Dedication

I dedicate this work:
To my Family, (great mother - brothers),
To all knowledge seekers and providers,
To all my teachers and instructors,
To all my colleagues,
And to my all friends and classmates,

Finally to the spirit of my father, who always I wished to share our joy, and also be seen the fruits of his labor and effort with us, his mercy and forgiveness.

Acknowledgement

First I would like to thank God – Allah for what I could achieve and to complete this research.

I would like also to express my deepest thanks to my thesis advisor and supervisor Prof. Dr. Dieter Fritsch, Director of the Institute for

Photogrammetry, University of Stuttgart. He kept advising me and correctedmy mistakes while doing the research.

I would like to grasp this opportunity foremost to express my greatest thanks to all who have helped me towards the successful completion of this research.

Beside those, I cannot express enough thanks to my professor of computer science,Sudan University of Science and Technology, Prof. Dr. Izzeldin Mohammed Osman, as long as we turned to him and remained in a state of constant follow-up with Professor Dieter, and those who provide us with the information and data required.

Last but not least, I have to confirm that my completion of this project could not have been accomplished without the support of my family especially my mother, my colleagues at work, and also my classmates, in particular, the brother communications engineer, Abu bakr Abu Elgasim for the trouble with me and his guidance.

Abstract

Telecommunications today is one of the most important means of sharing information and data, to get out of the small space to the great world, so that the world has become a small village through the signals provided by telecommunication companies. So it has to be of continous interest in providing communication services to facilitate the lives of people, and moreover, work on expansions to ensure the availability on a wider scale.

In this research, we discussthe lack of signals and weaknesses in the Kassingar area of the Northern State as a solution to provide service for lowland areas. It should be mentioned here, that the area of scope is covered by just two telecommunication towers, after the exclusion of the far towers and another one located at the other side of the riverNile because the signal after impinged the surface of water is reflecation.

The main objective of this research is to study and analyze the nature of (height – low levels) to the test area and to investigate the impact of highs and lows, that mighteventually disrupt signals, and the distribution of towers in terms of coverage using GIS techniques. The results hadshown in a clear and direct way the strong relationship between the height of the tower positions and the lower area under study indicating some weak signal strength, or sometimes absences. We found out, that by adding a new tower at the coordinates [31° 54' 45.0828"E-18° 35' 48.7422"N], it can be made sure to provide signals in the first and second level for all regions.

This research experiment is considered as a basis and support for telecommunication companies to enable further studies of regions of uncovered or weakly- covered communication signals, and to support decision-making to put the towers in the right place ensuring the Quality of Service (QoS) for each part, no matter ofthe surrounding environmental nature.

المستخلص

الاتصالات في وقتنا الراهن تعتبر واحدة من اهم وسائل تبادل المعلومات والبيانات والخروج من الحيز الصغير الي العالم الكبير بحيث أصبح العالم قرية صغيرة بفضل الاشارة التي توفرها شركات الاتصالات. لذلك لابد من الاهتمام بتوفير خدمة الاتصال لتسهيل حياة الانسان، والتوسع لضمان توفرها على اوسع نطاق. في هذا البحث تطرقنا لعدم وجود الاشارة او ضعفها في منطقة الكاسنجر بالولاية الشمالية كحل لتوفير الخدمة بالمناطق المنخفضة مع الذكر بأن المنطقة توجد ضمن نطاق تغطية برجين بعد استبعاد الابراج التي تبعد عنها بالإضافة الي تلك التي تقع في الضفة الأخرى من النيل لانعكاس الإشارة عند ارتطامها بالسطح العاكس (الماء). ان الهدف الرئيسي من هذا البحث هو دراسة وتحليل طبيعة المنطقة قيد الدراسة وتأثير الارتفاع والانخفاض في اعاقة الاشارة، وتوزيع الابراج من حيث مدي تغطية كل برج وذلك باستخدام تقنيات نظم المعلومات الجغرافية. اوضحت النتائج النهائية التي تم الوصل اليها بشكل واضح ومباشر الي العلاقة القوية بين ارتفاع مواقع الابراج وانخفاض المنطقة قيد الدراسة في ضعف قوة الاشارة او انعدامها احيانا، ووجدنا أنه لابد من اضافة برج جديد في الاحداثيات[N"18° 35' 48.7422-E"31° 54' 45.0828]، وبذلك نضمن توفير اشارة في المستوي الاول والثاني لجميع مساحة المنطقة والمناطق المجاورة لها. تجربة هذا البحث تعتبر اساس ودعم لشركات الاتصالات لتمكينهم من دراسة المناطق الغير مغطاة بإشارة الاتصالات واتخاذ القرار في وضع الابراج في المكان المناسب لضمان وصول الخدمة لكل جزء منها بمختلف طبيعتها البيئية.

Acronyms

Acronym	Meaning
GIS	Geographical Information System
RF	Radio Frequency
DEM	Digital Elevation Model
2D	2 Dimensional
3D	3 Dimensional
BSTs	Base Transceiver Stations
GPS	Global Positioning System
IRS-LISS P6	Indian Remote Sensing Satellite
COGO	Coalition of Geospatial Organizations
NDVI	Normalized Difference Vegetation Index
RS	Remote Sensing
SOI	Survey of India Report Maps
DTM	Digital Terrain Model
NTCS	National Telecommunications Corporation Sudan
DMS	Degrees Minutes Seconds
UTM	Universal Transverse Mercator
NE	North and East
SCBS	Sudan Central Bureau of Statistics
SRTM	Shuttle Radar Topography Mission
TIN	Triangulated Irregular Network
RGB	Red Green Blue color model
MSL	Mean Sea Level
dB	Decibel

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CHAPTER ONE

Introduction

Chapter (1)

Introduction

Keywords: Signal Coverage, distribution towers, broadcast signal, cellular network, GIS, low-land areas, Kassingar.

1.1 Research Background

A Geographic Information Systems (GIS) is a computer software system that stores, displays, manipulates, and analyzes information that contains, or can be associated with, a geographic location [7]. The first system was developed in the early 1960's by Roger Tomlinson and was used by the Canadian government to aid in the preservation of natural resources.

Since then GIS has evolved into a multimillion-dollar industry due to its ability to discover trends and new information about a particular area by placing layers of different types of data on top of one another and performing varied analyses.

Telecommunications had become a very big challengein the present time, as it basically has impact onto most or all aspects of daily life, for instance on education, health, business management, communication, and banking transactions, to name only few. Furthermore, it carries a very important economic component, which helps in the development of experienced communication technologies.

In that last 20 years we had seen an expansion of wired networks, wireless networks and microwaves to allow for mobility or roaming at any time and any place.

Therefore, telecommunication companies have to overcome a big challenge to provide services on wider areas, which allows for stable connection while roaming.

The expansion of services depends on many factors, for instance choosing the appropriate location of the tower, which depends on other factors, including the distance between the towers and the number of participants expected,to revenues in the coverage area and so forth.

Thus, telecommunication is spatially dependent, a reason to use GIS. Surprisingly, however, it is only in recent years that GIS has become widely accepted.

Therefore, telecommunication companies are increasingly becoming very large users of GIS technology. Over the last years, GIS has become an effective tool for businesses, because of its unique ability to tie attribute data to specific locations and usage, to plan, build, and operate telecommunication networks and associated services as well as many other use cases.

This research aims to apply GIS techniques in the field of telecommunications to become familiar with the different information related to this field, such as the coverage of the network signal towers, and to know the impact of geographical factors such as topography ranges, and how it does effect the broadcast of telecommunication signals.

1.2 Problem Statement

There are a number of problems in the field of telecommunications. Areas with mountainous or low terrains are lacking signals and have weak access to them. This affects outgoing and incoming phone calls and internet services, which is the biggest problem for many people .

1.3 Research questions

- Strength and weakness of network signals in the testbed area, with regard to different height levels and the standard broadcast signal?

- What is the impact of a mountain chain for blocking the signal for the testbed area?
- Is the current distribution of towers in the testbed area considered optimal?
- What are the possible solutions to resolve problems in these areas in general?

1.4 Research Motivation

To overcome a region of non-coverage or weak signal by a detailed simulation study.

By experiences in daily life we can say, that communication amongst people has got a new quality, as we are dealing with various communication forms and in particular using the Internet, making the world a small village.Being blocked from this communication isolates, and therefore this research will help to overcome natural factors.

1.5 Research Scope

Researchis carried out in thisstudy,justto test signalzonesin terms ofseveral height classes,to be comparedwith neighboringareas determining the amount ofsignal decline, which affects the process of receivingthe signalfromthe towersin the area and its surroundings.Afterwards it is tried, todrawpossible solutionsthat will helpto solve this problem.

1.6 Research Objectives

- Study and analysis of a testbed with different geographical nature.
- Performance analysis and distribution of existing towers of the surrounding area under study.
- The impact of natural factors (mountains, low-land areas) on weakness or blocking the signal.

- Find a solution, that solves the absence of service and provide proposals and solutions to hand-over to professionals.

1.7 Research Methodology

First of all a literature review is carried out and related work using Geographic Information Systems in the field of telecommunications is presented. The next chapter deals with an analysis of the topography of the region,in particular in terms of heights above mean sea level and the know-how about the dependence of signal coverage and terrain parameters of the study area. This is to be compared with areas with strong signals. Afterwards, a suitable location is chosen for placing a new tower in the testbed area, which represents the best solution to this problem.As simulation tools we will use Arc GIS and Google Earth. The overall flow of the proposed work is shown in the figure [2.2].

1.8 Expected Results

The expected results of this research is to learn about the distribution of tele-communication towers in the testbed area, especially those which are located properly and those, which are placed in wrong locations. In order to get the appropriate location, taking into account the geographical nature, the wrongly placed towers should be redistributed with respect to the total area of the region (high & low-lands areas) and the option of expansion.

Furthermore, we want to give recommendations for creating new towers in convenient locations, which cover the exact area and relieve pressure on the rest of towers, and may also help in the enlargement process. This option represents an attractive economic factor for competition between companies.

1.9 Research organization

Chapter (1) represents the introduction, highlighting a brief history of telecommunications and its evolution, the methods of Geographic Information Systems, and their entry into the field of telecommunications. The literatures review and related work appears in chapter (2). Chapter (3) presents new ideas to be applied, followed by the methodologiesimplemented. Chapter (4) is a narrative of the region under study in terms of natural terrain parameters. Chapter (5) inserts the data of towers and the region under study to analyze and produce final results with some discussions. A conclusion and recommendation chapter (6) summarizes the thesis. Final references are given in Chapter (7).

CHAPTER TWO
Related Work and Literature Review

Chapter (2)

Related Work and Literature Review

2.1 Literature Review

2.1.1 Introduction

As mentionedabove aGeographical Information System is a“computer based system for theacquisition and update, storage and query, analyses and simulation as well as output and presentation of spatial data”.

Another interpretation sounds as follows: GIS is a highlight or a specific part of the ground (specific spatial patch) under the scrutiny in terms of analysis and viewing its details to be displayed in the form of layers. Each layer is containing the type of data or the details of that label, as it is shown in figure [2.1]:

Figure 2.1: Set of layers that display data of a piece of land

In a general sense, the term GIS describes any information system, that integrates, stores, edits, analyses, shares, and displays geographic information. GIS applications are tools, that allow users to create interactive queries (user-created searches), analyze spatial information, edit data in maps, and present the results of all these operations.
GIS is part of the Geographic Information Science, which is the science of underlying geographic concepts, applications, and systems [4].

