# Analysis of Cell Planning and Link Budgeting in WiMAX Communication

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**Abstract**

This thesis is related with the WiMAX (Worldwide Interoperatibility for Microwave Access) technology. Today, different types of cellular networks are actively working on the radio links. For instance, the Global System for Mobile Communication (GSM) is being used in nearly all of the countries of the world and currently it has around three billion users all over the world. Universal Mobile Telecommunication System (UMTS) is currently deployed in many countries and it is providing increased data rates, coverage and mobility as compared to GSM. Wireless Local Area Networks (WLAN) are very famous when we have a small area and none real time services. Worldwide Interoperability for Microwave Access (WiMAX) is a new technology and it is in deployment phase. In all these cellular technologies, we have very limited resources and we have to make best use of them by proper management. Radio Resource Management (RRM) is a control mechanism for the overall system which is being used to manage radio resources in the air interface inside a cellular network. The main objective is to utilize the available spectral resources as efficiently as possible. Our aim is to use them in the best possible way to maximize the performance and spectral efficiency in such a way that we have maximum number of users in our network and Quality of Service (QoS) is up to the mark. In a cellular communication system, a service area or a geographical region is divided into a number of cells and each cell is served by an infrastructure element called the base station which works through a radio interface. The frequency license fees, real estate, distribution network and maintenance are the issues which dominates the cost for deploying a cellular network. In RRM, we control parameters like Radio Frequency (RF) planning, link budgeting, modulation schemes, channel access schemes etc. RF planning includes cell planning, coverage of the network and capacity of the network. Our main focus in this thesis will be on cell planning and link budgeting and we will discuss them in context of a WiMAX network.

***Keywords:*** *WiMAX, Link Budget, Cell Planning, Patch Loss*

## 1. Introduction

Most of the communication networks used today are wireless in nature. WiMAX or Wireless MAN is a 4G technology but some organizations refer it as a 3G technology [1,4]. This paper, discuss Radio

Resource Management (RRM) which is very important in cellular networks. In cellular networks the available resources are very limited and have to be utilizing them in the best possible manner. There should be an optimized solution to utilize the spectral efficiency. This will increase the overall coverage, capacity and QoS of the network [5]. The main objective of radio resource management is to maximize the number of users in the network and minimize the cost of the network while the QoS should be there as well. In RRM, control parameters like radio frequency planning, cell planning, link budgeting, modulation schemes, channel access schemes etc are used. RRM involves techniques and algorithms for controlling parameters which are as follows:

- Frequency Band Allocation
- Cell Planning
- Link Budget
- Call Admission Control
- Modulation Schemes
- Multiple Access Scheme

