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Investigating of Signal Propagation Characteristics in a Realistic Rural Scenario using Verified Tools: A Case of South Chunya-Tanzania”

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Abstract

Effective radio network planning requires understanding an area's radio propagation characteristics. This investigation uses dependable techniques to examine the movement of wireless signals in Tanzania's rural locations. Propagation characteristics in selected rural Tanzanian communities (South Chunya) are examined as a case study, and recommendations are made based on the findings, particularly for wireless service providers or researchers looking to improve wireless connectivity in rural communities. Important radio parameters such as Pathloss, Signal to Noise ratio, Bandwidth throughput, Spectral efficiency and Spectral band were examined. This was done after simulating signal transmission from the Base station transmitter to the Base station receiver and observing power and attenuation. Their corresponding results are discussed and evaluated. The general observation of the pass loss results for both operating frequencies 800MHz and 2000MHz have shown that only few areas are experiencing strong signal after initial signal power transmission, large areas served by these macro sites are experiencing huge path loss. This is evidently affected by the terrain of an area and the carrier frequency of operators.

A. Introduction

Path loss, which is primarily influenced by the distance between the transmitter and receiver's antennas, the antenna's characteristics, and the operational frequencies [1][2][3][4], affects the signal transmission over a radiocommunication channel. Path loss is also suffered by the actions of things that block the wireless radio signal, such as topography, walls, vegetation and supplementary matters [5][6] [7]. It's crucial to note that every wireless (mobile) communication system in a particular area must be designed and improved with understanding of a mobile radio network's propagation characteristics [8],[9]. The three primary propagation processes of reflection, diffraction, and scattering are typically used to transmit radio signals in terrestrial cellular radio systems[10]. In the propagation area, path losses is the most important factors [11][12][13][14]. Numerous factors can contribute to path loss, includes penetration, diffraction, free-space, reflection, aperture-medium coupling and losses.

Numerous researches were conducted to understand the features of the concerning regions and the specific operational frequencies at which the devices were to be installed [14]. In the north of India, study in [5] looked into path attenuation and the path loss exponent in relation to distance. To perform a comparison analysis using path loss exponents and path attenuations, the height of the receiver antenna was extended from 4m to 9m. According to their findings, a receiver antenna changes from 4m to 9m caused a 7dB path loss and a somewhat smaller path loss exponent.

The Hata-Davidson, free space, Hata-Okumura, and extension of Hata models' performance evaluations were compared in [6], and the authors made predictions about which model would be best for a planar area in northern India. Data from two North Indian FM radio transmitters, one operating at 50 dBm, with 45m antenna height and the other at 70 dBm with an antenna height of 100 meters, were used to compare the six related route loss models. According to their research, the Hata-Davidson model performed best than the Hata model's extension over longer distances, although COST 231's mean square error was determined to be the lowest of all the models.

The authors of [3] measured radio signals at the frequencies of 800MHz and 900MHz throughout Australia employing a GPS, omnidirectional antenna, and CDMA plot scanner. To compare the Okumura-Hata models P.1546-0, P.1546-2, and the free space model P.1546-1, the authors first created a propagation model using data. According to a study, P.1546-0 and P.1546-1 offer more accurate predictions of overall path loss than the standard Okumura-Hata model. Transmissions at the 900MHz and 1800MHz frequencies were measured in metropolitan India by the authors of [2]. The measurements were taken with a spectrum analyser. The Okumura model performed better in that particular research region, according to their data analysis.

No propagation model is accurate enough to guarantee a recommendation, based on specialists in the field of radio waves[2]. This is because atmospheric factors that might differ from place to place and affect radio transmission include pressure, temperature, and relative humidity [15][16].

In designing and analysing wireless network systems, precise radio wave propagation modelling is crucial [7]. The most important performance metrics that are typically influenced by received signal strength and cochannel interference are determined by radio wave propagation models. Researching a propagation model specific to a region is essential since underprediction leads to interference on a cochannel cell and overprediction leads to episodic outages, both of which increase system latency, decrease system availability, and result in lost revenue[17].
Due to this challenge, additional research was done in Europe, Japan, America and India in to comprehend an accurate radio wave propagation model prior to deployments. Though, rural areas' radio wave propagation model has not been sufficiently researched in many African locations. Limited research has been done, particularly in East Africa, by [7], [8] in Ethiopia [4] who examined how the radio wave propagation model is affected. This study aims to analyse how wireless signals travel in rural areas of Tanzania using reliable methods to understand the impact of multipath propagation in the area of our investigation (i.e., Chunya). references.

B. Literature Review

Different prediction models included in Verified Tool (WinProp)

Prediction models typically consist of a collection of equations obtained from in-depth field measurements [16]. For macrocellular areas, WinProp includes a number of path loss prediction models, including the Okumura-Hata model, the irregular terrain model, the empirical two-ray model, the deterministic two-ray model, and the dominant path model[18]. These models take into account the location, range, frequency, and kind of clutter, such as urban, suburban, and rural [18]. The next sections go through each model's explanation one by one.

Okumura model

The Okumuras model is extrapolates up to 3000MHz and is based on extensive drive test measurements taken in Japan at various frequencies between 150 and 1920MHz.It was designed for macrocells with cell diameters between one and one hundred kilometers. The macrocells for which it was intended have cell sizes between one and one hundred kilometers. The base station antenna is 30-100 meters high [19]. The Okumuras model takes into account a number of propagation criteria, such as environmental characteristics and topographic irregularities. The signal's frequency, the separation between the emitter and the receiver, the height of the transmitter and reception antennas, the height of neighbouring buildings, and the type of terrain are some of the parameters that the model employs to estimate the additional route loss.

