Inter and Intra-Cluster Networks Signal Coverage Impact and its Importance for Migration of 3G to 4G Network among Tourism Lake Tana in Bahir Dar -Ethiopia

Pushparaghavan Annamalai, Fekadu Mihret, Solomon Lule, Mesfin Mulu, Malmurugan Nagarajan

Abstract*: Tourism is one of the leading economic sources for several countries compared to modern IT industries growth. Ethiopia is one of the leading cultural and tourism revenue-based country, and having huge tourism hot spots for national and international tourist visitors. Specifically, in the Amhara national regional state capital, Bahir Dar, Lake Tana (origin of Blue Nile River) has been very well known to national and international tourists. However, the Lake Tana Basin is still unable to provide sufficient high bandwidth and good signal reception though 3G wireless mobile technology service is deployed. Bandwidth constraint and weak signal strength is creating problems for the society residing and for visitors in-and- around many islands of Lake Tana geographical areas. The research work carried out the study for 3G wireless mobile radio access and microwave transmission path link performance in the city and around Lake Tana Basin. Out of two phases of research works, in this paper, we focus the first phase and partly second phase research results for both Inter and Intra- Cluster 3G Network in complete manner. Hence, we analyzed various measures like coverage signal power conditions, various BTSs antenna sizes, geographical mapping issues and other supporting performance parameters. All importance analytical performance study and measures for two major cluster networks both inter and intra-cluster 3G Networks which are geographically located edging curve in and around Lake Tana Basin. Ultimately, complete analysis and results are supported as prime study for Ethiopian Telecommunication Corporation (ETC) technical support before expanding / migrating to 4G from 3G WCDMA network on Lake Tana Basin and also enhance the culture and tourism cost trade -off for both Amhara region of Ethiopia and national wide Ethiopia.

***Keywords:** 3G WCDMA, free space path link (FSPL) loss, microwave access, radio access, receive power (PRx), signal coverage, transmit power (PTx)*

I. INTRODUCTION

Ethiopian Telecommunication Corporation (ETC) service covers 45% mobile, 13% Internet and 1% fixed line users. Presently 83% covered telecommunication services and aiming 100 % coverage by ETC for the next years by expansion of 3G to 4G UMTS - WCDMA technology set up [1].Origin of Blue Nile River from Bahir Dar Lake Tana is the largest lake in Ethiopia as well as in the world and nearly 37 islands scattered on the surface of this Lake Tana with many famous monasteries [3]. As per the tourism report nearly 127,872,522 national and 94,721,790 international tourists visited Lake Tana with the total income of 222,594,312 Birr in the 2018[4]. But Lake Tana has facing not only with changing climate conditions and water degradation issues, but also facing the problem of poor telecommunication network services and no data management system [14]. In Ethiopia, most of the villages, semi urban and urban areas, specifically in Lake Tana's islands and in- and -around [15] residing societies and national / International tourist visitors are more. But still this Lake Tana residing societies unable to access 3G wireless mobile services and internet due to huge signal coverage and interference ratio. From the above bottleneck problem of ETC 3G UMTS -WCDMA technology services, many of the residing society in-and-around Lake Tana including various islands societies and visitors are unable to receiving 3G mobile phone signals and sufficient bandwidth for the communication purpose. The above discrepancy of 3G service affects the socio-economic promotions of Bahir Dar. The poor signal reception and coverage of 3G WCDMA at Lake Tana has is one of the key analytical research issues. So, we have taken as research work and focused to study the phase 1 for Inter cluster Network and partly Phase 2 work for Intra-Cluster network analysis towards the 3G WCDMA Network signal coverages in-and around Lake Tana Basin. The following logical diagram Fig. 1.1 depicts the microwave / radio access link and various Base Transceiver Stations (BTSs) which is supported by fiber optic backbone network. All the research work of phase 1 and partly Phase 2 have been organized and carried out by following sections. In the section I ended with basic approach and logical diagram of Bahir Lake Tana microwave link including various islands accessing BTSs transmission set up. In section II, a complete phase 1, two major cluster network performance analyses with measures for in-and-around Lake Tana have been explained.

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The section III, describes partly Phase 2 intra - cluster network analysis by chosen six BTSs performance and it has been selected many aspects; poor signal reception, distance coverage and located cutting edges and islands in and around Lake Tana geographical areas. Also, section III, deeply analyzed with many subsections, Auto Regressive (AR) model for received random signal power reception, extended to analyze the free space path loss model and antenna transmission models for all six BTSs microwave and radio access links. Section IV dealt the interpretation and discussion of the research work so far. Finally, the conclusion and further study has been illustrated whichever planned for remaining research work phase II in section V in brief.

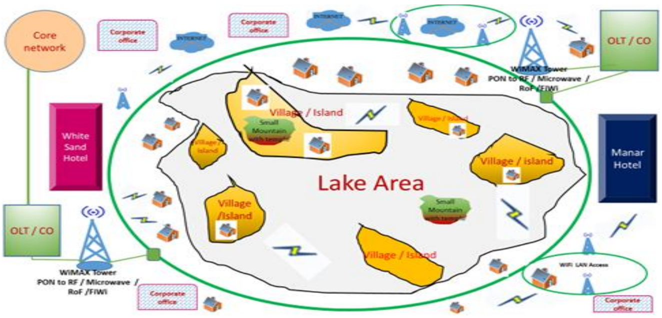


Fig. 1.1: Bahir Dar Lake Tana -Microwave Link Access BTSs set up with back bone support of Optical Fiber Back haul network -Model logical diagram.

II. INTER CLUSTER NETWORK

The performance analysis of Inter cluster network has been carried out for 3G WCDMA networks in-and-around Lake Tana basin. The analysis has been carried out for cluster networks 1 and 2. Many measures were found out with measuring devices. The critical parameters such as User Equipment (UE) transmitted Power, Received Signal Code Power (RSCP), Energy per Chip per Interference (Ec/No) and High-Speed Packet Access Downlink (HSPADL) and its throughput have been collected for the Bahir Dar two cluster network 1 and 2. Complete measures have been carried out for various BTSs and inter cluster Network wise.

In general, the critical parameter RSCP has measured for BTSs cluster wise. RSCP helps to support for the power margin level of Common Pilot Channel (CPICH). The CPICH is the basic measurement to provide the selection and reselection of handover among cells. CPICH reception level depends by adjusting its power level, and the load can be balanced in different cells [7].

As per the WCDMA planning and optimization, the signal condition and coverage (Good to bad) of Downlink (DL) verified by the Common Pilot Channel (CPICH). The coverage and reception of radio access is determined by not only by the RSCP of CPICH margin level but also it has been determined by the interference occurrence with other cells. The occurrence of interferences has been found by amount energy per chip to the received power (Ec/No) of CPICH. These two critical parameters play an important role and impact the loading of the 3G WCDMA network. The RSCP is constant when increasing loading capacity, but the Ec/No is degraded. The relationship of received power RSCP and Ec/No determines the load capacity of WCDMA systems.

