ADDIS ABABA UNIVERSITY
ADDIS ABABA INSTITUTE OF TECHNOLOGY
SCHOOL OF ELECTRICAL AND COMPUTER ENGINEERING

Dual Band UMTS Network Energy Saving using Base Station Sleeping Mode: The Case of ethio telecom

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A Thesis Submitted to the School of Graduate Studies of Addis Ababa University in Partial Fulfillment of the Requirements for the Degree of Masters of Science in Telecom Network Engineering

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I declare that this written submission represents my ideas in my own word and wherever others' ideas or words have been included, I have adequately cited and referenced the original sources.

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Date of Submission: December 20, 2019

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Abstract

Base stations represent the core contributor to the energy consumption of a mobile network. Since traffic load in mobile networks significantly fluctuates during a day and night time, it is important to quantify the influence of these variations on the base station energy consumption. Therefore, this thesis proposes energy-saving technique to reduce energy consumption at the base station level. One of the approaches is the base station sleeping technique which takes advantage of varying traffic patterns on a daily or weekly basis and selectively switches some lightly loaded base stations to the sleep mode.

Various literatures have investigated the potential of energy-saving technique. However, those studies have made a simplifying assumptions that leads to inaccuracy in overall results. This thesis considers the effect of traffic load on energy consumption instead of making assumptions. Ethio telecom deployed UMTS network on two separate frequency bands: 900MHz and 2100 MHz. While applying energy-saving techniques, data service and radio coverages provided by the remaining active base stations need to guarantee the requirement over the whole area at all times. To this end, optimization of the SINR value of the coverage area is carried out by considering received signals of the base stations using genetic algorithms. As input data, real traffic statistics are used on a fully operated base station traffic load along with its power consumption. The tools utilized for analysis include MATLAB, MapInfo and WinProp.

Performance results show that the proposed energy saving technique and algorithm can achieve energy savings of up to 25%, corresponding to the annual reduction of over 2,520 KWh per-site. Considering the selected case study area of ethio telecom mobile network, the use of energy-saving solutions allowed annual savings of more than 73,990.00 Birr per 12 square kilometers.

Key words: *- Energy Saving, Base Station sleep modes, Dual-band UMTS network, Genetic Algorithms.*

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Acronyms

3G	Third-Generation
3GPP	Third-Generation Partnership Project
BSC	Base Station Controller
BTS	Base Transceiver Stations
CAGR	Compound Annual Growth Rate
CCO	Coverage Capacity Optimization
CDF	Cumulative Distribution Function
CO2	Carbon Dioxide
CPEX	Capital Expenditures
DB	Decibel
DL	Downlink
DSA	Dynamic Spectrum Allocation
DTX	Discontinuous Transmission
EE	Energy Efficiency
EEU	Ethiopian Electric Utility
ET	Ethio Telecom
ESM	Energy Saving Mode
GA	Genetic Algorithm
GSM	Global System for Mobile
ICT	Information and Communication Technology
KPI	Key Performance Indicator
KWh	Kilo Watt Hour
MHz	Mega Hertz

MS	Mobile Station
OpEx	Operational Expenditure
P-CPICH	Primary Common Pilot Channel
PRS	Performance Report System
QoS	Quality of Service
RAN	Radio Access network
RET	Remote Electrical Tilt.
RNC	Radio Network Controller
SINR	Signal to interference and noise ratio
SON	Self-Organizing Network
Twh	Terra watt hour
UMTS	Universal Mobile Telecommunication System
UE	User Equipment
UL	Uplink
VET	Variable Electrical Tilt
WCDMA	Wideband Code Division Multiple Access

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Chapter 1

1 Introduction

This chapter provides a brief overview of background to the thesis. Before establishing the main contributions motivations, statement of the problem, scope, objectives and methodology of the thesis are presented. At the end of the chapter, the layout of the thesis is described.

1.1 Background

In recent years, the telecommunications sector has advanced at a high pace. Nowadays, users are able to use a vast range of services thanks to technologies such as Internet, multimedia and latest wireless communication standards and devices, which permit to have in a single mobile device, huge computing capabilities with almost unlimited access to the useful contents and information coming from the world wide web. These trends of advance in the mobile sector come along, however, with an exponential growth of traffic which carry together some tough challenges for the world telecommunications. Such an increase in the traffic levels year-by-year bring as a consequence an increased need for network capacity and, along with that, the necessary network infrastructure to support it. This implies larger capital investments from the operators to provide such an infrastructure as well as the associated operation costs also increase (i.e. Operational Expenditure (OPEX). These costs are influenced by an important element that enters here to play a role: the increase of the mobile network energy consumption [1].

Mobile networks in literature give us figures of how energy consumption is distributed throughout the different sections of the network. According to [2] approximately 57% of the consumption comes from the Radio Access Network (RAN) as seen in Fig. 1.1. Two main reasons explain this large percentage of energy consumption from this network section: Firstly, the inefficiency of internal BS components, above all, the Power Amplifier (PA) section that consumes around a 60-80 % of the total energy consumed by the BS [2],

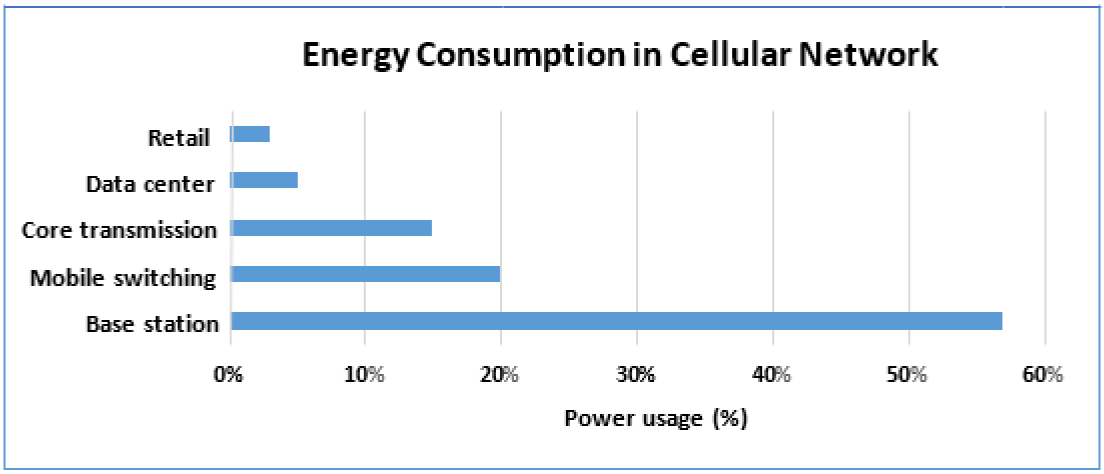

Figure 1-1 Energy consumption percentages for each one of the network sections in a cellular network infrastructure [2]

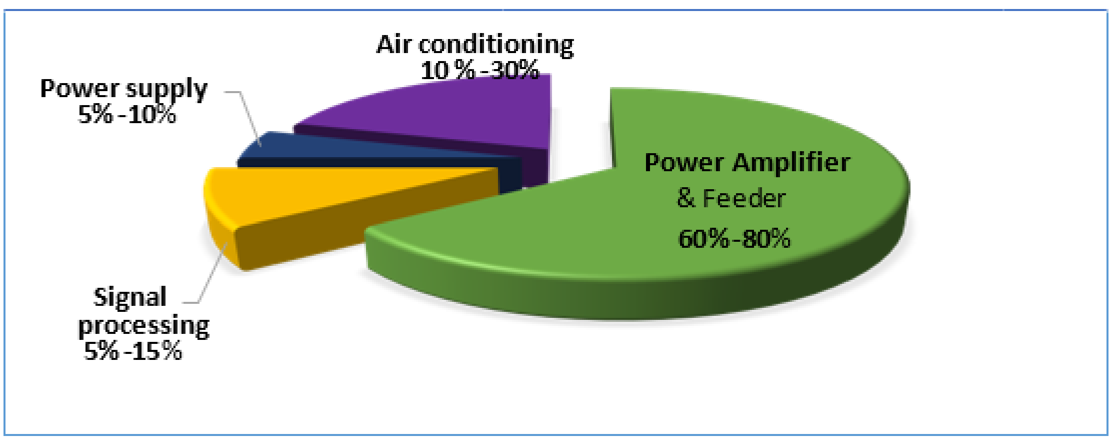

Figure 1-2 Estimated BS energy consumption for each component section [2]

additionally, accompanied by the associated need of having the cooling components kept on running to refrigerate the system due to the resulting heat dissipated (see Fig. 1.2). Second, due to the continuous fluctuations of traffic, temporally and geographically as seen in Fig. 1.3, it exists an inefficient usage of the BS systems, when having the whole radio infrastructure continuously active everywhere.

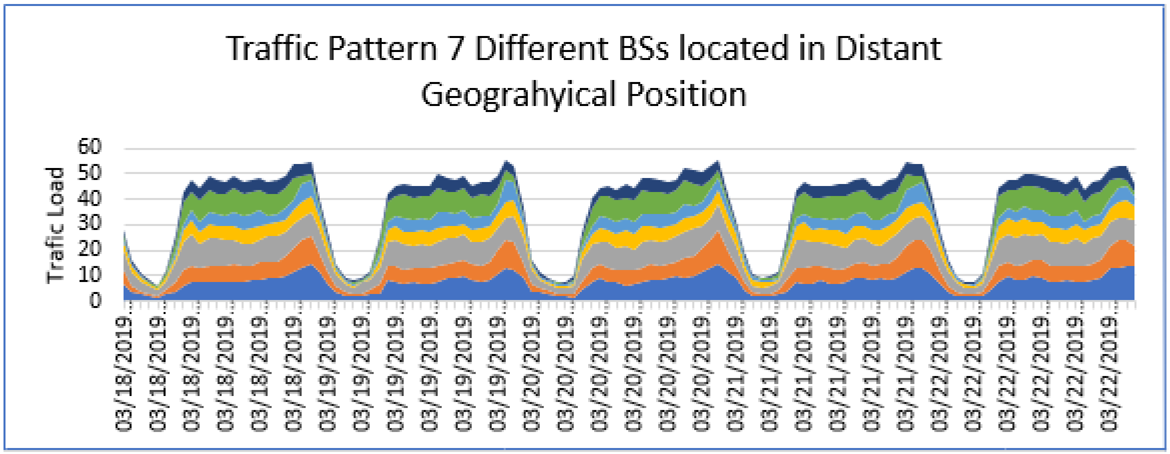

Figure 1-3 A drawing example of Seven BSs geographically located in distant positions with different traffic load patterns throughout the week

However, there is more behind the economic issues around the energy. There exists a genuine environmental concern based on the limitations of the energy resources and the associated carbon-footprint emissions. Commonly here, the literature in this domain often cites the figure provided in [3] as of 2% contribution from the ICT sector to the Green-House Gas (GHG) emission. By the end of 2030, it is expected that this figure will grow to 3% [4]. This has drawn great attention to the community. To avoid excessive greenhouse gas emission in the ICT industry, it is vital to control the energy consumption, and meanwhile, to fulfill the ever-growing user's requirement and reduce the operational cost.

1.2 Statement of the Problem

Earlier, deployment of base stations in ethio telecom's cellular mobile networks, and wireless communication networks, in general, have been designed with the objectives of maximize coverage, capacity, spectral efficiency or throughput. Obviously, this doesn't necessarily maximize energy efficiency. Also, traditional approach was mostly designed to sustain peak loads in extreme traffic conditions. Many such networks are even dimensioned with redundancy, providing extra capacity to accommodate possible peak load, in order to allow for unexpected events. As a result, the system is significantly under-utilized during off-peak hours, this situation creates an opportunity for potential energy savings. It is worth noting that traditional design objectives are potentially opposing with green ones, thus making green networking an interesting and technically challenging research area. As a result, a new mode of thinking is urgently needed for existing networks that will maintain the same level of QoS while reducing the amount of consumed energy. In this thesis, we define an energy-efficient cellular network as one in which as few BSs as possible are switched on while still satisfying all the user's demand and quality of service.

1.3 Objectives

1.3.1 General Objective

The general objective of this thesis is to propose an energy-saving technique for the existing Universal Mobile Telecommunication System (UMTS) cellular network base stations during off-peak hours with minimum QoS constraints by scheduling base stations sleeping mode techniques (on/off) in order to reduce base stations energy consumption and study its performance.

1.3.2 Specific Objectives

- Identify study area for Addis Ababa;
- Analyze hourly traffic requirement of BSs of study area;
- Evaluate the available network capacity;
- Investigate ethio telecom base stations from energy consumption perspective and the challenges of applying energy saving on current base stations deployment;

- Optimal selection of base stations to switch off during off-peak hours;
- Study and apply genetic algorithm for optimal selection of BSs;
- Based on analysis results, recommend energy-aware network solutions.

1.4 Literature review

Approaches to realizing Energy Efficiency (EE) in cellular wireless networks can be broadly classified into the improvement of hardware components, sleep mode techniques, optimization in the radio transmission process, network planning and deployment, and adoption of renewable energy resources. Each of them has its own share of advantages and limitations [2]. In this study, we first review those literatures whose focus is on the efficient management of the currently deployed for networks to increase their EE.

The authors in [5] investigated the user association process in BS sleeping operations. As related to the conventional user association scheme based on maximum instantaneous received signal power (MRSP), the authors suggested a new user association mechanism based on maximum mean channel access probability (MMAP). In the proposed scheme, any user originally associated with a cell/BS that went to sleep chooses a new associated cell/BS based on the maximum probability that it can obtain a channel in the new cell. This probability depends on a number of factors, including traffic load inactive BSs prior to the sleeping operation, receiving signal power strength, and cumulative interference power from neighboring BSs. The authors presented that the proposed scheme and the conventional scheme both have pros and cons in different scenarios, and suggested that a hybrid approach may achieve the best performance in terms of spectral and energy efficiency.

The authors in [6] also proposed a traffic forecast scheme based on transferred learning expertise from historical periods or neighboring regions, by formulating traffic variations as a Markov decision process. The proposed scheme is then utilized to minimize the energy consumption of cellular radio access networks with the help of BS sleeping operations

The authors in [7] addresses the challenge of how to reduce the energy consumption of a multi-cell network under a dynamic traffic load. The body of investigation first shows that the energy reduction upper-bound for transmission improving techniques is hardware-limited, and the bound for infrastructure reduction is capacity-limited. It proposes a novel cell expansion technique, where the coverage area of cells can expand and contract based on the traffic load. This is accomplished by switching off low load cell sites and compensating for the coverage loss by expanding the neighboring cells through antenna beam tilting. The multi-cell coordination is resolved by using either a centralized controller or a distributed self-organizing-network (SON) algorithm. Dynamic cell reconfiguration framework has been proposed in [8] that jointly tackles the problem of base station selection, transmit power budget adaptation, and user association in a cellular network which achieve significant power savings at low load and considerable saving at high load. Base station sleeping strategies along with small cell deployment techniques have been study. All the above literature made simplifying assumption in their study. In this thesis realistic ethiotelecom network environment is considered.

1.5 Methodology

This thesis targets to set a strategy for applying a load adaptive approach by sleep mode technique of base station through opportunistically reallocating users to other bands at times of low load, under the assumption that the network equipment operating in many frequency bands at the same location. This thesis concentrated specifically on the UMTS network where ethio telecom operate on two separates frequency bands: 900/2100 MHz. Performance evaluation is done while users are re-assigning to the lower band during the low-load period to determine if the lower frequency band can handle all the traffic demands. Data considered for this study includes traffic statistics, site mapping, traffic Key Performance Indicator (KPI) for UMTS cell-sites. For optimal base station sleeping mode operation, a genetic algorithm is applied with SINR metric. Finally, a discussion will be set based on the result found and then we conclude.

