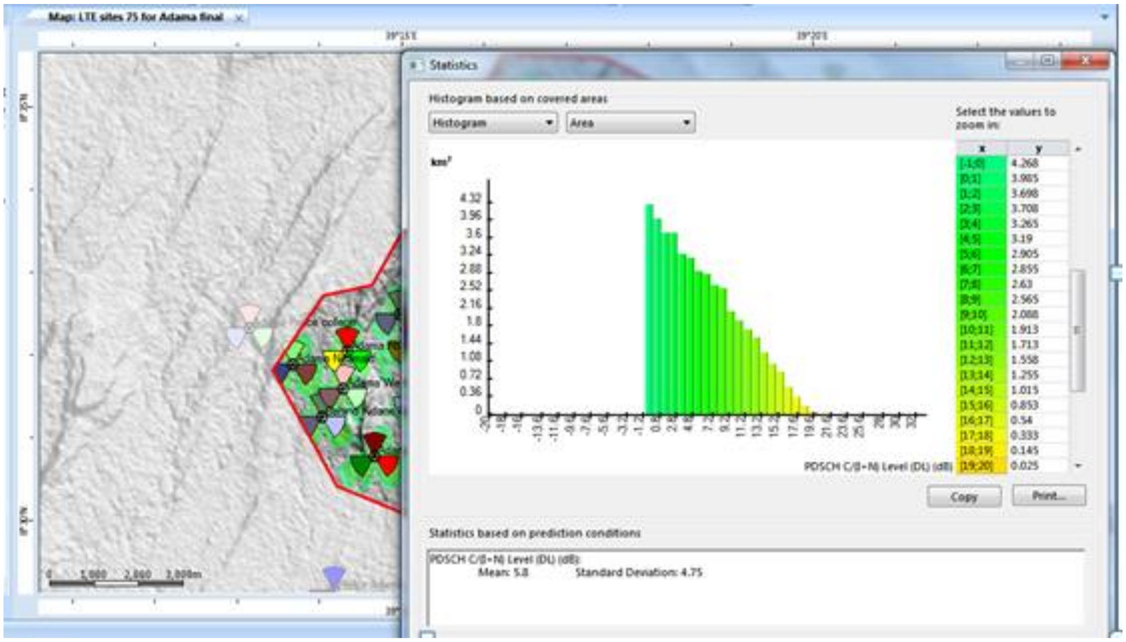


Figure 21 Histogram of Overlapping Server in percentage

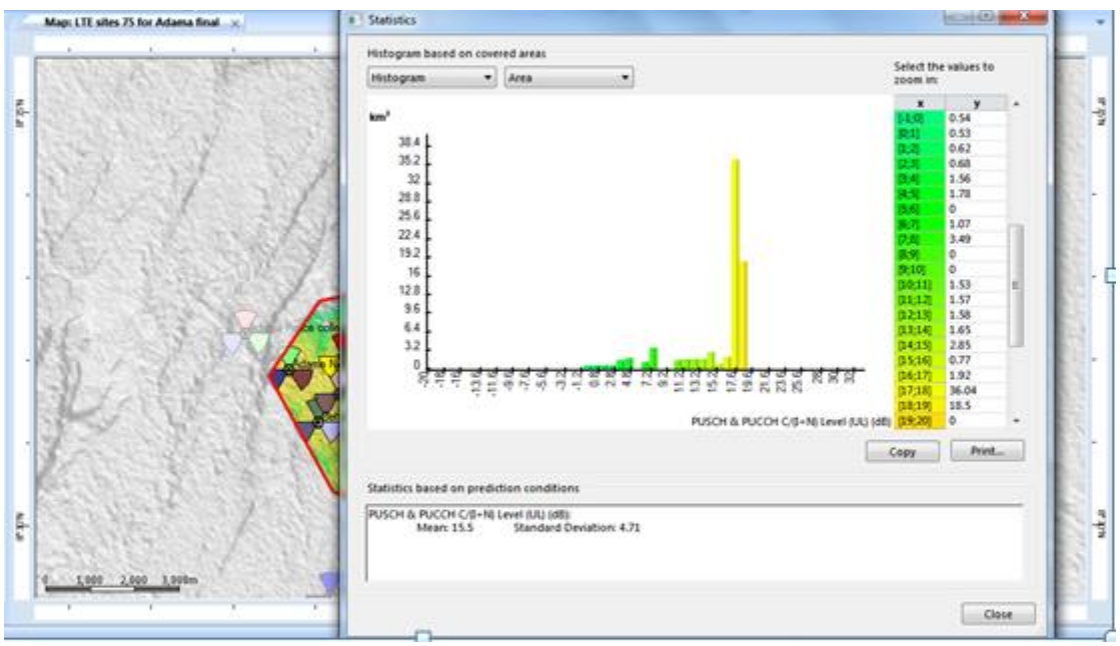
Analyzing the Signal Quality (Coverage by C/ (I+N) Level (DL) or (UL))