GIS is a broad term, that can be referred to a number of different technologies, processes, and methods. It is attached to many operations and has many applications related to engineering, planning, management, transportation, logistics, insurance, telecommunications, and business [6].For that reason, GIS and location intelligence applications can be the foundation for many location-enabled services that rely on analysis and visualization.
In the history of the development of GIS [11], the first known who uses that term was Roger Tomlinson in the year 1968 in his paper "A Geographic Information System for Regional Planning". Tomlinsonhas been acknowledged as the "father of GIS"[5][15].

WithinGIS applicationsone can takea specific areaofland ora particular locationto be added to the applicationand conductingsome operations. Thoseprovide eithergeographicreferences (coordinates)to the maporsatellite imageand, moreover, may add all datapertaining tothe region.

After this general review, we can say that all kind of geospatial data serve for several models, that reflect the form of the results that have been deduced and therefore may help considerably in making the right decisions.

2.1.2GIS in Telecommunications

By any measure, telecommunications is a big business. The huge amount of outside plants, the many and varied communication links, and the need to attract and keep customers in a changing world are all significant reasons to use GIS. Surprisingly, however, it is only in recent years that GIS has become widely accepted in this discipline.

Telecommunications companies are increasingly becoming very large users of GIS technology. Today GIS is extensively used to plan, build, and operate telecommunication networks and associated services.

The applications of GIS include activities such as planning transmission capacities, locating cellular telephone transmitters, recording customer complaints, and using geo-demographic information to find new customers [8].

2.1.3WHO USES GIS IN TELECOMMUNICATIONS?

GIS is now a standard technology applied throughout the telecoms industry. Telecommunications service providers in most parts of the world use this technology to plan, build, and operate telecommunication networks and associated services.

In today’s competitive market, the wireless telecommunication industry is being driven by the need to provide better service coverage while reducing infrastructure costs. The solution lies in determining the optimum location of towers for telecommunication by means of GIS technologies.

GIS for telecommunication services provide clutter data that has been developed for the radio frequency (RF) propagation to help engineers refine their signal loss prediction models according to the characteristics of the underlying terrain and ground cover [8].

In addition, it requires mapping of land cover data, which is critical to wireless network design because the surface cover affects propagation of the digital wireless signal. GIS for telecommunication’s clutter data is classified as the man-made and natural features – both may impact radio frequency propagation by reflection, diffraction, absorption, or scattering of the transmission waves. Engineers can determine the optimum location for towers by integrating clutter data with elevation data (DEM), and physical attribute data, and applying propagation models implemented in RF software programs.

2.1.4MobileCommunication Network Planning

Optimal signal coverage has always been a fundamental issue for cellular network operators. Other issues related to capacity, quality of service and cost efficiency are also rapidly gaining prominence. In order to determine signal coverage, network engineers usually rely mainly on two-dimensional (2D) terrain maps and rather simple empirical propagation-prediction models. In the following study [9] a framework that provides a more efficient and cost-effective network coverage optimization for a dense urban environment was investigated.

For this reason a 3D Geographic Information System (GIS) of the study area was developed. The signal propagation-prediction tool based on ray-tracing coupled with the 3D geo-information was used to model the radio signal coverage for the Base Transceiver Stations (BTS) for one of the mobile phone operators licensed to provide mobile phone services in Kenya. To determine the best locations of the BTSs for optimal signal coverage of the study area, spatial analysis tools in GIS were employed.

Comparing the proposed methodology with classical methods demonstrates that this spatial analysis approach can be used to optimize mobile signal coverage in any dense urban environment without resorting to lengthy field measurements, thus minimizing the costs of wireless network planning.

A description of the study area with all the details of the region and natural landmarks, buildings and geographic location to determine the factors, that affect the movement or distribution of the signal, is given.

With regard to the preparation of the propagation environment for an implementation of the ray-tracing model, the most important geospatial data are the clutter data, i.e. buildings, trees and any obstacles within the environment, which influences radio wave propagation, and the BTSs data. This clutter data was extracted from a topographical base map.

In order to get signal strength recordings, needed for validating the prediction model used, actual signal strengths were measured at different locations within the study area. For this an Alcatel mobile phone delivered the signal values and the geographic locations were simultaneously recorded using handheld GPS (Global Positioning System) equipment.

2.1.5Mobile Network System

The use of wireless systems is a very attractive option in the design and development of communication networks, especially with the expansion of cellular telephony and wireless computer networks, as their industries seek to increase the number of services and speedy transmissions to their customers. This transmission needs towers and the location of these towers is a very important factor in network coverage. With this regard a study has been carried out in Bhadravathi town, India [2], for which the network coverage of all networking companies has been analysed, using remote sensing, GIS and GPS technologies. It was found, that the network coverage in the southern part of the city has some deficits and needs new towers for improving the communications. For the generation of a base map and contour map, national surveysare used. IRS LISS P6 imagery is used for updating the road network and to make further analysis. For BTS data generation the GPS (Global Positioning System) is a part of GNSS (Global Navigation Satellite System) was used to locate the position of towers. To finally carry out this study ERDAS Imagine 9.1, and ARC View 3.2a are used as GIS software.

2.1.6 Cellular Signal Distribution

The application "Cellular Signal Distribution through Spatial Visualization" when implemented in a cellular telecom system network, interacts with positional information collected by GPS receivers. This positional information is used by the application to calculate the distance, direction and coverage angle along each transmitter on the telecom towers[10].

The related information is stored in Arc Map attribute tables and retrieved through the COGO tool functionality of ArcGIS, to provide regular and sufficient rate of signals to the user. The positional and the coverage information are displayed on a Google map or Google earth sheet. This project is focussing on the tower heights and distribution of its signals. The frequency and strength of signal passes are checked by a device attached on the antenna, defining the appropriate angle, for which the maximum signal is provided.

The main objective behind developing this system is to attain a high level of accuracy in signal distribution through the appropriate angles. Without the map it is impossible to locate the possible range and direction of the target from the BTS towers. However, the proposed system will increase the accuracy by filtering out the problematic areas from the coverage area of the tower transmitters, showing the transmitter angle situation from base and height of tower, along the distance and direction.

In the requirements specification, some information related to Cellular Signal Distribution through Telecommunication Corporation are mentioned. For example, the company name, location, historical background, current status in market, and existing systems.
A basic requirement for the success of this project is that data which are used must be properly georeferenced, digitized and free of some errors, which can easily be removed by using the ArcGIS functionality tools.

2.1.7 Signal Strength Measurements and Coverage Estimation

The efficiency of a radio wave propagation prediction system can be improved with powerful capabilities of handling geo-spatial data through remote sensing and GIS techniques.

Signal strength predicted by the integration of NDVI methodology and view shed analysis, which takes into account for factors like terrain height, building height and distance from a tower, is represented in a comprehensive paper [3].

Foliage loss depends on the signal frequency and varies according to the season. According to this quantitative analysis, it has been found that RS/GIS oriented signal strength prediction method using NDVI significantly improves the prediction quality compared to the theoretical free space model, which does not take into account any local terrain feature effects.

The multi-spectral and stereo satellite data in conjunction with GIS/GPS techniques can be utilized to formulate suitable plans and strategies for an effective telecom planning and development. The study mainly involves the applications of Remote Sensing and GIS techniques.

A major part of the work has been carried out by making use of the satellite data (both hard copies and digital data), SOI topographical maps, Google maps and other maps.

The satellite data taken for this study are the multispectral Linear Imaging Self Scanning-III (LISS-III) sensor data of the Indian Remote Sensing satellite IRS-1C and a regular DEM has been generated at 1-5m grid interval. Finally an ortho-image is generated and features have been extracted in 2D mode by on-screen digitization. The same model has also been used for 3D feature extraction.

All the man-made structures (buildings, fence etc.) and trees have been captured in 3D environment in stereo mode. The accuracy achieved for DEM and the ortho-image is better than 5m. Finally using Super GIS 3D analyst, 3D modeling is realized using GIS environments, followed-up by various 3D analyses.

The variation in signal strength depends upon many factors, such as the type of trees, trunks, leaves, branches, their densities, and their heights relative to the antenna heights. When the signal strikes the surface of a building, it may be refracted or absorbed. This is an important consideration in the coverage planning of a radio network manipulation and compression.

2.1.8 Most Suitable Locations for Telecommunication Services

The applications of Geographic Information Systems (GIS) in the telecommunication sector is also outlined by [1]. Here the study area is located in the South-eastern part of Khartoum City at Al-Marmora District. The main objectives of the study are to find the suitable locations for telecommunication services for the study area and design suitable plans for towers spacing.

For this purpose, information about the study area was collected for the following items: major towers heights and offsets, minor towers and their associated cable length, streets, switches, building distribution, and customer services.

The resulting buffer suggested, that the major towers should be arranged from 200 to 400m apart, depending on the geography of the area. One tower is expected to cover an area of approximately about $1000m^2$. The connected cables between towers and switches are of different length and size, depending on the area of connection.

This study highlights the importance of using GIS in telecommunication industry. It indicates, that GIS may provide best location selection not only for telecommunication services, but also for other services needed in residential areas.

The system consists of towers, which send signals to the switches by cable0T2T, which in turn 0T2Tsend a signal to the columns by cables and is linked to home phone lines by columns through copper wires.

2.2 Related Works

Communications in lower-terrain areas or abnormal terrain arise several questions. With the support of GIS appropriate decisions can be deduced and the necessary steps are listed by the chart shown in figure [2.3].

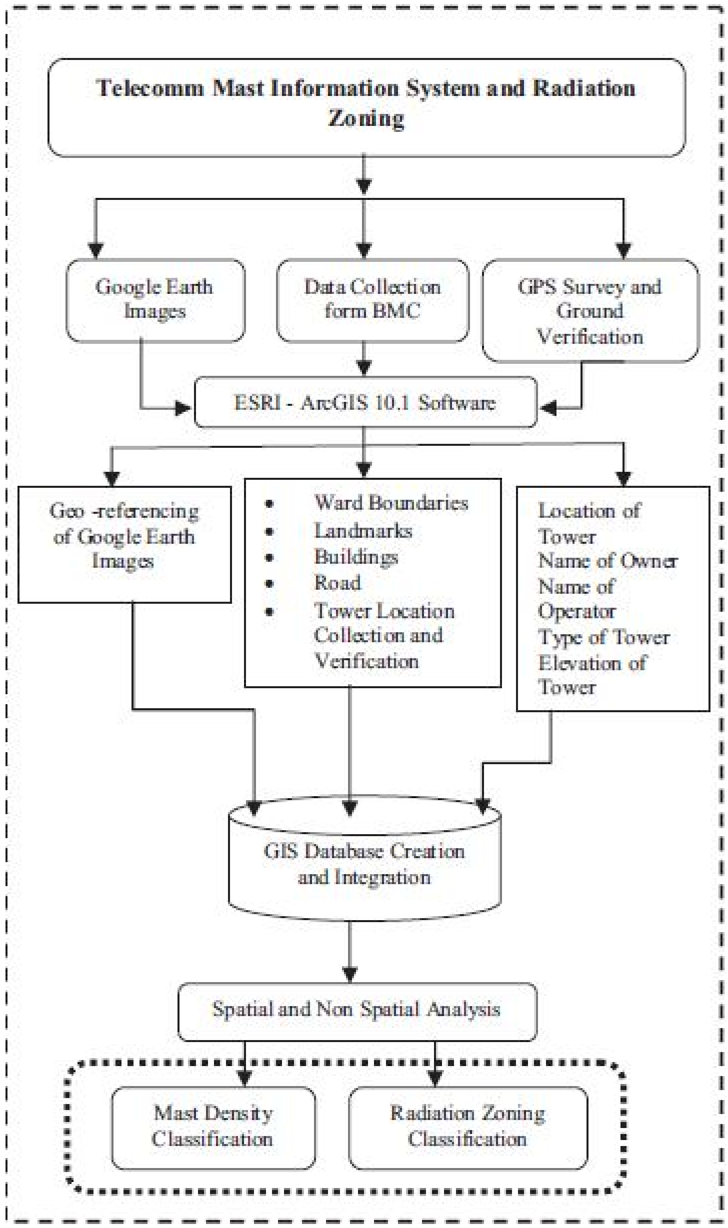

Figure 2.2: Schematic representation of steps analysis

Itdelivers contents to those areas, in which difficulties on the force of the signal [13] are to be expected: by gradient rises, declined earth surfaces and mountains, trees, rivers and seas.