Irregular Terrain Model (ITM)

The Irregular Terrain Model (ITM) was established in order to forecast radio signal propagation over irregular terrain. It is frequently used to estimate how electromagnetic waves will be attenuated, refracted, and diffracted as they move

through the lower atmosphere. It is frequently used to estimate how electromagnetic waves will be attenuated, refracted, and diffracted as they move through the lower atmosphere [1]. The fact that ITM takes into consideration a variety of atmospheric effects, such as atmospheric attenuation, refraction, and scintillation, is a key component. Particularly at higher frequencies and over greater distances, these factors can significantly impact radio signal propagation.
The frequency of the radio signal, the height of the antenna, the separation between the transmitter and receiver, and the height and roughness of the terrain are just a few of the input factors used by the ITM model. The model takes into account the earth's curvature, the dielectric constant of the atmosphere, the terrain, and features like hills and valleys [3].
ITM has significant limitations even though it is a very good model for simulating radio wave propagation over irregular terrain. Significant processing resources are needed to compute the radio signal propagation for a particular scenario, which is a costly computational task. Furthermore, it disregards the influence of artificial constructions, metropolitan settings, and other intricate aspects [4].
ITM is a crucial tool for simulating radio signal propagation over irregular terrain in a variety of settings. It is notably effective in estimating signal quality for microwave communication and radar applications since it can consider atmospheric factors and concerns for terrain roughness[5].

Empirical Two-Ray Model

An analytical propagation model called the Empirical Two-Ray Model calculates the signal intensity of radio waves passing through a two-ray propagation channel [6]. It is a straightforward but efficient model that only needs a few parameters to be implemented in order to estimate the received signal power at a receiver [7]. The model implies that the transmitted signal travels along a direct and reflected path. It accounts for the amplitude, phase, and antenna height changes between the two pathways, all of which depend on the separation among the transmitter and receiver [9].
A straightforward equation can be used to determine the received signal power, which is determined by the superposition of the two paths: PR = (Pt.Gt.Grλ2)/(4πd)2),, where PR is the received power, Pt is the transmitted power, Gt and Gr are the gains of the transmitter and receiver antennas, is the signal's wavelength, and d is the distance between the transmitter and receiver. Modelling signal propagation between a base station and mobile users in broad spaces like plains and deserts is especially easy with the empirical two-ray model [10]. It is less effective in settings with many obstacles and reflection pathways, such as cities and other complicated situations.
Overall, by taking into account the direct and reflected pathways, the Empirical Two-Ray Model is a useful tool for determining the signal intensity of radio waves in straightforward circumstances between a transmitter and receiver.

Deterministic Two-Ray Model

An analytical model called the deterministic two-ray model predicts how far a radio signal will travel in a two-ray environment over a short distance. The model's nature is deterministic, so it considers the propagation environment's physical properties [11]. The model, which is comparable to the empirical two-ray model, takes into consideration the two paths (direct and reflected) among the transmitter and receiver. On the other hand, the deterministic model takes other variables like antenna height, ground reflection coefficient, and the separation between the reflecting surface and the receiver into account [12].
The model is predicated on the idea that the signal sent by the transmitter directly reaches the receiver and also goes through a path along which it has been reflected from the ground. A phase inversion is experienced by the signal following the reflected path [13]. The received signal power is the sum of the two signals, and the formula to compute the received signal power is given by PR = [(Pt.Gt.Gr.σtσrλ2)/(4πd2)] [cos(θt)cos(θr)/(σt + σr)], where PR is the received power, Pt is the transmitted power, Gt and Gr are the gains of the transmitter and receiver antennas, λ is the wavelength of the signal, d is the distance between the transmitter and receiver, θt and θr are the angles of incidence and reflection, and σt and σr are the surface reflection coefficients for the receiver and transmitter respectively.
The deterministic two-ray model, which considers the surroundings and the reflection of the signal from the ground, is useful for predicting radio signal propagation over a short distance. This technique often accomplishes line-of-sight communication between two stationary or mobile devices across short distances.
Deterministic two-ray modelling is useful for studying radio signal propagation in a two-ray environment overall.

Dominant Path Model

The Dominant Path model, sometimes referred to as the Multipath Propagation model, is a radio propagation model used to examine the results of many radio wave reflection paths in complicated environments including barriers like trees and buildings. The model, which incorporates the reflected trajectories and phases of the radio waves, is seen as a variation of the traditional two-ray model [14].
The Dominant Path model presupposes that a transmitter's signal can travel to a receiver along numerous paths via refraction, reflection, or diffraction in a complex environment. Among the different signal paths, the model identifies the "dominant path," which is the path that contributes the most to the received signal strength [20]. After that, the model determines the signal energy received from each of the other signal pathways and phases each signal separately [21].
The model is similar to the empirical two-ray model in that it takes into account both direct and reflected paths between the transmitter and receiver. The signal power of the dominant path plus the phase-adjusted power of the other paths is added to determine the received signal power.
The Dominant Path model is helpful for examining how radio waves propagate in metropolitan settings and other environments with lots of obstacles and reflection routes. Compared to other models, like the Two-Ray and Free-Space models, which

do not consider multipath propagation, it can offer a better assessment of the received signal quality [15].
The Dominant Path model is a useful tool for investigating radio signal propagation in complex settings with multipath effects. By determining the dominant path and taking into account the impact of the other signal paths on signal quality, it gives a more thorough and accurate study of the signal propagation[16].

Fundamental Metrics of Wireless Communication Systems

The exchange of radio waves between devices is the foundation of wireless communication. However, the range and calibre of wireless communication are constrained by attenuation brought on by path loss, which weakens the signal. Understanding the concepts of route loss, spectral efficiency, signal-to-noise ratio, and signal-to-interference ratio is crucial since they all contribute to the propagation and improvement of wireless communications that are reliable and efficient [20].

Path loss

When an electromagnetic wave travels over space, its power density decreases, which is known as a path loss. The power density drops as the separation between the sending and receiving antennas widens and as the signal comes into contact with obstructions like structures, trees, and other objects like buildings [21].
The equation for path loss is given by:
$PL = 10 \log10((4\pi d/\lambda)^2)$
where PL is the path loss in decibels (dB), d is the separation between the sending and receiving antennas, λ is the signal's wavelength, and π is the mathematical constant pi (approximately 3.14).
The equation demonstrates that the path loss rises with both frequency and distance. Due to their shorter wavelengths, higher frequencies have higher path losses. Additionally, obstacles and terrain can also contribute to additional losses.