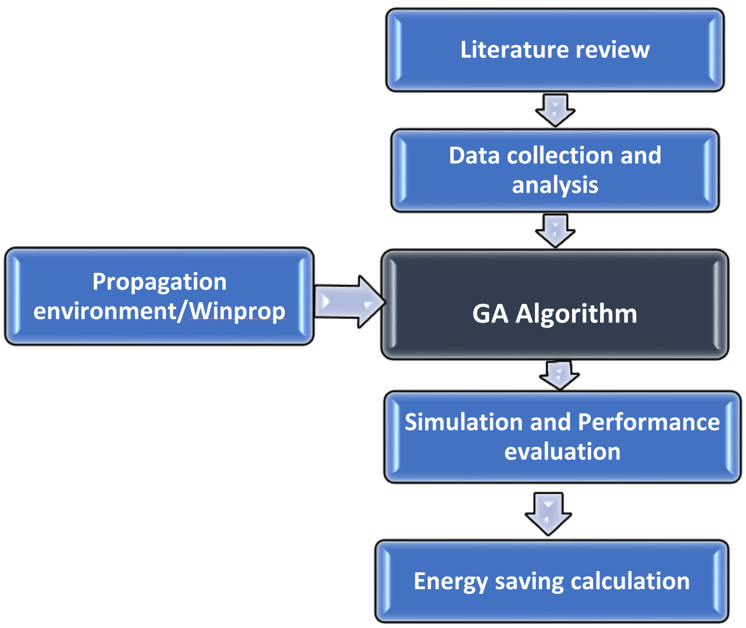

Figure 1-4 Summary of Methodology

1.6 Scope and Limitation

1.6.1 Scope of the Thesis

In this thesis power consumption reduction of ethio telecom UMTS base stations is studied and implemented using simulation tool by applying base stations scheduling into sleeping mode techniques during off-peak hours with minimum QOS constraints in the area of Addis Ababa city of, Ethiopia.

1.6.2 Limitations of the Thesis

This thesis focused specifically on the UMTS system where ethio telecom operate on two separate frequency bands: 900/2100 MHz only.

1.7 Contributions

This thesis investigated the possible energy-saving technique that takes ethio telecom in to consideration. In doing so, we propose optimal energy- saving techniques with possible economic and technical indicators which can serve as an input for ethio telecom to apply and save OpEx cost for energy consumption.

1.8 Thesis layout

This thesis work is organized in six chapters. Chapter one introduces a statement of the problem, objectives, methodologies, scope and limitations. Chapter 2 presents the theoretical framework to follow the current work including an overview of the UMTS technology. Chapter 3 an introduction about energy efficiency approaches and related literature then current mobile traffic profile usage worldwide, the analysis of ethio telecom data traffic usage and the power consumption at a BS level. Chapter 4 will present optimization algorithms and optimization frameworks. Chapter 5 will introduce deployment scenario, performance analysis, and simulation results Finally, Chapter 6 finalizes this work, summarizing conclusions and pointing out aspects to be developed in future work.

Chapter 2

2 Basic Concepts

This chapter presents the theoretical background to follow the current work. Firstly, an introduction about the mobile system technology in which this thesis is based on UMTS network along with its network architecture is presented. Then the radio interface describes briefly. Finally, the frequency bands and the key performance indicator discussed.

2.1 WCDMA - UMTS Overview

This section presented the fundamental concepts regarding UMTS network according to the most recent 3rd Generation Partnership Project (3GPP) release.

2.1.1 System Architecture

This chapter is based on [9] and presents the background of UMTS network architecture. UMTS is regarded as a third generation (3G) wireless communication system that acts as a successor to the second generation (2G) communication technologies and is an evolved version of GSM GPRS and EDGE. The GSM network was used to provide voice capabilities to subscribers but they need to support the increasing number of subscribers while providing high speed data services. The Third Generation Partnership Programme (3GPP) was formed to oversee the implementation of a system that could offer support to those services. The first release of the UMTS system was called release 99 due to its year of release, and it was an enhancement to the GSM/GPRS architecture and consisted of three main portions: Core Network, User Equipment and the UMTS Terrestrial Radio Access Network (UTRAN).

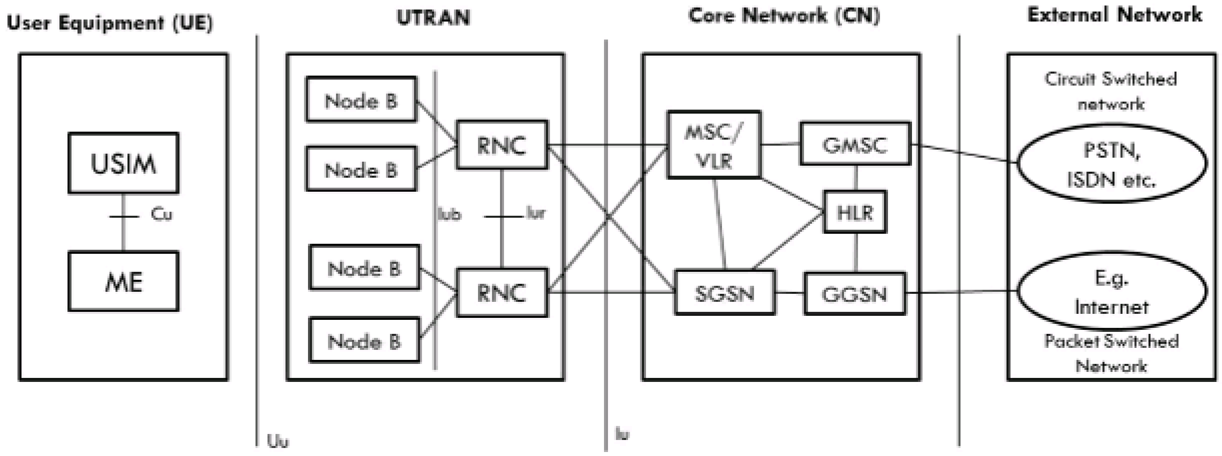

Figure 2-1 UMTS network architecture [9]

The UE consists of two elements: Mobile Equipment (ME), which is the end user equipment and the Universal Subscriber Identity Module (USIM), a smart cart that holds the client information and an authentication key required to access the network. These two components are connected through the Cu interface. The ME is linked to the Node-B in UTRAN by the Uu interface.

Regarding the UTRAN, there are two elements: The Node-B and Radio Network Controller (RNC). The term Node-B results from the 3GPP specification for 3G and it can also be commonly called as Base Station (BS). The Node-B is the hardware that holds the radio link with the ME using the Uu interface and it is connected with the RNC by the Iub one. It is also responsible for the radio resource management. RNC is a governing element and is responsible for controlling the Node-Bs that are connected to it including the radio resources. Unlike the UE and the UTRAN that use completely new protocols specially designed to operate with Wide-Band Code-Division Multiple Access (WCDMA) radio technology. The CN has adopted the structure from the Global System for Mobile Communications (GSM) with a few enhancements namely to support higher data rate throughputs. The CN includes elements with a Circuit-Switch (CS), a Packet-Switch (PS) nature and a few more that are based in the both types. In the first category we find the

Mobile Switching Centre (MSC)/Visitor Location Register (VLR) and the Gateway Mobile Switching Centre (GMSC). The first one is responsible for the voice CS transactions MSC and includes a VLR database that holds a copy of the visiting user's profile as well as the location of these temporary subscribers within the system. The GMSC is in charge of making the bridge between the MSC/VLR and the external CS networks. The PS category comprises the Serving GPRS Support Node (SGSN), a switching node similar to MSC but now in the PS domain and also the Gateway GPRS Support Node (GGSN), a switching node like the GMSC which is responsible for making the link between the CN and the external PS networks. Moreover, the Home location register (HLR) is accessed in both PS and CS domain and it consists of a database of all the network users profile containing information about the allowed and forbidden services or roaming areas. This information is stored upon a new user registration and is kept as long as this user is active on the network.

2.1.2 Radio Interface

This section describes the radio interface used for UMTS based on [9]. UMTS' radio spectrum is defined in between two frequency bands, [1900, 2025] MHz and [2110, 2200] MHz The Frequency Division Duplex (FDD) mode has two paired bands, with 60 MHz each, [1920, 1980] MHz for uplink and [2110, 2170] MHz for downlink. Figure 2.2 presents the distribution of UMTS frequency spectrum.

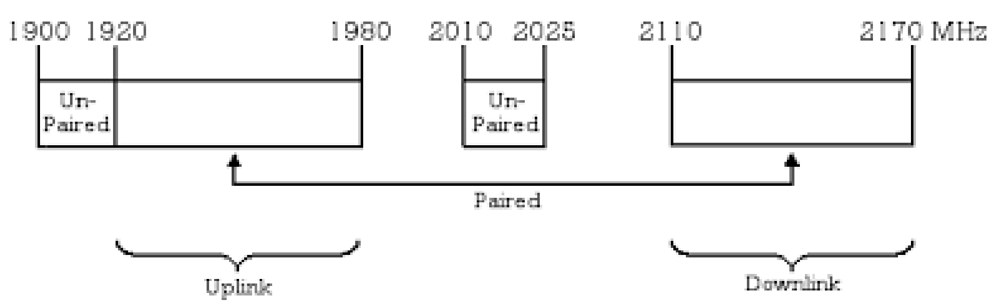

Figure 2-2 Frequency spectrum for UMTS [9]

To ensure multiple access, UMTS uses Wideband Code Division Multiple Access. In this technique, each user has an orthogonal code, which grants an easy understanding of the information sent to him. In this way, all users are able to operate the same band simultaneously, without causing harmful interference problems to each other, over ideal conditions.

FDD uses WCDMA which is an air interface standard. It supports conventional voice calls, text and data services. Since it was defined by the 3GPP in Release 99 it met many improvements. Besides the higher throughput rates achieved, it also allowed the possibility to provide variable bit rates according to each user or application needs. It uses a chip rate of 3.84 Mcps (mega chips per second) leading to a radio channel of 4.4 MHz and separation of 5 MHz between channels. In UMTS networks two different kinds of codes are used for scrambling and multiple access: channelization and scrambling [10]. The channelization codes are used in Downlink (DL) for UE differentiation although in the Uplink (UL) they isolate the physical data from the control channels. The chip sequence is multiplied by the user's information combined with a Spreading Factor (SF). The Spreading factor is a concept imported from the Code Division Multiple Access (CDMA) system and it is the ratio of chip rate to bit rate. In UMTS the spreading factor may vary from 4 to 512. As for scrambling, it is used for UE separation in DL and sector isolation in UL.

Defined in 3GPP Release 99, the UMTS evolved in subsequent releases. The first release defined bearer services, throughputs of 64 Kbit/s for CS and 384 Kbit/s for PS and retro compatibility with legacy systems like GSM. High-Speed Downlink Packet Access (HSDPA) and High-Speed Uplink Packet Access (HSUPA), defined in 3GPP Release 5 and 6 respectively were considered breakthroughs as they further improved the performance of existing WCDMA systems. The upgrade from UMTS Release 99 to HSDPA/HSUPA - commonly known together as High-Speed Packet Access (HSPA) - is often just a software update for most WCDMA operators [10]. UMTS Rel 99 defined three different packet data oriented channels: Dedicated Channel (DCH), Forward Access Channel (FACH) and Downlink Shared Channel (DSCH). However, the DSCH was removed from Release 5 onwards.

DCH that can be used for any kind of service, with a fixed Spreading Factor (SF) in DL reserving a fixed code space capacity in line with the peak data rate for the connection. This results in an inefficient code allocation. FACH also uses a fixed SF but lacks the physical layer feedback in the UL and operates without fast power control or soft handover. DSCH has dynamically varying SF in a 10 ms period and allows resource sharing between users supporting also single-code or multi-code channel transmissions but it doesn't support soft handover. This allows a more efficient resource sharing and uses a similar principle than the one employed with HSPA. 3GPP acknowledged that HSDPA was such a major step and recognized that there was no motivation to keep DSCH along with HSDPA and decided to remove it from the Release 5 specifications onwards.

HSDPA moved the scheduling and link adaptation control from the RNC to the Node-B, and thus guarantees faster link adaptation and Channel-Dependent scheduling. Node B uses a channel quality estimation functionality for each user adapting the radio link individually. Also the variable SF and fast power control features were replaced by means of Adaptive Modulation and Coding (AMC), extensive multi-code operation (each user may use up to 15 multi-codes in parallel) and a fast and spectrally efficient retransmission strategy [9]. Besides the use of a more robust coding scheme it also features fast Hybrid Automatic Repeat Request (HARQ) for error correction.

For the UL case 3GPP Rel 99 defined the DCH, the Common Packet Channel (CPCH) - which use was discontinued on Rel.5 onwards, and the Random Access Channel (RACH).

HSUPA is included in 3GPP Release 6 specifications and it was designed to enhance uplink packet data rate using fast physical layer retransmission and transmission combining and also fast Node B controlled scheduling. The specified transport channel which carries the user data is the Enhanced Dedicated Channel (E-DCH).

HSPA+ (also called as HSPA Evolution) was specified latter and it aims to improve the end user performance by higher throughput rates, lower latency and UE power efficiency. It also features inter-compatibly with Long Term Evolution (LTE). The noteworthy features of this system are the higher-order modulation schemes available (up to 64 QAM), Multiple-Input and Multiple-Output (MIMO), enhanced rake receivers, interference cancellation techniques, multicarrier HSDPA and dual-carrier HSUPA.

2.1.3 Handover

This section describes the handover procedure based on [10] [9]. The Handover (or handoff) consists in the process of transferring an ongoing call or data session from one channel to another. It can be triggered by several reasons, being the most common one the UE mobility. When moving away from a serving BS towards another one, the received power from the original BS decreases while the new one may offer a better radio link connection. In this situation there is the need to conduct all the procedures to offload the UE from one cell to another. The handover may also be set off by Load Balance (LB) mechanisms, interference or operator policies. In UMTS there are several types of handovers:

- **Hard Handover** - In this type of handover all the previous radio links are removed before setting up the new ones and it can be seamless or non-seamless. The first type means that the handover is not perceptible to the user. The handover that requires a change of the carrier (inter-frequency handover) is an example of a hard handover.

- **Soft Handover** - Unlike in the hard, in the soft handover the radio links are added and removed in a way that the UE always keeps at least one radio link to the UTRAN so several radio links are active at the same time. When a UE changes cell but continues operating in the same frequency it is usually a soft handover.
- **Softer Handover** - Softer handover is a special type of soft handover where the added/removed radio links belong to the same Node B.

  During the soft/softer handover procedure the UE is connected to several cells simultaneously therefore the following several sets are considered in UE [9] [11].
- **Active Set** - Is the set of cells which signals are used during a soft handover. If an eligible cell signal, in terms of Ec/Io or Received Signal Code Power (RSCP) is found, it is added to the active set.
- **Monitored Set** - Contains the cells included in the UE cell info list but not in active set.
- **Detected Set** - All the remaining discovered cells which don't belong to neither of the other groups.

2.1.4 Frequency Bands

In 1992, World Radio-communication Conference (WRC-92) allocated the frequency bands for the 3G mobile communication, with a total bandwidth of 230 MHz The introduction of UMTS required new radio frequencies allocation. In the European case, 3GPP in its Release99 defined the [1920, 1980] MHz frequency range for UL and [2110, 2170] MHz for DL. These correspond to the 2100 frequency band. More recently 3GPP studied the possibility of GSM spectrum reframing to UMTS, i.e. to use the remaining spectrum available in the 900 MHz band in which the GSM system is based on [12]. In Figure 2.3 is presented the reframing process in which the UMTS carrier (at the center) is located between the UL and the DL GSM channels. In 2005 3GPP released a technical report [13] in which studied the co-existence between the two systems and has concluded that GSM 900 and UMTS 900 can co-exist in both coordinated and uncoordinated ways. In the first operation mode both systems are overlay and operational in the same area unlike the un-coordinated deployments. For each UMTS 900 Carrier are allocated 5 MHz plus a guard-band with 200 KHz on each side [13] [14].