(**Munene, et al., 2014 [8]):**This paperis dealing with improving thecoverage ofthe signal andbearing in mindpublic buildings and facilitiesin terms ofaltitudeandlocationsto suit thesignal orthe mobile networktechnologyusersprotrudingthe third dimension(3D), and measuringthe signal strengthfor the selection ofsuitable sitesfor the development ofbroadcastservicedevices.

Theresearchers found out, thatwireless network planning is a complicated task for network engineers. The most important consideration, particularly at the beginning of the wireless network design process, is optimizing the radio signals' spatial coverage of the target area.

Dense urban environments characterized by high-rise buildings are particularly challenging to the network engineer owing to the numerous factors, which affect the signals and which must be modeled as accurately as possible. As demonstrated in this study, the 3D ray-tracing model, when used with 3D geodatabases of the target area, is the most accurate method of modeling signal coverage.

The location of BTSs plays a crucial role in ensuring optimal signal coverage. Thus in wireless network design the determination of the best BTS sites that offer optimal signal coverage is a very important consideration, which must be handled with utmost seriousness. This is particularly important due to the fact that setting up of a single BTS requires colossal amounts of money and thus elimination of any redundant BTS(s) would result in significant savings for the network operator.

(Basavaraja Simpi, et al., 2011 [2]): This study is aimed to know the locations of all towers of different companies such as (BSNL- Airtel- Hutch-Tata-Indicom- Reliance) spice towers with elevation pattern of the city and to understand the availability of the network coverage by their buffer zone, to identify the network shadow zones and to suggest the construction of new towers for further improvement of the network coverage of the city. Bhadravathi town has been taken up for the details study.

Bhadravathi lies in the central part of Karnataka state, in the south-east corner of shimoga district and has spread over an area of $67km^2$.
The Survey of India (SOI) top sheet no. 48 O/9 SE of the scale 1:25,000 is used for the generation of a base map and contour map. IRS LISS P6

imagery is used for updating the road network and to make further analysis. For getting position data GPS (Global Positioning system) is used to locate the position of towers.
The software used are ERDAS Imagine 9.1, and ARC View 3.2a. Peak hours of each tower are discussed .

Getting all the details and making a buffer zone of individual companies an overall buffer is generated to get all networks in single platform .
Mobile towers constructed without much consideration of the elevation factor and having good network coverage results in a shadow zone in the southern portion of the city. It is better to construct towers in the southern part of the city to get better network services.

(Muhammad Fahad Aslam, 2010 [10]): The purpose of this paper is a fully functional regular signal distribution system with animated maps. One can search and find the places, where the signal frequency rate is not sufficient and is not meeting the user requirement with respect to communications. Furthermore, it finds the correct coverage angle of each tower transmitter covering the minimum or maximum volume of population.

It is a well-known fact that a high level of accuracy in signal distribution is obtained using an appropriate angle. Without amap it is impossible to locate the possible range and direction of the target from the BTS tower. However, the proposed system will increase the accuracy by filtering out the problematic areas from the coverage area of the tower transmitters, and shows the transmitter angle situation from base and height maps with regards to long distances and directions.

The researchers are using the ArcGIS tool (COGO/Coordinate Geometry) for tower data calculations, mark the distance and direction of one transmitter to another by applying two point-lines views. Furthermore, the calculationof the distance and direction between tower height and base helps to find the bestlocationfor future services, in particularby thehigh qualityof thesignalnearitstowers.

(Naveen Chandra, et a., 2011 [3]): The larger the number of users, especially mobile users, the more capacity a network should have. As a result network planners are increasing the system capacity by locating transmission antennas at heights overlooking surrounding trees and buildings. The propagation algorithms that determine path loss and signal coverage are important for successful wireless network planning and deployment.

Trees, no matter to appear as single or in a group, can be found in cells of rural mobile systems as well as in fixed access systems. The trees act as obstacles in the radio path causing both absorption and scattering of the radio signals. The scattering and absorption need to be accounted for in radio planning tools to improve their accuracy, with improved co-ordination of radio links and optimum use of the radio spectrum. Depolarization of the incident signal arises, when it encounters a scattering medium such as vegetation. Models are available for predicting depolarization from backscattered signals such as those encountered in remote sensing. Prevalence of mobile radio systems requires studies of spectral characteristics of electromagnetic wave attenuation by vegetative media in wide frequency range.

Theoretically, it is possible to exactly predict the strength of the signal from any transmitter at any other location, if all elements of the propagation environment are correctly taken into account. In so-called “free space” (actually a vacuum), there are no elements in the propagation environment and the signal strength at some distance from the transmitter can be exactly calculated.

It is found that RS- and GIS-aided signal strength prediction can significantly improve the prediction quality compared to the theoretical free space model, which does not take into account any local terrain feature effects.

The study also suggested that future research in radio wave propagation modeling and analysis should be carried out in a more strategic way and

field measurement should provide various representations of land cover types in order to make the statistical analysis more efficient.
The multi-spectral spatial analysis and analysis of stereo satellite data for obtaining terrain height information in conjunction with GIS/GPS solution have helped to formulate and derive an algorithm for calculating signal strength and coverage estimation.

(Amir Abdelrazig Merghani, et al. , 2012 [1]): The roleof geographic information systemssupporting urban governanceprocessesfor creating jobs, thatdevelopandassist inthe expansionand developmentof urbanity,has encouragedresearchers toapply GIS for telecommunications.

They improve thesitesorchoose the bestsiteforthe service providerin the region, after theanalysisoperationsusing theprogram(ArcGIS 9.3).

The researchers concluded, that the project has resulted in a reduction of labor and time costs when carring out the actual work on site.

The ideathatwe are going toimplementin this studyis to solvethe problem of critical regions, such asnaturalmountainous terrainand lower altitude areas, where thevalidity ofthe signal andthe possibility ofselectingsuitablesites fortowers, taking into account all influencingfactors. We will consider the summary from related works in table [2.1]:

Author	Title	Methodology	Comment

Basavaraja Simpi, Chandra Shekarappa K.N, Nirmala Nadan, Bhargavi Prabhuswamy,2011	Mobile network system of Bhadravathi Town using Remote Sensing, GIS & GPS	Imagery. Surveying. Case study. GPS.	This paper covers a Project Case Study in India similar to the area under study for this dissertation. The researchers have come to a solution to increase the number of towers in the area to become fully covered.
Munene, E.N., Kiema, J.B.K., 2014	Optimizing the location of base transceiver stations in mobile communication network planning.	Case study. Propagation Environment. Signal Strength Measurement	This project is addressing the case Signal Coverage Optimization based on the new distribution of towers in the best locations, depending on the size of the area.
Muhammad Fahad Aslam,2010	Cellular Signal Distribution through Spatial Visualization.	Case study. Data collection. Surveying.	The application Cellular Signal Distribution through Spatial Visualization, when implemented in cellular telecom system network, interacts with positional information receivers like GPS and collects positional information. The aim is to provide regular and sufficient rate of signals to the user.
Faisal Mukhtar,	Selection of the Most Suitable	Surveying. Case study.	The success of this project is to provide a good

Amir A. Merghani, 2012	Locations for Telecommunica-tion Services in Khartoum.	Satellite Images.	quality of service throughout the region. The simulation of the signals transmitted and which are affected by many factors, it is possible to propose new infrastructures at much lower cost and higher performance.
Naveen CHandra.k. n., Lokesh, Usha, H.Gangadha-ra bhat,2011	Signal Strength Measurements and Coverage Estimation of Mobile Communication Network Using IRS-IC Multispectral and CARTOSAT-1 Stereo Images.	IRS-IC Multispectral. CARTOSAT-1 Stereo Images. MAP 3D Modeling.	This work proposes to provide various representations of land cover types to make the statistical analysis more efficient. The multi-spectral spatial analysis and processing of stereo satellite data for obtaining terrain height information in conjunction with GIS/GPS solution have helped to formulate and derive an algorithm for calculating signal strength and coverage estimation.

Table 2.1: Summary of related studies

Chapter 3

New Idea and Methodology

Chapter (3)

New Ideas and Methodologies

3.1 Overview

As a follow-up of the previous chapters we found out, that it is possible to increase the signal strength or cover a wider area of the towers just by increasing their numbers.

While we try to increase the signal strength or improving it, the communication networks in areas of abnormal terrain are first to be discussed using GIS techniques. The distance, e.g. the length between the transmitting and receiving station, has a direct correlation to setup requirements such as signal power and frequency.

In addition to terrain parameters, this is a most crucial factor in our research and has a great influence in the outcome of our research, as this is a key variable and can be assessed with the help of GIS.This is one of our main focus, as that has been considered weakly in most of the existing studies.

Terrain also plays a major role, as it is the reference surface for existing installations and buildings. In particular, the following parameters have to be studied: roughness, slope,and aspect.

3.2 Proposed method

We had been used a set of programs and applications of GIS in the collection, sampling and processing not only the heights of the testbed, but also to carry out an analysis of spatial and non-spatial data to come up with recommendations and results. This will help with the interpretation of lacking communication signals and the strong relationship between the force of reference and natural obstacles.

Therefore we start with digital elevation models (DTMs) and contour maps as 2.5D references for the towers and the surrounding regions, to determine the extent of signal declines.

3.3 Methods Flow Diagram

The methodology used for carrying out the GIS research work is shown in figure [3.1].

3.3.1Procedures for Data Acquisition

3.3.1.1: First, a user assessment study had been carried out to identify the user information needs. This was primarily concerned with telecommunicationcompanies, their desire to effectively and efficiently provide communication services, and the citizens in the regions of weak signal coverage.

3.3.1.2: Second,data identification involved determining the various datasets to be used in the analysis like boundary data, satellite imagery, elevation data etc.

3.3.1.3: Third,data were collected from companies, relevant ministries, and other sources like National Telecommunications Corporation Sudan (NTCS).

3.3.1.4: Forth,data collection and processingvalidating the information collected and then incorporating all available data in software, for map data processing and images analysis.

3.3.1.5: Fifth, theanalysis was carried out using mainly ArcGIS software andother software.

3.3.1.6: Sixth,tabulation and display of results.