Hence, fixing as well as finding the threshold level is an important parameter for RSCP and Ec/No for good coverage and signal reception WCDMA network systems [5]. Compared with other performance parameters of DL-WCDMA, the critical parameters RSCP, EC/No and path loss have been calculated by following expression (2.1); [6]

Path loss (PL) between the Cell and UE has given by

PL=CPICH Tx(dBm)-CPICH RSCP (dBm) .... (2.1)

If we take cell 1 to cell 2 link analysis of cluster network, UE equipment's reported value for measuring quantity values for CPICH -EC/No is normally -24dB to 0 dB, for CPICH-RSCP is -120 to -25 dBm, the details are given below as per the reference Table I and II and 2.2 [6]

Table I: CPICH Ec/No Reported Value Mapping to Measured Quantity

CPICH Ec/No Reported Value	Measured Quantity Value	Unit
0	Ec/No < -24	dB
1	-24 ≤ CPICH Ec/No < -23.5	dB
...	...	...
48	-0.5 ≤ CPICH Ec/No < 0	dB
49	0 ≤CPICH Ec/No	dB

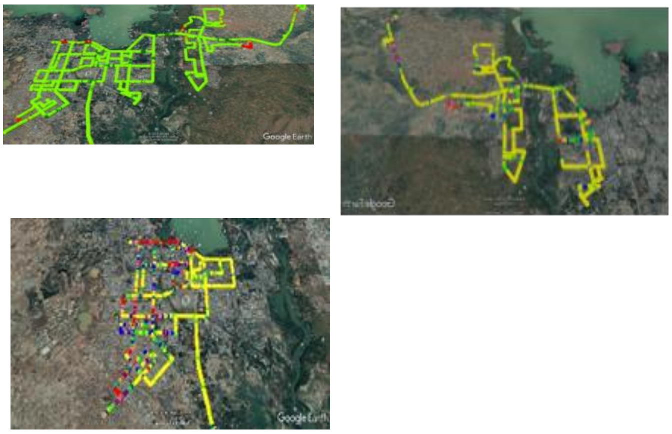
Table II. CPICH RSCP Reported Value Mapping to Measured Quantity

CPICH RSCP Reported Value	Measured Quantity Value	Unit
-5	CPICH RSCP < -120	dBm
0	CPICH RSCP < -115	dBm
1	-115 ≤CPICH RSCP < -114	dBm
...	...	...
90	-26 ≤ CPICH RSCP < -25	dBm

Many statistical analyses by graph have been brought with the measured values. The graphs for the most important critical performance parameters such as DL throughput, RSCP, Ec /No with respect to the counts are depicted. The counts have been considered with the random messages' occurrence in different time to time (random) among for the various BTSs in cluster Network 1 and 2.

All the snap shots and graphical plots are depicted in the following Fig. 2.1 to 2.7. As per the Fig. 2.4 result, the counts almost 15,000 as highest and its Ec/ No lies in between -13dB to -6 dB. The other two range counts range 2000 to 3000 at Ec/No value of less than -13dB and similarly, the counts 2000 to 7000 at Ec /No value -6.0 dB to 0 dB. It is shown that the Ec/No is one of the crucial parameters and it has optimum value at -13dB to -6dB and it has been like a threshold value for cluster network 1 & 2 in the 3G WCDMA networks. The Fig. 2.1 (a) and (b) describe the transmit power user equipment (UE) of Bahir Dar cluster network 1 and 2.

Most of the geographical areas are good in signal coverage in normal climate clear-sky condition, whereas few areas with curving and cutting edge of the Lake Tana have been affected with the poor signal coverage which are indicated as red color in the diagrams.



(a) (b)

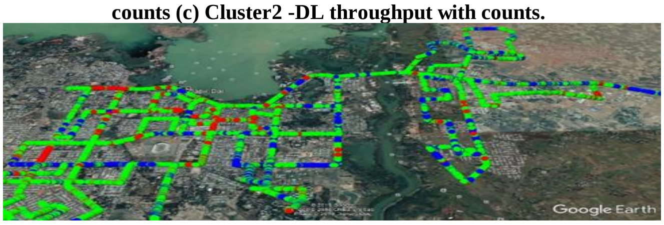
Fig. 2. 1: Transmit Power (Ptx) of UE Bahir Dar Lake Tana in-and-around: (a) Cluster network 1 (b) Cluster Network 2

Fig. 2.2: Transmit Power (Ptx) of UE for Cluster network 1 and 2 - Lake Tana – in- and-around together

(a)

(b) (c)

Fig. 2.3: (a)Throughput for DL for Cluster network 1 and 2 -Bahir Dar Lake Tana – in- and-around together. (b) Cluster1 -DL throughput with counts (c) Cluster2 -DL throughput with counts.



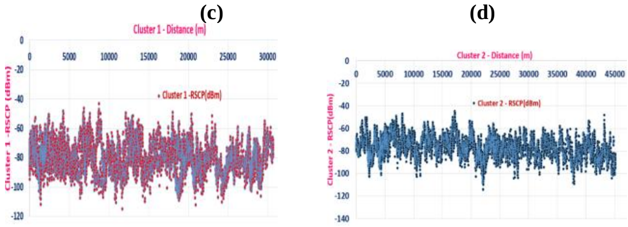
(a)

(b) (c)

Fig. 2.4: (a) Ec /No for Cluster network 1 and 2 -Bahir Dar Lake Tana – in- and-around together. (b) Cluster 1 -Ec/No with counts. (c) Cluster 2 – Ec /No with counts.

(a) (b)

(c) (d)

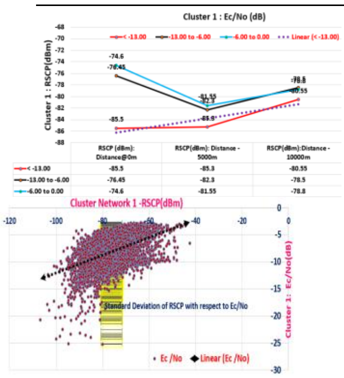


(e) (f)

Fig. 2.5: (a & b) RSCP for Cluster network 1 and 2 -Bahir Dar Lake Tana – in- and-around together. (c) Cluster 1 - RSCP with counts. (d) Cluster 2 – RSCP with counts. (e) Cluster 1 - RSCP with distance. (f) Cluster 2 - RSCP with distance.