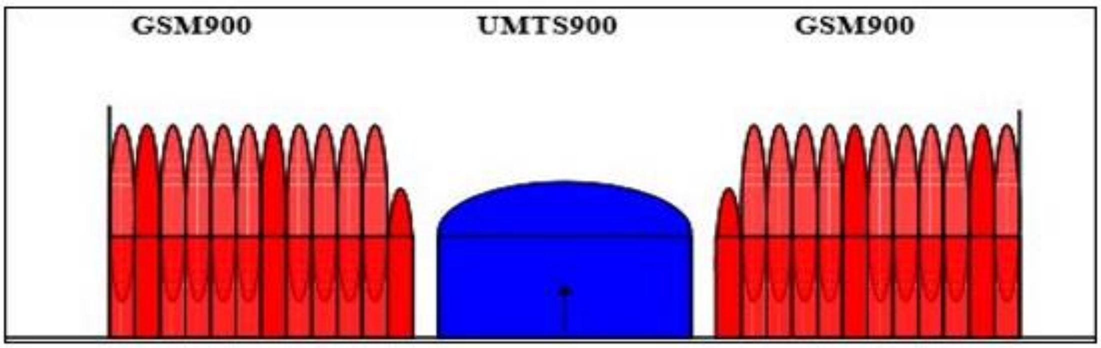

Figure 2-3 UMTS 900 MHz band reframing [12]

The possibility of implementation of the UMTS system in this new frequency band was welcomed by many telecom operators worldwide. By operating at a lower frequency than the traditional UMTS band it enables a better radio propagation, including in the indoor case [14]. It is an efficient solution to economically roll out higher data rate services to rural and sparsely populated environments. From the coverage/cost ratio point of view it means that less sites are needed to cover an area that otherwise would require several more ones operating in the 2100 MHz Band. This all results in lower Operational Expenditure (OpEx) and Capital Expenditure (Capex). The increasing availability of UMTS 900 capable mobile terminals was also crucial to the successful roll-out of the technology [12].

2.1.5 Performance Analysis & QoS

Quality of Service (QoS) in mobile networks is defined as the capability of the operator to provide a satisfactory service in terms of voice quality, signal strength, low call blocking, low dropping probability and high data rates. It depends on factors like the throughput, data delivery delay, packet loss, error rate and reliability.

2.2 Key Performance Indicators (KPI)

The Key Performance Indicator (KPI) are parameters used to monitor the Radio Access Network (RAN) performance and represent a valuable information for several categories of users such as operation and maintenance personnel, engineers, and managers. These metrics are divided into six categories: Accessibility, Retain ability, Integrity, Utilization, Mobility, and Availability [15] [16].

The Radio network KPI can be used for the following tasks:

- Quickly detect poor performance in the network, enabling the operator to take immediate actions.
- Troubleshooting on cell clusters of interest.
- Monitoring and optimizing the RAN performance to have a better user-perceived quality or to allow a more efficient usage of resources.
- Provide valuable information to radio network planners in order to dimension the network for optimal use. The KPI indicates the end-user perception of a network on a macro-level and are usually used to benchmark networks against each other and to detect problematic areas. These are mainly calculated from the counters in the BS and in the RNC which are continuously gathering a wide range of usage logs.

2.2.1 KPI Categories in a UTRAN network

A general model of end-user perceived quality was developed by the ITU Telecommunication Standardization Sector (ITU-T) organization including three main KPI categories: Accessibility, Retain ability and Integrity. In addition, it is a common practice of each vendor to develop its own KPI categories to complement the standardized ones for each part of the subsystem. For the RAN subsystem the following additional categories are commonly considered: Mobility, Utilization and Availability [16] [15].

QoS KPI Indicators

Accessibility -These metrics indicates the capability of a service to be accessed upon user request, with a specified target-quality and other given conditions. In practical terms it can be described as the percentage of successfully call attempts. The failed call setup attempts can be caused by the lack of resources at the transmission network, channel elements, DL power or a radio link or signaling failure. Some of the most important KPI of this category are:

- Call Setup Success Rate (CSSR) - It is the probability of successfully initiating, holding and then terminating a speech call or a data session from an end user perspective.
- Call Setup Time (CST) - Time duration taken to access the speech or data service and to establish a successful connection.

Retain ability- The ability to continuing providing the service within a determined grade of quality after the initial connections is setup. A common retain ability KPI is the Drop Call Rate (DCR).

- DCR - Corresponds to the ratio of abnormal call disconnections to the total number of successful call setups for speech calls or data sessions.

Integrity- The degree of capability in offering the service without excessive impairments. Represents the overall quality experienced during the call (or session). The Block Error

Rate (BLER) is useful as an indication of the service integrity for both CS and PS although in the last one the throughput is also used.

- BLER - Represents the ratio of faulty transport blocks to transmitted transport blocks for a CS/PS connection and is a meter that indicates the perceived quality of the connection.

UTRAN Specific KPI Indicators

- **Mobility-** Analyses the performance of the different types of handover: Inter, Intra frequency and Inter-Radio Access Technology (IRAT) Handover (HO), Soft and softer, PS and CS.
- **Utilization**- Evaluates the network overall utilization using traffic level and capacity management measurements (congestion, admission/load control).
- **Availability**- Presents the system performance for the main Managed Objects (MO) in the UTRAN and provides an analysis of the downtime of different components [9].

Chapter 3

3 Energy Efficiency Approaches and Data Traffic in Mobile Networks

This chapter is dedicated to the wide energy-saving techniques classified into the domain of the green radio. A global overview of the fundamental concepts which are discussed over the work is presented. Afterward, the focus is then turned onto the energy-saving RAN equipment (more precisely, BSs and sectors) switching based approach and a comprehensive study of the existing related schemes are presented. In the end, the frequency allocation and data traffic trends are presented.

3.1 Energy Efficient Strategy

Nowadays, energy consumption has become a key issue, from both environmental and economic side. ICT alone is responsible for a percentage which varies between 2% and 3% of the world power consumption [17] Besides reducing the carbon footprint of the industry, there is a strong economic encouragement for network operators to decrease the energy consumption of their systems. Currently, over 60% of the power in mobile telecommunications is consumed in the radio access network, more specifically the base stations [1].

The massifcation of mobile telecommunications was made possible by the development of highly energy-efficient terminals, but only recently the radio access network side of the network has received the same kind of attention in this field. Several factors contributed to these phenomena. Mobile operators usually have multi-technology systems in simultaneous operation (GSM, CDMA, WCDMA, LTE) and as each system evolves becoming more and more complex, delivering a higher volume of traffic data and ubiquitous mobile connectivity, it usually is a higher energy spender and this cost is a significant expense for the mobile operator. So, on the operator side, the pressure to reduce expenses is huge. Plus, on the emerging markets, many sites are located in an off-grid location, which means that they are usually Diesel-powered, increasing even more energy bill. In fact, this kind of energy provision may be responsible for up to 50% of their total OPEX [17]. On the other side, there is also an increasing global awareness to reduce (GHG) emission, since only a small fraction of the energy produced worldwide comes from renewable sources. All of these circumstances covered the way for operators to explore the possibility of increasing energy efficiency, not only on the mobile devices but also in base stations and core (back-haul) networks. Nevertheless, the biggest chunk of energy consumption (60 %up to 80%) is consumed by the base stations [1].

3.2 Energy Saving Techniques

The common idea of the BS switching in all the thesis is fairly simple and can be summarized as: Depending on the instantaneous traffic conditions within cells and their spatial positions in a network, the number of active BSs (and hence the overall energy consumption) is dynamically minimized, while the remaining active BSs provide the radio coverage and service provisioning (required QoS) for all users within the network. In other words, the objective is to keep the number of active BSs within the network at any instant of time that makes the network energy consumption proportional to traffic. the energy saving scheme are as follows accordingly.

3.2.1 Dual-Carrier Operation

Spectrum usage in mobile networks has traditionally been very conservative, with each spectrum band at a particular location being constrained to a single operator and usage purposes. Recent developments are, however, pointing to a new direction where, for instance, an operator may have an extended range of available spectrum band [18]. This improvement is a promising feature in the "green communications field" for the below reasons:

- Dynamic Spectrum Allocation (DSA) in order to opportunistically take benefit of spectrum a more suitable propagation and decrease essential transmission power.
- DSA to allow channel bandwidths given to users to be increased or more suitably balanced, hence facilitating transmission power being meaningfully decreased.
- Moving users into predominantly active bands to allow radio network equipment in the bands they originated from to be turned off when possible using DSA. Hence, the multi-carrier operation in different frequency bands creates new opportunities which can potentially be explored in green operation.

As stated before, carriers situated in lower frequency bands have better penetration capabilities providing better coverage under the same transmission power constraint. Overlapping a UMTS 2100 and 900 MHz carrier guarantees an extended coverage by the second one as long as the transmission power of both is similar. It can be proved using a simple path loss model requirement on frequency can lead to a 7 dB gain in the lower frequency band. In situations where there is no need to keep all the carriers active at the same time, e.g. during low traffic periods, it may be advantageous and profitable to switch off one or more carriers at higher frequency bands [12] [19].

3.2.2 Energy Savings in Self-Organizing Networks

Self-Organizing Network (SON) are often associated with LTE technology and were introduced by the 3GPP standardization body in its December 2008 Release 8 [20] [21] [22]. The self-organizing networks intend to optimize network capacity, coverage and service quality. The idea is to integrate several network tasks as planning, configuration, optimization and self-healing into mostly automated process which ideally will require the minimal manual intervention. The whole process was made possible by the own evolution of the eNodeBs and the new interface X2 that connects different eNB. This allowed to create new distributed central control functions and move some of this features from the core network. UE also present increased technical capabilities and processing abilities to perform, store, process, and act upon measurements. These were important key-enablers for self-organizing networks. 3GPP recognized the significance of Energy Savings Management for Network Operators and provided means for these agents to set policies in order to minimize consumption of energy, while maintaining coverage, capacity and quality of service. 3GPP Rel-11 has defined two energy saving states: with energy Saving(ES) state and without Energy Saving state(WES). The mechanism includes two procedures to switch between these two situations: energy saving activation and deactivation [22]. When a cell is in the energy Saving state it must before handoff all its traffic to the surrounding or overlaid cells and this cell can never be a candidate for energy savings if its deactivation leads coverage holes. Likewise, a cell in this state is not considered a cell outage or a fault condition and thus no alarms should be raised. SON introduced several use cases that used together may prove to be very useful for energy saving purposes: Automatic Neighbor Relation (ANR), Mobility Load Balancing (MLB) and Capacity and Coverage Optimization (CCO) [21].

3.2.3 Discontinuous Transmission on BS Sleep Modes

In the UE side, the energy saving concern has been around since the beginning of the development of mobile devices in order to allow long standby and call duration. The use of schemes like Discontinuous Transmission (DTX) modes, where power consuming components are periodically switched off when possible, is very common [23]. Unfortunately, the own nature of the components and protocols in the BS side of the network makes it very difficult to apply this principle, namely because of the continuous transmission of pilot signals in WCDMA/HSPA. Nevertheless, there is potential for exploring different kinds of DTX schemes in DL, and the following BS sleep modes may be considered:

- **Micro sleep mode** - The BS transmission is suspended in order of milliseconds. In this situation the components have to wake up almost immediately when the transmission resumes.
- **Deep sleep mode** - The BS transmission is suspended in extended time periods and the number of daily switch-offs is reduced. Unlike in the micro sleep mode, it's allowed for components to take longer to wake up so many circuits may be completely switched-off.

The concept behind green cellular operation is to attenuate the inefficiencies resulting from the fact that BS are deployed and operated continuously based on peak traffic estimates. Relevant energy saving can thus be achieved by carefully turn off underutilized devices during off-peak times, while guaranteeing coverage. To achieve this can be used a smart combination of several kinds of sleep modes.

2.3.4 Coverage and Capacity Optimization (CCO)

The changes in the environment, the insertion or removal of base stations in the network, a failure in a base station or a wrong set of parameters may result in changes of capacity and coverage area of a cell. It is also crucial to avoid coverage holes when a cell is switched-off for energy saving purposes and the neighbor ones must provide the extra needed coverage. To solve these cases, 3GPP introduced the CCO SON use case. One important mechanism that can be adjusted and has a great influence on this use case is the correct set of the Remote Electrical Tilt (RET) of the BS antenna. This type of antennas allows the configuration of a tilt angle remotely through Operations Administration and Management (OAM) subsystem. Antenna tilt is the angle of the antenna's main beam bellow the horizontal plane. If this angle is negative the tilt is defined as a down-tilt and if this angle is positive, it is referred to as up-tilt. The electrical tilt can be archived by different techniques such as RET, Variable Electrical Tilt (VET) and fixed electric tilt. The remote tilt, which enables a non-disruptive tuning of live networks is usually implemented using RET. However, RET antenna tilt range variation is typically limited to less than (<10◦) [24]. This constraint may be insufficient for some situations, like for installations in high buildings. The combination of electrical and mechanical tilt may be useful, to get the required tilt interval. In the mechanical tilt, the antenna is physically rotated about a horizontal axis changing the radiation pattern perceived from the ground but leaving actual the emission pattern is unchanged [24]. In the electrical tilt, the phases of the antenna components are adjusted so that the preferred tilt angle is obtained by tilting main, side and back lobes equivalently. It differs from the mechanical one because in this situation, by applying a phase (or time) taper to the element excitation alters not only the radiation pattern perceived from the ground nevertheless actual radiation pattern. It should be taken into account that because the effective radiation pattern depends on the tilt type different system behaviors may occur when dissimilar kinds of tilt are applied. So the system performance impact of the combined two techniques should be considered. Figure 3.1 presents the several angles on a down-tilted antenna where θ and φ are the spherical angles and α is the elevation angle, αe is the electrical tilt, αm is the mechanical tilt and αtilt are the total tilt angles.

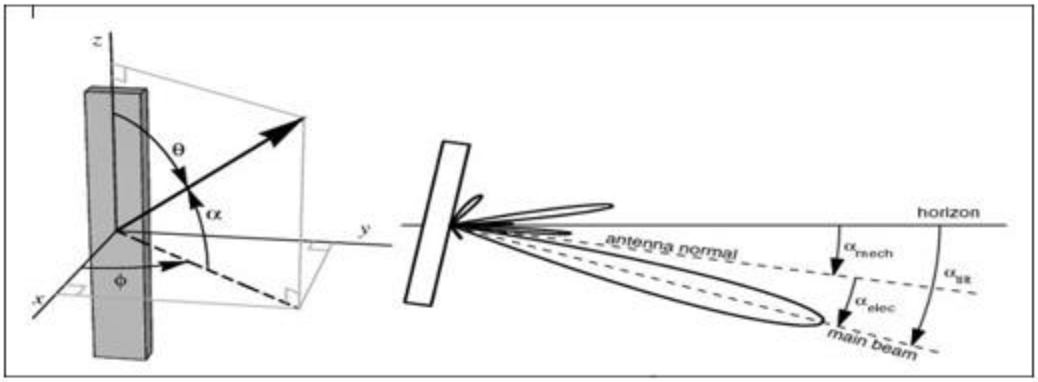

Figure 3-1 RET Antenna [24]

3.2.5 Energy Saving on Operational Network Data in Literature

In literature, few studies assess the energy saving potential of the temporary cell deactivation application. To compensate possible limitations of simulated data models, we restrict the studies to those, using data and network configurations from operational networks.

Table 3.1 summarizes the results of three papers, evaluation of 3G networks. Besides the average and maximum saving potential, the activation trigger is provided, which is a major concern in this thesis.

TABLE 3-1 ENERGY SAVING POTENTIAL FOR TRAFfiC PROfiLES OF OPERATIONAL NETWORKS

Average Saving	Switch On/ Off time	Reference
30-40%	periodic traffic patterns	[25]
23-53%	traffic increase	[26]
4-72%	neighbor cells: number, distance, utilization	[27]

The first paper [25] evaluated both a homogeneous and a heterogeneous 3G network. For the homogeneous network the coverage holes of the switch off cells are compensated by the power increase of the active neighbor cells. Based on the traffic profiles corresponding low-power network configurations for the business and residential areas are derived. The Switch on and switch off follows a predefined schedule derived from historic daily traffic patterns. The resulting energy saving for the homogeneous network achieves 30-40%.

The second paper [26] is based on 3G traffic data, measured in 4 areas served by 45 to 177 BSs. Each area represents a different density level from very dense to medium dense. The user density corresponds closely to the BS density in the homogeneous networks, providing strongly or partially overlapping coverage. In case of low traffic, preselected underutilized BS within a grid are switched-off, assuming that the coverage is still provided by the close-by active BS within the same grid. Depending on the area density, energy consumption is reduced by 23.4% to 52.7%. The best results are achieved in dense networks during weekend and night periods.