In LTE, the capacity and the effective service coverage areas of cells are influenced by network loads. As the network load increases, the area where a cell provides service decreases. For this reason, network loads must be defined in order to calculate these coverage predictions.

ATOLL offers a series of coverage predictions which are based on the predicted signal level from the best server and the predicted signal levels from other cells (interference) at each pixel, i.e., carrier-to-interference-and-noise ratio, or C/(I+N). In this section, these coverage predictions will be calculated using downlink traffic loads and the uplink noise rise values defined at the cell level. Before making a prediction, the downlink traffic loads and the uplink noise rise, and the parameters that define the services and users are defined. Downlink and uplink coverage predictions by C/(I+N) level predict the interference levels and signal-to-interference levels in the part of the network being studied. ATOLL calculates the serving transmitter for each pixel depending on the downlink reference signal level. The serving transmitter is determined according to the received reference signal level from the cell with the highest power. If more than one cell cover the pixel, the one with the lowest order is selected as the serving (reference) cell. Then, depending on the prediction definition, it calculates the interference from other cells, and finally calculates the C/(I+N). The pixel is colored if the display threshold condition is fulfilled (in other words, if the C/(I+N) is higher than C/(I+N) threshold). Coverage prediction by C/(I+N) level calculates the co-channel interference as well as the adjacent channel interference, which is reduced by the adjacent channel suppression factor defined in the Frequency Bands table. The carrier to interference plus noise (CINR) is the ratio of the signal carrier best servings for the intervention seemed at all other sites/sectors, plus all the noise. If a signal goes below the level of noise, it cannot be decoded and no useful information can be recovered from it.



a) Coverage by C/ (I+N) Level Downlink



b) Coverage by C/ (I+N) Level uplink

Figure 22 Coverage by C/ (I+N) Level a(DL) or b(UL)

Coverage by Throughput DL

Downlink and uplink throughput coverage predictions calculate and display the channel throughputs and cell capacities based on C/ (I+N) and bearer calculations for each pixel. ATOLL calculates the peak MAC channel throughputs from the information provided in the frame configurations and in the terminal and mobility properties for the terminal and mobility selected in the coverage prediction. ATOLL determines the bearer at each pixel and multiplies the bearer efficiency by the number of symbols in the frame to determine the peak MAC channel throughputs. The effective MAC throughputs are the peak MAC throughputs reduced by retransmission due to errors, or the Block Error Rate (BLER). ATOLL uses the block error rate graphs of the reception equipment defined in the selected terminal for downlink or the reception equipment of the cell of the serving transmitter for uplink. The application throughput is the effective MAC throughput reduced by the overheads of the different layers between the MAC and the Application layers. The cell capacity display types let to calculate and display the throughputs available on each pixel of the coverage area taking into account the maximum traffic load limits set for each cell. In other words, the cell capacity is equal to channel throughput when the maximum traffic load is set to 100%, and is equal to a throughput limited by the maximum allowed traffic loads otherwise.