Spectral Efficiency

The spectral efficiency is a metric indicating how well data or information is sent using the available bandwidth or frequency spectrum [15]. It is a crucial parameter in wireless communication systems and is often measured in bits per second per Hz (bps/Hz). In simpler terms, spectral efficiency is the amount of information that can be transmitted within a given frequency band. The higher the spectral efficiency, the more data can be transmitted per unit of bandwidth, allowing for faster data transfer rates and better use of available resources [22].

Signal-to-noise ratio (SNR)

The Signal-to-noise ratio (SNR) is a measurement of the strength of the signal compared to the background noise around it. In cellular networks, it is the ratio of the received signal power to the power of the background noise. A high SNR indicates a strong and clear signal, while a low SNR indicates a weak and noisy signal that may lead to poor call quality, slow internet speeds, or dropped calls [23]. To maintain good network performance, operators strive to maximize the SNR by optimizing the network configuration and deploying advanced technologies such as MIMO, beamforming, and interference mitigation techniques[24].

Signal-to-Interference Ratio (SIR)

The Signal to Interference Ratio (SIR) is a crucial performance measure in cellular networks. It is the ratio of the power of the desired signal to the power of the interfering signals. In other words, it measures the strength of the signal received by a mobile device compared to the strength of the unwanted signals that are present in the same frequency band[18].

In a cellular network, interference can occur due to several factors such as co-channel interference, adjacent channel interference and multipath fading. A high SIR is desirable because it indicates that the desired signal is not significantly affected by the interference and, therefore, can be better decoded by the receiver. A low SIR, on the other hand, indicates that the interference significantly affects the desired signal and can lead to poor call quality, dropped calls, or slow data speeds [19].

Therefore, network operators and engineers strive to optimize SIR by using techniques such as power control, frequency reuse, adaptive modulation, and coding, antenna diversity, and interference cancelation in the receiver.

C. Research Method

Data Collection and Experiment setup

The electronic sources, particularly the Open Cell ID online tool, were used to obtain the operators' macro-station information. The location of the cell and base station were in longitude and latitude points which were then supposed to be converted to Universal Transverse Mercator (UTM) coordinate. UTM coordinates were extracted to locate the base station's location before conducting simulation of the current rural broadband model.

Locations on the surface of the Earth are given using the 2-dimensional Cartesian coordinate system known as UTM coordinate. It is a horizontal position representation, meaning it may be used to locate points on the Earth without regard to vertical position, but it differs in a number of ways from the conventional approach of latitude and longitude. A single map projection does not comprise the UTM system. Instead, the method uses a secant transverse Mercator projection in each of the sixty zones, each divided into six-degree longitude bands[25]. Table 1 lists the operators' (Airtel-Tanzania) macro base stations in the Chunya district whose data was examined.

Table 1 :Airtel(Service Provider) Cell location in Chunya District [http://opencellid.org/]

MACRO SITES IN CHUNYA DISTRICTS			
SiteID	**Northing**	**Easting**	**Height (m)**
site1	9067103	447778	50
site2	9067370	501310	50
site3	9052492	506717	50
site4	9053074	545338	60
site5	9069156	517951	45
site6	9065755	529850	45
site7	9112639	531107	50
site8	9076876	500178	50
site9	9044254	561913	45
site10	9067005	596783	50

Simulation Area, Population and Topography

The realistic geographical area was used to conduct the simulation. Population distribution, topographic and geospatial data available in the selected study area was investigated to accomplish the task. These were the essential input for conducting our Propagation modeling which is detailed in chapter four.

Chunya district in Tanzania particularly "South Chunya" was used for conducting simulation. Chunya district has a population of 290,478 people with average household of 4.9 per square kilometers. Chunya district is among the sparsely populated areas with low population density. **Figure 1** shows the villages in Chunya district with population more than 192 people identified with **dots**.

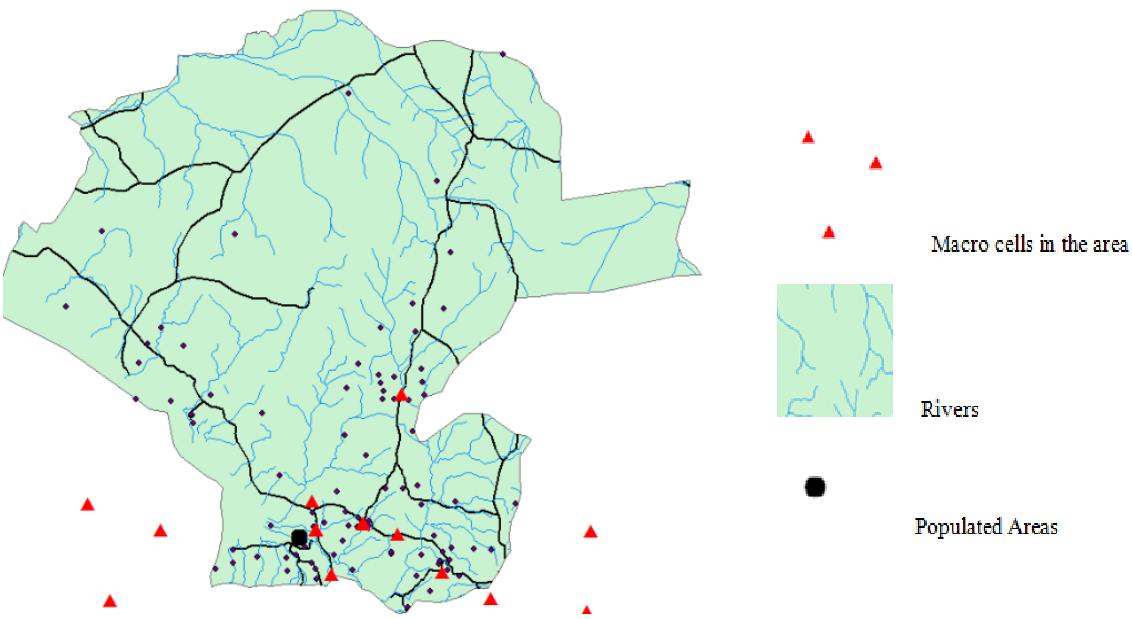


Figure1 Chunya district Population [Source: Spatial GIS Data]