Lastly, the last paper [27] maps a traffic profile, originally derived from a wired network, on an operational homogeneous 3G network. Three types of areas are evaluated: rural, urban and suburban area. The switch on/off algorithm are based on energy saving potential as well as the individual cell load. Input for the algorithm include the number, distance and utilization of neighbor cells. Then, the load levels of the serving cell are correlated with the load level of neighbor cells, similar to a load balancing approach. The achieved energy saving varies strongly for a different area classifications. For the rural area a maximum saving potential of 4% was achieved, while the urban area during low traffic periods achieved up to 72%.

3.3 Global Mobile Data Traffic

There are numerous factors and trends that are contributing for the growth of mobile services around the globe. According to the Mobile traffic forecasts 2017-2022 by the UMTS forum [28], the booming of the ICT industry in Middle East and Africa the demographic evolution with a more and more urban population are the main ones. Also, the social network fever has contributed for the necessity to have ubiquitous connection everywhere. The mobile devices industry is constantly achieving breakthroughs in technology developments in areas such as semiconductors, nanotechnology, processing power and storage capacity which enable the development of smaller, increasingly complex and intelligent devices.

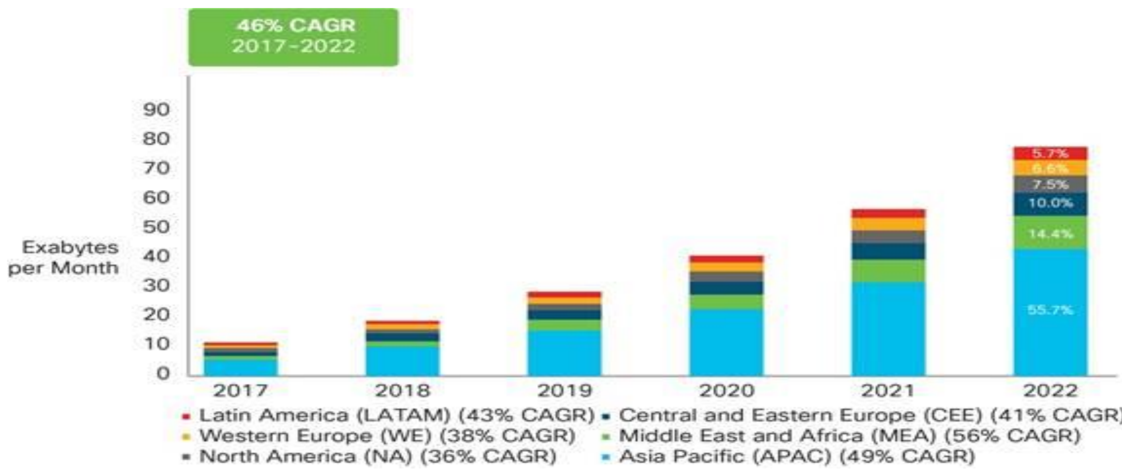

FIGURE 3-2 DATA TRAFFIC DISTRIBUTION BY LOCATION [29]

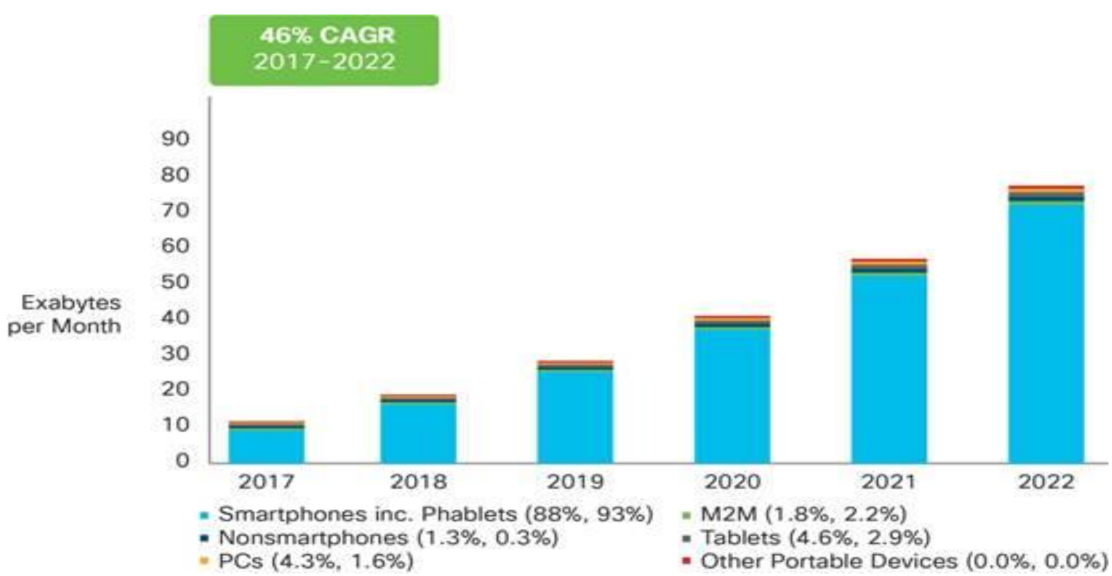

Figure 3-3 Data usage by service [29]

According to [28], The growth of wireless devices that are accessing mobile networks worldwide is one of the major contributors to global mobile traffic growth. Every year a number of new devices in different form factors and improved capabilities and intelligence are introduced in the market. In the last few years, we have seen growth of tablets and more recently many new M2M connections coming into the mix. Greater than 600 million (648 million) mobile devices and connections were added in 2017. In 2017, global mobile devices and connections grew to 8.6 billion, from 7.9 billion in 2016. Globally, mobile devices and connections will raise to 12.3 billion by 2022 at a CAGR (compound annual growth rate) of 7.5 percent (Figure 3.3).

By 2022, there will be 8.4 billion handheld or personal mobile-ready devices and 3.9 billion M2M connections. County-wide, North America and Western Europe are going to have the fastest growth in mobile devices and connections with 16 percent and 12 percent CAGR from 2017 to 2022, respectively.

3.3.1 Ethio telecom Mobile Data Growth Trend

Mobile data in a cellular network has been increasing for the past couple of years in ethio telecom as we can see in figure 3.4 it increases every year.

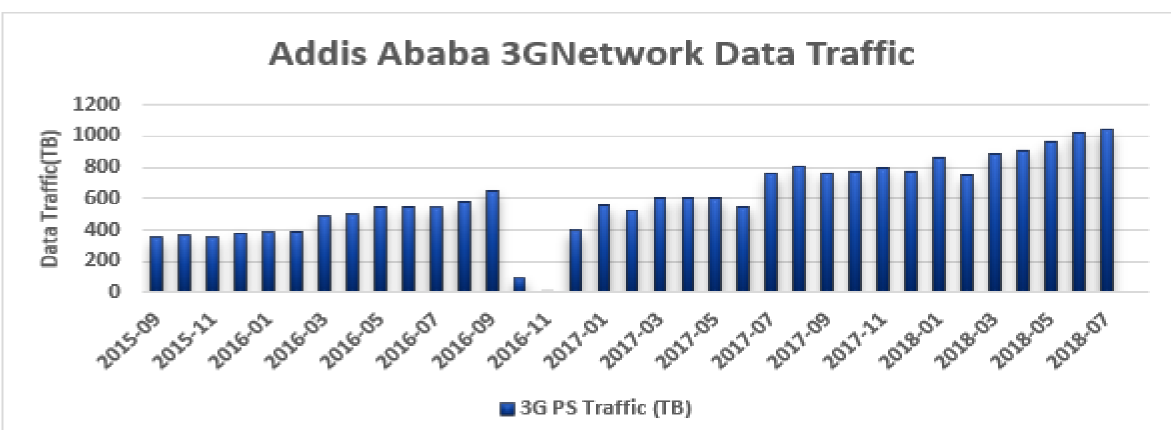

Figure 3-4 Addis Ababa Mobile Data growth trend (PRS) [30]

Total mobile data traffic is expected to rise at a compound annual growth rate (CAGR) of around 43 percent, reaching close to 107 Exabyte (EB) per month by the end of 2023 [29].

3.4 Daily Traffic Models

The mobile traffic is highly heterogeneous. Firstly, the geographical position must be considered, i.e. the mobile traffic pattern in the business district, or in a residential area of a city has its own unique characteristics. Also, the rural and suburban areas have their own mobile traffic nature, so the analysis must be done on a temporal and spatial basis. In this section, the main aspects of data traffic services are outlined and the typical daily traffic patterns are presented. To see the relationship between mobile data traffic growth and the power consumption of UMTS network in ethio telecom BSs are as shown in Figure 2.5 bellow.

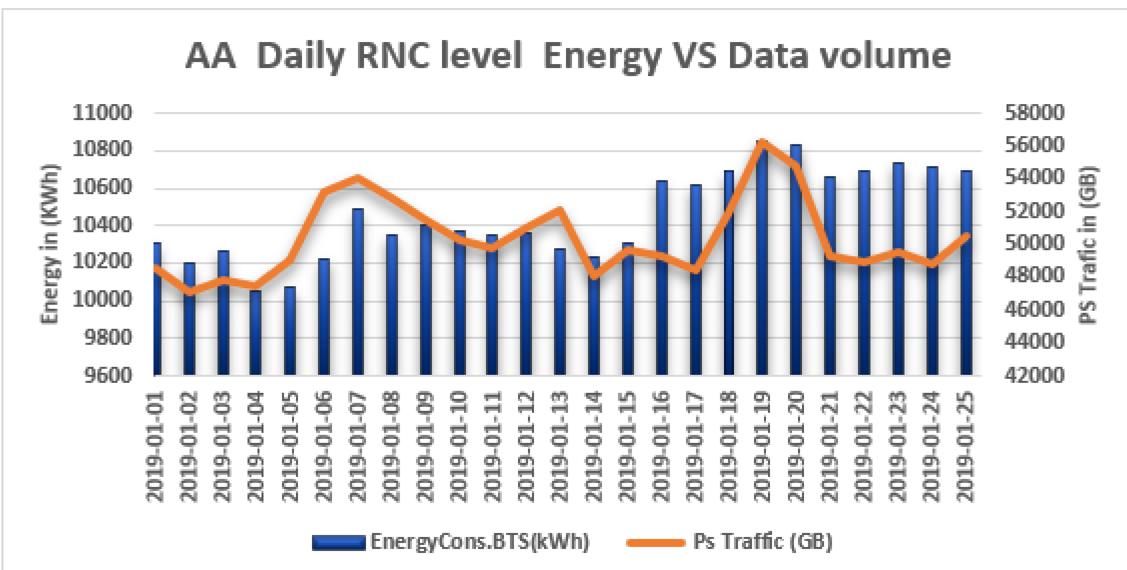

Figure 3-5 Traffic and Power pattern of AA one-month statics [30]

3.5 Radio Frequency Allocation in Ethiopia

In this section we presented the fundamental concepts regarding UMTS according to the most recent 3rd Generation Partnership Project (3GPP) release. According to ethio telecom the allocations of radio frequency bands for these network operators are shown in Table.

TABLE 3-2 900 MHZ FREQUENCY BAND [31]

Operator	Uplink (MHz)	Downlink (MHz)	Technology
Ethio telecom	902.6 -907.6 [MHZ]	947.6 -952.6 [MHZ]	UMTS

Table 3.2 Shows the frequency band allocation around 900 MHz the frequency bands are divided into uplink and downlink bands. Ethio telecom can use UMTS as the cellular mobile technology around 900 MHz frequency band [31].

Table 3.3 Shows the frequency band allocation for ET around 2100 MHz It also shows the operator can use UMTS technology [31].

TABLE 3-3 2100 MHZ FREQUENCY BAND [31]

Operator	Uplink (MHz)	Downlink (MHz)	Technology
Ethio telecom	1924.9 -1945.1	2114.9 - 2135.1	UMTS

As a final point, Ethio telecom UMTS system operate on both upper and lower band frequency in the same area as shown in table 3.2 and table 3.3.

Chapter 4

3 Optimization Background

In engineering, mathematics, and economics, optimization is used to find inputs that maximize or minimize the outputs of functions or methods. In order to design a system with maximum efficiency, optimization provides good insight. However, the complexity of optimization problems may cause trouble for designers in relation to solving optimization problems. Optimization is used to find optimal solutions from a candidate solution. It means that optimization provides possible results which maximize or minimize the output of a function [32].Depending on results, decisions are made by engineers or designers.

4.1 System Model

Consider a network with $f1$ base stations. The idea of base station sleeping is that when the users service demand decreases (at night time for example), the demand could be supported by only fraction ρ of BSs. Without loss of generalization, we assumed, for a given service level, the required number of active BSs $\rho f1$ is proportional to the decrease in demand. Moreover, additional BSs might be switched off as the SINR improves.

Genetic algorithm is used in different sets of combinations of $\rho f1$ active BSs. We are concerned about assessing these algorithms to find the one that results in the best downlink SINR. In order to assess these algorithms in different spatial regularity levels, we first need a point process that has the ability to vary the spatial regularity of BS locations.

The goal of the study is to optimize the power that is composed of macro cells in a service area A. The service area is divided into some small area elements which are also known as pixels. The average signal received power is assumed to be constant inside the entire pixel area, thus the pixel resolution provides a trade-off between computation complexity and accuracy of the simulations.

In this study, UMTS network wireless system is to be considered with system bandwidth B. The considered service area has a maximum of L predefined existing macro cell positions. Each BSs position represents a possible maximum transmit power P_{max}.

The radio frequency propagation path loss matrix can be characterized by the matrix L ∈ R^{A*L}, where, $L(i, l)$ represents the path loss between the a^{th} pixel and the macro cell deployed in the i^{th}candidate location and A, is the total area. The selection of serving macro cell in each pixel is based on maximum received signal power in that pixel. To that end, the received signal power at the a^{th} pixel of the signal from the macro cell deployed at the i^{th} predefined position is given by:

$$P_{rx}(a, i) = (P_{tx} - L(a, l)) \cdot x(l) \quad (4.1)$$

where the vector $x \in \{0, 1\}$ L indicates whether a macro cell is used at the i^{th}existing location. If the existing macro cell is On, then $x(l)$ = 1, otherwise, $x(l)$ = 0. In fact, x could be considered to denote the network topology as it represents the actual cellular design.

The average SINR at i^{th} pixel each pixel is formulated as

$$\gamma_{(a)} = \frac{P_{rx}\max(\mathrm{a,l})}{\sum_{i\neq 1,\mathrm{l}\neq \mathrm{l}*}^{L} P_{rx}(\mathrm{a,l}) - P_{rx}\max(\mathrm{a,l}) + \sigma^2} \quad (4.2)$$

where, $\sigma^2$is the noise power, $P_{rx}\max(\mathrm{a,l})$ is the serving cell of the pixel and $\sum_{i\neq 1,\mathrm{l}\neq \mathrm{l}*}^{L} P_{rx}(\mathrm{a,l})$ is the interference among the i^{th} pixel and the macro cell deployed in the i^{th} position. Then, the throughputs τ (a) attainable in the i^{th} pixel is obtained through mapping SINR results by means of modified Shannon formula [33].

4.2 Performance Metrics for Network optimization

In order to achieve the best solutions in wireless system design, different metrics are considered. Generally, the aim of network operators is to maximize capacity and coverage in a service area. Likewise, network operators are also willing to minimize their costs. However, more BSs can provide more capacity and coverage. This circumstance creates a trade-off for network operators. In order to characterize these in simulations, two dissimilar metrics are considered in this thesis. The metric used in power optimization is created. These metrics and their explanations are given below:

• The number of base stations ($f1$): This metrics is representing the number of BSs in the wireless system design. More BSs can provide more capacity and coverage; however, more BSs increase the costs of the network operators.

• Pixel SINR of 10^{th} percentile ($f2$): The metrics represent the 10^{th} percentile of the whole pixel SINR values. It is used in order to examine power optimization.