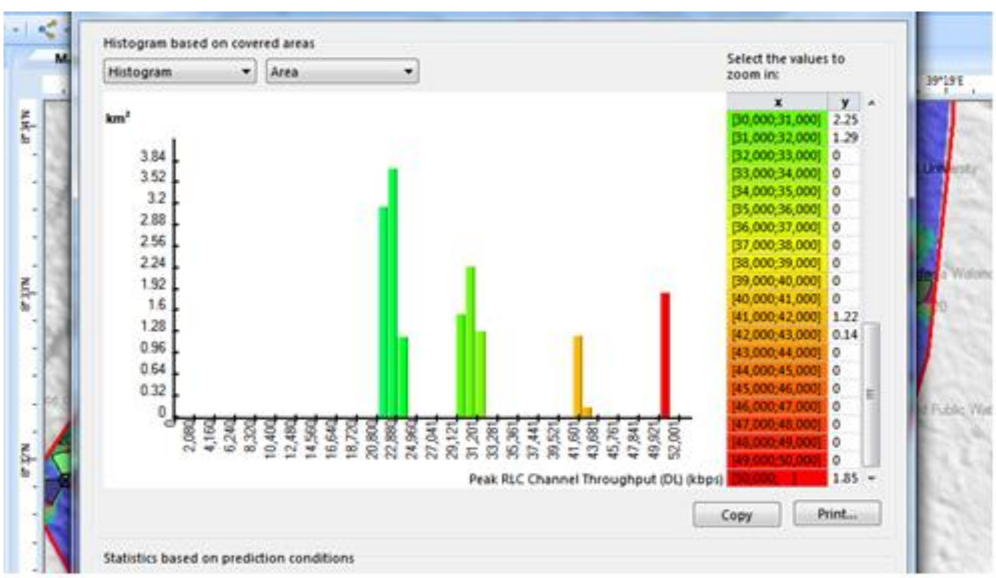


Figure 23: Coverage by Throughput DL

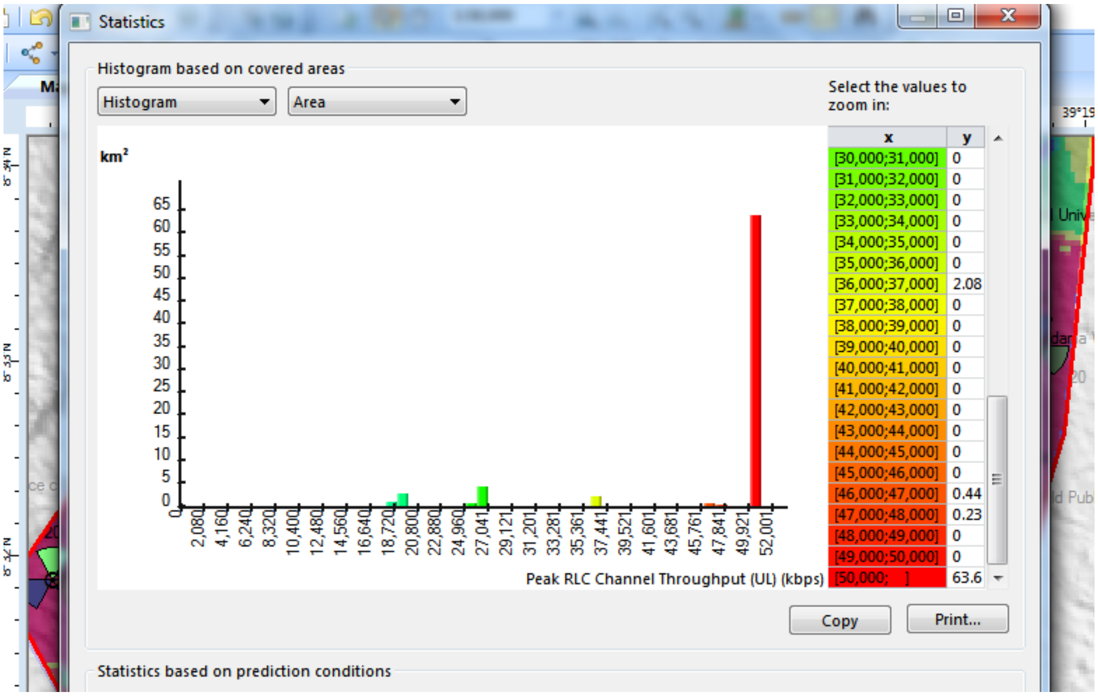


Figure 24 Coverage by Throughput UL

CHAPTER SIX

Conclusion and Future Work

6.1 Conclusion

The objectives of this study of 4G LTE radio network dimensioning is to introduce the relevant LTE features, to define the basic models for radio propagation planning, to estimate coverage and network element count for Adama city which minimize the level of planning challenge. This study is useful for future deployment of 4G LTE networks in urban area of Adama city. Here we obtained results of coverage and capacity analysis (75 sites for urban). Using ATOLL and taking Adama digital map as input we modeled the network and simulate it. From the simulation we can conclude as:

- ✓ More than 91.72% of the area covered by optimum signal strength i.e. greater than -97.23dBm (Figure 18).
- ✓ More than 69.38% of the area covered by single cells (Figure 21).
- ✓ From the capacity perspective, the maximum throughput that we're expecting is 129.6Mbps and 32.4Mbps per site for downlink and uplink respectively.

6.2 Recommendation for Future work

The main objective of this thesis is to dimension 4G LTE Radio frequency network in particular; Capacity planning and coverage planning for Adama City. Planning and dimensioning LTE Core Network is out the scope of this thesis which will be done as a future work.

This study on LTE coverage and capacity analysis was done assuming only urban area. Therefore, the LTE radio planning could be expanded to other environments such as sub-urban and rural area of Adama.

Deployment of LTE femtocells known as home evolved node base station (HeNB) in dead-zone areas of the city can satisfy customer indoor needs since studies on wireless usage show that more than 50% of all voice calls and more than 70% of data traffic originates indoors. Indoor planning using LTE femtocell is an interesting area of future research work for Adama city.

REFERENCES

[1] E.T. Tchaol, J.D. Gadze2, Jonathan Obeng Agyapong3 Kumasi, ‘‘Performance Evaluation of a Deployed 4G LTE Network’’ Ghana 2018(*IJACSA)*.

[2].Nafiz Imtiaz Bin, Mohammad T. Kawser, Md. Ashraful, ‘‘Coverage and Capacity Analysis of LTE Radio Network Planning considering Dhaka City Hoque’’ Department of EEE Islamic University of Technology Gazipur-1704, Bangladesh (*IJCA*)

[3] Penttinen, Jyrki T.J. ‘‘The LTE/SAE Deployment Handbook. United Kingdom: John Wiley & Sons, Ltd.’’ Jan. 2012.

[4] A.Ahson, Syed, ‘‘Long Term Evolution: 3GPP LTE Radio and Cellular Technology’’ s.l. : Taylor & Francis Group, 2009.

[5] Yiming Sun, ‘‘Radio Network Planning for 2G and 3G” 2004

[6] Reshma Begum Shaik, T.Krishna Chaitanya, ‘‘Simulation of GSM Mobile Networks Planning Using ATOLL Planning Tool’’ *International Journal of Engineering and Innovative Technology (IJEIT)* 2012.

[7] Anteneh Temesgen, “WCDMA Radio Network Dimensioning and Planning for the case of Bahir Dar City” 2015.

[8] A. Benjamin Paul & Sk.M. Subani, “Code Planning of 3G UMTS Mobile Networks using ATOLL Planning Tool”, *International Journal of Engineering Research & Technology (IJERT.* 2012.

[9] Abdul Basit, Syed, “Dimensioning of LTE Network Description of Models and Tool, Coverage and Capacity Estimation of 3GPP Long Term Evolution radio interface” 2009.

[10] Liang Zhang, “Network Capacity, Coverage Estimation and Frequency Planning of 3GPP Long Term Evolution”, Linköping University Master Thesis, 2010.

[11] Bethelhem Seifu, “LTE Radio Network Planning: Modeling Approaches for the Case of Addis Ababa” 2012.

[12] Marwa Elbagir Mohammed & Khalid Hamid Bilal, “LTE Radio Planning Using Atoll Radio Planning and Optimization Software”, *International Journal of Science and Research (IJSR)* 2012.

[13] CK Toh, PhD, Chief Technology Advisor, ALICO Systems Inc., CA, US : “4G LTE Technologies: System Concepts” White Paper 2011

[14] Ajay R. Mishra' "Fundamentals of Cellular Network Planning and Optimization 2G 2.5G 3G... Evolution to 4G" 2007.

[15] White paper: The LTE Network Architecture, strategic, Alcatel- Lucent, 2009.

[16] White paper: SAE: the Core Network for LTE, Ericsson May 2012.