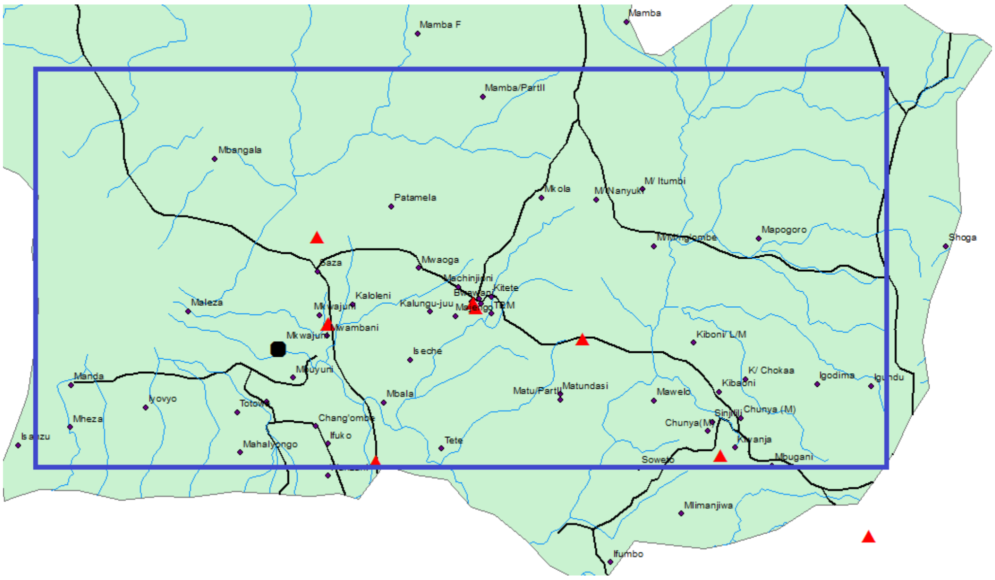


Figure2 South Chunya map box, the boundary of South Chunya

As pointed earlier population data is among the important inputs for Propagation modeling specifically when locating a base station and small cells in the areas. Small cells were located in villages where there are more populated as the means of last mile connectivity and coverage extension. For the context of this dissertation, we considered the small portion of Chunya district identified as "South Chunya" for our propagation modeling. The area has 100 square km, with 40 villages identified. The South Chunya area has an average of 11 people per square kilometer. The demarcation and the boundary of our realistic study area are shown on **Figure2**. The boundary in closed covers the forty villages in which our main study was centered. The topographic variation of South Chunya ranges from 700m to 1700m; the area is open door area, characterized with sparse household with vast of area on hills and valleys.

Data Conversion and setting up Simulation

Before conducting simulation, it was necessary to convert the GIS digital elevation model data into digital topographical data, which could be readable in WinProp format. This was done in WinProp tool using WallMan module. WallMan converts files from Digital Elevation Model (DEM) data files (extracted from GIS) which are digital representations of cartographic information in a raster form, to topography (.tdb) file which can now be used for network planning and Propagation modelling in WinProp tools. DEMs comprises of a sampled array of elevations for a number of ground spots at regularly spread out intervals.

Macro cell deployment

The Converted topography database was used as one of the inputs in ProMan module of WinProp software for prediction area. **Figure 3** illustrates the general topology data of Chunya district after Conversion and importing it to WinProp ProMan module. The topography database contains the spatial data presented by height variation for each pixel in our database. Propagation modeling began by deploying macro cells in this converted data.

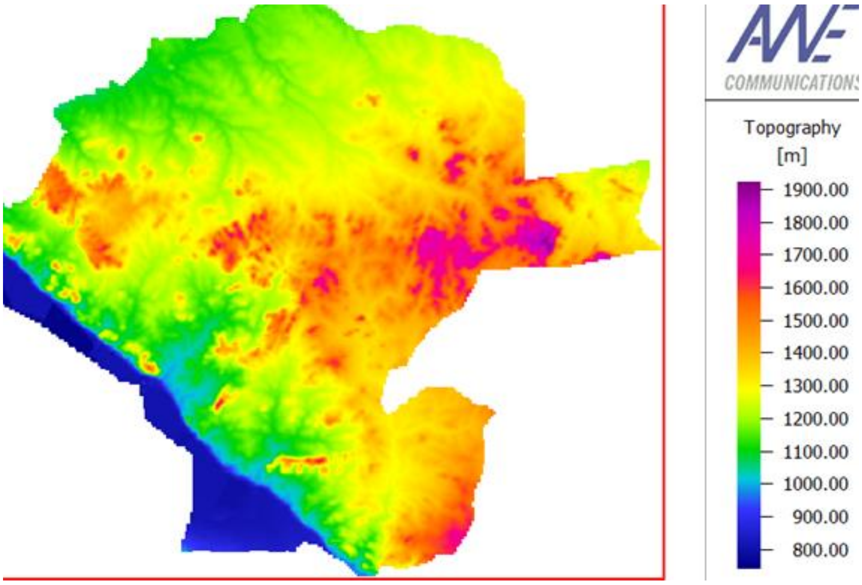
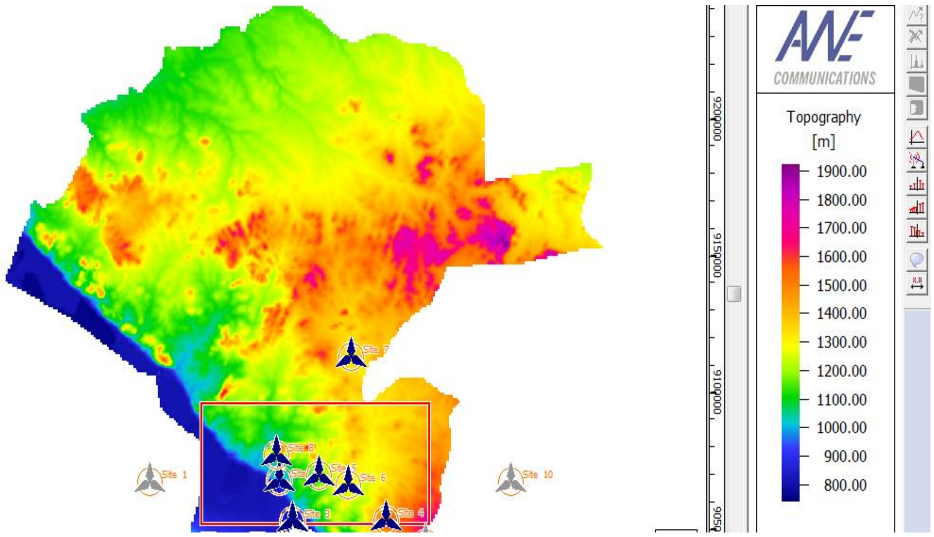