Single objective optimization is also used in order to optimize the transmit power levels. The purpose of power optimization is to maximize the SINR values of pixels. Hence, it can be formulated as follows:

$$\text{Minimize } f = [\ f2]. \quad (4.3)$$

equation (4.3) are combinatorial problems belonging to the NP-Complete class. In this thesis search space of optimization is a set of $2^{C}- 1$, where C represented a number of candidate sites in the service area. For a small number of the set, the search space can be large. So, it makes difficulties for the simulations.

4.3 Background of Optimization Algorithms

The birth of wireless communication has led to a host of design concerns that are very complex involving network design, interference cancellation, resource allocation and signal detection. Most of these problems have a huge search space which makes them (NP) hard hence solutions using analytical approaches have proved to be tedious. The reasons made numerous researchers propose several methods of heuristics techniques for solving these problems. Heuristic techniques are part of an optimization algorithm it uses the information currently collected by the algorithm to help for the decision which candidate solution should be tested next or how the next individual can be created. Heuristics are usually problem class dependent [34]. Most essentially, heuristic techniques lie in the fact that they are not limited by restrictive assumptions about the search space like continuity, in the existence of derivative of objective function etc.

Numerous heuristic methods are in existence. These include: Simulated Annealing (SA), Tabu Search method (TS), Gradient Descent Search (GDS), Ant Colony Optimization (ACO) and Genetic Algorithms (GA) [35] [36].

The Genetic Algorithms is a stochastic global search method that mimics the comparison of natural biological evolution. They operate on a population of possible solutions applying the principle of the existence of the fittest to produce, hopefully, a better approximation to a solution. They always produce good quality solutions since they are independent of the choice of the primary configurations. In addition, they are computationally simple and easy to implement. The drawbacks are the probability to converge prematurely to a suboptimal solution. Use of heuristic approaches like genetic algorithm used to solve these problems. As new technologies come to the market network providers have to employ intelligent optimization means to ensure that networks are correctly designed to meet the demands of, and profit from, the new generation of high-speed data users [37], for instance, 3G network coverage optimization depends on the optimal location of facilities in the cellular network as there is no constraint for frequency optimization.

4.3.1 Genetic Algorithm for Coverage Optimization

GA is a Sophisticated nature, however an efficient searching tool as it found application in complicated problems in pattern recognition, scheduling and business, etc. [38]. The application of GA in solving telecommunications challenges can be justified in a point that factors challenge optimal service is generic in nature; GA is an optimization tool capable of giving optimum outcomes in a situation where there are many conflicting options, this is because it has the capability to search large spaces efficiently without the need for derivative information.

GA utilizes a clearly defined procedure to solve problems with a finite time for termination. Three major issues are addressed in the implementation of GA's these are;

- Coding of the parameters
- Development of the fitness function
- Chromosome selection strategy Basic steps uses for the implementation of GA start with defining the optimization variables, its constitution and cost. It ends by testing for convergence.

Research works reviewed for this paper are on optimal selection of network facilities i.e. antennas and base transceiver stations (BTS). The optimization objectives common to all are coverage and the use of fewer facilities represented as economy or cost reduction. Optimization using genetic algorithm have been handled by the researchers under review, followed the process of application which is in line with the flow chart in Figure 4.1.

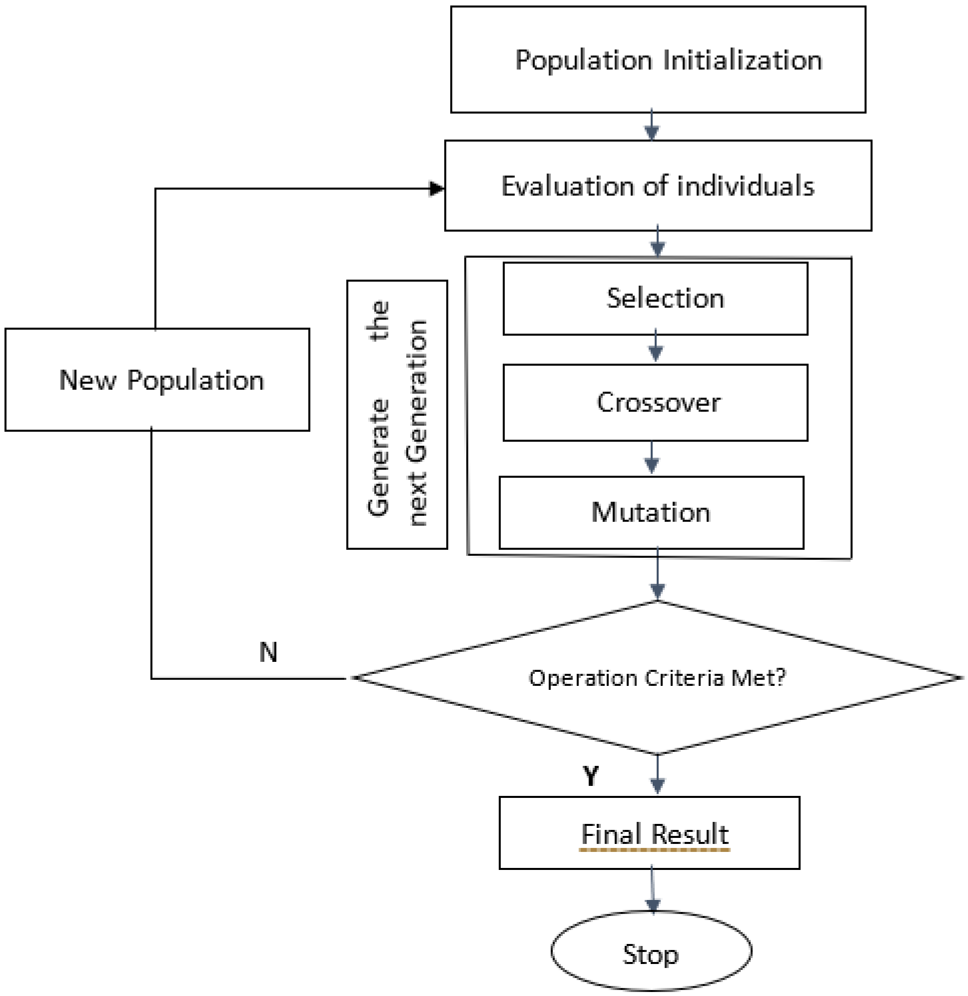

Figure 3-1 Flow chart GA in a facility location optimization problem

4.3.2 Problem Representation

The first step in the implementation of a GA is taking a decision on what mode/form the information about the system will be represented, this usually includes encoding all relevant parameters, this can be either direct encoding where strings can be read directly or indirectly where a decoding algorithm is used to expand the strings into meaningful information. Originally GA used binary numbers in its operation, in which case a binary string representation of 1's and 0's constitutes the system representation. However, another coding system is being used which include integer values, real values and ordered set of symbols. In representing a problem with binary strings, the resolution, and number of bits that will adequately represent the chromosome will be calculated, this however will depend on the type and range of parameters.

4.3.3 Initial Population

The population is a collection of "candidate solutions" usually referred to as chromosomes or individuals, the first generation of a population is made up of individuals composed of 'genes' which are the defining characteristic of that individual making it eligible to be referred to as a candidate solution for the optimization problem. The initial pollution size is usually based on an estimate of the site requirement which involves determining the number of base stations required to meet adequately the coverage and capacity constraints. The site estimates are usually determined based on cell computation using wave propagation models and basic cell planning calculations, most commonly used is the Okumura model Hata, dominant path loss model [39] [40] Initial population are generated from a cell plan map with likely base station location chosen based on coverage, the larger the initial population the longer it takes to run the algorithm as the GA spends most of the time on evaluating population. The chromosome can be represented as an array of bits, a number, an array of numbers, a matrix, a string of characters or any other data structure and must satisfy given precision and constraints and be suitable for the implementation of genetic operators [38] [41] .

4.3.4 Fitness function Assessment

Fitness assessment is the process of assessing the fitness of a chromosome, using a mathematical function generated based on the optimization objective. Definition of the fitness function is the heart of the design of a suitable GA to solve an optimization problem; this function is made up of the evaluation function which determines if the goals of the optimization have been achieved.

4.4 Transmit Power Optimization

Power optimization has a key role in coverage and capacity because of interference that is created by neighboring cells. If transmit power levels of neighboring cells are optimally adjusted, interference can be reduced drastically and therefore SINR can increase. In addition to interference, cell transmit power can be optimized to decrease energy consumption.

As indicated earlier, simulations are conducted in order to examine the performances of different types of topologies. In order to conduct simulations, the simulation area is divided into pixels and there are 510239 pixels in the simulation area. Each pixel has its own area which is 5x5 m^2.

The main purpose of power optimization is to find the optimum transmit power levels for different base stations in order to serve users with the best performance. In this sense, in order to serve user with the best performance, SINR values of pixels could be optimized and therefore pixel SINR values could be increased. After increasing pixel SINR values, SINR values of users are expected to increase automatically. In this regards, it is possible to enhance the SINR values without evaluating each UE in the transmit power optimization phase. Thus, in this phase, it is assumed that there is no UE in the simulation area.

Step in transmission power optimization

- Propagation environment capture by WinProp
- Obtain the path loss of each pixel
- Calculate the received signal (RX) of each pixel using Eq.4.1
- After obtaining the (RX) signal calculate the SINR of each pixel using Eq.4.2
- Then compute the 10^{th} percentile of SINR using GA and Eq.4.3
- Finally obtained the optimal cell/site of the considered case study area.

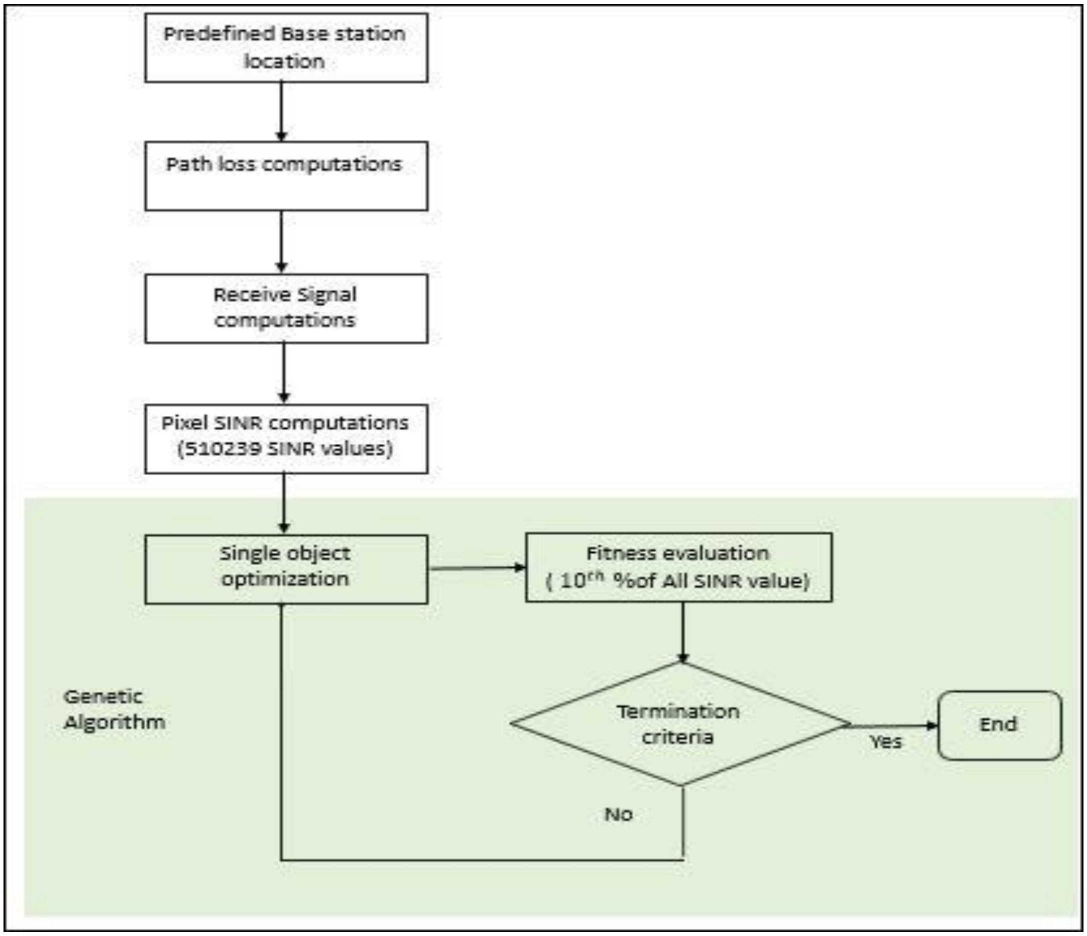

Figure 4.2 Flow chart of transmission power optimization.

Power optimization is investigated by allowing for the 10^{th} percentile of all values of the pixel. It means that 10^{th} percentile of all pixel values (510239 Pixel SINR values) is optimized in order to maximize the pixel SINR values. In order to maximize 10^{th} percentile of all pixel values, ($f2$) metric is used in the single objective optimization.

To investigate the optimum, transmit signal power levels, macro cell locations are predefined. Thus, macro cell locations are unchanged with single-objective optimization. After computing the SINR values of each pixel. Then, the values used for the input of single-objective optimization that means 10^{th} percentile of all SINR values.

Chapter 5

4 Results and Discussion

In this chapter we describe the implemented simulations for the evaluation of the sleeping cell procedures using network simulation. First, the network structure and radio environment relevant are introduced, followed by the simulation model with a focus on the particularities of cell.

5.1 Deployment Scenario

In order to contextualize the dual-band UMTS network optimization context, a real case UMTS network scenario in a high data downloading area is considered. In this study, Addis Ababa around megenagna, is assumed as a place where the base station is to sleep is deployed.

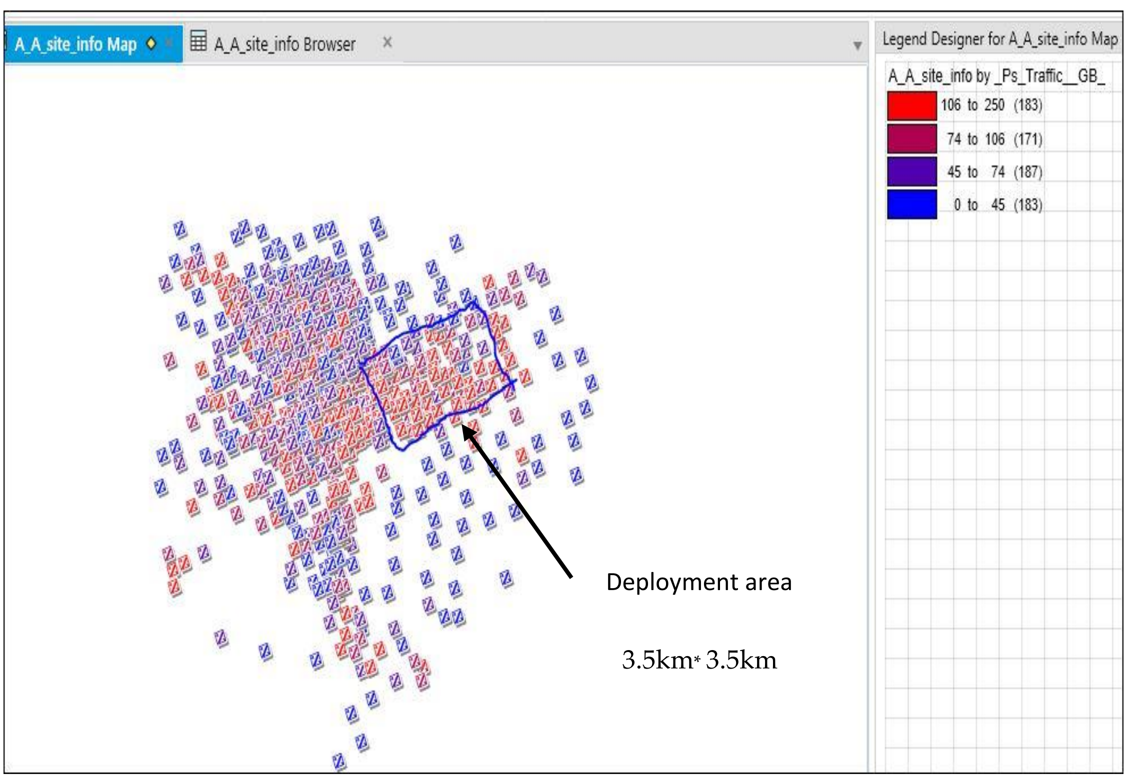

Figure 4-1 All Addis Ababa UMTS Network Sites and traffic Generated

As shown in Figure 5.1 above the red color indicates a high data generated site and the blue one is fewer data generated. The selected case study area covers 3.5km* 3.5km to include BS with high Data download.