[17] Furht, Borko and Ahson, Syed "Long Term Evolution: 3GPP LTE radio and cellular technology. USA" Auerbach:Taylor & Francis Group, 2009.

[18] Rumney, Moray, "3GPP LTE: Introducing Single-Carrier FDMA, USA" Lead Technologist, Agilent Technologies, 2008.

[19] Li Xi, "Radio Access Network Dimensioning for 3G UMTS, China" University of Bremen, 2009.

[20] Ayman Elnashar, Mohamed A. El-saidny, Mahmoud R. Sherif, "Design, Development and Performance of 4G-LTE Networks a Practical Approach" © 2014 John Wiley & Sons, Ltd.

[21] Lin Guangpu, Dong Fei, Ying Weimin, He Gang, Tan Zhu, "Guide: Long Term Evolution (LTE) Radio Access Network Planning," huawei technologies CO., LTD, 2011.

[22] Palat, Sudeep and Godin, Philippe, "The LTE Network Architecture" s.l. : Alcatel-Lucent‟s LTE solution.

[23]. 3GPP Technical Specification 36.211, "Physical Channels and Modulation (Release 8)", www.3gpp.org.

[24] Asad Saeed, Habib Ur Rehman & Muhammad Hassan Masood, "Performance Analysis and Comparison of Radio Frequency Propagation Models for Outdoor Environments in 4G LTE Network".

[25] Huawei, "Long Term Evolution (LTE) Radio Access Network Planning Guide", May 18, 2016

[26] www.3GPP.com

Annex A

Sites Placement Geographical Information

Name	Longitude	Latitude	Altitude (m)
Adama Abageda	39°14'20.04"E	8°32'2.4"N	[1,698]
Adama ACOS	39°14'40.35"E	8°30'45.86"N	[1,609]
Adama Adulala	39°17'44.88"E	8°28'42.6"N	[1,659]
Adama Behind University	39°19'31.53"E	8°33'44.12"N	[1,490]
Adama Berecha	39°16'17.4"E	8°31'42.6"N	[1,622]
Adama boku	39°16'39.36"E	8°30'20.16"N	[1,606]
Adama Bole	39°17'31.56"E	8°34'32.88"N	[1,717]
Adama Cear Eth.	39°16'45.48"E	8°31'11.28"N	[1,588]
Adama Chore Ber	39°17'27.24"E	8°32'6.36"N	[1,611]
Adama Dashen Bank	39°15'59.51"E	8°32'29.36"N	[1,617]
Adama Dejensime school	39°15'7.2"E	8°32'8.88"N	[1,623]
Adama Denbela	39°15'40.82"E	8°32'0.64"N	[1,609]
Adama ET office	39°16'19.14"E	8°32'55.21"N	[1,630]
Adama Expressway wanji exit	39°15'33.34"E	8°29'42.19"N	[1,671]
Adama Gend hara	39°15'59.4"E	8°34'3"N	[1,679]
Adama Gende gara	39°17'28.68"E	8°32'54.96"N	[1,633]
Adama Giorges	39°15'49.1"E	8°30'54.4"N	[1,633]
Adama Goro school	39°15'41.04"E	8°33'21.24"N	[1,657]
Adama Kela	39°18'22.68"E	8°32'27.6"N	[1,545]
Adama Luugoo	39°18'10.88"E	8°30'37.21"N	[1,612]
Adama Mdhanialem church	39°16'46.56"E	8°34'9.12"N	[1,687]
Adama Migera	39°16'56.28"E	8°31'39.36"N	[1,591]
Adama Neamald	39°13'41.81"E	8°32'38"N	[1,870]
Adama No 3 school	39°15'29.16"E	8°32'47.4"N	[1,622]
Adama No 4 school	39°16'50.45"E	8°32'24.04"N	[1,611]
Adama Police college	39°13'22.8"E	8°33'17.64"N	[1,796]
Adama Railway camp	39°16'28.7"E	8°29'22.32"N	[1,747]
Adama Sekekelo	39°16'25.68"E	8°34'59.16"N	[1,700]
Adama Textil	39°17'4.92"E	8°33'15.84"N	[1,646]
Adama University Compound	39°17'6.4"E	8°33'45.07"N	[1,671]
Adama University Stadium Compound	39°17'42.65"E	8°34'9.26"N	[1,702]
Adama Universty	39°17'27.96"E	8°33'27"N	[1,657]
Adama Walanciti Exit	39°20'14.78"E	8°33'9.6"N	[1,452]
Adama walanciti Road	39°21'29.22"E	8°33'25.91"N	[1,452]
Adama welenchti road North	39°22'0.47"E	8°34'46.02"N	[1,456]
Adama West	39°13'59.88"E	8°33'7.2"N	[1,867]