## 2. Signal availability test using Link Budget Calculator

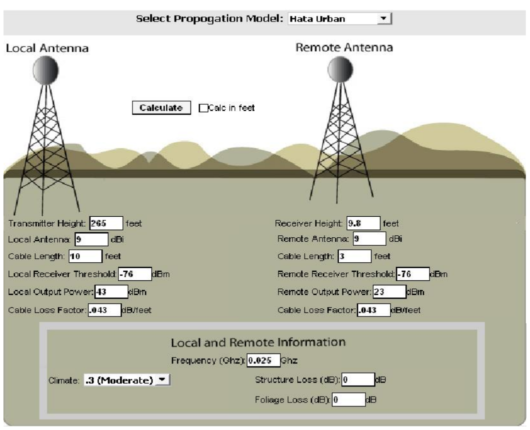


Figure 1: Link budget calculator

Table 1: Signal availability test output

| Miles | Kilometers | Path Loss | Upstream Signal Level | UpStream Fade Margin | Availabilty | Downstream Signal Level | Downstream Fade Margin |
|---|---|---|---|---|---|---|---|
| 0.5 | 0.805 | 75.59 | -35.15 | 40.85 | 100.000% | -15.15 | 60.85 |
| 1 | 1.609 | 85.33 | -44.89 | 31.11 | 100.000% | -24.89 | 51.11 |
| 1.5 | 2.414 | 91.04 | -50.6 | 25.40 | 100.000% | -30.6 | 45.40 |
| 2 | 3.218 | 95.09 | -54.65 | 21.35 | 100.000% | -34.65 | 41.35 |
| 2.5 | 4.023 | 98.23 | -57.79 | 18.21 | 100.000% | -37.79 | 38.21 |
| 3 | 4.827 | 100.80 | -60.36 | 15.64 | 100.000% | -40.36 | 35.64 |
| 3.5 | 5.632 | 102.97 | -62.53 | 13.47 | 100.000% | -42.53 | 33.47 |
| 4 | 6.436 | 104.85 | -64.4 | 11.60 | 100.000% | -44.4 | 31.60 |
| 4.5 | 7.241 | 106.50 | -66.06 | 9.94 | 100.000% | -46.06 | 29.94 |
| 5 | 8.045 | 107.99 | -67.54 | 8.46 | 100.000% | -47.54 | 28.46 |
| 5.5 | 8.849 | 109.33 | -68.89 | 7.11 | 100.000% | -48.89 | 27.11 |
| 6 | 9.654 | 110.55 | -70.11 | 5.89 | 99.999% | -50.11 | 25.89 |
| 6.5 | 10.459 | 111.68 | -71.24 | 4.76 | 99.999% | -51.24 | 24.76 |
| 7 | 11.263 | 112.72 | -72.28 | 3.72 | 99.998% | -52.28 | 23.72 |
| 7.5 | 12.067 | 113.69 | -73.25 | 2.75 | 99.997% | -53.25 | 22.75 |
| 8 | 12.872 | 114.60 | -74.16 | 1.84 | 99.996% | -54.16 | 21.84 |
| 8.5 | 13.677 | 115.45 | -75.01 | 0.99 | 99.995% | -55.01 | 20.99 |
| 9 | 14.481 | 116.26 | -75.82 | 0.18 | 99.992% | -55.82 | 20.18 |
| 9.5 | 15.285 | 117.02 | -76.58 | -0.58 | 99.992% | -56.58 | 19.42 |
| 10 | 16.090 | 117.74 | -77.3 | -1.3 | 99.992% | -57.3 | 18.70 |

## 3. Link Budget

Link budget is the calculation of the received level of the signal strength by calculating all the gains and losses from the transmitted signal [2]. These gains and losses are introduced in the channel due to air interface, connecting cables etc. Building a MATLAB program which can be used to predict and analyze the effects of different losses on the received signal. In Figure 2, the flow chart of the process is depicted.

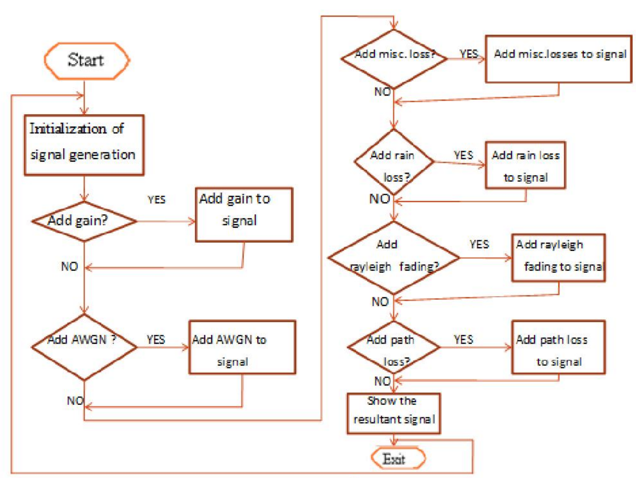


Figure 2: Flow chart for Link Budget

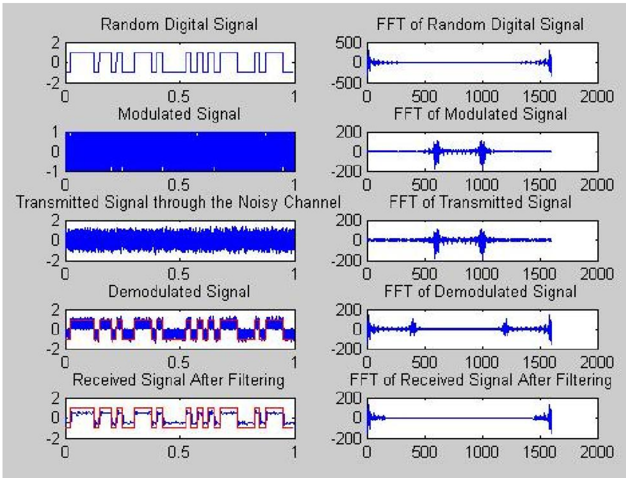


Figure 3: Output signals for link budget analysis using MATLAB program (given below)