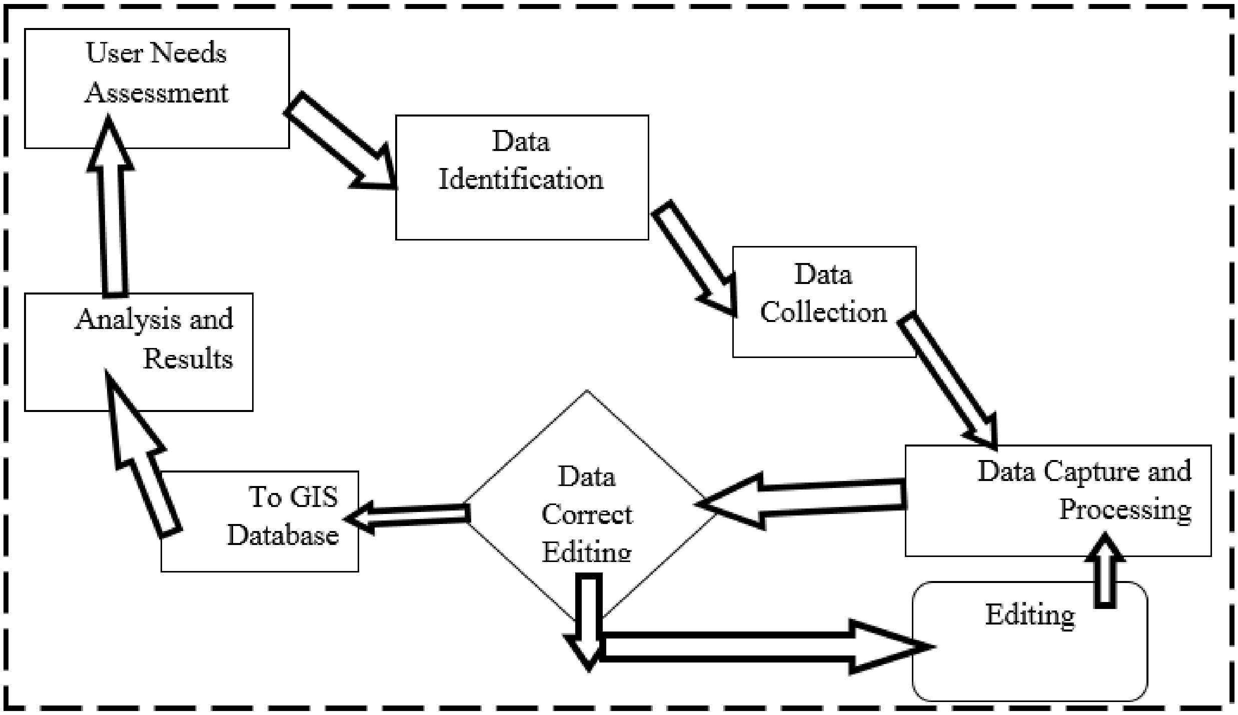

Figure 3.1: Methods flow diagram

3.4 Application and tools

3.4.1ArcGIS for Desktop

For this thesis, we are using ArcGIS Desktop 10.1, but ArcGIS Desktop 10.4 is the latest version of the popular GIS software produced by ESRI[16]. ArcGIS for Desktop allows to analyze any kind of spatial and non-spatial data and to author geographic knowledge to examine relationships, test predictions, and ultimately make better decisions.

ArcGIS Desktop is comprised of a set of integrated applications, which are explained in the following:

- Arc Map is the main mapping application, which allows you to create maps, query attributes, analyze spatial relationships, and layout final projects.

- ➢ Arc Catalog organizes spatial data contained on your computer and various other locations and allows to search, preview, and add data to Arc Map as well as manage metadata and set up address locator services (geocoding).
- ➢ Arc Toolbox is the third application of ArcGIS Desktop. Although it is not accessible from the start menu, it is easily accessed and used within Arc Map and Arc Catalog. Arc Toolbox contains tools for geoprocessing, data conversion, coordinate systems, projections, and more. This workbook will focus on Arc Map and Arc Catalog.

With ArcGIS extensions, you can do the following:

- Analyze data in a realistic perspective.
- Conduct advanced spatial analysis to get specific answers from data.
- Use advanced statistical tools to investigate data.
- Perform complex routing, closest facility, and service area analysis.
- Reveal and analyze time-based patterns and trends.
- Represent and understand any network.

3.4.2Google Earth Pro

For this thesis, we are also usingGoogle Earth Pro v.4.2.0205.5730 [17],Google Earth displays satellite images of varying resolution in accurately about (2-5) m of the Earth's surface, allowing users to see things like cities and houses looking perpendicularly down or at an oblique angle (see also bird's eye view). The degree of resolution available is based somewhat on the points of interest and popularity, but most land (except for some islands) is covered in at least 15m of resolution (GSD, Ground Sampling Distance). Google Earth allows users to search for addresses for some countries, enter coordinates, or simply use the mouse to browse to a location.

Google Earth is simply based on 3D maps, with the capability to show 3D buildings and structures (such as bridges), which consist of users' submissions using SketchUp, a 3D modeling program software. In prior versions of Google Earth (before Version 4), 3D buildings were limited to a few cities, and had poorer rendering with no textures. Many buildings and structures from around the world now have detailed 3D structures. They have been produced by photogrammetric Dense Image Imaging (DIM).

Google Earth may be used to perform some day-to-day tasks and for other purposes.Some of them are mentioned in the following:

- Google Earth can be used to view areas subjected to widespread disasters.
- One can explore and place location bookmarks on extraterrestrial bodies, such as Moon and Mars.
- One can get directions using Google Earth, using variables such as street names, cities, and establishments.
- Google Earth can function as a hub of knowledge, pertaining the users location. By enabling certain options, one can see the location of gas stations, restaurants, museums, and other public establishments in their area.
- One can create custom image overlays for planning trips, hikes on handheld GPS units.
- Google Earth can be used to map homes and select a random sample for research in developing countries and more.

3.5 Data Set

The data sets of key interests are the location and extension of towers in and near the region of interest, and data pertaining the study area. In order to determine the nearest tower it is supposed to cover the affected area within the space of coverage, and knowledge of the factors that impede the signal transduction process (height, rise, fall ...).

Chapter 4

The Testbed Kassingar

Chapter 4

The Testbed Kassingar

4.1 Study Area

Kassingar (Kassingar) is a railroad station (class S - Spot Feature) in Northern Sudan (SU30), with the region font code of Africa/Middle East. Elevation of 838 feet's above mean sea level. Kassingar is also known as Kassingar, Kassinger[18].

Its coordinates are 18°45'0" N and 31°54'0" E or 18.75 N and 31.9 E (in decimal degrees). Its UTM position is UF87 and its Joint Operation Graphics reference is NE36-06.

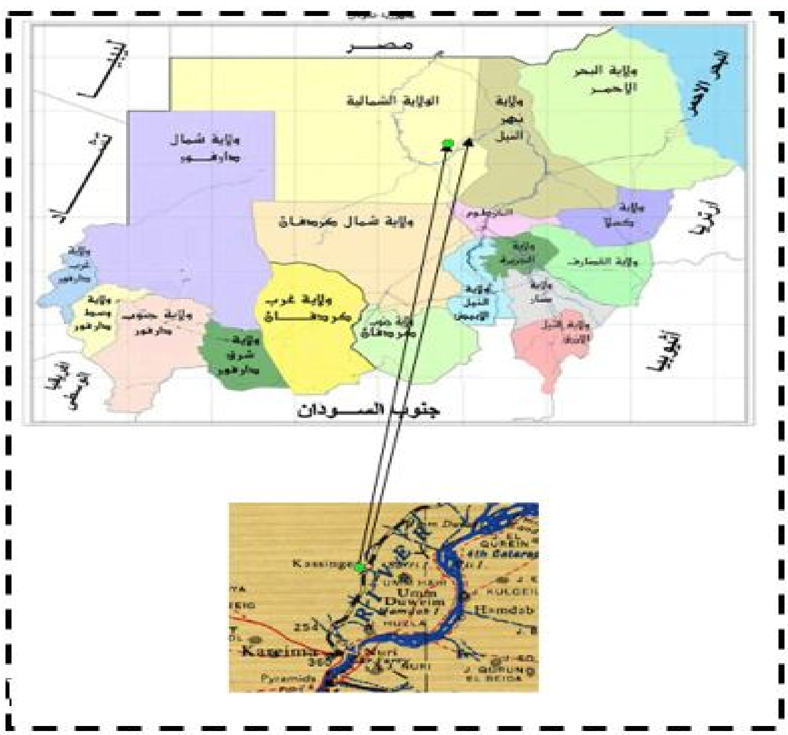

Figure4.1: Study area

A Railroad station is a facility comprising ticket office, platforms, etc. for loading and unloading train passengers and freight.

The area extends about 8-10 kilometers in length in addition to 2-2.5 kilometers in width, to Alswyqat and the Alkooa area. The study area is divided into Kassingar gable with a population of about 1639 persons and 1505 persons in the second part of Kassingar bahary.The neighboring Alkooa area has a population of about 562 persons, in addition to the 642 persons in the Alswyqat area, using projection 0f 2015 from the lastpopulation survey in 2010 from the central Bureau of Statistics (SCBS) [14].

The topography of this region is given in the contour map of figure [4.2], in which the contour lines show some steep increases in the study area.

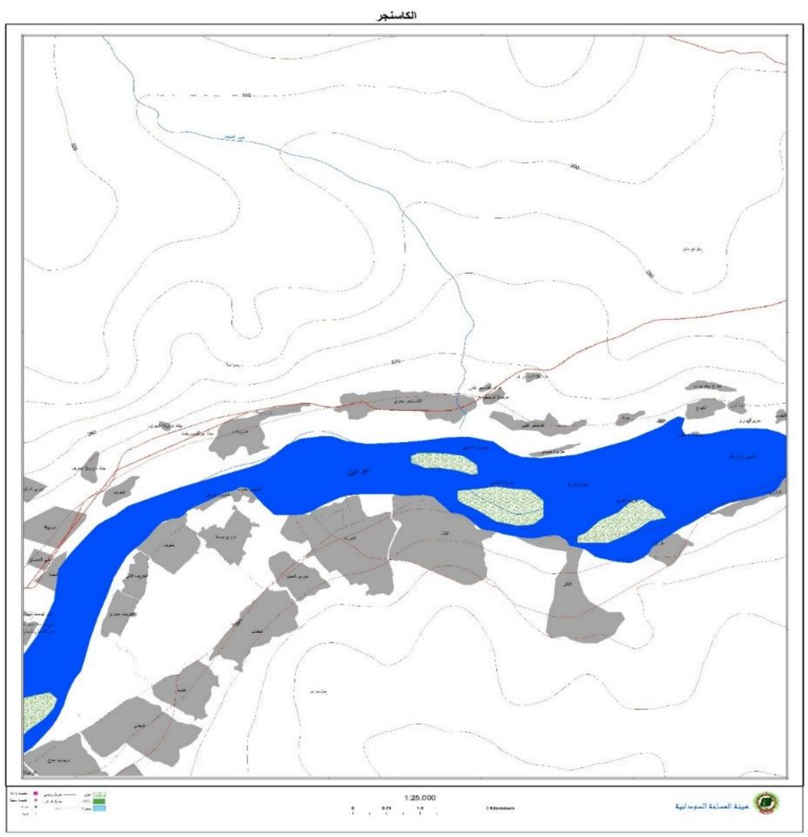

Figure 4.2: Contour lines in the study area

4.2 Data Collection:

A satellite perspective image map is used from the Side Topography Radar Mission (STRM). The STRM data is divided into tiles of 1° x 1° of latitude and longitude. It is downloaded from the CSI.CGIAR.ORG website[19].

