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Performance Analysis of Fixed WiMAX in Metropolitan Area

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Abstract

Fixed WiMAX is being deployed worldwide, and the networks are increasing in size. Measurements have been performed, but the amount of measurements are few and do therefore not demonstrate performance in a real life deployment. We have performed analyses of the physical performance in a fixed WiMAX deployment. The analysis presented in this paper focus on received signal strength and signals to noise ratio.

Keywords*:* Fixed WiMAX, Physical Analysis, RSSI, SNR, NMS.

Introduction

Broadband wireless is a technology that promises high-speed (minimally, several hundred kilo bits per second) data transmissions occurring within an infrastructure of more or less fixed points, including both stationary subscriber terminals and service provider base stations, which themselves constitute the hubs of the network [1].

Worldwide Interoperability for Microwave Access **(**WiMAX) is a broadband wireless access system which offers high throughput, great coverage, flexible Quality of Service (QoS) support and extensive security. WiMAX is certified by the WiMAX forum [2], which is a certification mark based on the IEEE 802.16 standard [3, 4] that pass conformity and interoperability tests. Two major way of accessibility is offered by WiMAX standard namely Fixed WiMAX (802.16d) and Mobile WiMAX (802.16e). Fixed WiMAX delivers point to multipoint broadband wireless access to our homes and offices. WiMAX forum promises to offer high data rate over large areas to a large number of users where broadband is unavailable [5].The forum describes WiMAX as "a standards-based technology enabling the delivery of last mile wireless broadband access as an alternative to cable and DSL".

The system studied here is a fixed WiMAX system. It uses an air interface based on orthogonal frequency division multiplexing (OFDM), which is very robust against multi-path propagation and frequency selective fading. An adaptive modulation technique is used to enhance performance when the link characteristics vary. Our system used Frequency Division Duplexing (FDD), where the Base Stations (BSs) and the user terminals transmit in different frequency bands. The MAC layer is connection oriented and uses Time Division Multiplexing (TDM) for the downlink (DL) and a Time Division Multiple Access (TDMA) scheme for the uplink (UL). This reflects the Point to Multipoint (PMP) architecture.

Background Study

Most people these days access the Internet by using wired broadband access, usually DSL, cable modem or a leased line in Bangladesh. Some are lucky enough to use WiFi access, at home or in restaurants, hotels, coffee shops and libraries with WiFi hot spots.[7] If there is no chance of finding or affording a broadband access provider, people usually use dial-up, although it is considered a technology of the past. However, there are problems with each of these technologies. Generally, broadband access isn't available in all areas and if it is, it can also be quite expensive. The alternative, WiFi, has limited coverage and people have to move from one hot spot to another to use the service. But the new technology, WiMAX solves all these problems. It is wireless, which makes it cheap and easy to implement in suburban and rural areas and also it reaches the high speeds that broadband wired technologies are capable of. On top of that, WiMAX gives a broader coverage, similar to that of cell phone networks. With all these advantages, WiMAX might easily replace some of the wireless and wired technologies in use today [8]. Qubee launched wireless broadband Internet services for residential and business customers in Dhaka in October 2009. Initially, the Qubee service is available for businesses and residential customers in Gulshan, Banani, Baridhara, Mirpur and Uttara. Qubee will be available across Bangladesh soon [9]. Fixed WiMAX technology started its journey with Qubee and then BanglaLion Communication Ltd. in Bangladesh. BanglaLion Communications Ltd has the largest coverage in Bangladesh [10]. It is the largest 4G Wireless Broadband service provider of Bangladesh in terms of coverage, subscriber number and revenue. It operates a wireless 4G mobile data network at 2.6 GHz frequency based on IEEE 802.16e standard of ITU. The aim of the paper is to study the physical parameters mainly RSSI and SNR, to evaluate the performance of fixed WiMAX in Dhaka metropolitan area.

Evolution of WiMAX

WiMAX technology has been developed in four stages [4]:

- Narrowband wireless local-loop systems.
- First-generation line-of-sight (LOS) broadband systems.
- Second-generation non-line-of-sight (NLOS) broadband systems.
- Standards-based broadband wireless systems.

