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Capacity Dimensioning and Network Planning of UMTS Network for Hawassa City

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Abstract — *There has been a demand for growth in wireless communication technology over the past decade. With an increase in subscribers and traffic, new bandwidth-consuming applications will place new demands on capacity. The answer to the capacity demand is the provision of a new spectrum, and the development of a technology UMTS is preferred among the others in Ethiopia.*
In this paper, a dimensioning of HSDPA network capacity is carried out for Hawassa city. The propagation modeling for capacity dimensioning was done after the link budget calculation and cell ranges calculations considering real environmental factors. Among various propagation models, the Okumura-Hata model has better signal strength than Cost Hatta and Others. Simulation is carried out using Atoll, and Based on these results, the optimized number of sites in an urban and suburban network of Hawassa is proposed.

Keywords — *UMTS, HSDPA, Okumura-Hata model.*

I. INTRODUCTION

The main aim of radio network planning is to provide a cost-effective solution for the radio network deployment in terms of coverage, capacity, and quality, such as estimating the optimum number of base stations and their location, determining the type of the antenna, the receiver or transmitter power and the environmental characteristics of the propagation environment [1].

The radio network planning process and design criteria vary from place to place depending upon the dominating factor, which could be capacity or coverage. Based on such criteria, the final target of planning, namely, defining deployment requirements and network design, can be achieved.

The RAN planning can be divided into different phases. Since the steps are mostly overlapping and can be done hand-in-hand, most pieces of literature had followed the planning assumptions of UMTS to be having three main steps.

- Initial phase: This includes a collection of pre-planning information and starting network dimensioning.
- Nominal and detailed planning: This planning phase includes the selection and use of a radio planning tool. This step involves propagation model tuning, defining thresholds, checking network capacity against more detailed traffic estimates.
- Optimization: This includes network performance analysis and analytical results, making decisions about some parameter settings. This process is repeated until achieved results are in an acceptable range.

When UMTS service deployment planning is done, several tasks need to be performed to achieve the optimum service performance in terms of coverage, capacity, and quality.

Information about final paper submission is available from the conference website.

II. DEMOGRAPHIC AND GEOGRAPHIC INFORMATION ABOUT DEPLOYMENT AREA

Hawassa city is located in southern Ethiopia with a 157.2 km^2 area. It is a seat for the SNNPR regional state and has a population number of 409,734 inhabitants with an annual average population growth rate of 4.02 based on the 2009 E.C national population and housing census. Starting from the year 2009 E.C, the city has been showing a dynamic change in its business, social, political, and economic activities. It has also been the visitor's choice since its being one of the main tourist destination places in the rift valley lake regions and near Addis Ababa. Considering the above-stated status of the city and its future, there must exist a wireless network to deliver next-generation broadband services effectively. However, the currently deployed GSM network lacks to cover all areas also and adequately its technology to support higher data rate, requiring an application.

In this paper, Hawassa is assumed to be a suburban region based on the population density, land area used, and the scale of existing infrastructure. Based on the total area of Hawassa, we determine the number of base stations needed for coverage. Demographic data include population number, density, and population growth in a particular area. Table 1. Presents the assumed key characteristics defining the demographics of Hawassa city. Although the data are taken from the census conducted in the year 2009, the estimated population growth rate quoted in the document allows us to make a sensible estimate of what the current demography might resemble.

Element	Amount
Population in the year 2009 E.C	409,734
The growth rate in the year 2009 E.C	4.02%
Expected population in the year 2014 E.C	491,681
Geographic area	157.2 km^2
Population density	2606 per km^2

Table 1: Demographic information about Hawassa city

III. COVERAGE PLANNING

Coverage Planning is the first step in the process of dimensioning. It estimates the resources needed to provide services in the deployment area with the given system parameters. Therefore, it assesses the resources needed to cover the area under consideration so that the transmitters and receivers can listen to each other. In achieving coverage in a certain region, several factors have to be considered, such as building heights, terrain, building densities, and so on. UMTS can be deployed for coverage without regard to capacity requirements. This means at the outset, the minimum number of base stations are deployed to provide ubiquitous coverage in a particular area.