Figure3: The topology variation of Chunya districts in ProMan module

Before setting up important propagation parameters, the Macro cells data in which details are provided in **Table 1** were set in their appropriate locations, bases on their UTM coordinate using WinProp tool. Macro base station were located in their origin position so that they can coincide the position, height and other settings as those of the operator (Airtel Tanzania in this case) to gain some realistic insight into the broadband model currently implemented in the study area. In this case there were ten Macro-sites deployed in Chunya, of which only six lie in "South Chunya" were studied as shown in **Figure 4**, where the sites in the area of interest are closed in a box.



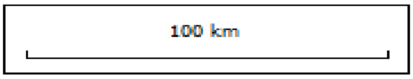


Figure4: The UTM coordinate location of the Macro Cells in Chunya

Simulation

After successfully allocating the macro cells in our study area using the UTM coordinates and set up of the important parameters of the prediction as shown in **Table 2**, the next step was to perform simulation to obtain "Path loss" data for each antenna in each site. Additionally, the area was set with important coordinate of the simulation area in UTM x and y coordinate in a rectangle defined area. **Table 2**, gives the details of the parameters set before simulation in Macro base station.

Table 2: Simulation parameters for Macro base path loss prediction

Parameter		Assumption/Value
Frequency used for Propagation		800MHz , 2000MHz
Transmit Power		43dB
Resolution		50m
Orientation	Azimuth	0o, 120o, 240o
	Down tilt	3o
Height (m)		45, 50, 60
Prediction Model		Dominant Path Model.
Prediction height relative to ground		1.5 m
Environment for Loss data prediction		Open door area
Maximum interaction loss		13db

D. Result and Discussion

This section presents results that were obtained from analysis and design performed during the study of Propagation Modeling for rural broadband coverage capacity based on Simulation studies. The results are presented in tabular form and graphical form then are discussed. Results in both works using WinProp tool and Matlab simulation tool for propagation analysis are discussed.

Results of Macro-base deployment for the current system

Macro-base Simulation for 800MHz and 2000MHz were considered, the sample results when 800MHz frequency band was set is presented in in next section. The discussion is centered on the path loss obtained and the CDF plots developed by WinProp tool, for Path loss developed by each Macro-base station in the area.

Results at 800 MHz

As pointed out earlier in the design phase, we identified that there were six (6) macro-base stations for the operator chosen (Airtel) in our Study area (South

Chunya). After setting 800MHz as operating frequency band, in the macro-base stations and did simulation, the path losses results were obtained which are presented and discussed hereunder:

Path loss Results for Macro-sites

For instance, macro site (site 2) had three antennas, Antenna 1, 2 and 3 respectively. After simulation the sample observation of Path loss obtained for these antennas after simulation are presented on **Figures 5** and **6** for Antenna 1 and 2 respectively.