This high-speed wireless broadband technology promises to open new, economically viable market opportunities for operators, wireless Internet service providers and equipment manufacturers. The flexibility of wireless technology, combined with high throughput, scalability and long-range features of the IEEE 802.16 standard helps to fill the broadband coverage gaps and reach millions of new residential and business customers worldwide [1].

We decided to extract the most important parameters from the system, which are Received Signal Strength Indication (RSSI) and Signal to Noise Ratio (SNR), over which extensive analysis was performed. GPS coordinates were also available for each of the subscribers, which gave us the possibility to choose a Path Loss model with great precision due to the large amount of measurement points. The measurements will be affected by possible co-channel Interference (CCI) by the adjacent Base Stations, which can be solved by analyses of the linear definition of SNR and RSSI [6].

System description

The system in use is a fixed WiMAX system operating in the 3.5 GHz frequency band. We have considered three Base Stations where Subscriber Units (SU) are operative. The system utilizes FDD with 3.5 MHz channels in both uplink and downlink. Each BS sector has a 120° beamwidth, and required frequencies are available for use. Each BS is configured to transmit at a 24 dBm maximum where the BS antenna gain is 15 dBi.

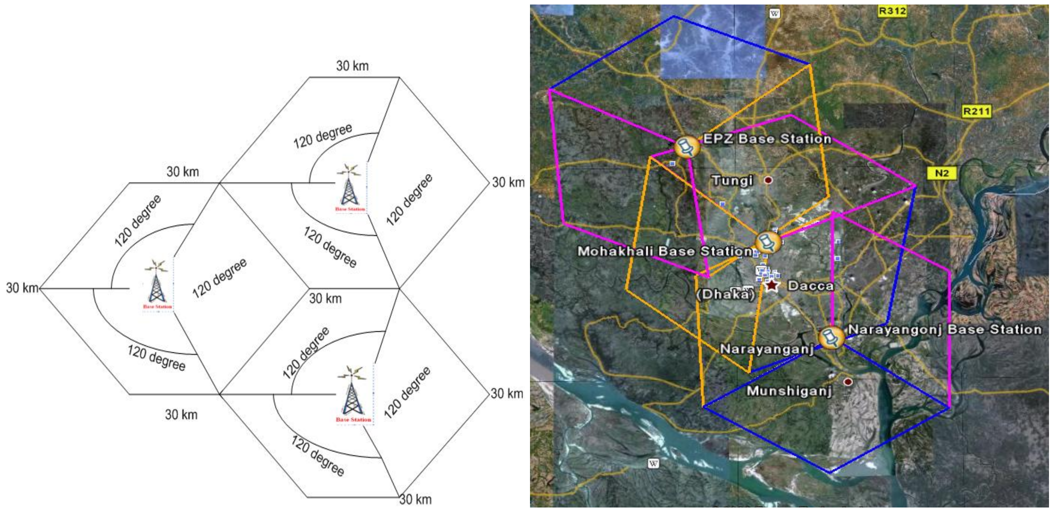
The SUs are fixed antennas, which are located outdoor at the house wall or roof. Automatic Transmission Power Control (ATPC) is enabled at all the SUs where the maximum transmitted power is 20 dBm. SU antenna gain is 15 dBi. If possible, the SU is setup within Line of Sight (LOS) to the BS, but there are also SUs with Non Line of Sight (NLOS) conditions. The NLOS sites are mostly present in areas close to the BS, whereas LOS becomes more common and also more important at farther distances [6].

To deploy this fixed WiMAX system Dhaka Metropolitan Area has been chosen. It is one of the most highly dense populated cities in the globe. To study the performance of the system we maintain the following consideration:

- Used frequency**:** 3.5 GHz
- Number of Base Stations**:** 3
- Sector in each base station: 3 (Each sector cover 120 degree)
- Name of the Base Stations**:**
    - Mohakhali Base Station
    - EPZ Base Station
    - Narayangonj base Station

Clients Information:

Client B (Located in Uttora) under Mohakhali Base Station and Client C (Located in Motijheel) under Narayangonj base station.