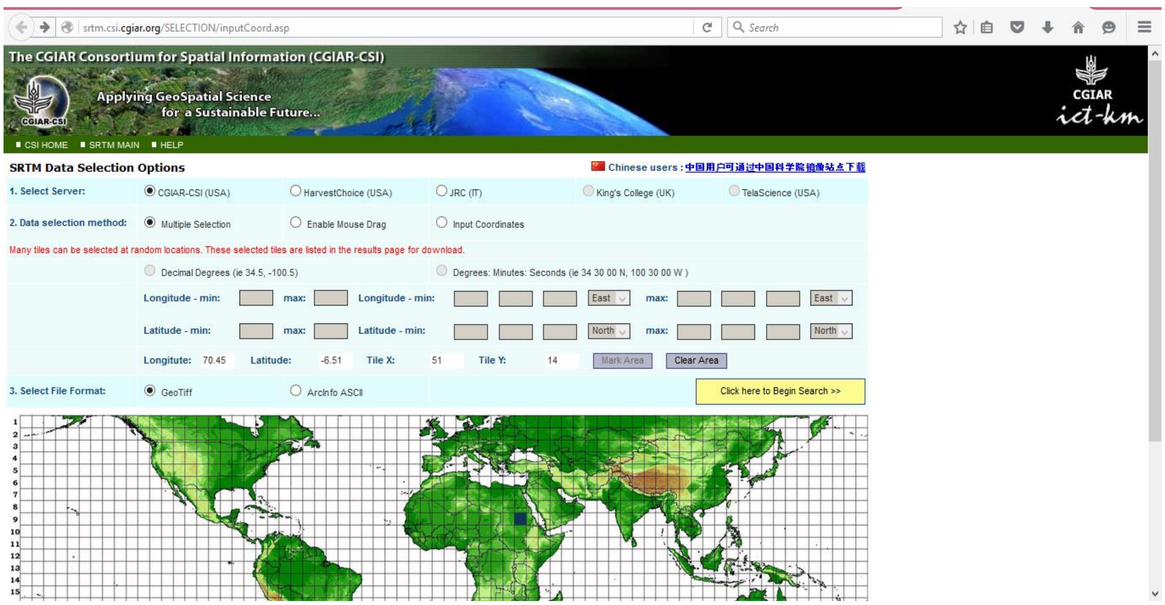

Figure 4.3: STRM data selection

- **Latitude min:** 15 N Max: 20 N.
- **Longitude min: 30 E Max: 35 E.**
- **Center point:** Latitude 17.50 N and Longitude 32.50 E.
- Tile x: 43 - Tile y: 9.
- Selection server is CGIAR-CSI (USA).

- The downloaded image format is GEO TIFF.

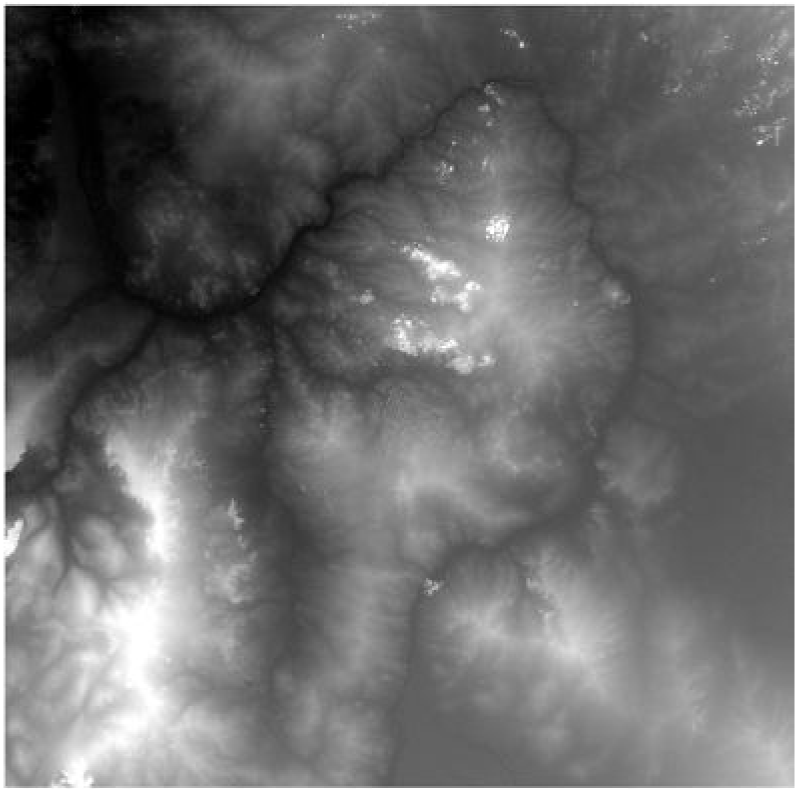
Figure 4.4: Height class coded STRM satellite image

Chapter 5

SIMULATION AND ANALYSIS

Chapter 5

Simulation and Analysis

5.1 Overview

Using the ArcGIS software an interpretation of the DEM could be made. The DEM of the Northern State shows, that the study area is considered one of the villages – an area located at the minimum altitude, where the blue color indicates the boundaries of the testbed, see Figure [5.1].

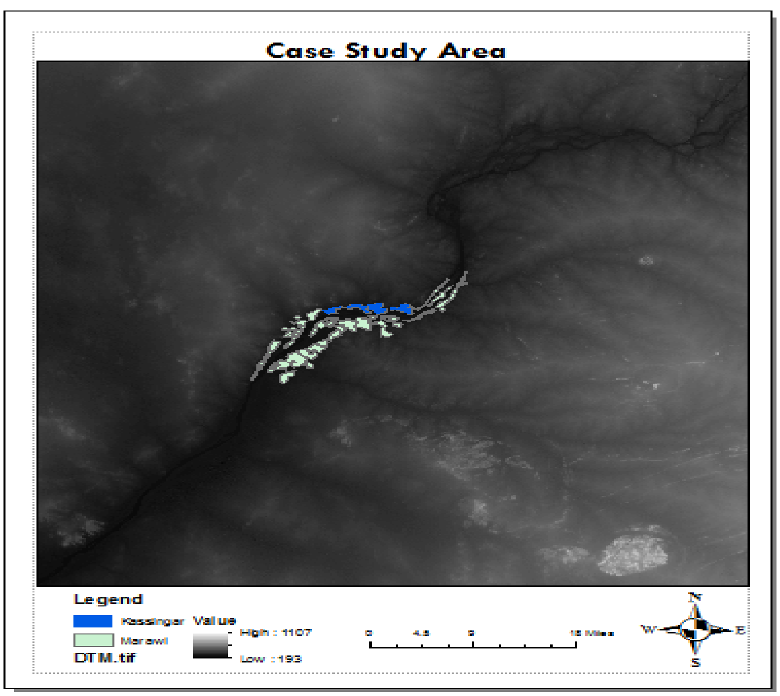

Figure 5.1: DEM map of the study area

Analyzing and processing the obtained satellite image, Digital Elevation Model (DEM) of Kassingar from (STRM) [19] could be generated.

Using the boundary shape file obtained from the survey of Sudan, we were able to clip the DEM to our study region, which is Kassingar village. We then took various map sheets being obtained from the survey of northern Sudan, merged those using ArcGIS, and clipped to obtain our study region, as shown in Figure [5.2].

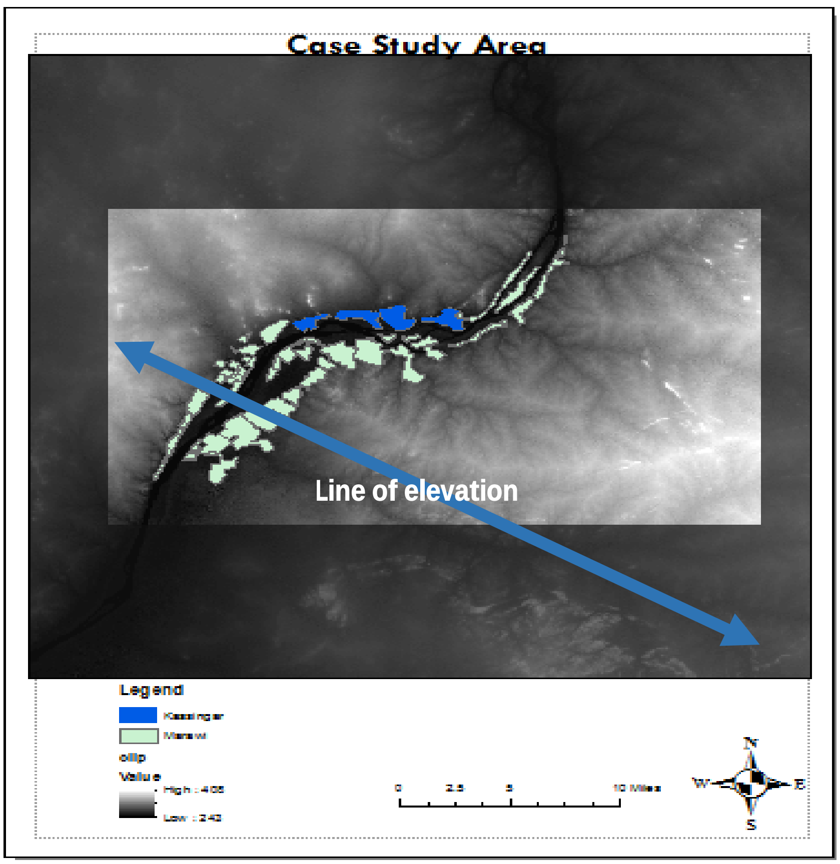

Figure 5.2: Clip to Scope of Kassingar

5.2 Analysis andResults

5.2.1Profile graphs

Profiles had shown the change in elevation of a surface (raster, TIN, or terrain) along a line. They can help to assess the difficulty of a trail or to evaluate the feasibility of placing a rail line along a given route, and to select the suitable sites.

As it is evident by the profile given below the higher elevation 370 m.s.l but 240 m.s.l is lower elevation , the study area has its lowest heights at about 245 m.s.l, as shown in Figure [5.3]. This indicates, that the testbed area is located at a lower altitude compared with neighboring areas, which fall in the same line.

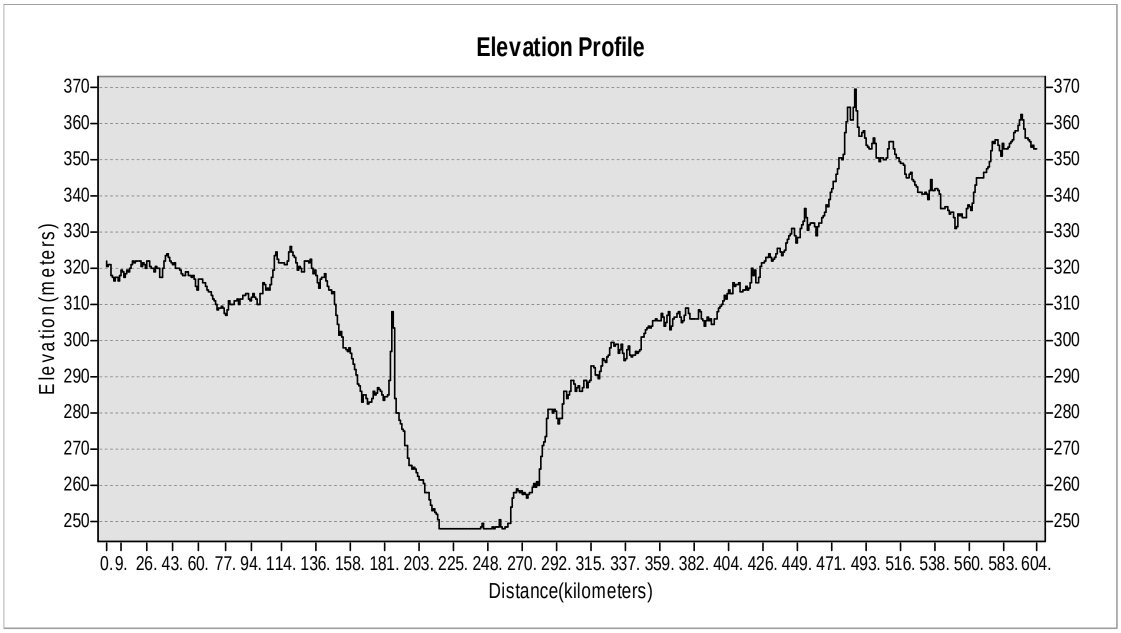

Figure 5.3: Elevation Profile Graph of Kassingar

5.2.2Color map of study area

The Color map process is a type of raster data renderer. It transforms the pixel values to display the raster data as either a grayscale or a red, green, blue (RGB) image, based on a color map. Color maps are used to represent analyzed data, such as a classified image, or when displaying a topographic map using gradient colors, which reflects the proportional disparity in specific examples of this phenomenon of high and low surface of the earth, as shown in Figure[5.4].