## 4. Okumura Model

Okumura model is one of the most commonly used models [1]. It can be used for frequencies up to 3000 MHz. The distance between transmitter and receiver can be around 100 km while the receiver height can be 3 m to 10 m. The path loss in Okumura model can be calculated as

$$PL(dB) = L_f + A_{m,n}(f,d) - G(h_{te}) - G(h_{re}) - G_{AREA} \quad \textbf{(1)}$$

Here $L_f$ is the free space path loss

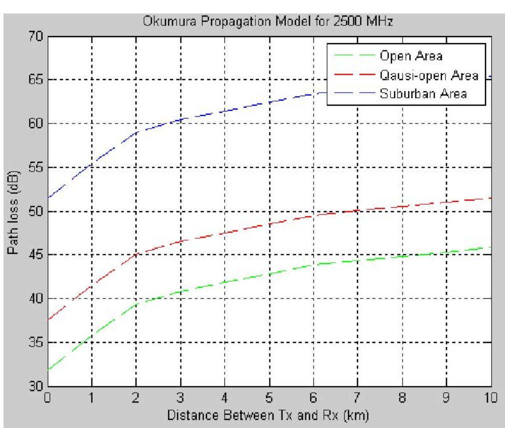


Figure 4: Path loss given by Okumura model using MATLAB.

## 5. SUI Model

This propagation model has three different types of terrains or areas [4]. These are called as terrain A, B and C. Terrain A represents an area with highest path loss, it can be a very dense populated region while terrain B represents an area with moderate path loss, it can be a suburban environment. Terrain C has the least path loss which describes a rural or flat area. In Table 2, these different terrains and different factors used in SUI model are described.

Table 2: Different terrains and parameters

| Parameters | Terrain A | Terrain B | Terrain C |
|---|---|---|---|
| a(1/m) | 4.6 | 4 | 3.6 |
| b(1/m) | 0.0075 | 0.0065 | 0.005 |
| c(1/m) | 12.6 | 17.1 | 20 |

The path loss in SUI model can be described as

$$PL = A + 10\gamma \log_{10}\left(\frac{d}{d_o}\right) + X_f + X_h + S \quad (2)$$

Where

PL = Path Loss in dB

d = distance between the transmitter and receiver

$d_o$ = 100m used as a reference

$X_f$ = Correction factor for frequency

$X_h$ = Correction factor for BS height

S = Shadowing

$\gamma$ = Path loss component

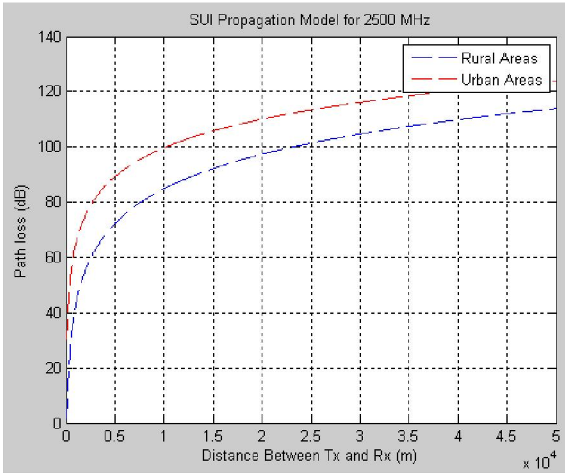


Figure 5: Path loss given by SUI propagation model for 2500 MHz using MATLAB

## 6. Ericsson Model

This model is implemented by Ericsson as an extension of the Hata model. Using this model, parameters can be adjusted according to the given scenario. The path loss as evaluated by this model is described as

$$PL = a_o + a_1 \log_{10}(d) + a_2 \log_{10}(h_b) + a_3 \log_{10}(h_b) \log_{10}(d) - 3.2(\log_{10}(11.75 h_r))^2 + g(f)$$

Where

$$g(f) = 44.49(\log_{10}(f)) - 4.78(\log_{10}(f))^2$$

The values of $a_o$, $a_1$, $a_2$ and $a_3$ are constant but they can be changed according to the scenario (environment). The values which is used in the calculations are $a_o$ = 36.2, $a_1$ =30.2, $a_2$ =12.0 and $a_3$ =0.1. These are the defaults values given by the Ericsson model. The parameter f represents the frequency which is 2500 and 3500 MHz. The base station and receiver heights are same as used earlier.