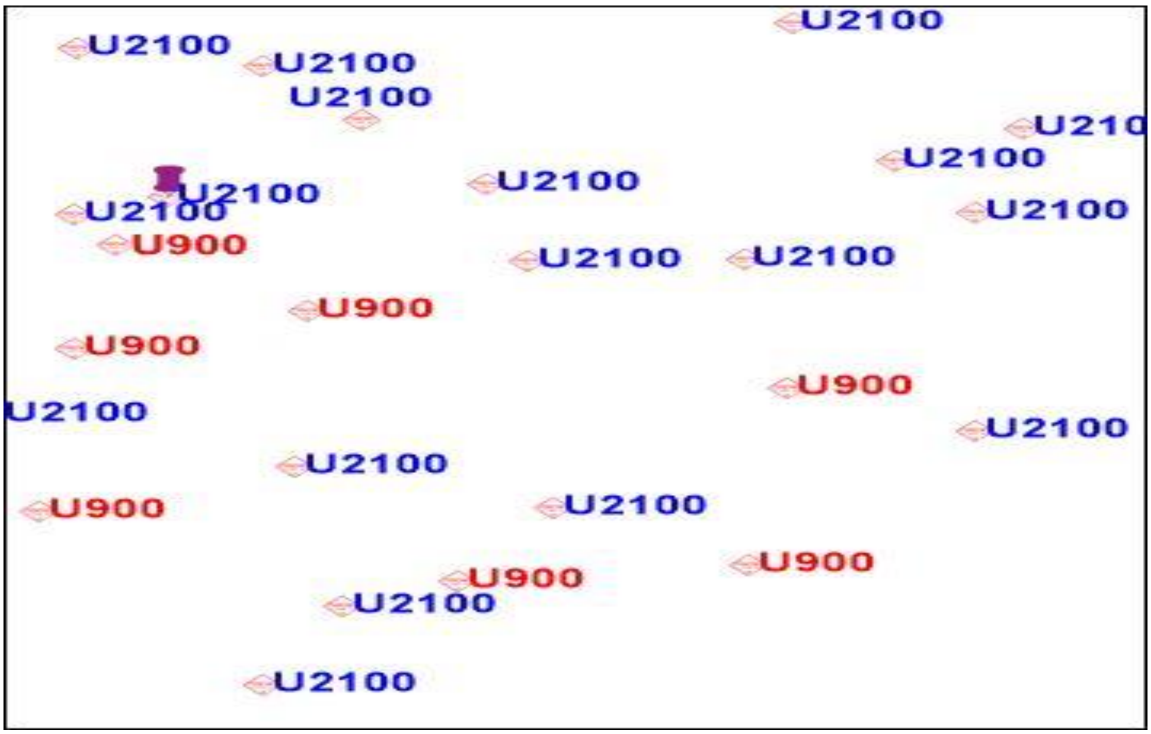

Figure 4-2 Spatial distribution of Case study deployment scenario

The spatial distribution and their network topology of the selected case study areas is shown in Figure 5.2 by using MapInfo tool.

5.1.1 Simulated Network

The basic simulated network consists of 27 existing UMTS BSs, 20 of the sites are U2100 MHz configured and the remaining 7 sites are U900MHz configured. each placed in the center of a grid (see Figure 5.3). One BS consists of 3 transceivers, each of which represents the coverage area of a cell. Two-dimensional (2D) representation of the deployment scenario is given below.

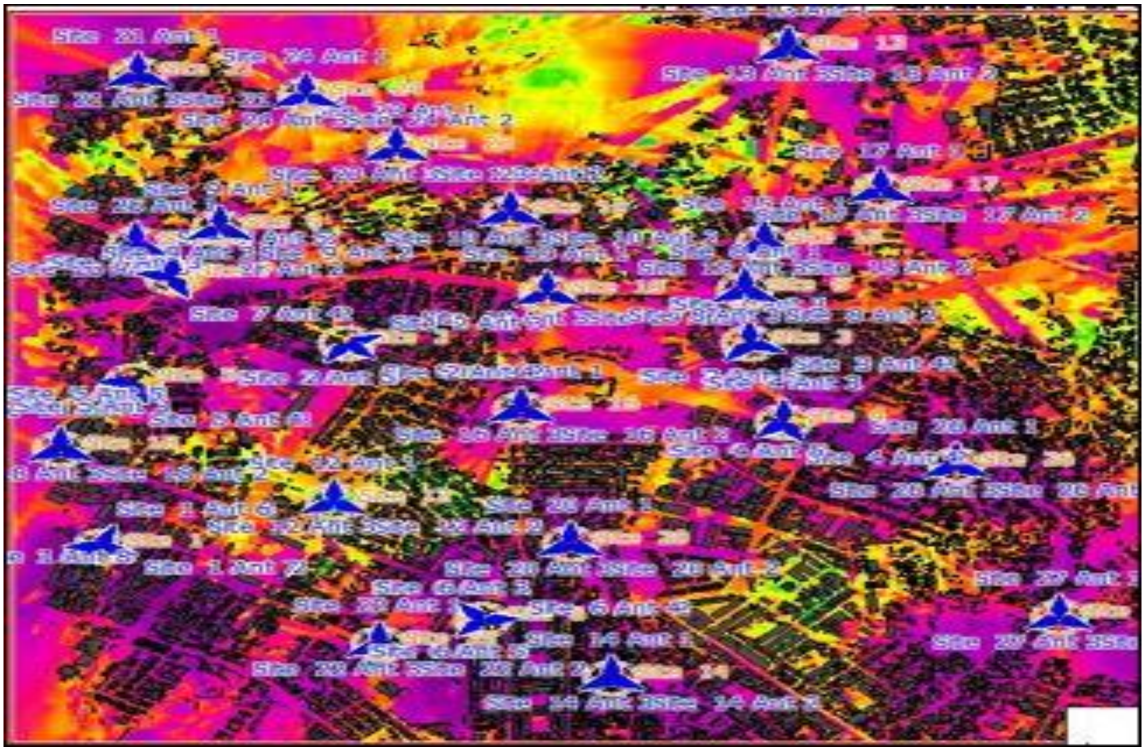

Figure 4-3 Case study of deployment scenario Two-dimensional (2D) representation

5.2 Hourly base stations Traffic Analysis

This section investigates sample base stations daily traffic per hour to determine traffic volume fluctuations during days and nights. Figure 5.4 easily describe these.

5.2.1 Temporal Traffic Diversity

Real data from ethio telecom mobile network operator in a metropolitan urban area analyzed to understand the traffic dynamics. The graph shown in Figure 5.4 is produced from the real data available in (Ethiopia; ethio telecom). It shows the aggregated traffic trace with a resolution of 1hour from twenty-seven BSs for one week. It can be observed that the traffic in each cell is a seasonal profile and notice that the traffic during daytime (9 am – 10 pm) or peak periods is much higher than at night time (11 pm – 5 am). The temporal variation also depends on the natural lifestyles and locations. For example, the business areas may be heavily loaded during daytimes but only lightly loaded at night times. Additionally, the traffic profile during weekends, even during peak hours are different. But in this thesis the selected case study area traffic is the same pattern as a normal weekday because the deployment area is mixed-use or residential and business center. So, weekdays and weekends appear to show the trends in Figure 5.4. Based on the traffic profile in Figure 5.4, percentage of duration the traffic is lower than α percent of the weekday peak for the period of weekdays and weekends, for $\alpha = 10, 20, 30$ is shown in Table 5.1. For instance, during weekdays, just over 24 percent of the time the traffic is smaller than 30 percent of the peak traffic.

As a result, some cells will always have traffic loads much lower than the network capacity for a large fraction of time in a day (5~6 hours), which indicates the underutilization of each BS in the temporal domain. Indeed, this will result in network wide energy inefficiency at BSs.

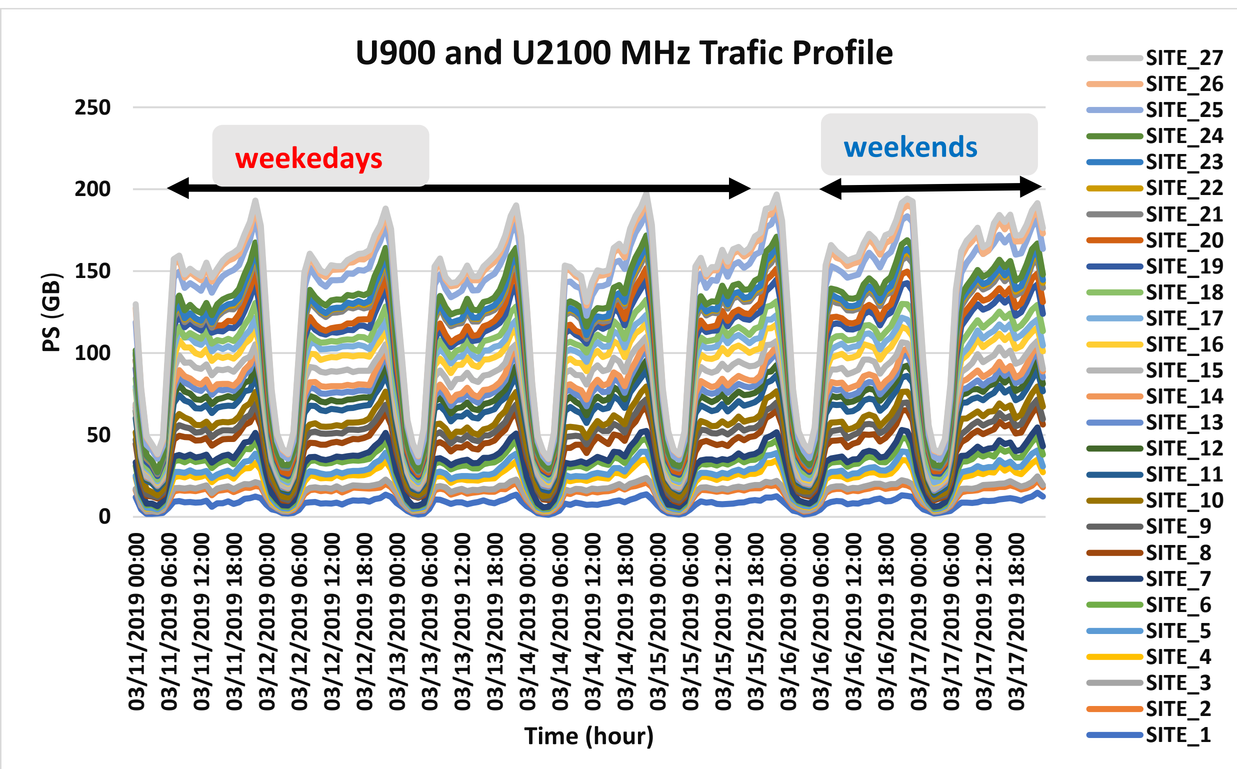

Figure 4-4 Traffic Dynamics over one week in both Time and Spatial Domains

The investigation of sample cellular traffic load profiles percentage of time the traffic is lower than the α percent weekday peak for α = [10, 20, 30] as shown in table 5.1 bellow.

TABLE 4-1 ANALYSIS OF SAMPLE CELLULAR TRAFFIC LOAD PROFILES

% of the weekday peak	Weekdays (Gb)	Weekends(Gb)	Average(Gb)
10%	18	19.5	18.75
20%	36	39	37.5
30%	54	58.5	56.25

The numbers are presented in Table 5.1. In the following discussion, for ease of explanation, we shall focus on a time when traffic is less than 30 percent of peak (further work is needed to better understand exactly what fraction of peak traffic should be chosen as the threshold for dynamic base station operation). So that during weekdays, above 24 % of the time the traffic is fewer than 30 % of peak traffic.

So, to figure out the allowed capacity in a day with low traffic intensity hourly traffic profiles are generated for lower band (900MHz) configured site only to analyze the capacity whether accommodating all the off-peak traffic generated by both upper and lower band of the selected case study area (i.e. 30 percent of the peak traffic).

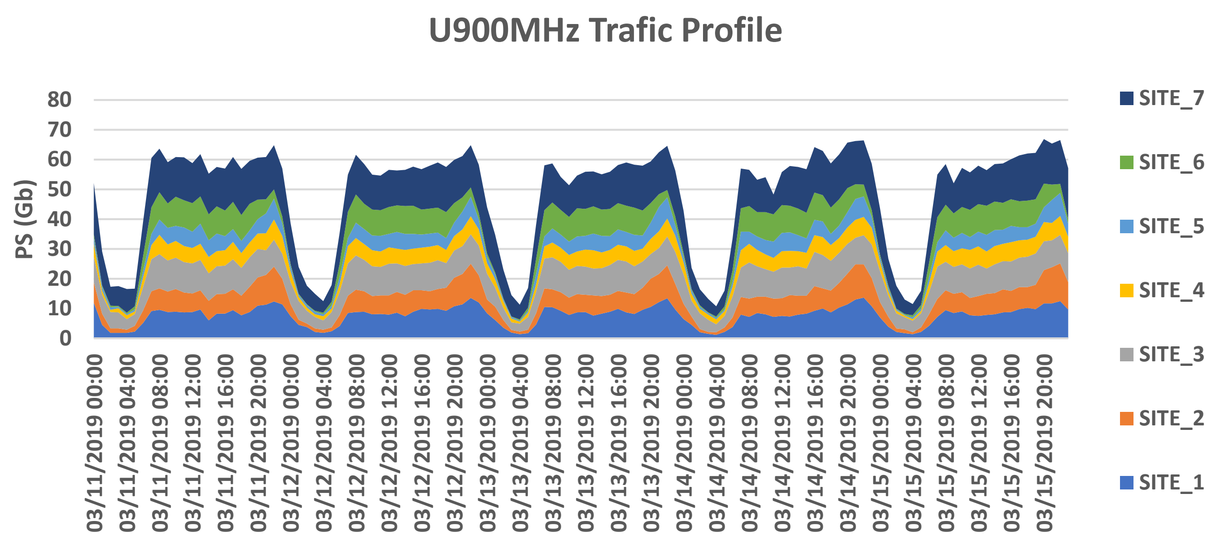

Figure 4-5 Data Traffic Profile of U900MHz. in Considered sites by Day [30]

In Figure 5.5 it shows that the lower band traffic profile indicates that it has enough room to accommodate the traffic generated by both upper and lower band in a period of low load (off-peak hour) of a day. Since the peak hour traffic generated by U900MHz only site is greater than 30 percent of the off-peak hour traffic generated by both band.

In summary, the traffic in a cellular network is quite diverse over time and space. Such strong temporal and spatial traffic diversity indicates the underutilization of BS resulting in both system and network-wide energy inefficiencies at BS. However, traffic dynamics can provide significant opportunities for energy savings. For example, if the traffic variation can be traced and the resource allocation strategy for individual or the whole network is adopted accordingly; a significant amount of energy saved. From the above discussion, it can be concluded that the variation of traffic density in cellular networks in both the temporal and spatial domains show significant under-utilization of system capacity given the network is designed based on the peak-traffic scenarios.

5.1.2 Simulation Approaches, Parameters, and Assumptions

In order to investigate different network topologies, a simulation is performed by considering real wireless networks. In actual wireless networks, there are different parameters to consider and parameters used in this thesis are given in table 5.2.

Simulations could be run in any environment such as a local computer. Actually, the local computer could have been considered as a simulator environment.