Adama, Kebele 11 Office compound	39°16'22.4"E	8°31'56.67"N	[1,614]
ADAMMA ETHIO DJBUTE RAIL WAY STATION	39°16'11.24"E	8°33'8.68"N	[1,630]
Africa flour factory , Adama kebele 13	39°17'1.14"E	8°32'9.13"N	[1,596]
Amede Agricultural Office Compound	39°17'9.85"E	8°32'29.98"N	[1,600]
Atana Tera	39°16'6.31"E	8°33'38.56"N	[1,653]
Behind Brothers biscuit	39°18'56.79"E	8°30'58.73"N	[1,555]
Behind Hawas Prep school	39°18'53.28"E	8°30'14.77"N	[1,630]
Behind Kidane Miheret Church	39°14'2.09"E	8°31'14.35"N	[1,691]
Behind OBN	39°19'3.01"E	8°34'28.91"N	[1,584]
Behind the Condiminium	39°16'25.03"E	8°30'45.91"N	[1,605]
Beside the old Railway	39°17'9.2"E	8°32'54.19"N	[1,631]
Chigign Tabiya	39°15'12.24"E	8°31'28.2"N	[1,613]
Dabe Soloke Near the Old Public Water Tap	39°17'57.31"E	8°32'15.09"N	[1,594]
East Shoa Zone Office Compound	39°16'28.49"E	8°32'32.6"N	[1,625]
Gelawdios School	39°16'26.65"E	8°33'28.09"N	[1,653]
Gendahara Shopping Center	39°15'45.07"E	8°33'46.44"N	[1,680]
Guraja Mariam	39°18'11.65"E	8°34'53.34"N	[1,683]
H3Y International Hotel PLC	39°16'41.79"E	8°32'3.54"N	[1,598]
Hawas Preparatory School	39°17'44.77"E	8°29'58.02"N	[1,648]
Health Center	39°17'8.63"E	8°34'45.55"N	[1,705]
Hidasie Elementary School	39°15'51.7"E	8°32'51.29"N	[1,619]
Kebele 14 Office Compound	39°16'52.45"E	8°32'42.27"N	[1,611]
Ketena 4 Chereta Sefer	39°15'23.04"E	8°32'31.06"N	[1,618]
Legahadi	39°16'15.67"E	8°34'31.8"N	[1,697]
Mekia Garage Store Compound	39°14'58.96"E	8°32'29.29"N	[1,629]
Melka 2 Adama	39°14'7.63"E	8°28'26.41"N	[1,554]
Melka Adama	39°14'11.04"E	8°29'8.52"N	[1,567]
Meskel Square	39°16'20.97"E	8°32'16.21"N	[1,623]
MTS building Adama , kebele 16	39°15'16.16"E	8°32'19.03"N	[1,612]
NA	39°16'34.32"E	8°32'46.46"N	[1,626]
near Gabriel church keble 08 Adama	39°15'48.24"E	8°32'26.27"N	[1,612]
Near Hawas School	39°17'16.55"E	8°30'3.91"N	[1,628]
Near St Francisco	39°15'55.01"E	8°31'39.07"N	[1,616]
OBN Compound	39°17'14.1"E	8°34'6.17"N	[1,693]
Old Rob Gebeya	39°16'41.52"E	8°31'25.93"N	[1,599]
Peacock Behind the Mosque	39°16'2.34"E	8°31'13.23"N	[1,611]
St. Joseph School	39°16'0.98"E	8°32'5.23"N	[1,616]
Tank Brigade Camp Compound	39°15'17.38"E	8°31'47.5"N	[1,611]
Tesfaye Olympic Hotel Adama , kebele 06	39°16'10.24"E	8°32'39.12"N	[1,625]