Capacity is only increased whenever the need arises, and this can be done by adding more channels to the existing base stations assuming there is an available spectrum. This kind of technique is useful in situations where there are uncertainties about market requirements and, therefore, difficult to predict how the subscriber base will evolve, as the case with Hawassa city.

Network coverage is calculated based on the path-loss data between the base stations and users and using antenna configuration parameters such as antenna type, power, radiation characteristics, tilt, and azimuth.

IV. PATH LOSS MODEL SELECTION

The selection of a suitable radio propagation model for UMTS is of great importance. A radio propagation model describes the signal's behavior while it is transmitted from the transmitter towards the receiver. It gives a relation between the distance of transmitter & receiver and the path loss. From this relation, one can get an idea about the allowed path loss and the maximum cell range.

For the numerical simulation (and others that follow), Hawassa assumed a suburban environment area. Other assumptions include an average building-to-building distance of 50 m, street width 35m (width of most two-way streets), street orientation angle 30 degrees. Average building height is assumed as 10 m (most buildings in Hawassa are 2 to 3 stories high), base station height 30 m, carrier frequency 2.1 GHz.

From the above assumption, the maximum path loss is obtained in the Okumura-Hata propagation model. From a planning perspective, it is better to assume worst-case scenarios to avoid risking inadequate coverage. Hence, the Okumura-Hata model has been chosen in this work to develop the radio network-planning tool.

V. CELL RANGE ESTIMATION

The maximum cell radius of the NodeB can be determined based on the selected propagation model (Okumura-Hata) and using the maximum allowable path loss (MAPL) obtained from link budget calculation.

The resulting MAPL for a mobile handheld device would equate to 129.31 dB in the uplink and 141.47 dB in the downlink (using the Okumura-Hata model). For the value of the MAPL of the U.L. cases (since the range is limited by the uplink transmission rather than the downlink due to constraints on power and the antenna gain of U.E.s), it is possible to predict the coverage range using the Okumura-Hata propagation model. Assuming a base station antenna height of 30 meters and a mobile station height of 1.5 meters, on average, a cell radius of a single NodeB will approximately equate to 1.46 km.

VI. DETERMINING THE NUMBER OF NODE BS

The **UMTS** base station (Node BS) connects the core service network to the end-user equipment (U.E.s), and therefore it is an important metric in determining the coverage of the network and end-user experience.

Based on the cell radius, we can determine the coverage area of NodeB, and then it will lead to determining the total number of Node BS require to cover a particular region in a given metropolitan area.

For this work, tri-sector cells in a single base station are considered to provide precise coverage for the selected regions about the deployment. The coverage area, A_{cell}, of the tri-sector NodeB is determined using the following formula:

$A_{cell}=0.65d^2$

Where A_{cell}- Maximum area covered by a single base station and d – Diameter of a single cell.

The number of NodeBs required to cover an area of 157.2 square kilometers will be approximately 12;

therefore, with this number of NodeBs, the Hawassa city gets optimized network coverage.

VII. LINK BUDGET CALCULATION

A link budget accounts for all the gains and losses from the transmitter, through the medium, to the receiver in a telecommunication system.

Link budget calculation is used to determine the maximum allowable path loss (MAPL). MAPL is the link margin we get when we subtract all the loss parameters from the sum of our gain parameters. The path loss at any given point in our intended coverage area needs to be less than or equal to this link margin.