Table III: Cluster 1- Measured values for Ec/No and RSCP -Distance wise in Random

Ec /No (dB)	RSCP (dBm)		
	Distance @0m	Distance @5000m	Distance @10000m
< -13.00	-85.5	-85.3	-80.6
-13.00 to -6.00	-76.5	-82.3	-78.5
-6.00 to 0.00	-74.6	-81.6	-78.8
Average RSCP (dBm)	**-78.9**	**-83.1**	**-79.3**

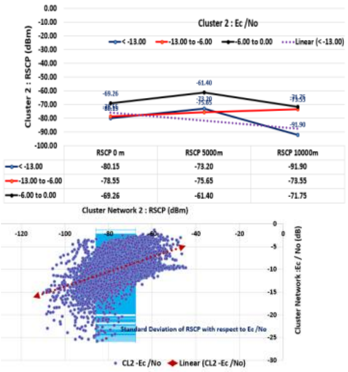


(a) (b)

Fig. 2.6: Plot for measured values as per Table 2.3 (a) RSCP and Ec /No different distance in Random (b) RSCP and Ec/No as per Overall counts in Cluster network 1- Random Analysis.

Table IV: Cluster 2- Measured values for Ec/No and RSCP -Distance wise in Random

Ec /No (dB)	RSCP (dBm)		
	Distance @ 0m	Distance @5000m	Distance @10000m
< -13.00	-80.15	-73.20	-91.90
-13.00 to -6.00	-78.55	-75.65	-73.55
-6.00 to 0.00	-69.26	-61.40	-71.75
Average RSCP (dBm)	**-75.99**	**-70.08**	**-79.07**



(a) (b)

Fig. 2.7: Plot for measured values as per Table 2.4 (a) RSCP and Ec /No different distance in Random (b) RSCP and Ec/No as per Overall counts in Cluster network 2- Random Analysis.

Apart from previous descriptions from above Figures, UE DL throughput was obtained and supporting maximum of 2048 Kbps (2 Mbps approximately) with respect to counts both in cluster networks 1 and 2 and measured values shown in the Fig. 2.3. (a) and (b). The various plots from Fig.2.4 to 2.7. and Tables III and IV noted that the major difference in cluster 1 and cluster 2 networks with important performance measurements. Mainly, the RSCP and Ec / No are the most deterministic parameters for the performance of variant stochastic conditions (different timing conditions in random) of cluster networks. The Ec /No has been occurred in the range -13 dB to -6 dB as a dominant range with respect to the maximum counts as shown in Fig. 2.4 (a) to (c).

Similarly, received power RSCP has been highly concentrated with maximum counts, distances and dominated range of RSCP from -95dBm to -60dBm which has been shown in Fig. 2.5 (a) to (f). Especially, the average value of RSCP has been varied for random distance measurements; say for 0m to 10000m in approximate, we obtained average values of RSCP ranges from -80 dBm to -70 dBm for both cluster networks 1 and 2 and it has been given in the Table III and IV. Additionally, we compared the graphical analysis Ec/ No and RSCP with random values for complete cluster 1 and 2 networks and it has been shown Fig. 2.6 (a) & (b) and Fig. 2.7(a) & (b). The RSCP values from -115dBm and maximum of -40 dBm found out for the overall Ec /No variations for cluster network 1 and 2, which has been depicted in Fig. 2.6(a) and 2.7(a). The RSCP range has been marked as -80dBm to -70dBm if RSCP standard deviation has the value of 1, which also highlighted in Fig. 2.6(b) and 2.7(b).

From the above values and graphical results, we observed that the RSCP has been changed from time to time (as per number of counts) due to variations of noise power Ec / No and many interference issues in the free space transmission of cluster networks 1 and 2. Any wired / wireless links, and its transmission systems, compared with transmit power, mainly the parameter called 'maximum received power' has helped to determine the best performance and justify the solution for any effective wired/wireless transmission systems.

Based on the key logical concept of wired/wireless communication network systems that we suggested and recommended, the importance of received power RSCP for cluster networks 1 and 2 is important. At the same time, from the implications of research study of cluster networks 1 and 2 performance in Phase 1, instead of continuing inter-cluster network received power performance study, we extended our study in-depth for the received power (RSCP) performance for intra-cluster networks as in partly Phase 2. This intra-cluster networks study has been carried out selectively for six BTSs microwave and radio access link performance located in-and-around networks of Lake Tana. The in-depth analysis of six BTSs performance study and we carried out as major research work in phase 2 partly and it has been described in the section III with various sub sections.

III. INTRA-CLUSTER NETWORKS: SIX BTSS MICROWAVE LINKS

In the section III, the paper describes the major core partly phase 2 of our research works about the intra-cluster network for six BTSs Microwave-link power analysis and its impact in 3G WCDMA received signal code power (RSCP) / received power (Prx). The intra-cluster RSCP / Prx analysis carried out for the signal coverages mostly affected areas of cutting edges and islands of the Lake Tana Basin. Based on this approach, we have taken a 3G WCDMA microwave link intra-cluster network performance study has been carried out partly in the Phase 2 research work. The affected RSCP and its location of BTSs have been identified in an arbitrary (random) way among urban, semi-urban and villages / remote areas / Islands of Lake Tana Basin.

In overall phase 2 of research work, we carried out with few specific objectives. The first is to analyze the microwave link signal degradation at normal / clear-sky conditions (weather condition is good). The second is for robust condition (weather condition is bad), that is, Prx degradation occurrence due to atmospheric turbulence effects, and scintillation issues.

Due to the non-availability of measurements of BTS for robust condition and availability of measurements for clear-sky condition, we carried out thoroughly only the normal / clear-sky condition analysis with many models. Apart from that, before proceeding the two robust condition analysis, it is necessary first research work for the clear-sky condition and its performance study. The in-depth clear-sky condition analysis arises as a completion of first specific objective. The identified six BTSs location map, microwave transmission link details of all six BTSs and its accessing parameters have been measured. Mainly, the following core performance parameters of BTS have been measured for the analytical purpose of received power degradation issues such as transmitting frequency (f_{tx}), transmitting power (p_{tx}), receiving frequency (f_{rx}), receiving power (p_{rx}), distance (d) between the BTS to BTS link. Additionally, the details of various parabolic reflection antenna (dish antenna) sizes, and its diameter (D) ranges 0.8 m, 1.0m and 1.2m for the BTS microwave link transmission in-and around Lake Tana basin have been measured and noted. The below Table V describes the various parameters collected and used for six BTS microwave link power estimation analysis. Most of the parameters were noted as the differences as per the BTS to BTS link wise. BTS3 to BTS4 link has identified in the curving / cutting edge of Lake Tana. Other BTSs links; say BTS1 to BTS2 and BTS5 to BTS6 links were taken as interior island in Lake Tana.