The picture shows the gradient in the colors of blue, which represents the lowest rate in terms of the rise in a gradual increase up to the dark brown color, which may indicate the highlands and mountains.

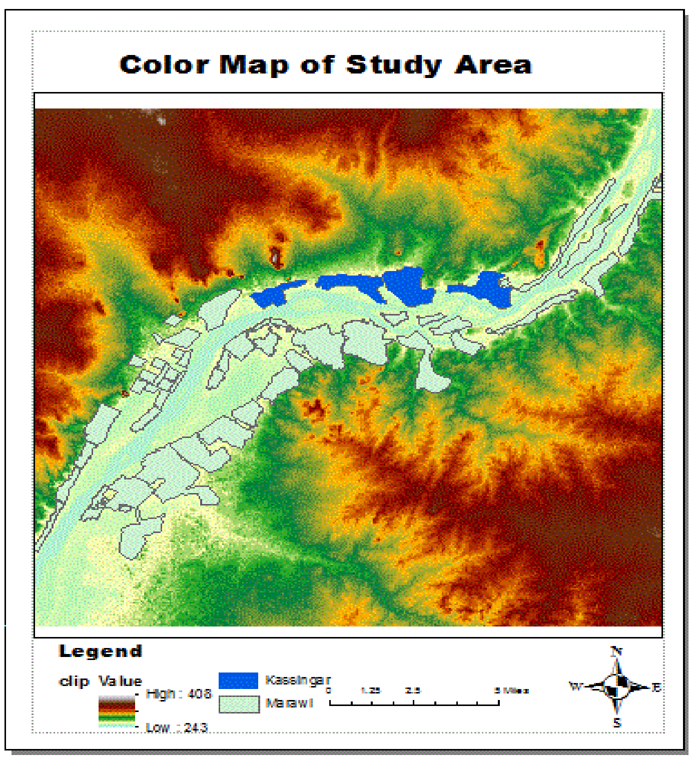

Figure 5.4: Color map of study area

5.2.3Classes Color Map

The lowest area is dark blue, while the areas of light green represent heights between 243 to 271m. The other height classes are as follows: bright green (271-293m), light brown (293-313m) and dark brown (313-334m), see Figure[5.5].

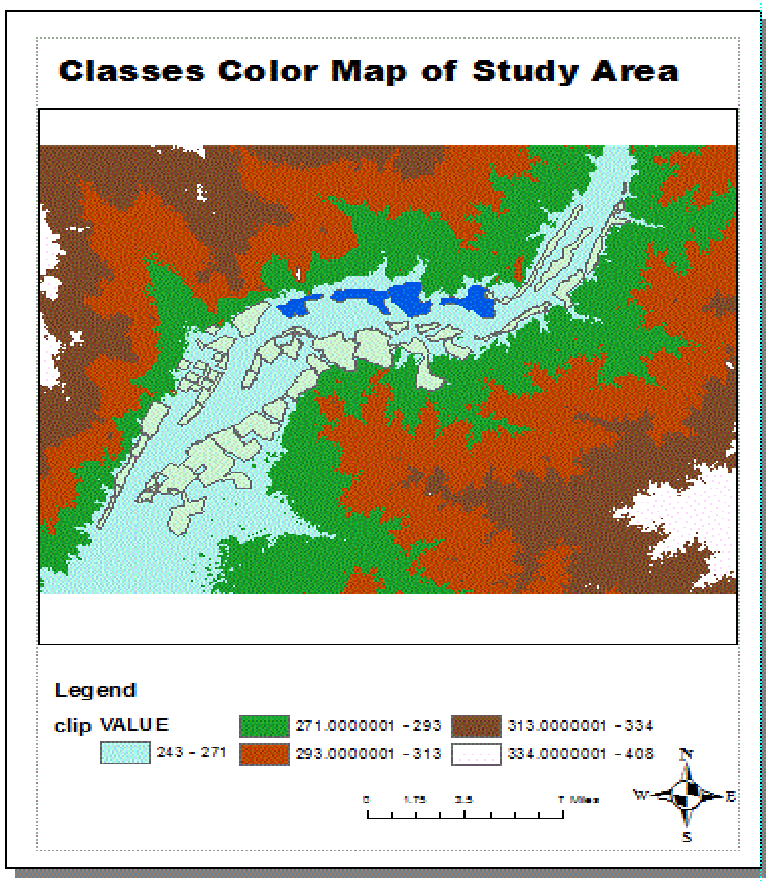

Figure 5.5: Classes of the color map of the study area

5.2.4Contour map of study area

Contour lines connect a series of points of equal elevation and are used to illustrate relief on a map. They show the height of ground above mean sea level (MSL), either in meters or feet, and can be drawn at any desired vertical. For example, numerous contour lines that are close to one another indicate hilly or mountainous terrain - when further apart they indicate a gentler slope, and when far apart they indicate flat terrain. We found out, that the area under study is located on the contour line of about 200m, as shown in Figure [5.6]:

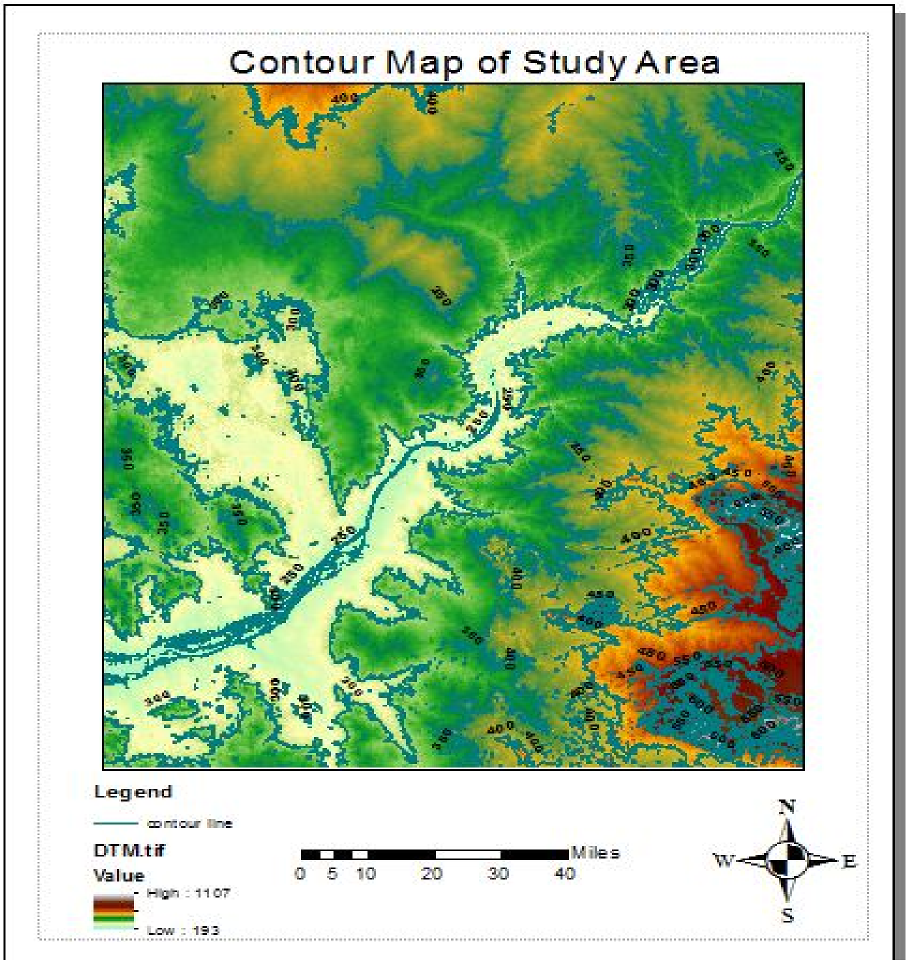

Figure 5.6: Contour map of the study area

5.3 Towers Distribution

The number of towers that are found near the study area vary in terms of ownership or subordination to the companies working in the field of communications. In Sudan this is limited to the three companies Zain, MTN, and Sudani. In order to not mentioning names we used the aliases to symbolize each company and each tower, as shown in table [5.1]. The distribution of the towers for the Kassingar area is shown in Figure [5.7].

Company	**Tower name**	**longitude**	**latitude**	**technology**	**Power(dB)**	**Sectors no**
A	P-A1	31.960669°	18.544511°	2G	43	2
A	P-A2	31.972911°	18.614461°	2G	43	3
A	P-A3	31.842667°	18.552389°	2G	43	3
A	P-A4	32.043665°	18.660158°	2G	46	3
A	P-A5	32.039222°	18.605333°	2G	43	2
B	P-B1	31.957090°	18.562593°	2G	46	3
B	P-B2	32.042975°	18.659467°	2G	46	3
C	P-C	31.974350°	18.560890°	2G	49	6

Table 5.1: Summary of Telecommunication Towers

5.4 Buffer Analysis

Buffer Analysis is a basic GIS spatial operation. It automatically builds zones with a certain width around a point, line, or region, and represents extended geometric objects according to a specified buffer distance.

The region has been divided into domains depending on the area covered by the towers in terms of distance, which we referred to above. A division has been made such, that the signal should have four levels as shown in the table [5.2].

Buffer Analysis is useful for a proximity analysis,where we have buffered the coverage of towers into multiple ranges depending on signal levels into four classes, as shown in Figure [5.7].