Parameters	**Downlink**	**Uplink**	**Notes**
Max. Transmit power	43 dBm	25 dBm	a
Transmit antenna gain	20 dBi	0 dBi	b
Transmitter losses	0.9 dB	2 dB	c
EIRP	62.1dBm	23 dBm	d=(a+b-c)
Channel bandwidth	10 MHz	10MHz	e
Receiver antenna gain	0 dBi	20 dBi	f
Receiver losses	2 dB	0.9 dB	g
Receiver noise figure	7 dB	2 dB	h
Thermal noise	-104.44 dBm	-109.9 dBm	i=kTB
Required SINR	-5.23 dB	0.9 dB	j
Receiver sensitivity	-102.66 dBm	-107 dBm	k=(h+i+j)
Penetration loss	12dB	12dB	l
Slow fade and Interference margin	9.9 dB	7.7 dB	m
Max. Path loss	141.47 dB	129.31 dB	n=(d+f-g-k-lm)

Table 2: Link budget obtained from the point analysis tool

VIII. SIMULATION RESULTS AND ANALYSIS

In this paper, Atoll was chosen as a simulation environment for its in-depth input analysis, flexible working environment, and since the outcome of this work is expected to be a source for practical deployment.

A. Designing UMTS Network using Atoll Software

We can create an Atoll document from a template with no base stations or a database with an existing set of base stations. In Atoll, a site is defined as a geographical point where one or more transmitters are located. Once we have created a site, we can add transmitters. A transmitter is defined as the antenna and any additional equipment. The process of environmental loading is to identify the different environmental factors that directly or indirectly affect the radio network planning process and as well to list out them as planning parameters. As this work is a case study, Hawassa city was an interesting region for deployment.

The digital map shown in Figure 1 has been used for radio network coverage planning in this stage. These maps consisted of Hawassa Lake, main road, secondary road, street, and swap areas.

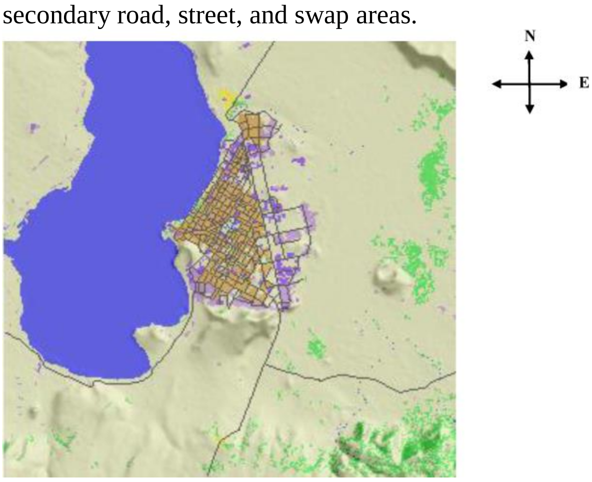


Figure 1: Hawassa city and surrounding areas Digital Map screenshot from the map window

B. Coverage Prediction

Atoll allows us to make various coverage predictions, such as signal level, signal quality coverage predictions. The results of calculating coverage predictions can be displayed, compared, and studied on the map. Atoll enables you to model network traffic by creating services, users, user profiles, traffic environments, and terminals. This data can then be used to make coverage predictions that depend on network load, service area, radio bearer, and throughput coverage predictions. Initially, to cover the whole Hawassa city Node, BS was placed as shown in Figure 2.