Table V: Various parameters collected and used for six BTSs-Microwave link power estimation and its performance analysis

Parameters	BTS1	BTS2	BTS3	BTS4	BTS5	BTS6
As Node: TXR	Node1: TXR1	Node2: TXR2	Node3: TXR3	Node4: TXR 4	Node5: TXR 5	Node6: TXR6
Location of BTS	SOS- FW Hospital	Azewa Monastery	Delgi Sub urban Lake border	Easy Debir Lake Border	Legidya Village	Sash Ato Bezegate NWR Island Lake
BTS No	171158	171166	171125	171201	171446	173214
Transmit freq. (MHz)	14501	14991	7747.7	8059.02	7777.35	8088.67
Receive Freq. (MHz)	14991	14501	8059.02	7747.7	8088.67	7777.35
As Link	BTS 1 and BTS 2		BTS 3 and BTS 4		BTS 5 and BTS 6	
Modulation /Bit rate	16 QAM / 86 Mbps		256QAM/ 183 Mbps		16 QAM / 86 Mbps	
Distance between BTSs (Meters) by air	9310 (9.3Km)		20000 (20 Km)		28260 (28.26 Km)	
Transmit Power (dBm)	24		28.5		30.5	
Actual TX power dBm)	23.8 to 24.0		28.3 to 28.5		30.3 to 30.5	
Power to be received (dBm)	-40.5		-41.2		-37.5	

Measured Received Power Prx (dBm) with respect to Transmit Power Ptx- BTS wise

t_n	BTS1@ Ptx=24dBm	BTS2@ Ptx=24dBm	BTS3@ Ptx=28.5dBm	BTS4@ Ptx=28.5dBm	BTS5@ Ptx=30.5dBm	BTS6@ Ptx=30.5dBm
t_1	-37.4	-37.2	-44.5	-41.1	-55.2	-57.5
t_2	-37.4	-40.5	-55.9	-42.2	-57.9	-55.3
t_3	-37.4	-41.5	-46.6	-44.2	-59.8	-56.8
t_4	-38	-43.3	-41.8	-43.3	-61	-57.4
t_5	-39.2	-36.7	-48.4	-45.1	-66.1	-59.1
t_6	-38.7	-37.2	-51.5	-43.8	-58.5	-54.9
t_7	-38.4	-38.4	-43.2	-42.3	-58.4	-55.5
t_8	-36.4	-38	-41.8	-44.7	-62.4	-58.7
t_9	-36.7	-39.2	-50.5	-42.9	-57.6	-55.2
t_{10}	-39	-36.2	-42.7	-53.9	-59.2	-57.2
t_{11}	-39	-38	-48.1	-43	-60.2	-55.2
t_{12}	-37.1	-37.4	-43	-47.2	-58.7	-56.4
t_{13}	-38	-38.9	-46.6	-42.5	-59.6	-55.6
t_{14}	-38.3	-36.6	-49.2	-42.4	-58.3	-63.3
t_{15}	-37.6	-37.5	-41.7	-42.6	-61.8	-54.9

t_{16}	-38.3	-38.9	-47.6	-41.8	-57.3	-55.6
t_{17}	-38.2	-37.4	-47.4	-41.2	-60	-57.2
t_{18}	-37.5	-38.2	-44.7	-41.5	-57.3	-56
t_{19}	-37.3	-38.9	-44.6	-40.7	-53.2	-52.9
t_{20}	-37.5	-39.2	-42.3	-52.2	-56.2	-54.2
t_{21}	-37	-38.4	-42.3	-47.3	-58.2	-54.8
t_{22}	-38.8	-39.4	-43.2	-42.4	-58	-54.8
t_{23}	-37.5	-38.9	-42.8	-42.1	-59.9	-54.6

Table VI: Received power at random time(tn) for Six BTSs Links

The snap shot of the three set of BTS links are shown in the Fig. 3.1 (a) to (c). The Fig. 3.1(a) has the location of BTS link; BTS1 -No: 171158: SOS FW hospital to BTS2 – No: 171166: Azewa Monastery with operating transmit and receive frequency range of 14.5 GHz to 14.9 GHz. The Fig. 3.1(b) has the location of BTS link: BTS3 -No: 171125 – Delgi Sub urban Lake border to BTS4-No: 172101 – Easy Debir Lake border and its operating frequency range of 7.7 to 8.0 GHz. The Fig.3. (c) has the location of BTS link; BTS5-No:171446-Legidya village to BTS6 -No:173214 – Sash Ato Bezegate NWR island Lake with operating frequency range of 7.7 to 8.0 GHz. The operating microwave frequencies has been almost same for BTS3 to BTS 4 and BTS5 to BTS 6 links except BTS1 to BTS2 link. Similarly, the Modulation/ Bit rate has been same for BTS1 to BTS2 and BTS 5 to BTS6 links except BTS3 to

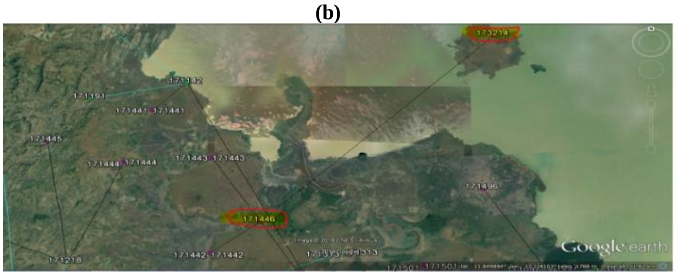
BTS4 link. But distance wise, all BTS to BTS links have not been the same.

Overall, among six BTSs through the different combination of link parameters, the link power analysis has been carried out the received power (Prx), (called RSCP) for all six BTSs. Any wireless link set up parameter is received power (Prx). Based on the received power, the performances have been suggested as good or bad as wireless link. With this research idea and motto, in the Partly phase 2 research work, we have been extended and approached with following mathematical and modelling under the parameter values as per the Table V.

(i) Mathematical model using Auto Regressive model (AR model) for finding the average received power analysis among all BTSs at random interval of time.
(ii) Free space path loss model (FSPL model) – found out the path loss between every BTSs links.
(iii) Firis Transmission (FT) model to find the received power every BTSs along with FSPL.
(iv) (Okumura -Hata (O-H) model also analysed for the result of remote (open areas, villages, islands), semi urban and urban based BTS power links performance with respect to the height of the BTS and distance.

(a)

(b)



(c)

Fig. 3.1 Chosen and identified various location of BTS links between (a) BTS 1 to BTS2 (b) BTS3 to BTS4 (c) BTS5 to BTS6.

All above models were analysed with the all BTSs received power (Prx) in random (t_n - different interval of time and different days responses) as per measured and noted values. The random measure received power for all six BTSs has given in the Table VI. All the above models have been analysed in constructive way with necessary equations and described shortly in the following subsections.