(a) (b)

Figure 1: (a) Theoretically Three Base Stations, (b) Practically Three base Stations

Practically three base Stations

The following figure shows a clear view of frequency pattern, cell coverage area of three base stations. An observation drawn from the above figure is that the three base stations coverage area is overlapping with each other. Here Base 1, Sector 2 use frequency F2 and Base 2 Sector 2 also use frequency F2 and this apparently seems to a problem. But actually that is not a problem.

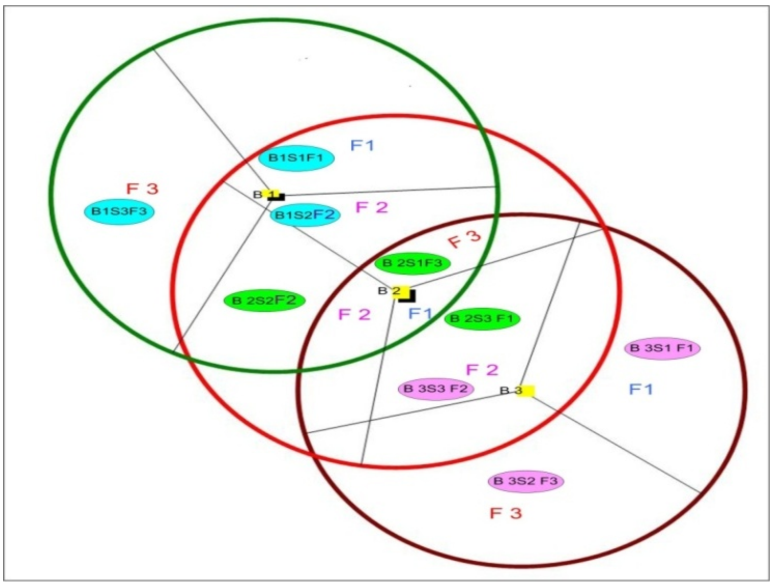


Figure 2: Clear view of Practically Three Base Stations

This phenomenon is also observed in the other coverage maps, and confirms the great LOS coverage of WiMAX. Thus NLOS conditions are more commonly experienced by SUs located close to the BS, while LOS conditions are most frequent for SUs farther away from the BS. A reason for this is that high buildings inside cities interfere with the signal path between BS and SU, and that the BSs are often located near or within cities. SUs located at farther distances from the BSs require LOS for optimal performance.

Physical Parameters for Client B & C

The following table 1 represents required parameters considered for the deployment of fixed WiMAX system. Client locations or the position of subscriber unit and the distance from the adjacent base stations is taken from GPS system. The antenna height is also calculated for the specific locations considering the effect of earth bulge.

Table 1: Physical Parameters for Fixed WiMAX

Client Name	**Client B or SU (B)**	**Client C or SU (C)**
Client Location (GPS Value)	Latitude: 23°47'13.84"N Longitude: 90°23'53.02"E	Latitude: 23°57'19.74"N Longitude: 90°26'23.32"E
Base name	EPZ	Narayangonj
Base Sector Name	3	3
Distance from Base	15 km	10 km or 6.5 mile
Frequency	3.5 GHz	3.5 GHz
Minimum Antenna Height	125.85 ft from ground level Appro. 30 ft	95 ft from ground level (No Earth Bulge) Appro. 100ft
Required Receive Signal Strength	-76.8 dBm	-64.58 dBm
Have sufficient Fade Margin?	**(**Yes**)** Fade Margin = **-**76.8-(-88.0) = 11.2 dBm	**(**Yes) Fade Margin = -64.58-(-88.0) = 23..42 dBm

Software Management

The Wimax Management system is equipped with all the necessary features that have to be considered while establishing a fixed WiMax system. WiMAX Modem Management Software is vendor defined software. We have calculated and evaluated all the signal parameters related to this system such as Cell Planning, Frequency Planning, Site survey, RSSI calculation, SNR and Fade Margin calculation.