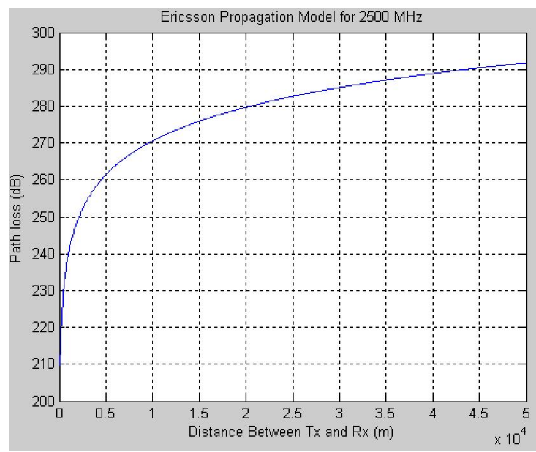


Figure 6: Path loss given by Ericsson propagation model for 2500 MHz using MATLAB.

## 7. Comparison among different propagation models

Table 3: Propagation models and their path loss for 1 km [11]

| Propagation Model | Terrain | Frequency Band (MHZ) | Transmitter Power (dBm) | Path Loss (dB) | Receiver Power (dBm) |
|---|---|---|---|---|---|
| SUI | Urban | 2500 | 43 | 100 | 23 |
| SUI | Rural | 2500 | 43 | 82 | 23 |
| SUI | Urban | 3500 | 43 | 48 | 23 |
| SUI | Rural | 3500 | 43 | 32 | 23 |
| Ericsson | Urban | 2500 | 43 | 270 | 23 |
| Ericsson | Urban | 3500 | 43 | 272 | 23 |
| Okumura | Open | 2500 | 43 | 36 | 23 |
| Okumura | Qausi-open | 2500 | 43 | 42 | 23 |
| Okumura | Suburb-an | 2500 | 43 | 55 | 23 |