(i)Auto Regressive / Auto Correlation Model for Six BTSs Received Power

Many data analysis tools and models are available today. In specific, the Statistical package for Social Science (SPSS), mainly using for statistical data analysing purposes like for ANOVA, correlation, regression, Linear regression (LR), Auto Regression (AR), Multiple Regression (MR) models [8]. The AR model predicts future performance based on past performance (time to time study of previous action). It's used for forecasting when there is some correlation between values in a time series and the values that series precede and succeed them. Based on the SPSS and AR approach, we have chosen the AR model to analysis the complete time series (t_n) based received power in statistically for every BTS. In this statistical contest of link power analysis of six BTSs, it is necessary to time dependent / independent event of BTSs receive power has a big issue. The receiving power of BTS has chosen as case of 'lags' with respect to time series.

The lags meant here as past series values. The lags provide the results for the situation wherever one time period affect from its immediate /next following time periods.

Such a support of lags statistical concept in AR model, it has an advantage for any model that tries to predict the next value of a series based on past values alone. An AR(p) model is an autoregressive model where specific lagged values of Y_t are used as predictor values. AR model defined by the equation [9] which helps to find the received power for every node 1 to node 6, (i.e., six BTS1 to BTS6) as in equation (3.1)

$$Y_t = \beta_0 + \beta_1 Y_{t-1} + \beta_2 Y_{t-2} + \cdots \beta_p Y_{t-p} + e_t ....(3.1)$$

Where, Y_t is the current received power for each node /BTS and Y_{t-1}, Y_{t-2} ......Yt-p are the past series values(lags), and et is the white noises (i.e., randomness). The SPSS provides the following AR model for different nodes / BTSs with following steps of equations (a) to (f) as expression (3.2)

Table: VII: Various lag measured values for Six Nodes / BTSs by Autocorrelation model

Lag	Autocorrelation					
	Node1/ BTS1	Node2/ BTS2	Node3/ BTS3	Node4/ BTS4	Node5/ BTS5	Node6/ BTS6
0	1	1	1	1	1	1
1	-0.13	0.05	-0.031	0.2099	0.1916	-0.0629
2	-0.25	0.04	-	-	-	0.03246

a) Y_t = 0.534Yt_{-1} + 0.448Yt_{-2}, AR model for Node1/ BTS1

b) Y_t = 0.47Y_{t-1}+0.52 Y_{t-2} , AR model for Node2/BTS2

c) Yt= 0.82Y_{t-1}, AR Model for Node3/BTS3

d) Y_t = 1.0006$Yt_{-1,}$ AR Model for Node 4/BTS4

e) Y_t = 1.002Y_{t-1}, AR model for Node5/BTS5

f) Y_t = 0.46Yt_{-1}+0.54Y_{t-2}, AR Model for Node6/BTS6

------- (3.2)

The above AR model shows that the current received power for node 1/BTS1, Node2/BTS2 and Node6/BTS6 depends / correlated on at lag 1 and lag2 while current received power for node3/ BTS3, node4/BTS4 and node5/BTS5 are correlated /depends on at lag1. This means, the regression coefficients at lag 3, lag 4 etc., for node1/BTS1, node2/BTS2 and node6/BTS6 are insignificant. In addition, the regression coefficients at lag 2, lag 3 etc., are insignificant for node3/BTS3, node4/BTS4 and node5/BTS5 at 5% level of significance. The above Table VII, represents the Autocorrelation model and measured values by different lag value ranges from 0 to 2.

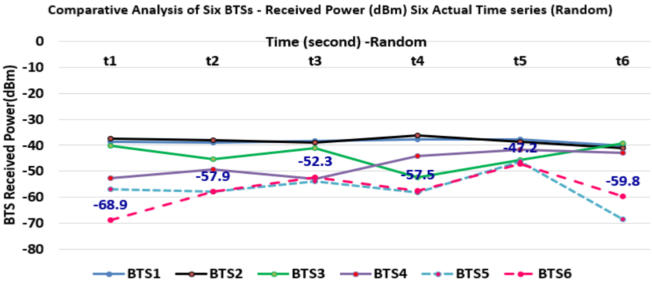
The following Table VIII provides the details of all six BTSs received power and randomly actual chosen the time series t1 to t6 for analytical purpose instead of samples taken from the Table VI and Fig. 3.1 shows the corresponding graphical approach.

Table VIII: Six BTSs measured values for received power along with different time period of interval

No.of BTS	Received power(dBm) in Random - Different day and Time @ Normal condition					
	t_1	t_2	t_3	t_4	t_5	t_6
BTS1	-38.6	-39	-38.4	-37.8	-37.8	-40.1
BTS2	-37.4	-37.9	-38.9	-36.2	-38.7	-41
BTS3	-40.2	-45.4	-41.2	-52.5	-45.5	-39.2
BTS4	-52.8	-49.3	-53.1	-44.1	-41.6	-42.8
BTS5	-56.9	-57.8	-53.9	-58.3	-46.3	-68.4
BTS6	-68.9	-57.9	-52.3	-57.5	-47.2	-59.8
BTS 1 and BTS 2 TX Power = 24 dBm Distance (d) = 9.31 Km by air						
BTS 3 and BTS 4 TX Power = 28.5 dBm Distance(d) = 20.21 Km by air						
BTS 5 and BTS 6 TX Power = 30.5 dBm Distance (d) = 28.26 Km by air						

The above Table VIII describes the six BTSs received power in different time or random time of interval responses at normal clear-sky condition. The received signal code power (RSCP) / BTSs receiver signal in random manner; selectively chosen here for six different time period signals (t_1 to t_6). The received power range also has taken link wise, that is, a quite difference among BTS links almost 2 to 3 dBm among the link BTS to BTS, 4 to 5 dBm difference among one BTS link to another BTS link. The highest received power and lowest received power have noticed in the Table VIII; such as BTS1 – BTS2 link has highest and BTS5 and BTS6 has lowest, whereas BTS3 – BTS 4 link has an average (optimum) received power in comparison.

The following Fig.3.1 has described the comparative analysis of six BTSs received power along with timeseries analysis.



.Fig.3.1: comparison of Six BTSs received power along with time series-analysis in random

(ii)Free Space Path Loss (FSPL) Model for Six BTSs Links

FSPL model analysis dealt to study the wireless communication and link its performance [11]. The FSPL is necessary for wireless link performance at normal and robust condition. In this research, FSPL has been carried out normal climate / clear-sky conditions. The path loss analysis has been mainly concentrated here for three set of links with six BTSs set up. The setup of links which has been chosen here; link between BTS1 and BTS2 as first, the second link between BTS3 and BTS4 and BTS5 and BTS6 as third link. All the six BTSs by design assumptions and we have taken here (presently ETC using different size of antennas for 3G WCDMA network BTSs). It is having parabolic antenna's (dish antenna) with different diameters 0.8m, 1.0m and 1.2m and we have taken for the FSPL analytical model. The diameter (D) of dish antenna and effective aperture (A_e) has taken as core parameters for finding the FSPL analysis. From the different antenna sizes, we first calculated FSPL with antenna transmit gain (G_t), receive gain (G_r) and (A_e) with following expressions. Many equations are noted for FSPL with respect to various standard expressions (3.3) to (3.5) follows [10]

$$FSPL = 20\log(d) + 20\log(f) + 20\log\left(\frac{4\pi}{e}\right) \quad (3.3)$$

$$FSPL = 20\log(d) + 20\log(f) - 147.55 \quad (3.4)$$

$$FSPL = 20\log(d) + 20\log f + 20\log\left(\frac{4\pi}{e}\right) G_{Tx} - G_{Rx} \quad (3.5)$$