TABLE 4-2 BS PARAMETERS AND VALUE

Parameter	Value/ Assumptions
Deployment Scenario	Outdoor macro cells deployment
Carrier Freq.	Carrier Freq. 900 MHz/2100MHz
Simulations	Radio propagation (WinProp), GA in Matlab, 5 m resolution
Number of Base Station Sites	7
Number of Sectors / Cells per BS	3
Access System	DS-CDMA/FDD
Chanel bandwidth	5MHz
Receive Antennas Type	731620X7
Antenna Height	25-35m
Antenna Gain	15 dBi
Propagation Model	Dominant path loss model

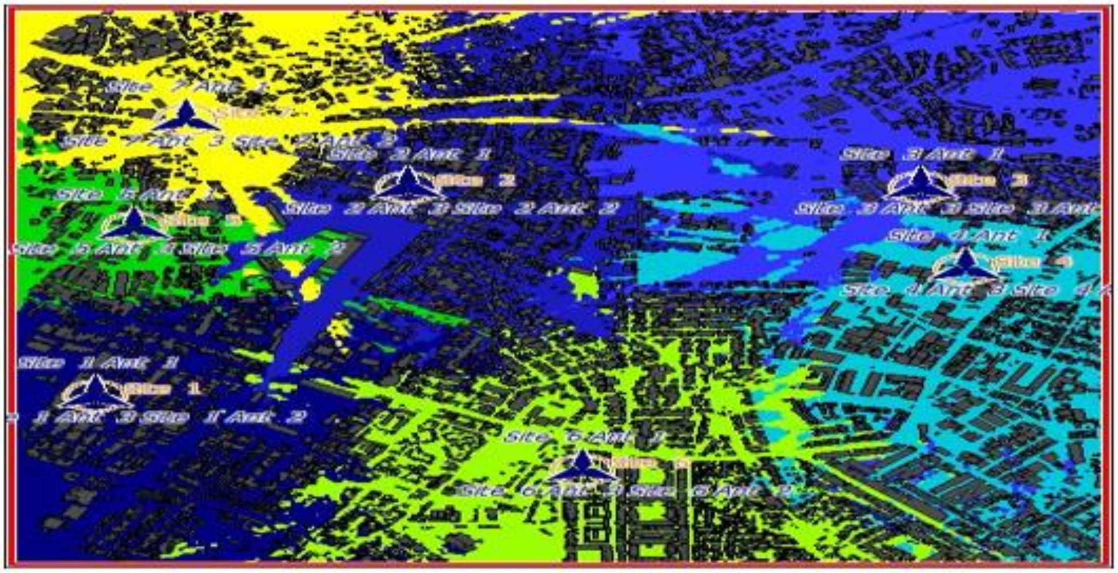

Figure 4-6 Base Station Network Coverage of U900MHz sites in simulation area

Power optimization has a key role in coverage and capacity because of interference that is created by neighboring cells. Figure 5.6 shows that the network coverage of U900MHz sites (i.e. only Seven sites) using equation (4.2) and (4.4) the average received power of the pixel are optimally adjusted, interference can be reduced drastically and therefore SINR can increase. In addition to interference, cell transmit power can be optimized to reduce energy consumption.

5.3 SINR results

The CDF plot of optimized and non-optimized scenarios are presented in Figure 5.7 and Figure 5.8. It shows that the optimized received signal scenarios have improved the SINR compare to non-optimized ones. The optimized received signal power increases the SINR from -14.50 dB to -14.30dB at 10-percentile.

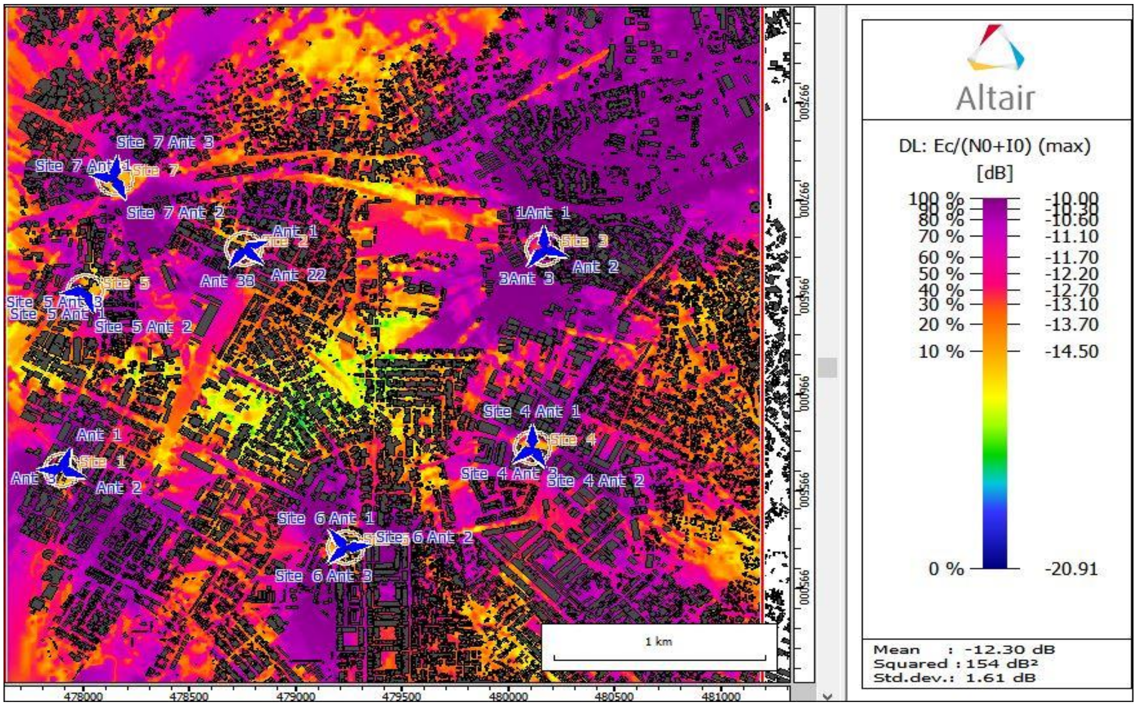

Figure 4-7 SINR before optimization

Figure 5.7 shows the coverage area SINR values of un optimized receive signals of the selected case study area.

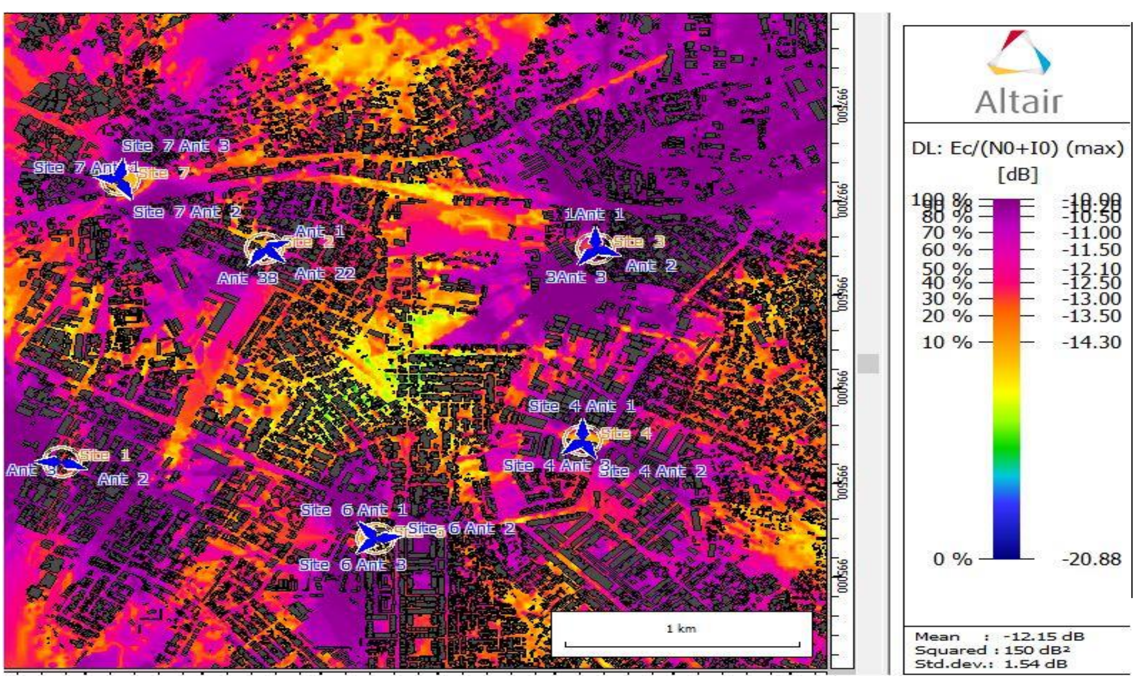

Figure 4-8 SINR After optimization

Figure 5.8 shows the coverage area SINR values of optimized receive signal of the selected case study area.

5.4 CDF plot

The CDF plot shows that the optimized scenarios have improved the pixel SINR value at 10, 50 and 90-percentiles are shown in Figure 5.9. As it can be seen, for optimized received signal power cases it improves the SINR by delivering 0.4 dB, 0.3 dB and 0.2 dB gains at 10, 50 and 90-percentile respectively compared to un optimized received signal power case. At 90-percentile, the results are small compared to values at 10 and 50-percentiles.

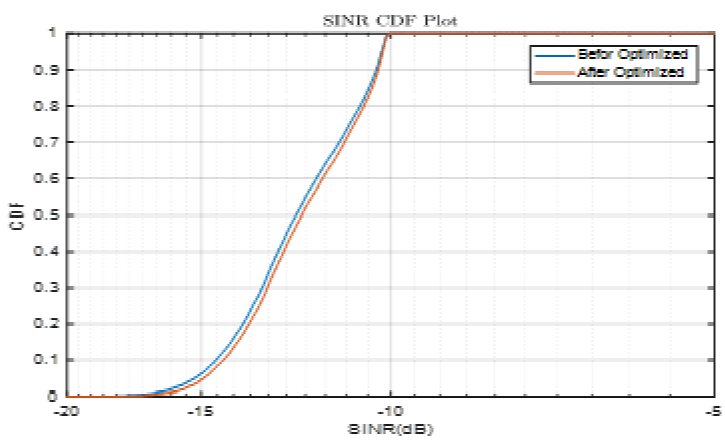

Figure 4-9 SINR CDF plot

5.3.1 DL throughput results

The plots of DL maximum throughputs are presented in Figure 5.10 performance gains when compared to optimized receive signal power deployments at 10, 50 and 90-percentiles are shown in Figure 5.11. WinProp uses discrete value while calculating DL throughput values, like 500kbps, 2Mbps and 4Mbps. The results show that the optimized receive signal power cases improved the Download throughput compares to a non-optimized one with 1% gain at 4Mbps and 2% gain at 2Mbps.

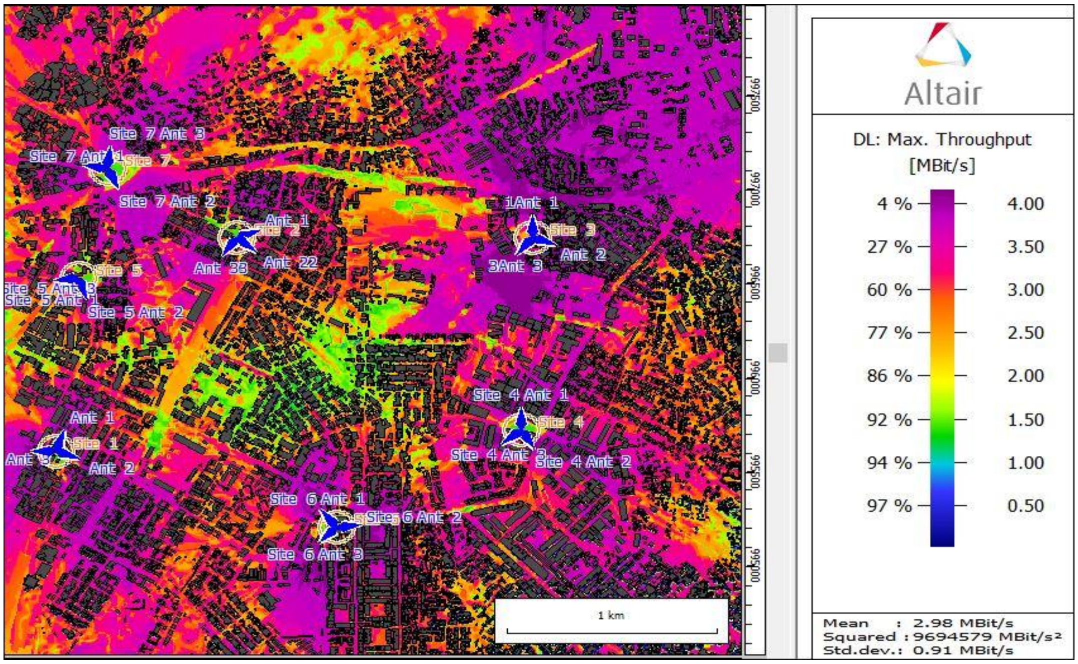

Figure 4-10 Throughputs Before Optimized

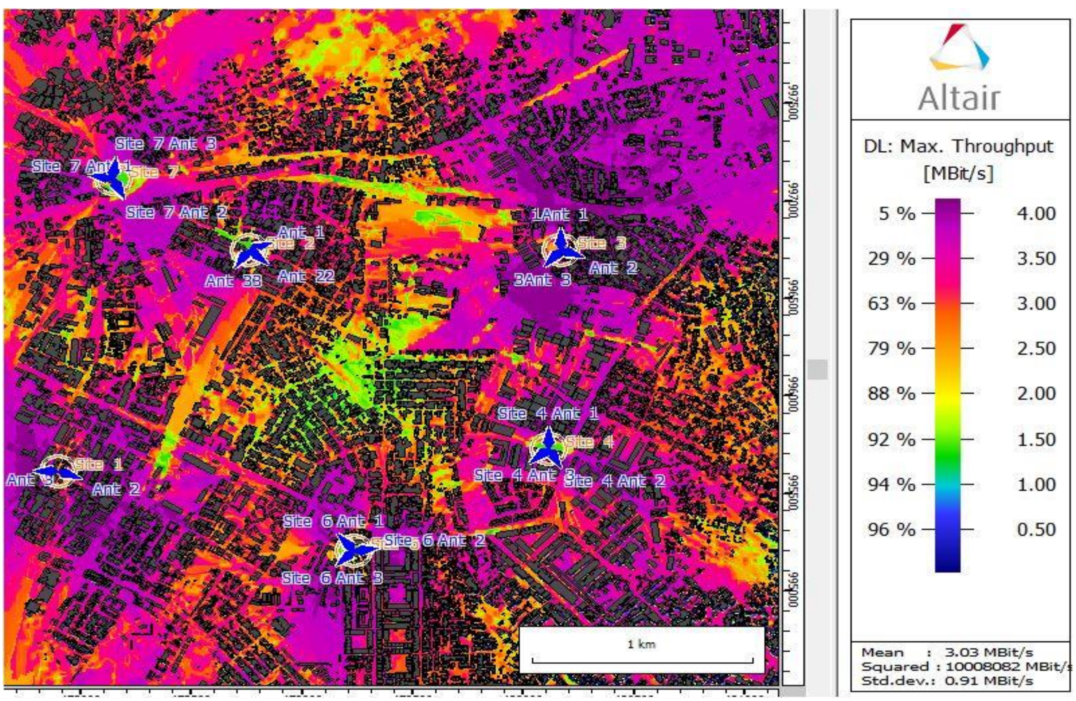

Figure 4-11 Throughputs After Optimized

Finally, results show that the optimized receive signal power cases the mean Download throughput compare to non-optimized one is improved from 2.98Mbit/s to 3.03Mbit/s.

5.4 Economical Aspect

In this section the energy consumption is translated into the most important factor of a mobile operator: the actual cost for any of the further calculations it was used the price per kWh in Ethiopia in 2018 which is indicated in table 5.3 and corresponds to the average electricity price for industrial consumers. Using the Ethiopian Electric Utility (EEU)/kWh reference price for the industrial users would lead to even greater energy costs [42] [43].