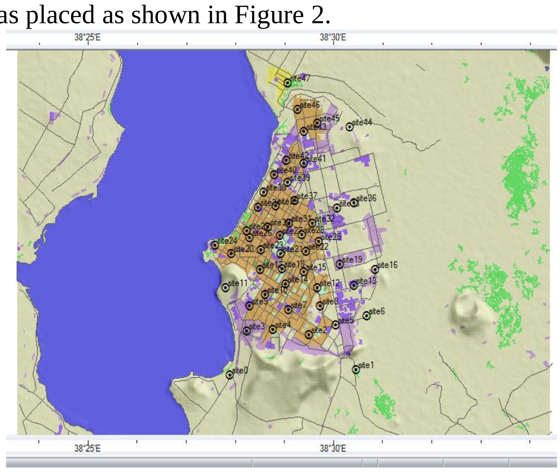


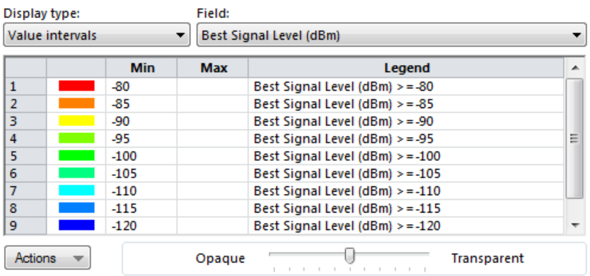
Figure 2: NodeBs (Sites) Placed on Hawassa city digital map

1. Coverage prediction by the best signal level

After placing the NodeBs, coverage prediction was done that helped to justify the placement of NodeBs.

A signal level coverage prediction displays the best servers' signal level for each pixel of the area studied. For a transmitter with more than one cell, the signal level is calculated from the cell with the highest reference signal power.

A separate table shows the simulation properties for each of the simulated traffic maps. Legends show each of them with different colors.



Display type: Value intervals

Field: Best Signal Level (dBm)

		Min	Max	Legend
1		-80		Best Signal Level (dBm) >=-80
2		-85		Best Signal Level (dBm) >=-85
3		-90		Best Signal Level (dBm) >=-90
4		-95		Best Signal Level (dBm) >=-95
5		-100		Best Signal Level (dBm) >=-100
6		-105		Best Signal Level (dBm) >=-105
7		-110		Best Signal Level (dBm) >=-110
8		-115		Best Signal Level (dBm) >=-115
9		-120		Best Signal Level (dBm) >=-120

Figure 3. Prediction properties for best signal level with different colors.

2. Coverage predictions by the signal level

Different colors indicate each base station (site) according to the received signal level measured in dBm.

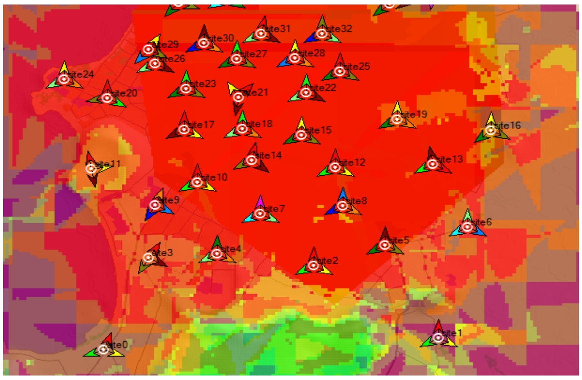


Figure 4: Coverage Prediction by Signal Level

3. Coverage prediction statically choosing a focus zone

The coverage prediction statically choosing a focus zone on the map window where there exist more clutters.

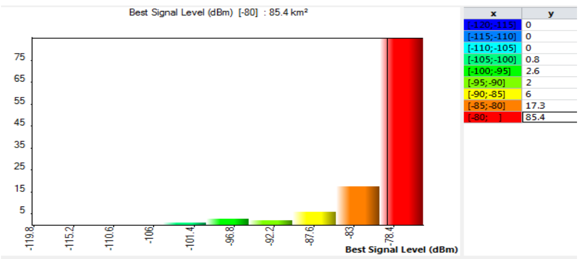


Figure 5. Coverage statics of areas where mean individual clutters

4. Coverage Prediction by Transmitter

A coverage prediction by transmitter allows us to predict coverage zones by the transmitter at each pixel. So we can base the coverage on the signal level, path loss, or total losses within a defined range. For coverage from different transmitters with more than one cell, the coverage is calculated from the cell with the highest power.