Also, another similar expression (3.6) for FSPL [11]

$$pathloss(L_p) = FSPL(dBm) = 10\log\left[\frac{(4\pi d)^2}{\lambda^2}\right] \quad (3.6)$$

Next, the effective aperture (Ae) of parabolic dish antenna has been calculated with the following expressions (3.7) and (3.8)

$$A_e = 0.5 \times \pi r^2 \qquad r = \frac{D}{2} \quad (3.7)$$

$$A_e = 0.5(\text{physical area of parabolic dish}) \quad (3.8)$$

Where r and D - the radius and diameter of the parabolic dish antenna, d- distance, f- frequency, wavelength; $\lambda = c/f$, c – velocity of light. Similarly, gain of the parabolic dish antenna has been calculated with the following equation (3.9).

$$G = 10\log k\left(\frac{(\pi D)^2}{\lambda^2}\right) \quad (3.9)$$

Where k is the efficiency = P_{rad} / P_t

P_{rad} and P_t – radiated power and transmit power from antenna

From all the above expressions, the FSPL have been calculated mainly with various diameter of the dish antenna, transmit power and values were given in the Table IX (a) and (b). Also, its effective aperture has been calculated for various dish sizes and its plot has given in Fig. 3.2. The overall FSPL has been calculated and plotted in the graph Figure 3.3 with respect to the three set of BTSs links located in different areas in and around Lake Tana.

Table IX(a): Various Link parameters for Three set of BTSs Links

BTSs Link power parameters calculation (approximately) with respect to dish antenna sizes									
	BTS1 and BTS2 dish size (m) if			**BTS3 and BTS 4 dish size (m) if**			**BTS5 and BTS6 dish size (m) if**		
	0.8	**1**	**1.2**	**0.8**	**1**	**1.2**	**0.8**	**1**	**1.2**
Ae	0.3	0.4	0.6	0.3	0.4	0.6	0.3	0.4	0.6
Gtx (dBi)	38	41	43	33	35	37	33	35	37
Grx (dBi)	40	41	43	32	34	35	32	34	35
GTx (dB)	3.8	4.1	4.3	3.3	3.5	3.7	3.7	3.5	3.7
Grx (dB)	4	4.1	4.3	3.2	3.4	3.5	3.2	3.4	3.5.

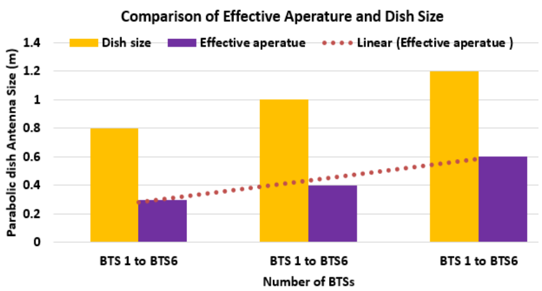


Fig. 3.2: Plot for measured effective aperture areas if various dish used for BTSs links

Table IX(b): Measured FSPL for BTSs links

Parameters	**BTS1-BTS2 link**	**BTS3 - BTS4 link**	**BTS5 - BTS6 link**
Distance (m)	9310	20000	28260
FSPL (dB)	135	136	139

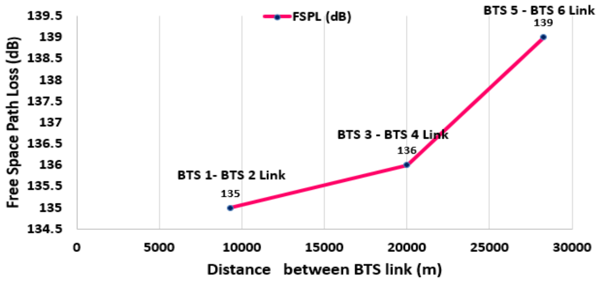


Fig. 3.3: Plot for FSPL for BTSs links distance wise

(iii)Firis Transmission (FT) Model for Received Power

In this paper, it has been explained the FT model from the partly research work phase 2. It has been carried out for received power with the FT model for various antenna sizes, aperture and gain of the various BTS. The various antenna sizes 0.8m,1.0m and 1.2m has been chosen for FT received power analysis of 3G network analysis. The Fig.3.4 depicts the basic BTS antenna logics of the FT model for wireless communication network. Based on the thematic idea, all the three set of BTSs links have been calculated the received power with following expressions (3.10) [10,12]

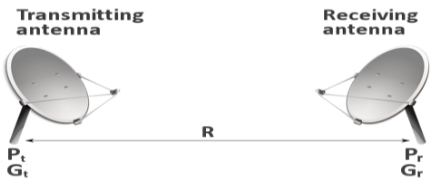


Fig. 3.4: Firis transmission model diagram for received power of BTSs link antennas. (courtesy: everythingrf.com)

$$P_r = 10\log\left[\frac{P_t\, G_t G_r\, \lambda^2}{(4\pi d)^2}\right] \ldots\ldots\ldots \quad (3.10)$$

(or) $$P_r = 10\log\left[\frac{P_t\, G_t\, G_r\, \lambda^2}{(4\pi R)^2}\right]$$

Where P_t,P_r ,G_t,G_r are transmitted power, received power, transmitter gain, and receiver gain of antennas respectively. 'R' or 'd' is the distance between the antennas of every BTS links. All the FT received power have been calculated mainly with the various dish antenna sizes and it has been compared the values based on following two situations; (i) Received power without FT and (ii) received power with FT. All the FT analysis of both situations have been carried out for normal clear-sky conditions. All the received power (dBm). for BTSs links have been calculated in three different (T1, T2 and T3) random time of interval for three dish antennas. The Table X(a) –(c) describes the measured values for actual received power without, with and comparison of both FT model calculations for all six BTSs. The Fig. 3.5 illustrates the received power actual and without FT model at normal clear -sky conditions alone as six BTSs with respect to different size of the three dish antennas used. The Fig. 3.6 (a) and (b) describe the received power without and with FT separately, whereas the Fig. 3.6(c) specifically represents the overall comparative analysis of received power dish size in different random time interval.

Table X: Received power with and without FT Model for all six BTSs.