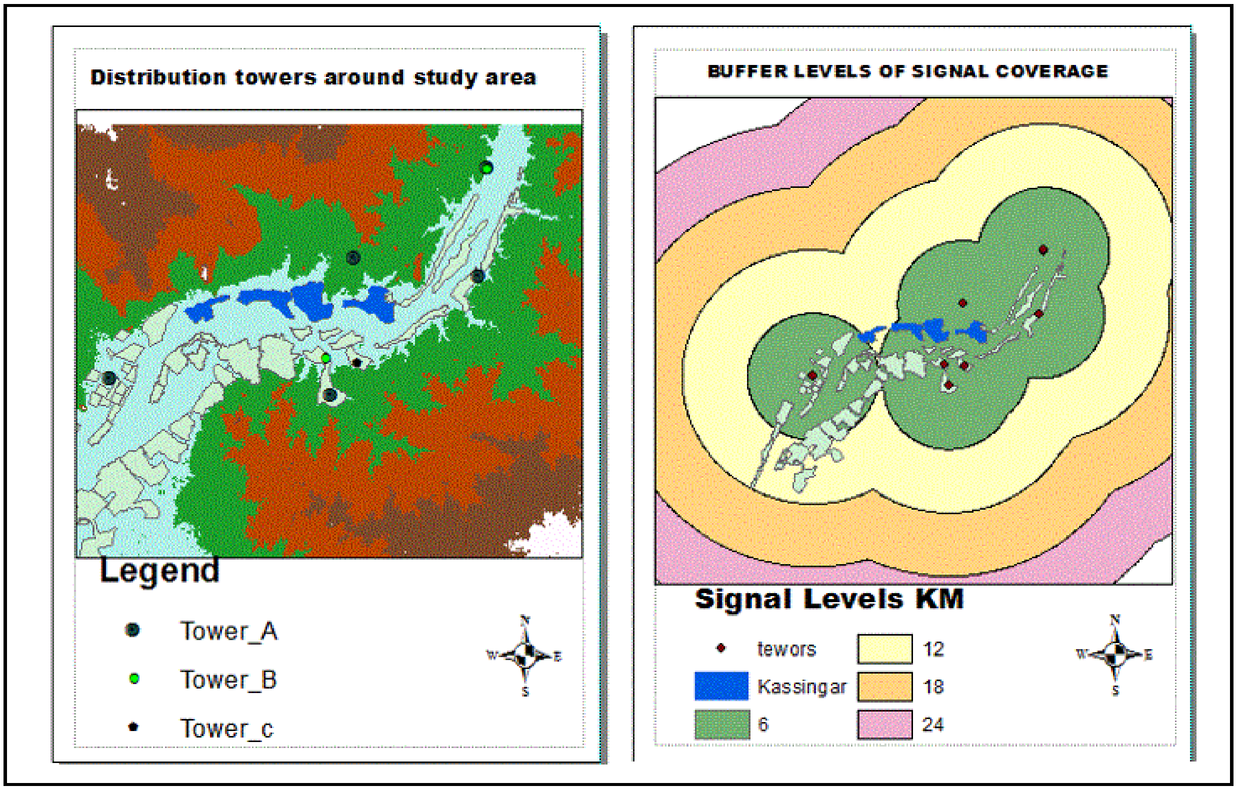

Figure 5.7: Distribution of towers & coverage by level buffering

5.5 Towers coverage analysis

We will use Google earth in order to calculate many processes, such as the distance between each tower and the study area (kassingar), and calculate the height of towers above sea level, compared with the study areas as follows.

5.5.1Distance between the towers and the study area

Distance is a very influential factor in the strength of the signal, so that the more we move away from the tower, the more the existence of other natural barriers, which represent essential factors in the non-arrival of the signal or decline, can be identified. Thus the distance between the study area and each tower in accurately about (2-5) m had calculated as follows [17]:

- Tower (A1) and the study areaof approximately: 7.82 Kilometers.
- Tower (A2) and the study areaof approximately: 6.18 Kilometers.
- Tower (A3) and the study areaof approximately: 8.95 Kilometers.
- Tower (A4) and the study areaof approximately: 15.7 Kilometers.
- Tower (A5) and the study areaof approximately: 12.8 Kilometers.
- Tower (B1) and the study areaof approximately: 5.71Kilometers.
- Tower (B2) and the study areaof approximately: 15.2 Kilometers.
- Tower (C) and the study areaof approximately: 7.28 Kilometers.

5.5.2Signal Levels

When a signal is transmitted, we know from experience that this signal is meeting many obstacles affecting the speed and strength. These factors can be man-made infrastructures and natural phenomenas decreasing the signal strength the more we move away from the tower. For this reason we introduce a classification for the signal level, as shown in table [5.2]:

Signal level	**Best signal (dB)**	**Signal Quality**	**Coverage (km)**	**Color**
Level 1	>= -75	Strong signal	6	Green
Level 2	>= -85	Good signal	12	Yellow
Level 3	>= -95	Weak signal	18	Orange
Level 4	>= -105	Faded signal	24	Pink

Table 5.2: Signal coverage levels (standard)

Including four levels covering up to 24 kilometers we know from experience, that the third and fourth level are most critical. Here we find quite often possible existence of barriers avoiding or disturbing the arrival of the signal up to a potential loss. Thus, we can rely confidently using the coverage of each tower up to a distance of 12 km (first and second level), where we receive a strong or good signal, as shown in Figures [5.8],[5.9] and [5.10].

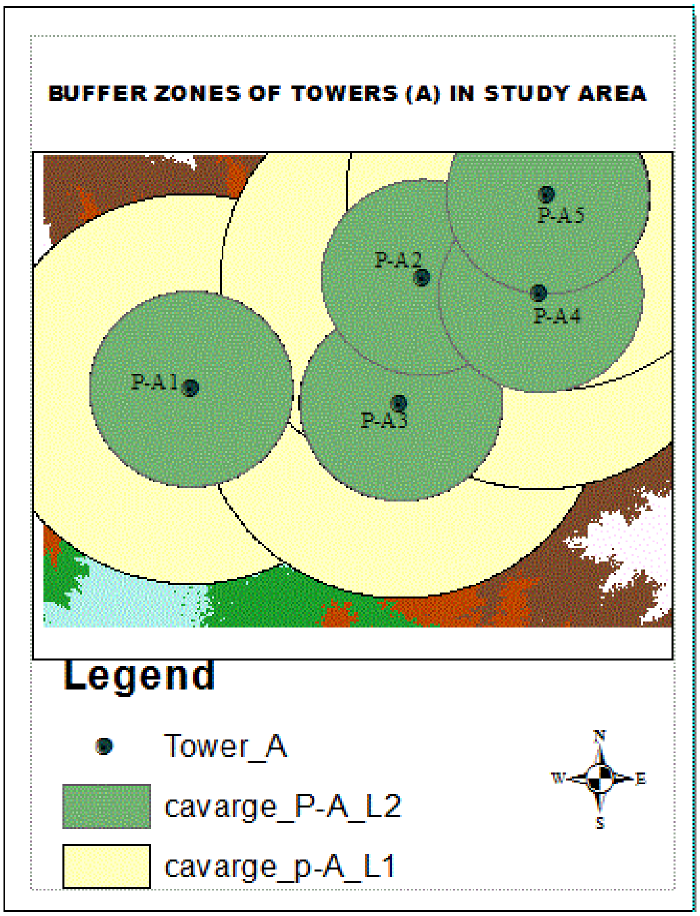

Figure 5.8: Coverage of Towers (A)

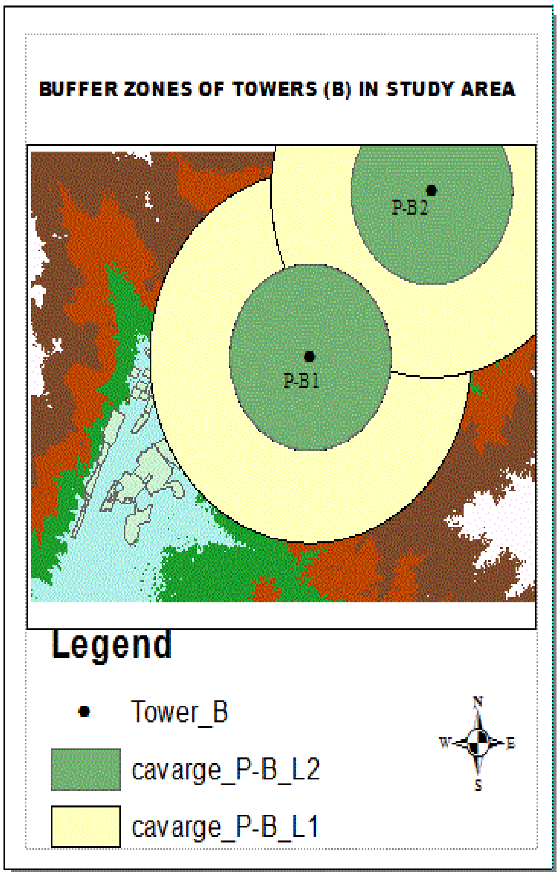

Figure 5.9: Coverage of Towers (B)

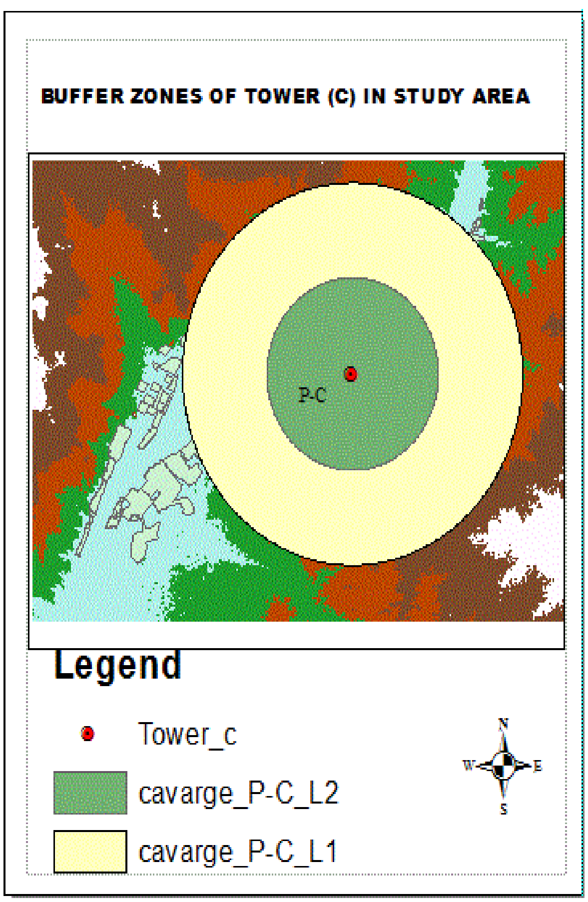

Figure 5.10: Coverage of Tower (c)

5.5.3Elevation Graph of Towers

A path analysis or calculating the distance between each tower and the affected areas is very important to know the height of each point in the line at sea level. Profile elevationsdelivered by Google Earth greatly support in reading the results,in particular to see points or areas, that are at low levels. Table[5.3] shows the height of towers with regard to sea level and high altitude areas of the testbed.

Tower name	**Start point (S.T)** **Feet (F)**	**Tower height(T)(Meters)**	**Total height (S.P+T) (F)**	**Study area height (F)**
A1	891F	30m	989F	838F
A2	941F	60m	1137F	838F
A3	863F	30m	961F	838F
A4	879F	30m	977F	838F
A5	869F	30m	967F	838F
B1	858F	30m	956F	838F

B2	881F	30m	979F	838F
C	856F	30m	954F	838F

Table 5.3: Summary of elevations

5.5.4Profile Graph of Towers

The Tower Graph Profile greatly facilitates the height of each tested point, compared to the highest point on the existing tower. This is a graph showing the nature of the chosen path between each tower and the area affected, as shown in Figures [5.11] and [5-12].