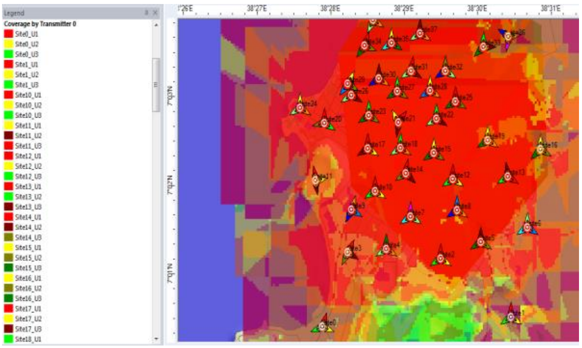


Fig 6. Coverage prediction by the transmitter

C. Performance Analysis of Planned Network

Using the point analysis tool of Atoll; Site_2 was chosen from the Hawassa map and a receiver to analyze the predicted signal level, and connection status of both uplink and downlink traffics. The point analysis results appeared as shown in Figure 7 (a-e), which states the performance results in the chosen location of the receiver.

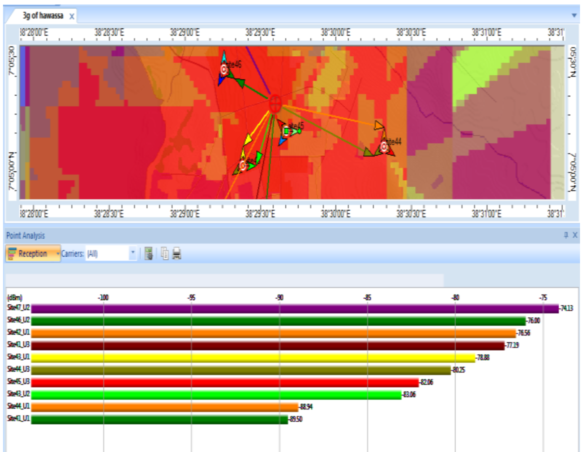


Figure 7 (a) point of a receiver for Site_2

Figure 7 (a) shows us the point of a receiver selected as a place where more blockage from buildings exists; it is also shown on the digital map that the area is dense collective clutter, meaning clutter density is higher than other places and the best point to perform performance analysis.

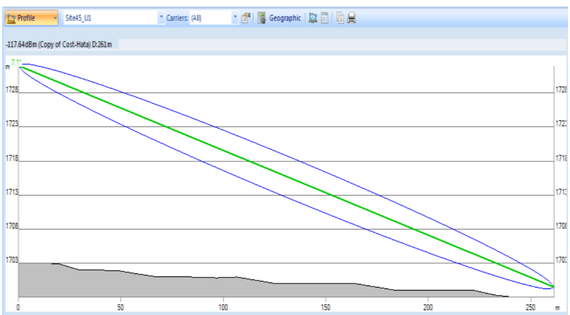
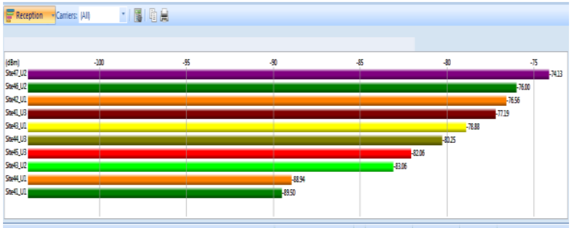


Figure 7 (b) geographic profile of the transmitter Site_2

Figure 7 (b) on the next page shows the geographic profile of the transmitter Site_2 and the altitude

versus receiver-transmitter distance. A blue ellipsoid indicates the Fresnel zone between the transmitter and the receiver, with a green line indicating the line of sight (LOS), and also the angle of the LOS read from the vertical antenna pattern is displayed.
Figure 7 (c) below shows the reception level, including the adjacent transmitters.



The figure 7 (c), the reception level

The predicted reference signal level from different transmitters is reported in the reception tab in a bar chart, from the highest predicted signal level on the top (Site_2) to the lowest one on the bottom (Site_1). Each bar is displayed in the color of the transmitter it represents.

Similarly, Figure 7 (d) and Figure 7 (e) also gives the reception signal analysis involving PDSCH, Downlink parameters of the adjacent sites.