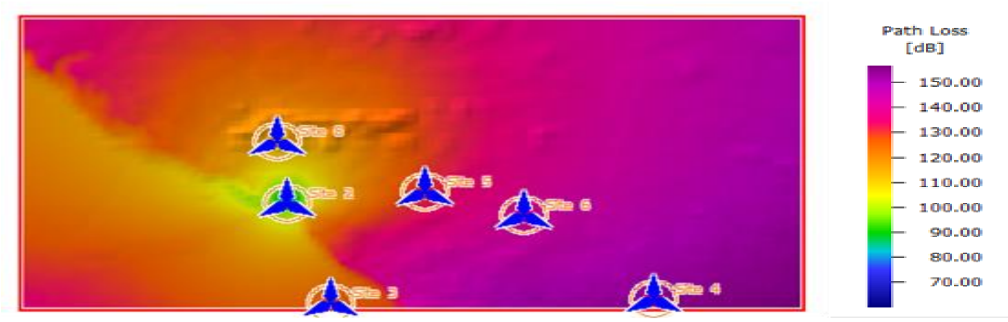


Figure 5: Path loss for Macro site 2 Antenna 1, in South Chunya

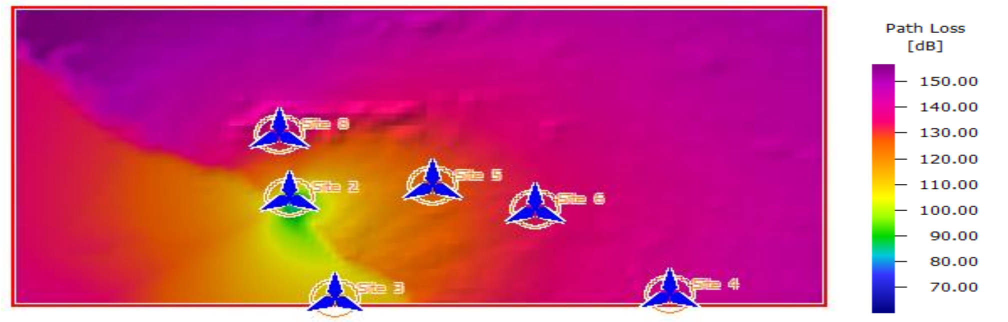


Figure 6: Path loss for Macro site 2 Antenna 2, in South Chunya

The general observation of the pass loss results of six (6) Macro cells studied in South Chunya, for both operating frequencies (at 800MHz and 2000MHz respectively) of graphs in WinProp tool, shows that only few areas are experiencing strong signal, large areas served by these macro sites are experiencing huge path loss that is above 140 dB.

```
File   Edit   Format   View   Help
ANTENNA "Site  2 Ant  1"
LOCATION 501309.940 9067369.560 50.000
FREQUENCY 800.000
POWER 19.953 W  Output
ANTENNATYPE SECTOR
PATTERN "Antennas\Kathrein_739665_0947_X_CO_M45_00T"
HORIZONTAL 90.000
VERTICAL 2.000
LOWER_LEFT 469434.54000000 9051196.97000000
UPPER_RIGHT 563534.54000000 9095496.97000000
HEIGHT 1.500
RESOLUTION 100.00000000
RECEIVER_GAIN 0.000

BEGIN_DATA
469484.54000 9051246.97000 -166.5653
469484.54000 9051346.97000 -166.5543
469484.54000 9051446.97000 -166.5324
469484.54000 9051546.97000 -166.5106
469484.54000 9051646.97000 -166.4889
469484.54000 9051746.97000 -166.4673
469484.54000 9051846.97000 -166.4457
469484.54000 9051946.97000 -166.4242
469484.54000 9052046.97000 -166.4029
469484.54000 9052146.97000 -166.3815
469484.54000 9052246.97000 -166.3603
469484.54000 9052346.97000 -166.3392
469484.54000 9052446.97000 -166.3182
469484.54000 9052546.97000 -166.2972
469484.54000 9052646.97000 -166.2764
```

Figure 7: Sample Path loss for every coordinate in South Chunya experienced

This can also be verified in Cumulative density function (CDF) plots in Figures 8 and 9 for macro sites site 1, site 2 and respectively which shows the path loss developed by each cell antenna.

In an ideal situation we expect for all macro sites the smaller path loss values that is to say for less than 100 dB path loss should at least fall in higher probability of 1, unlike in the CDF graphs as shown in Figures 8 and 9 respectively.

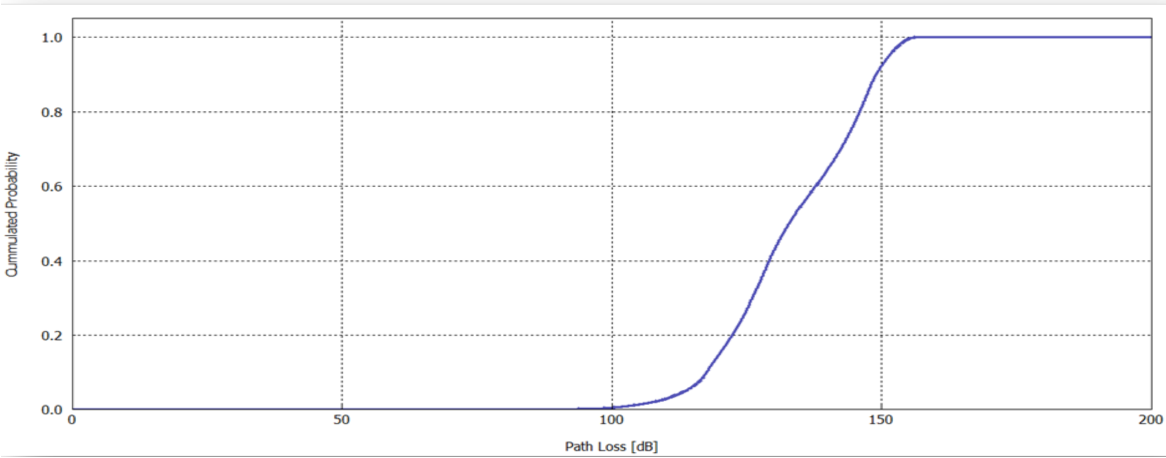


Figure 8: Cumulative Density Function (CDF) showing Path loss For Macro Site 2

The larger loss is more likely to fall on a higher cumulative probability. This signifies that broadband systems with macro sites only, expect to receive larger loss to the areas with variation of topographical features such as hills like in South Chunya.