## 8. Nominal Cell Site

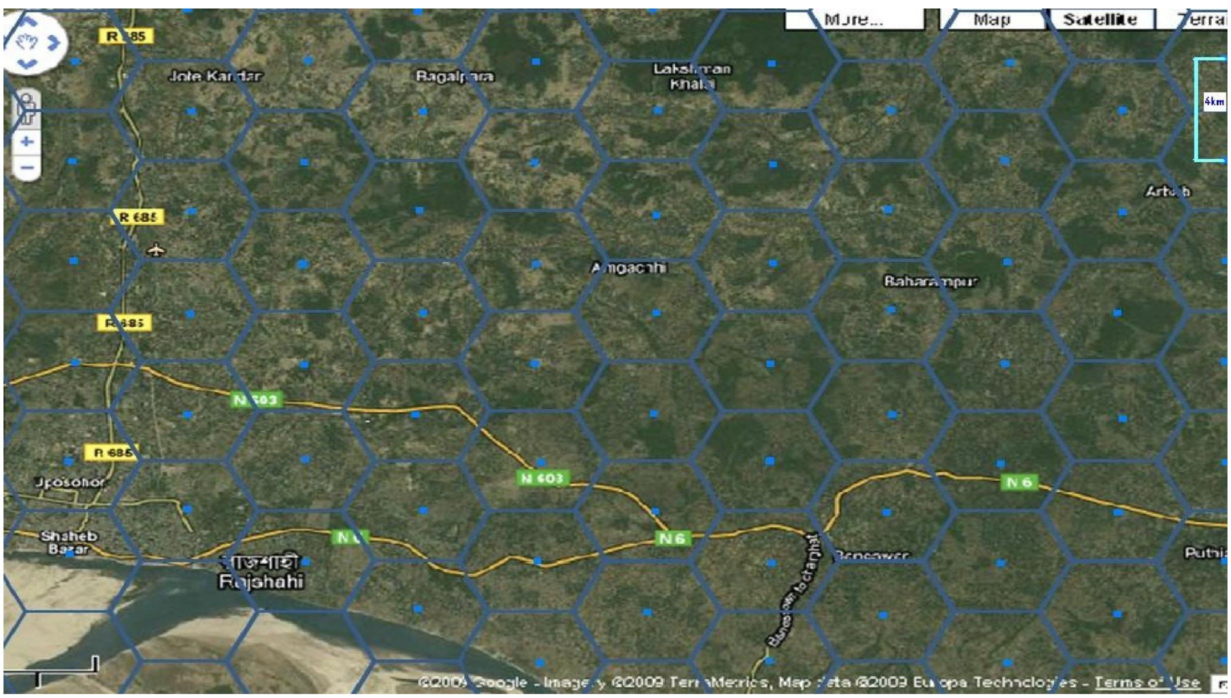


Figure 7: Design of nominal cell planning of Rajshahi city using Google Earth view

## 9. MATLAB program for link budget analysis in communication network.

```
clc
clear
n=40;   %Number of Random Number
SNR=15;
dt=1e-4;
Fs=1/dt;
fc=1000;
T=1;
t=(dt:1/(n*n):T)';
Nt=length(t);
r=randint(n,1);  % Random Sigmal
for i=1:n
   if r(i)==0
       r(i)=-1;
   end
end
m=kron(r,ones(n,1));   %Message Signal
subplot(5,2,1)
plot(t,m)
axis([0 1 -2 2])
title('Random Digital Signal')
subplot(5,2,2)
plot(real(fft2(m)))
title('FFT of Random Digital Signal')
Ac=1;
cs=Ac*sin(2*pi*fc*t);   %Carrier Signal
ms=m.*cs;       %Modulated Signal
subplot(5,2,3)
plot(t,ms)
title('Modulated Signal')
subplot(5,2,4)
plot(real(fft2(ms)))
title('FFT of Modulated Signal')
An=Ac/sqrt(2*SNR);
ns=An*randn(Nt,1);     %Noise Signal
 ts=ms+ns;      %Transmitted Signal With noise
subplot(5,2,5)
plot(t,ts)
title('Transmitted Signal through the Noisy Channel')
subplot(5,2,6)
plot(real(fft2(ts)))
title('FFT of Transmitted Signal')
dms=ts.*cs;     %Demodulated Signal
subplot(5,2,7)
plot(t,dms,t,m,'r')
title('Demodulated Signal')
```

```
subplot(5,2,8)

plot(real(fft2(dms)))

title('FFT of Demodulated Signal')

 Fc=1000;

order=5;

Fdig=Fc/(Fs/2);

[bb,aa]=butter(order,Fdig);

rs=filter(bb,aa,dms);

 rs=rs-mean(rs);   %Received Signal after
Butterworth Filtering

subplot(5,2,9)

plot(t,rs,t,m,'r')

axis([0 1 -2 2])

title('Received Signal After Filtering')

subplot(5,2,10)

plot(real(fft2(rs)))

title('FFT of Received Signal After Filtering')
```

## 10. Conclusion

A good management of radio resources can be achieve by suggesting and implementing an optimal solution for any of the above mentioned factors. For instance in a WiMAX network, OFDM is used as a transmission technique with BPSK, QPSK, 16- QAM and 64-QAM as modulation techniques in a particular cell depending upon the SNR. Similarly, propagation model with less path loss can be selected. The simulation results which have been shown above compared with different propagation models for a WiMAX network. On the basis of these numerical results, it can suggest that the SUI model has less path loss as compared to other models. In nominal cell planning, a map of a hexagonal cell structure over the geographical map of any location can be performed. The total number of base stations and their exact locations can be specified by nominal cell planning. The main factors that influence the capacity of the network are available frequency band, cell size, frequency reuse factor etc. In order to increase the capacity of the system, size of the cells is required to be adjusted. Hence, reducing the size of cells helps in the adjustment of the frequency reuse factor.

## 11. Future Works

The simulated propagation model results can be tested and verified in practical environment. Further study can also be made for a more suitable and optimal propagation model. Also it would be possible to develop a software or tool dedicated for cell planning in WiMAX by using the propagation models described in simulations. Traffic capacity and coverage features can also be added in that tool

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