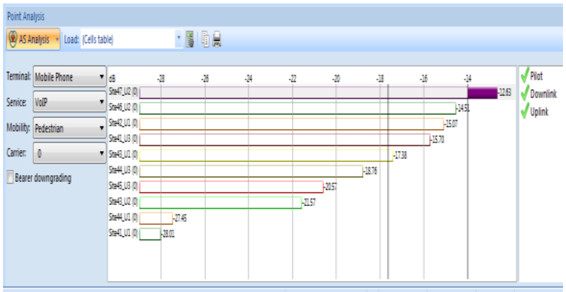
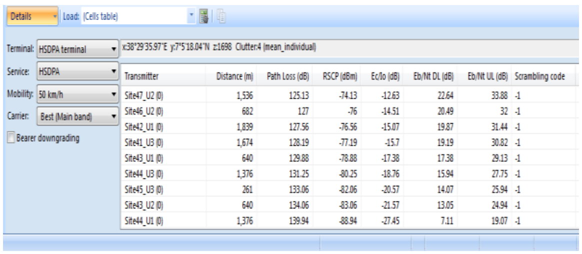


Figure 7 (d) Reception signal analysis involving PDSCH



Details | Load: (Cells table)

Terminal: HSDPA terminal | Service: HSDPA | Mobility: 50 km/h | Carrier: Best (Main band) | Bearer downgrading

x:38°29'35.97"E y:7°5'18.04"N z:1698 Clutter:4 (mean_individual)

Transmitter	Distance (m)	Path Loss (dB)	RSCP (dBm)	Ec/Io (dB)	Eb/Nt DL (dB)	Eb/Nt UL (dB)	Scrambling code
Site47_U2 (0)	1,536	125.13	-74.13	-12.63	22.64	33.88	-1
Site46_U2 (0)	682	127	-76	-14.51	20.49	32	-1
Site42_U1 (0)	1,839	127.56	-76.56	-15.07	19.87	31.44	-1
Site41_U3 (0)	1,674	128.19	-77.19	-15.7	19.19	30.82	-1
Site43_U1 (0)	640	129.88	-78.88	-17.38	17.38	29.13	-1
Site44_U3 (0)	1,376	131.25	-80.25	-18.76	15.94	27.75	-1
Site45_U3 (0)	261	133.06	-82.06	-20.57	14.07	25.94	-1
Site43_U2 (0)	640	134.06	-83.06	-21.57	13.05	24.94	-1
Site44_U1 (0)	1,376	139.94	-88.94	-27.45	7.11	19.07	-1

Figure 7 (e) signal level result list at the receiver

Figure 7 (e) also shows Details tab provides the signal level result list at the receiver by taking the comparatively better transmitters into account. So, from our receiver location, the signal level sensed from transmitter Site_2 is comparatively best, followed by Site_3 transmitter.

Analyzing the coverage prediction results with the placed NodeB concerning calculated values in section-VI, it is quite evident that the planned network provides reasonable coverage.
What is more, evaluation of the traffic map after simulation clarifies that subscribers mostly remain connected at both U.L. and DL, which also indicates a very positive sign for the planned network. Performance analysis with a point analysis tool strengthens the base behind the planned network as an effective one.

X. CONCLUSION

In this work, a dimensioning of HSDPA network capacity is carried out for Hawassa city. The propagation modeling for capacity dimensioning was done after the link budget and cell range calculations considering real environmental factors. Performance analysis of various propagation models is carried out using Atoll, and the Okumura Hata model has the best signal strength than Cost Hata and Others. Based on these results, the optimized number of sites for an urban and Suburban network of Hawassa is proposed. It is suggested that from the total area of Hawassa 157 square kilometers, Urban 48.22 square kilometers, and suburban 109.78square kilometers of Hawass, 26 Sites and 22 sites are required to provide seamless coverage and capacity of the HSDPA network.

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