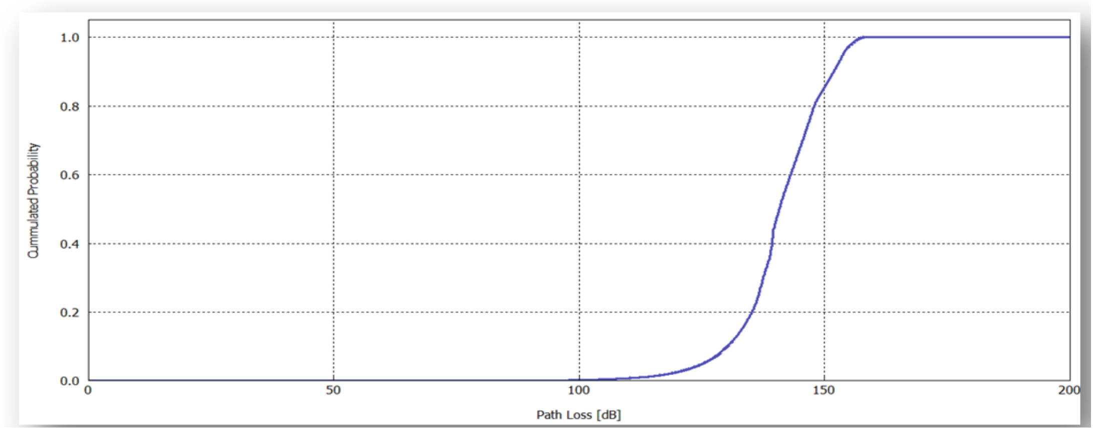


Figure 9: Cumulative Density Function (CDF) of Path loss For Macro Site 3

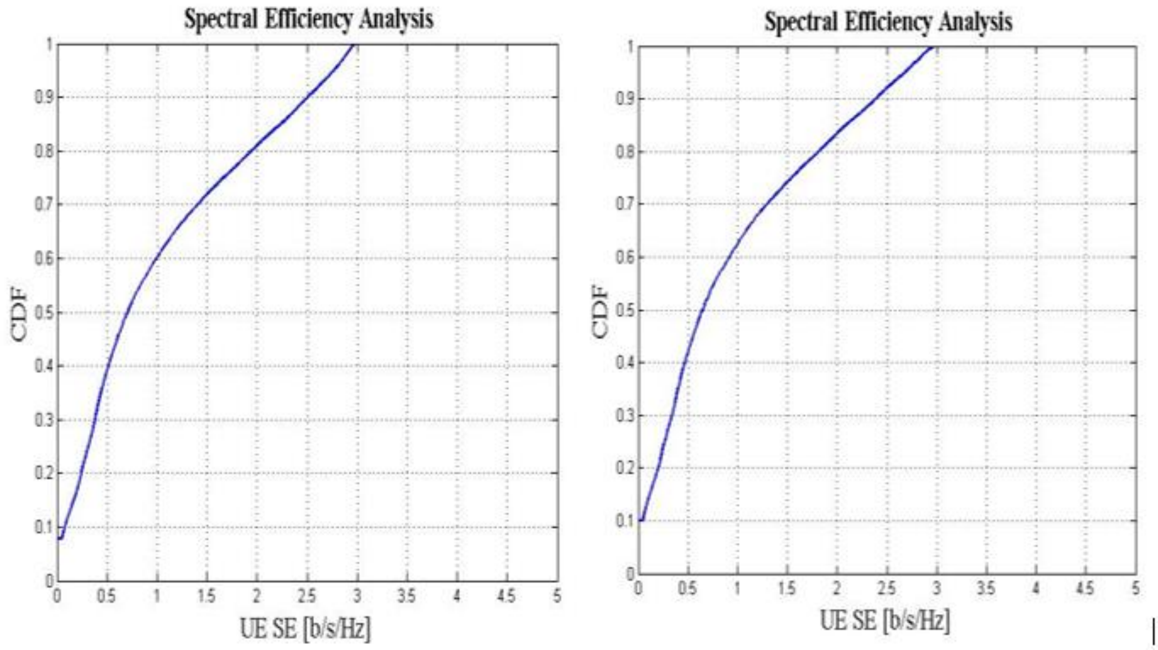
Performance Analysis of Signal Propagation

After obtaining the "Path loss Data" for each pixel in the study area for each Macro cell, Mat-lab static simulator was then built to analyze the performance of the Macro cells. Different functions were written in mat-lab tool and run to identify ability of Macro cells to transmit signal there is improvement in broadband performance indicators in our area that the user equipment's will get.

The Spectral Efficiency which is a measure of how efficiently the available bandwidth or frequency spectrum is used to transmit data or information, User Equipment' throughputs, Spectral efficiency which is a measure of the performance of channel coding, as well as Signal- to- interference noise ratio are among the parameters examined to understand the performance of the Macro cells signal propagation. As discussed above in the design section, for each parameter we highlight its performance in two operating frequencies of 800MHz and 2000MHz, the 800MHz frequency band represents the lower frequency band and the 2000MHz represent the higher frequency band.

Spectral efficiency

The aim of studying and analyzing Spectral efficient was to check how user equipment would utilize bandwidth efficiently in the area using the current Macro cells infrastructure and the current setup. This could clearly give the genuine picture on how users utilize the current system which uses Macro cells for signal backhauling and what actual signal reaches to users as presented in **Figure 10**.



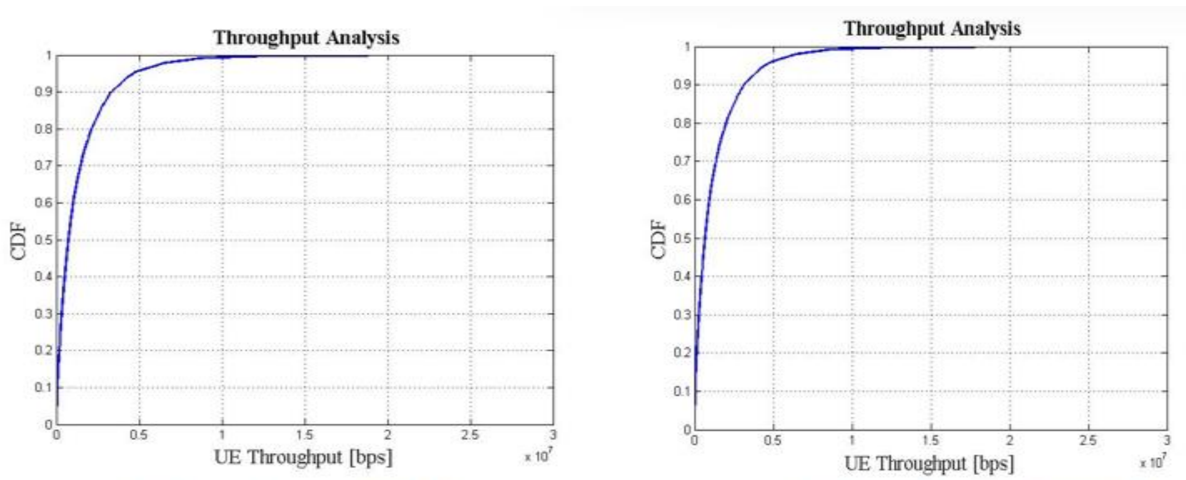
Spectral efficiency at 800MHz Spectral efficiency at 2000MHz

Figures 10: The probability density functions (CDF) of spectral efficiency

Spectral efficiency in the region when 800MHz and 2000MHz frequency bands are used respectively. It could be observed in Figure 10, that for both cases only few of frequency band are used. The graphs highlights only few users would utilize bandwidth efficiently. This is evidently justified following the earlier decay of the graph plots and this is for both cases of 800MHz and 2000MHz.