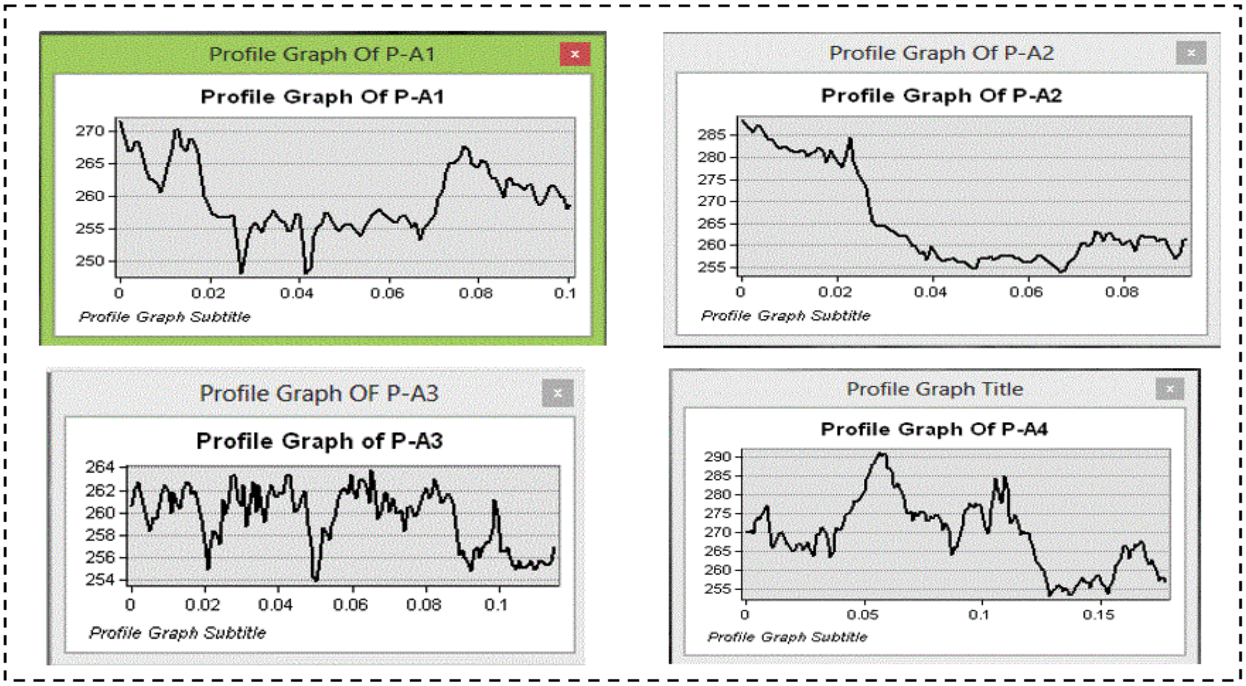

Figure 5.11: Tower Profile Graph of Towers A1, A2, A3and A4

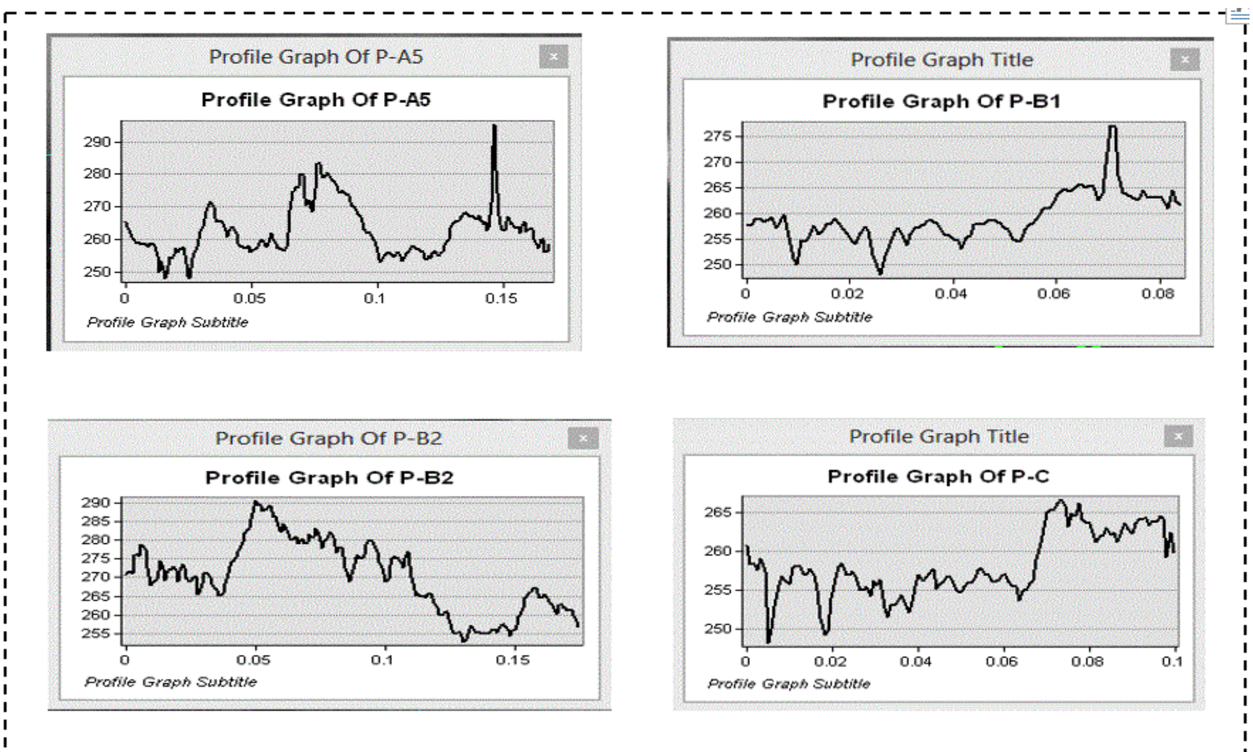

Figure 5.12: Tower Profile Graphs of Towers A5, B1, B2 and C

5.6 Discussion of Results

We have introduced an analysis method to get key terrain parameters of the region. Moreover, we measured the elevations and rate of decline in the region, with respect to the height of towers and distance to determine the impact onto communication signals. Results were given in both, a tabular representation and figures. They show, that in the region under study (Kassingar) there are some spots with a decrease in terms of height of sea level.

The average terrain height is about 838feet, which corresponds to 251,4 meters and is evident from the contour map, as the area is located on the contour line of 250 m. But there are areas, that are located in lines between 300-600m.

We found, that the number of towers surrounding the area is 8. Calculating the distance between each tower and the study area and the height of each tower above sea level in addition to its length, it seems to exclude those towers which are most-distant in terms of the distance ratio. Obviously the land north of Sudan is non-flat and there are natural phenomena, such as rocks, mountains and slopes.

In addition to the exclusion of towers we have found in the other part (the other side), that signal is reflected multi-path, when it collides water surfaces. This refers to the inability of the signal to cross the water with reference to the nearest tower for the region, in our case tower B1with minimum distance of 5.71km.

All analyses and calculations indicate, that the main tower to cover the affected area is A2. Having a distance amounting to 6.18 km and height of 346.558m it elevates from the height of the region under study with about91.135m. Our simulations have shown, that the biggest part of the area under study is located in the second signal level, taking into account the entire affected area, as shown in Figure [5.8].

5.7 ProposedTower

The current status of the two towers (A2 &A3) indicates a shared space located in the second signal level. As the signal is not strong, we propose to choose a suitable location to place a new tower such, that it covers the affected area fully with a strong signal and bridges the gap, that exists between the two existing towers.

Therefore we propose that new tower is to be built at coordinates [longitude 31.912523°, latitude 18.596873°] and height of 876feet, which is 262,8m. A simulation using the newly proposed tower and explore the coverage is shown in Figure [5.13].

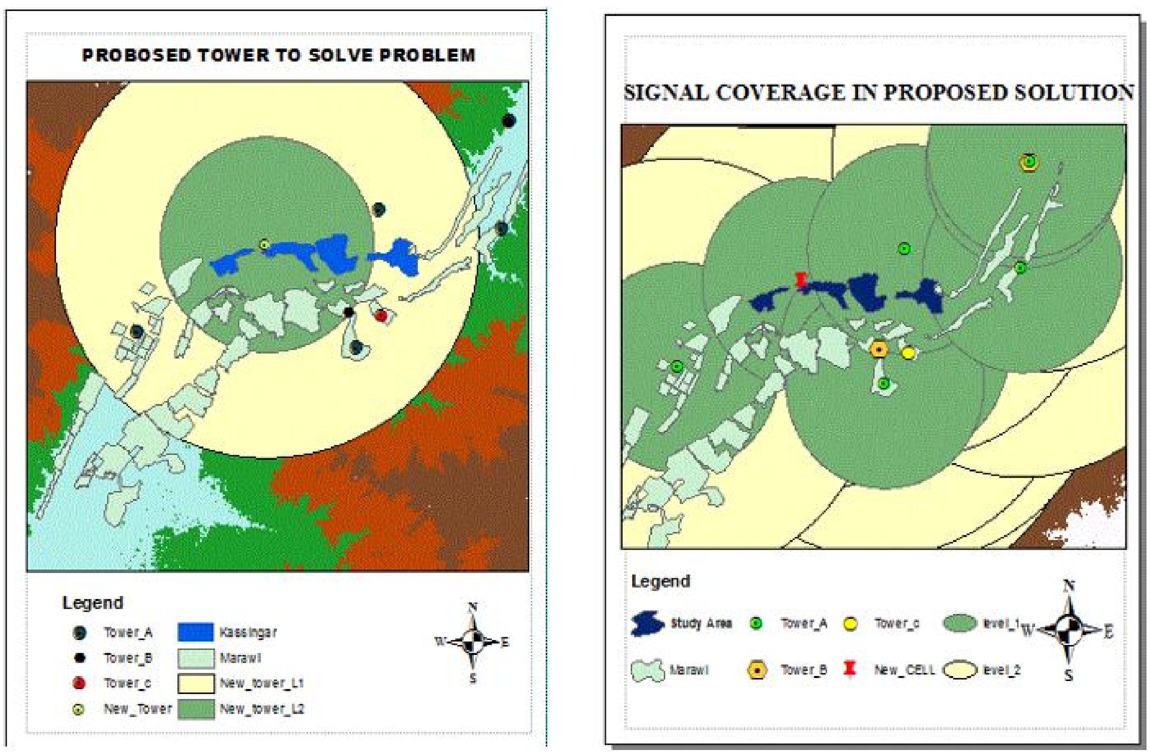

Figure 5.13: New tower& coverage

5.8 Summary of Results and Analysis

This chapter describes the analysis based on the methods to solve the problem of improving communication signals.Also, a brief explanation about the results and our comments on the results had been stated in addition to comparisons and analyses that help to get exact results.

Chapter 6

CONCLUSIONS AND OUTLOOK

Chapter 6

Conclusions and outlook

6.1 Conclusion:

In chapter one we introduced a brief description of our research background, motivation, research questions and objectives.
In chapter two we gave an overview of selected literature dealing with our problem. We learned about the scientific background of the methodology which was specified in the first chapter. Some studies have been discussed in this chapter.

Chapter three presented details of the methodology which was introduced in chapter one. Here we described how the experimentsto be performed will deliver the results we were looking for.

In chapter 4 and 5 we described the results obtained after the analyses of terrain parameters. Also, we gave a brief discussion about how our research and GIS can support actual issues providing better telecommunication services.

We can saying now, after the analysis and the results that there is a very strong inverse relationship between distances firstly and secondly decline in influencing the quality of the signal.Which we paid to make the decision and to propose the construction of a new towerbearing in mind the special nature of the area under study.

6.2 Recommendation:

In this research had shown how geographical information systems can be provide and helping in testing natural phenomena and their impact on public services and provide are several ways to solve these problems.

A very big economic factor in terms of profitability compared with the rate of population density in the region under study which ensures an increase in corporate profits and take advantage of the service is and this is called the exchange benefit in business so we recommend the establishment of the proposed tower site. This in itself is a competition between companies in the process of customer acquisition.

6.3 Future works

As mentioned before in chapter 1, the motivation for this research was to providebetter communication services, in particular to deliver stronger signals necessary general purpose applications. Thus,this work can be understood as a basic study to enable telecommunications service providers expanding the scope of service by placing the towers in the right location, at low cost in terms of time and efforts.

Future work can be briefly identified and some recommendations are given:

- Use of GIS techniques in the analysis of the impact of the distance between the transmitter and receiver in signal strength for each group of towers of various companies providing telecommunications services.
- Coverage of signalfor the whole region under study for various telecommunications companies - so that the customer can choose the appropriate network.
- Expand the scopeof this study to include all states of Sudan in terms of low-lying areas or highlands and its impact on the strength of the signal.

Chapter 7

REFERENCES

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