No. of BTSs	Time(T1) - Dish 0.8m	Time(T2) - Dish 1.0m	Time(T3) - Dish 1.2m
BTS1-Prx	-38.6	-39	-38.4
BTS2-Prx	-37.4	-37.9	-38.9
BTS3-Prx	-40.2	-45.4	-41.2
BTS4-Prx	-52.8	-49.3	-53.1
BTS5-Prx	-56.9	-57.8	-53.9
BTS6-Prx	-68.9	-57.9	-52.3

Table X (a): Calculated received power for Six BTSs without FT model

No. of BTSs	Time(T1) – Dish 0.8m	Time(T2) – Dish 1.0m	Time(T3) – Dish 1.2m
BTS1- Prx Firis	-32.58	-29.58	-25.78
BTS2- Prx Firis	-32.73	-29.83	-26.03
BTS3- Prx Firis	-41.44	-38.24	-35.24
BTS4 - Prx Firis	-42.7	-38.7	-36.59
BTS5 - Prx Firis	-43.48	-39.18	-36.98
BTS6 -Prx Firis	-43.82	-39.52	-37.32

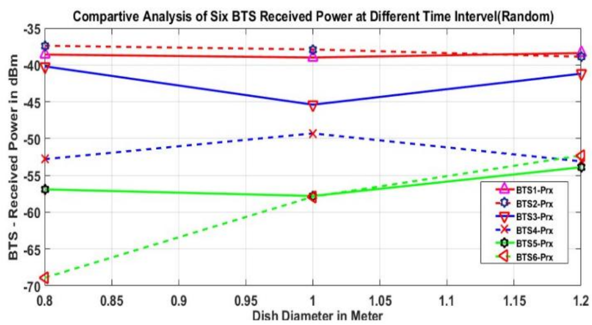


Fig. 3.5: Plot for random received power (actual) for three different dishes chosen for all six BTSs and its comparison without FT model at normal clear-sky condition.

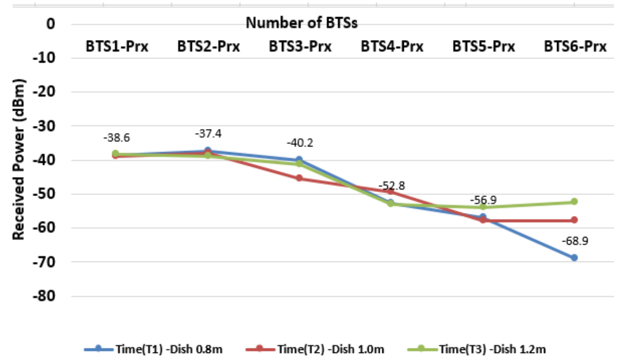


Fig. 3.6:(a) Without FT model – the received power for six BTSs

Table X (b) : Calculated Received power for Six BTSs with FT model

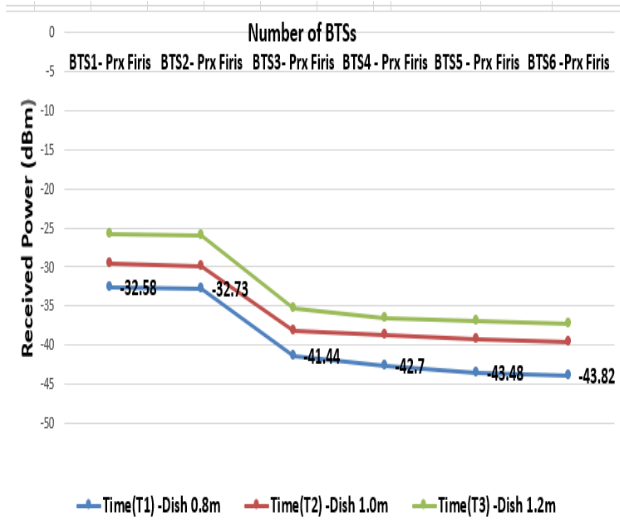


Fig. 3.6 (b) With FT model – the received power for six BTSs

Table X (C): Overall calculated received power for Six BTSs - both without and with FT model for six BTSs

No. of BTSs	Time(T1)-Dish 0.8m	Time(T2)-Dish 1.0m	Time(T3)-Dish 1.2m
BTS1 - Prx	-38.6	-39	-38.4
BTS1 - Prx Firis	-32.58	-29.58	-25.78
BTS2 - Prx	-37.4	-37.9	-38.9
BTS2 - Prx Firis	-32.73	-29.83	-26.03
BTS3 - Prx	-40.2	-45.4	-41.2
BTS3 - Prx Firis	-41.44	-38.24	-35.24
BTS4 - Prx	-52.8	-49.3	-53.1
BTS4 -Prx Firis	-42.7	-38.7	-36.59
BTS5 - Prx	-56.9	-57.8	-53.9
BTs5 - Prx Firis	-43.48	-39.18	-36.98
BTS6 - Prx	-68.9	-57.9	-52.3
BTS6 - Prx Firis	-43.82	-39.52	-37.32

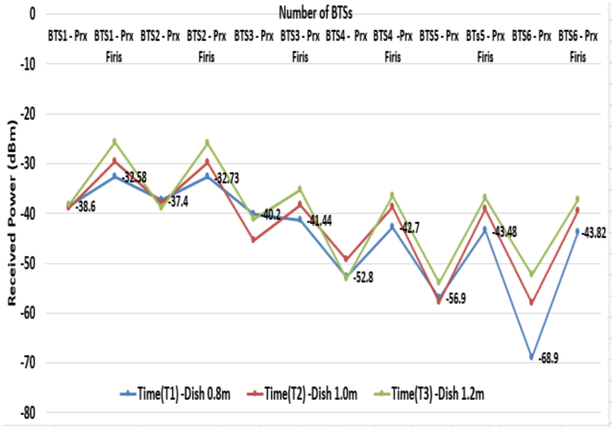


Fig. 3.6(c): Random received power at different interval of time (T1, T2 and T3), different antenna dish sizes for all six BTSs, and its comparison for without and with FT model at normal clear -sky condition

(iv)Okumura-Hata Model (O-H Model) -for Free Space Path Propagation loss- clutter Analysis

Finally, in the part of microwave link BTSs of 3G WCDMA network performances around Lake Tana, the six BTSs have been taken for different locations; various assumption of links follows. The urban area (BTS1 to BTS2), sub urban area (BTS3 to BTS4) and remote areas (BTS5 – BTS6). For this type geographical measurements, the Okumura model has support for the measurements to analyze signal conditioning level with respect to the distance.

The Hata model has one of the extensions of Okumua model which helps to clutter (disorder) based free space propagation loss analyses. So, in this combined Okumara-Hata model need her (O-H) model. The analysis of O-H model in this research work used with the following expressions (3.11) to (3.13) for various areas [13].