TABLE 4-3 ELECTRICITY PRICES FOR INDUSTRIAL USERS

Location	$Birr/kwh
Residential	0.5617
Industry flat rate	1.3982

For sleep mode techniques in particular, for a small fraction of time that element or BS applies in sleep mode (T sleeping) over a certain period of time (T total) is usually adopted as an approximated estimate of savings achieved at component or node levels. It is given by:

$$\text{Savings from sleep mode} = \frac{T\ \text{sleeping}}{T\ \text{total}}\ [\%]. \tag{5.1}$$

Assuming a static energy consumption in active mode, zero energy consumption in sleep mode and zero charges for switching between modes, the rough approximation of Eqn. (5.1) is used in various studies (e.g.[44]). To some degree more realistic modification considers active mode and sleep mode, each consuming a fixed amount of energy. The average power consumption during a certain period is then obtained by:

$$\boldsymbol{P}_{total=}\ \ T_{sleep}{}^{*}\ P_{sleep} + T_{active}\ {}^{*}\ P_{active}\ [\text{W}]. \tag{5.2}$$

where T_{sleep} and T_{active} refer to the fraction of time that the component or BS is in sleep or active state, while P_{sleep} and P_{active} are the power consumption in sleep mode and active mode, respectively.

The tables 5.4 presents the daily, monthly and yearly energy consumption of a 3G 2100 MHz BS with three carriers in the upper band which is the most typical type of deployment.

TABLE 4-4 DAILY ENERGY COST OF EACH BS SET

Daily Power consumption in the Urban Location				
Day Type	Consumption (kwh/day)	Consumption (kwh/day)	Savings	
	Without-ESM	With _ESM	Kwh	Percentage
Weekday	27.0237	20.2677	6.7559	25%
Weekend	28.0183	21.0137	7.0045	25.02%
Average	27.521	20.6407	6.8802	25%

5.4.1 Energy Savings in Ethiopia ethio telecom mobile network

After having figured out the average power consumption for each site with an energy saving solution, an analysis of the possible economical savings is drawn using as a framework ethio telecom mobile operator.

TABLE 4-5 MONTHLY ENERGY COST OF EACH BS SET

Monthly Power consumption in the Urban Location				
Day Type	Consumption (kwh/Month)	Consumption (kwh/Month)	Savings	
	Without-ESM	With _ESM	Kwh	Percentage
Weekday	810.711	608.031	202.677	25%
Weekend	842.43	630.411	210.135	25.02%
Average	826.571	619.221	206.406	25%

For the present work only a specific portion of the total space of cells in the networks are eligible for analysis. Those must fulfill a set of predetermined requirements that make them useful for energy saving purposes It was defined the following rules in order to decide whether the cell is valid or not: The considered area must have a dual-band mode with both the 900 MHz and 2100 MHz active simultaneously. As a gross estimate, one of the major Ethiopian telecom mobile operators owns 738 sites in Addis Ababa out of these 134 sites are U900 MHz layered sites with these kind of characteristics among its network. In the considered scenario the use of ESM solutions allowed annual savings of more than 73,990.00 Birr per 12 square kilo meter.

Chapter 6

5 Conclusion and Future Works

In this chapter, the main conclusions from this work are pointed out, as well as some future work suggestions.

With the threat of global warming and climate change, and the effects of increasing energy consumption, mobile network operators are putting energy efficiency within their requirements. The current trend clearly shows that a massive increase in data traffic is at this point unavoidable. While this increases revenue, network operators have to ensure that their networks can sustain this increase in traffic, ensuring that their subscribers are in no way limited from using their regular services. This will come in the form of a number of network upgrades, which besides boosting network capacity will also increase the overall energy consumption of the network. Improvements in the energy efficiency of used radio equipment help in limiting the overall increase in energy consumption. However, the gap between energy consumption and actual carried traffic is still very large, underlining the need for additional features to further reduce the energy consumption during low network traffic period.

The overall investigation on "Energy Savings in UMTS network base Station (BSs) sleep modes" realized a serious of stages. In this research, we have examined the possibility of decreasing the energy consumption of the UMTS network in the access portion of a cellular network mainly base transceiver stations (BTS), by reducing the number of active site in a period of low traffic because of they are under-utilized. Subsequently, GA based single object optimization technique has been proposed to achieve the energy optimized operation of a BTS.

The adopted solution was to use the Dual-band UMTS network in order to provide this coverage and capacity compensation in this critical period. Recently many mobile operators worldwide have deployed several bands in each technology, which use jointly in order to fulfill the increasingly traffic demands during the peak-periods. This work focuses specifically in the Third Generation of Mobile Telecommunications Technology (3G) case where many operators operate on the 900/2100 MHz bands essentially in Europe, Asia and Africa.

The performance of increasingly dense deployments is interference limited. Therefore, the use of macro cell transmits power signal optimization provides significant performance gains due to SINR improvements. In this study, pixel SINR values are used for the input to transmit the power signal optimization algorithm. Therefore, since the best received signal power case is used in user association, most of UEs connect to a smaller subset of the deployed macro cells. This situation reduces bandwidth allocation per user although SINR of UEs is increased. Hence, load balancing can be a good topic for further study in this context.

Using this method, it was possible to achieve power savings of up to 25%, corresponding to a reduction of over 2,520 KWh annually energy saving per-site. Considering as a context of Ethiopian ethio telecom mobile operator deployment, the use of ES solutions allowed savings of more than 73,990.00 Birr per 12 square kilometers. only in dual-band UMTS network deployments situation.

Annex A

Cell Dynamic Shutdown Parameters in the system

The dynamic cell shutdown algorithm applies to multi-carrier co-coverage scenarios. With the algorithm, the RNC determines whether to shut down one or more carriers based on the traffic and service load to reduce power losses on the NodeB. The dynamic cell shutdown algorithm shuts down the serving cell by handing over all served UEs to the inter-frequency neighboring cells under the same coverage. This reduces power losses of cells [30].

Note

Parameter ID	Parameter Name	Parameter Description
Start Time	First Cell Dynamic Shutdown Interval Start Time	Meaning: Start time of the first interval when the cell dynamic shutdown feature is valid. GUI Value Range: hour, min Unit: min Actual Value Range: 00:00~23:59 MML Default Value: None Recommended Value: None Parameter Relationship: This parameter is valid only when DYNSHUTDOWNSWITCH is set to ON_1, ON_2, ON_3. This parameter must be set when DYNSHUTDOWNSWITCH is set to ON_1, ON_2, ON_3. The value of this parameter must fulfill the following condition: First Cell Dynamic Shutdown Interval Start Time < First Cell Dynamic Shutdown Interval End Time. Service Interrupted After Modification: No (And no impact on the UE in idle mode) Impact on Network Performance: None.

Reference

[1] J. Wu, Y. Zhang, M. Zukerman, and E. K. N. Yung, "Energy-efficient base-stations sleep-mode techniques in green cellular networks: A survey," *IEEE Commun. Surv. Tutorials*, vol. 17, no. 2, pp. 803–826, 2015.

[2] J. Wu, Y. Zhang, M. Zukerman, and E. K. N. Yung, "Energy-efficient base-stations sleep-mode techniques in green cellular networks: A survey," *IEEE Commun. Surv. Tutorials*, vol. 17, no. 2, pp. 803–826, 2015.

[3] T. Postnote, "Postnote Number 319: ICT AND CO2 EMISSIONS.," *Parliam. Off. Sci. Technol.*, no. 319, pp. 1–4, 2008.

[4] M. Jo and M. Chen, "Rethinking Energy Efficiency Models of Cellular Networks with Embodied Energy," *IEEE Netw.*, no. April, pp. 40–49, 2011.

[5] H. Tabassum, U. Siddique, E. Hossain, and M. J. Hossain, "Downlink performance of cellular systems with base station sleeping, user association, and scheduling," *IEEE Trans. Wirel. Commun.*, vol. 13, no. 10, pp. 5752–5767, 2014.

[6] and H. Z. Rongpeng Li, Zhifeng Zhao, Xianfu Chen, Jacques Palicot, "TACT: A Transfer Actor-Critic Learning Framework for Energy Saving in Cellular Radio Access Networks," *Research Journal of Applied Sciences, Engineering and Technology*, vol. 13, no. 4, pp. 2649–2652, 2014.

[7] W. Guo and T. O'Farrell, "Dynamic cell expansion with self-organizing cooperation," *IEEE J. Sel. Areas Commun.*, vol. 31, no. 5, pp. 851–860, 2013.

[8] K. Son and W. A. U. States, "Dynamic Cell Reconfiguration Framework for Energy Conservation in Cellular Wireless," *J. Commun. NETWORKS*, vol. 18, no. 4, pp. 567–579, 2016.

[9] H. Holma and A. Toskala, *WCDMA for UMTS: HSPA Evolution and LTE: Fourth*

Edition. 2008.

[10] ETSI and 3GPP, "TS 123 107 - V12.0.0 - Digital cellular telecommunications system (Phase 2+); Universal Mobile Telecommunications System (UMTS); LTE; Quality of Service (QoS) concept and architecture (3GPP TS 23.107 version 12.0.0 Release 12)," vol. 0, pp. 0–43, 2014.

[11] ETSI, "Etsi Ts 123 002," vol. 0, pp. 0–106, 2013.

[12] D. Guidelines, "UMTS900 Overview & Deployment Guidelines," *QUALCOMM*, no. November, pp. 1–13, 2006.

[13] A. Orange, "Mobile broadband technology opportunities in emerging markets," in *ITU-D*, pp. 27-29 ,2009.

[14] F. Simba, B. Mwinyiwiwa, and E. Mjema, "Broadband Access Technologies for Rural Connectivity in Developing Countries," *Int. J. Res. Rev. Comput. Sci.*, vol. 2, no. 2, pp. 312–319, 2011.

[15] T. Specification, "ETSI TS 132 450-Universal Mobile Telecommunications System (UMTS); LTE; Telecommunication management; Key Performance Indicators (KPI)," *European Telecommunications*, vol. 0. pp. 0–17, 2009.

[16] M. Darlington, "Evolving 4G KPIs to improve end user QoE for 4G LTE broadband systems," Midlands State University, 2016.

[17] H. Technologies, "Trends to 2030," *Challenges*, vol. 6, no. 22 April, pp. 117–157, 2015.

[18] P. A. Carreira, "Data Rate Performance Gains in UMTS Evolution to LTE at the Cellular Level," T, 2011.

[19] P. S. Guidelines, "WCDMA Multi-Carrier Support:," *QUALCOMM Inc.*, vol. 3, pp. 1–62, 2007.

[20] 3rd Generation Partnership Project, "Self-configuring and self-optimizing network

(SON) use cases and solutions," *Third Gener. Partnersh. Proj. Specif. TR*, vol. 36, pp. 1–23, 2011.

[21] S. Hämäläinen, H. Sanneck, and C. Sartori, "LTE Self-Organising Networks (SON)," in *Nokia Siemens Networks*, pp. 1–422, 2012.

[22] J. Lorincz, I. Cubic, and T. Matijevic, "Adaptive and Resilient Solutions for Energy Savings of Mobile Access Networks," *Int. J. Adapt. Resilient Auton. Syst.*, vol. 5, no. 3, pp. 82–102, 2014.

[23] L. M. Correia *et al.*, "Challenges and enabling technologies for energy aware mobile radio networks," *IEEE Commun. Mag.*, vol. 48, no. 11, pp. 66–72, 2010.

[24] N. Seifi, M. Coldrey, M. Matthaiou, and M. Viberg, "Impact of base station antenna tilt on the performance of network MIMO systems," *IEEE Veh. Technol. Conf.*, pp. 1–5, 2012.

[25] M. Ajmone, L. Chiaraviglio, D. Ciullo, and M. Meo, "On the effectiveness of single and multiple base station sleep modes in cellular networks q," *Comput. Networks*, vol. 57, no. 17, pp. 3276–3290, 2013.

[26] C. Peng, S.-B. Lee, S. Lu, H. Luo, and H. Li, "Traffic-driven power saving in operational 3G cellular networks," *Proc. 17th Annu. Int. Conf. Mob. Comput. Netw. - MobiCom '11*, pp. 1–13, 2011.

[27] K. Son, H. Kim, and B. Krishnamachari, "Base Station Operation and User Association Mechanisms for Energy-Delay Tradeoffs in Green Cellular Networks," *IEEE J. Sel. Areas Commun.* ·, vol. 1, no. October, pp. 1–30, 2011.

[28] Cisco and S. Jose, "Cisco visual networking index (VNI) global mobile data traffic forecast update, 2017-2022 white paper," *Cisco*, no. February, pp. 3–5, 2019.

[29] Ericsson, "Ericsson Mobility Report," no. June. pp. 1–36, 2018.

[30] S. & experience quality analyst. C. software. H. Huawei and L. Technologies Co., “PRs.” .

[31] Ethiotelecom. sytem, “frequency allocation,” *v-2*. pp. 1–5, 1018.

[32] M. Gendreau and J.-Y. Potvin, “Tabu search,” *Handb. Metaheuristics*, vol. 146, no. May, p. 648, 2010.

[33] C. E. Shannon, “A Mathematical Theory of Communication,” *Bell Syst. Tech. J.*, vol. 27, no. April 1928, pp. 379-423,623-656, 1948.

[34] N. Kokash, “An introduction to heuristic algorithms,” *Dep. Informatics Telecommun.*, no. August, pp. 1–8, 2005.

[35] M. M. Mijwel, “Heuristic Algorithms,” *Ann. Discret. Math.*, vol. 53, no. C, pp. 221–242, 1992.

[36] Y. A. Adediran, H. Lasisi, and O. B. Okedere, “Interference management techniques in cellular networks: A review,” *Cogent Eng.*, vol. 4, no. 1, pp. 1–10, 2017.

[37] L. J. Vora, “Evolution of Mobile Generation Technology: 1G To 5G and Review of Upcoming Wireless Technology 5G,” *Int. J. Mod. Trends Eng. Res.*, vol. 2, no. 10, pp. 281–290, 2015.

[38] U. Mehboob, J. Qadir, S. Ali, and A. Vasilakos, *Genetic algorithms in wireless networking: techniques, applications, and issues*, vol. 20, no. 6. Springer Berlin Heidelberg, 2016.

[39] L. Mitikie, “UMTS Coverage and Capacity Planning for the case of Bole Sub City in Addis Ababa,” AAIT, 2016.

[40] R. Aldeen and M. Q. Abdulrazzak, “Optimization of UMTS network distribution using genetic algorithm,” *Int. J. Sci. Eng.*, vol. 7, no. 9, pp. 1135–1137, 2016.

[41] K. Sastry, D. Goldberg, and G. Kendall, “Genetic Algorithms,” in *University*

ofIllinois, USA, pp. 97-125,2005.

[42] E. E. Authority, "Tariff Guideline and Methology for Grid power supply," no. December, pp. 1–100, 2018.

[43] E. E. Authority, "Energy Tariff amendment study according to consumers class Service Charge rates amendment study for four years , starting 2018 GC." pp. 2–3, 2018.

[44] H. Holtkamp, G. Auer, V. Giannini, and H. Haas, "A parameterized base station power model," *IEEE Commun. Lett.*, vol. 17, no. 11, pp. 2033–2035, 2013.

Annex B

The RF propagation path loss sample notepad file with 5m resolution

ANTENNA " Ant 1"

FREQUENCY 932.500

POWER 20.000 W Output

ANTENNATYPE SECTOR

PATTERN "C:\Users\netsanet\Desktop\win\Antenna Patterns\739856x1"

HORIZONTAL 70.000

VERTICAL 6.000

LOWER_LEFT 477632.90000000 994489.78000000

UPPER_RIGHT 481197.90000000 998004.78000000

HEIGHT 1.500 TIME_STEP 0.000

RESOLUTION 5.00000000

BEGIN_DATA

477635.40000 **994492**.28000 -115.6857

477635.40000 **994497**.28000 -115.6674

477635.40000 **994502.**28000 -115.6170

477635.40000 **994507**.28000 -115.5765

477635.40000 **994512**.28000 -115.5342

477635.40000 994517.28000 -115.4759

477635.40000 994522.28000 -115.4143

477635.40000 994527.28000 -115.3526

477635.40000 994532.28000 -115.2906

477635.40000 994537.28000 -115.2364

477635.40000 994542.28000 -115.1884

477635.40000 994547.28000 -115.1213

477635.40000 994552.28000 -115.0541

477635.40000 994557.28000 -114.9869

477635.40000 994562.28000 -114.909