UE Throughput

User Equipment's throughput performance analysis was used to investigate the throughput penetration in the area when the system deploys Macro cells only for availability of signal to User Equipment in the area.



UE throughputs at 800MHz UE throughputs at 2000MHz

Figures 11: The probability density functions (CDF) of User throughput

The general observation of throughput revealed that, most of the areas had no better signal penetration, this is observed for both operating frequencies as it can be seen in throughput penetration plots in **Figure 11** for 800MHz and 2000MHz respectively. The earlier decay of the plots means the higher losses (path loss) the area is experiencing and hence the lower signal strength to the UE connected in the area.

Further throughput analysis has shown that the received signal at 800 MHz is significantly higher compared to the received signal at 2000 MHz, respectively, though the difference in throughput at both carrier frequencies the lower band 800MHz and the upper band 2000MHz, is significantly low. This is also explained by the author in [6] that the carrier frequency does not affect much the downlink (DL) and the uplink (UL). **Table 3** shows and verify the comparison of the received throughputs at 10th, 50th and 90th percentiles for 800MHz and 2000MHz respectively

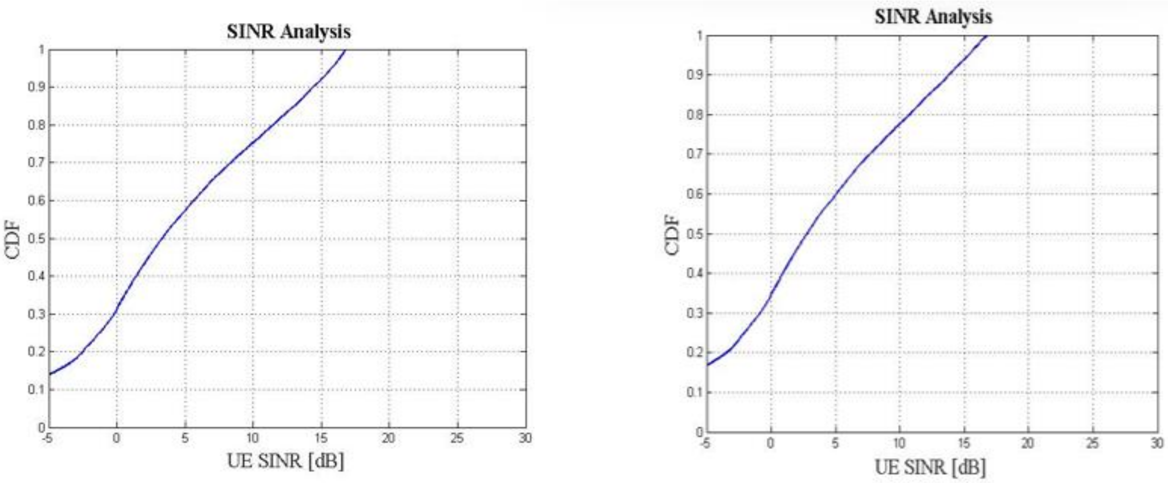
Table 3: User equipment's throughputs experienced in the area when Macro cells used for backhauling Signal.

Percentile (%)	Throughput (in bps)	
	800 MHz	2000 MHz
10th	0.01 x 107	0.0 x 107
50th	0.05 x 107	0.1 x 107
90th	0.3 x 107	0.3 x 107

Signal- to- interference noise ratio for Macro cell deployment

Comparison of SINR values between two selected operating frequency band of 800 MHz and 2000 MHz was made. Generally, the graphs of SINR values at different percentiles for both operating frequencies shows there is early decay of SINR plots. **Figure 12** presents the SINR analysis of current Macro deployed broadband system; it can be observed that the probability (CDF) increases as more as you get better values of SINR, however the plot decay as soon as you reach 16 dB approximately.

The earlier decay of graph plots of SINR reveals that there is weakening of signal and high loss of signal is experienced in the current Macro deployed system particularly in rural terrain affected areas.



SINR at 800MHz for Macro cells SINR at 2000MHz for Macro cells

Figures 12: The probability density functions (CDF) of UE SINR

As it was observed in case of throughput, the SINR values experienced at 800 MHz in different percentile are significantly higher compared to SINR values at 2000 MHz. A higher SINR value means that the signal strength is stronger in relation to the noise levels, which allows higher data rates and fewer retransmissions, so at 800 MHz the area is significantly receiving higher transmission rate than when 2000MHz.

Table 4:

Percentile (%)	SINR Analysis (in dB) for Macro Cells System pattern	
	800 MHz	2000 MHz
10th	-5 dB	-5 Db
50th	4 dB	2.5 dB
90th	15 dB	13 dB

Conclusion

Through Propagation Modelling, and establishing "Path loss" data using Simulation tools the study was able to analyzed and quantify the performance of the broadband signal and capacity of macro base stations in a network at different frequency band specifically at 800MHz and 2000MHz in rural areas a case of South Chunya Tanzania. Carrier frequency have little impact on signal propagation. Higher frequency bands are more vulnerable to attenuation, which can reduce throughput.

In this paper we concluded that, throughputs, Signal to Noise ratio and Spectral Efficiency which are all signal performance indicators, are directly affected by terrains. When the transmitted signal (Tx) passes from different terrains then the mentioned performance indicators and parameters are poorly experienced due to noise addition to the Rx.

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