(a): urban path loss for clutter situation

$$L_p(urban) = 69.55 + 26.16\log(f) - 13.82\log(h_b) - a(h_m) + (44.9 - 6.55\log(h_b))\log(d)$$

Where, $a(h_m) = ((1.1\log(f) - 0.7)h_m - (1.56\log(f) - 0.8$

----(3.11)

(b): Sub urban path loss for clutter situation

$L_{p(suburb)} = L_p(urban) - 2\{\log(\frac{f}{28})\}^2 - 5.4$...............(3.12)

(c): Remote / Open area path loss for litter situation

$Lp(remote) = L_p(urban) - 4.78\{\log(f)\}^2 + 18.33\log(f) - 40.9$ --------(3.13)

Where $a(h_m)$ and (h_b) are the antenna height of the mobile station and base station. Using O-H model all above equations, the free space path propagation loss(dB) has been calculated with the height (h) of the various parabolic dish antenna sizes, distance(d), frequency(f) and other related specifications. The Fig. 3.7 has been shown below for O-H model follows with the various free space loss for urban to remote area. That is for BTS1 to BTS6 located in different geographical areas. In this graphical analysis, the height of the BTSs tower hb1, hb2 & hb3 has taken values 10m,40m and 120m for the carrier frequency of 14501.65 MHz at the range of distances 0 to 30 Km as per various BTSs link distances.

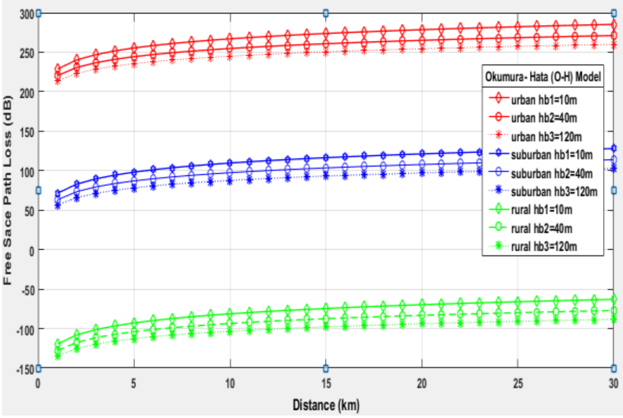


Fig. 3.7: Plot for free space path propagation loss- clutter analysis using O-H model for urban, suburban and remote area for 3G WCDMA signal condition rained Bahir Dar Lake tana basin.

IV. RESULT INTERPRETATION AND DISCUSSION

From all previous sections, we obtained many graphical results and noted the values in tabular forms. The cluster networks 1& 2 and intra-cluster network of microwave links of all six BTSs Lake Tana basin gives many results for RSCP. In this section, few results have been interpreted and discussed in brief manner. As per the cluster network 1 and 2 analysis, the cluster 1 has ahead of counts and E_C/N_0 with respect to the RSCP. The average of RSCP of nearly 4 to 5 dBm difference due to counts variations from the results of Table III and IV and respective Fig. 2.6 and 2.7. Also, the impact of RSCP in between -80dBm to -40dBm has confirming the good signal coverage of 3G WCDMA network for cluster network 1 and 2. Above and below these ranges noted that as bad coverage reception of signal. Even we saw in-depth of intra-cluster network that the RSCP or received signal power has obtained in the range of -35 dBm to -65dBm in the case of stochastical or random time of interval for all six BTSs. All these RSCP have received in different time and their given values in the Table VI.

The AR model has given major results that every time (second or minutes or random interval of time), the received power signal of every BTS depends on its preceding value of signal arrived to the BTSs. In the clear-sky condition case, the FSPL has very serious issues. As per FSPL results, the BTSs links; BTS5 to BTS6 has in difference of 5 dBm at distance 30Km, losses due to the variations in the free space path distance which has shown in Fig. 3.3. It has been confirmed that the path loss occurrence not only distances, mainly due to many atmospheric interferences apart from clear-sky conditions. From the Fig. 3.6(a) to (c), the Firis Transmission (FT) received power obtained from -25dBm to -43dBm which have been controlled one. In addition, it has been highly supported to validate the received power of FT while compared with actual received power in the range -35dBm to -60 dBm. FT model emphasis the difference in reception and highlights the importance of designing gain of the transmit and receive antenna, at the same time selection of dish antenna sizes for microwave transmission links among BTSs, antennas effective aperture and its efficiency or actually radiated power from antenna.

The O-H model has analyzed for the importance of geographical areas signal receiving conditions and coverage which depends on antenna heights without any free space interference /path loss. From the O-H model as per the Fig. 3.7 results that the FSPL severely affected from urban to sub urban and sub urban to remote areas with the difference of 50dB. As an average of 2dB difference has occurred for height of the antennas of mobile station and base station; hb_1, hb_2 and hb_3.

V. CONCLUSION AND FURTHER STUDY

This research has concentrated a complete study of microwave and Radio access link for 3G WCDMA network for the purpose of signal coverage, cost trade off of bandwidth and geographical areas signal reception issues among Lake Tana basin. Today, all business including tourism depends on high speed telecommunication network signal coverage and reception. Based on the above analysis and various results, it has been concluded that cluster network and signal measurements has very important in day-to-day to provide the 3G signal to all end users and tourists in consistent way among Lake Tana Basin. As per the result and inferences, the signal coverage and received signal (RSCP) fluctuation has been very high every minute and seconds. That is stochastically changing received signal normal climate condition itself. Most of the BTSs are not getting the signal reception due to the Line of sight, (LOS), directivity and receiving antenna gain, signal degradation due to path loss between BTS to BTS also very high even normal -clear sky condition.

Almost 20 % to 30 % of the signal has lost during the free space propagation clear-sky condition among the Lake Tana basin. Specifically, BTS3 and BTS4 have been located in the cutting edge of the Lake Tana and these BTSs highly affected the path loss and signal degradation from the results compared with sampled results of others BTSs in intra-cluster networks. These are the major losses and it has to be improved by signal coverage monitoring systems. Unless maintaining smooth signal coverage, reception, continuous signal monitoring system and minimizing the path loss interreference among BTSs in the cluster networks both in clear-sky and robust condition, which affects the revenue and cost trade off the economy for ETC and Amhara region culture and tourism revenue also.

From the conclusion of O-H model, it has been suggested that the path loss highly influenced by dish antenna height variations and also identified the path loss from urban to rural areas in-and-around Lake Tana. The O-H model path loss might be occurred due to the many interferences by constructing new tall building, trees and other atmospheric interference which disturb the height of the antennas and LOS of the dish antenna. In continuation of this partly second Phase2 research work, in future the microwave link based 3G WCDMA has been extend to study for robust (adaptive) climate and scintillation conditions from clear -sky condition. Additionally, it has to be compared with other broadband access including

FSO link performance analysis as a further study from the remaining part of Phase2 research work. Ultimately, all above 3G WCDMA network study extend to 4G and 5G WCDMA network for the betterment of Bahir Dar Lake Tana tourism cost trade off service along with ETC network performance and overall Amhara region / Ethiopian culture and tourism revenue point of view in future.

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