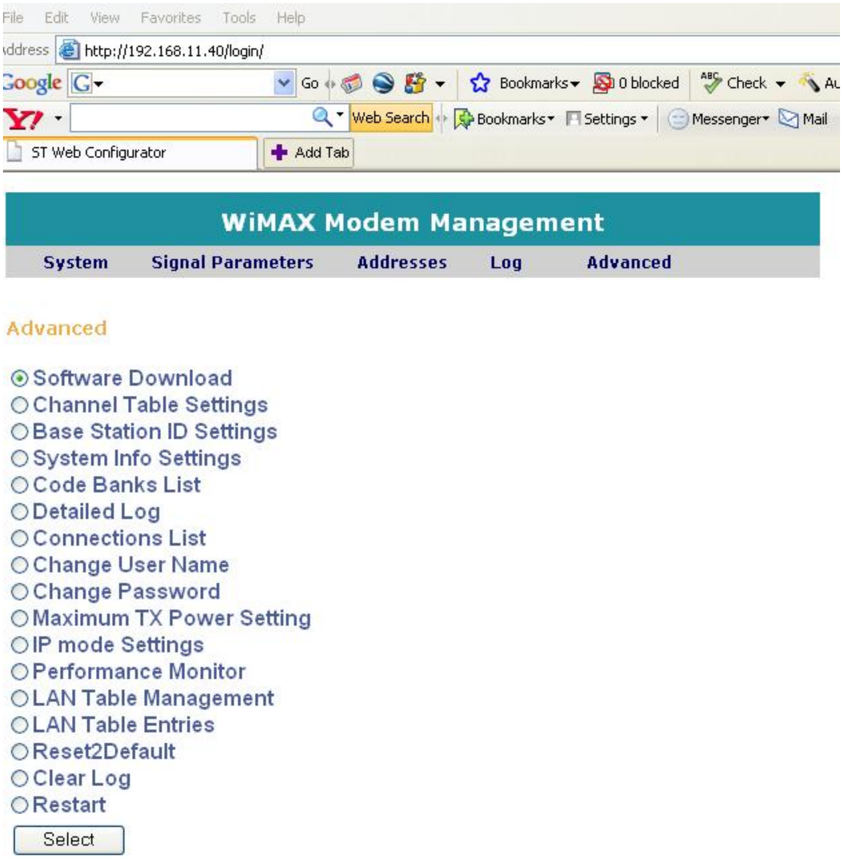


Figure 3: An overview of WiMAX Modem Management Software (WMMS)

Measurements

This paper used a noble research method for analysis performed over measurement data extracted from a fixed WiMAX system. A Network Management System (NMS) is used by the operator for administrating the BSs and SUs. The functionality in the BSs and SUs logs performance attributes. These performance attributes are DL and UL RSSI, DL and UL SNR, transmit (Tx) and receive (Rx) modulation rate and Tx power for the SU which is important due to the use of ATPC. The operator has implemented functionality to abstract the attributes and register them in a database. These performance attributes are logged for all subscribers present in the WiMAX deployment.

Physical performance

Received Signal Strength Indicator (RSSI)

As specified in IEEE 802.16-2004, sect 8.3.9, the WiMAX SUs and BSs have a Received Signal Strength Indicator (RSSI) [11]. The Network Monitoring System in use logs the RSSI for all the SUs which are operative during the day. The RSSI related to the distance between the SU and BS gives valuable information related to the power loss in the WiMAX system. The RSSI is measured for both uplink and downlink.

The received signal can be calculated with the formula:
Received signal = transmitter power – transmitter cable and connector loss + transmitter antenna gain - free space path loss + receiver antenna gain – receiver cable and connector loss

So, Received signal= 24dBm – 2 dB + 15 dB – 126.8 dB + 15 dB – 2 dB = –76.8 dBm

The following formulas can be used to determine if the fade margin meets the requirement:
Fade margin = received signal – receiver threshold

So, Fade Margin = -76.8-(-88.0) = 11.2 dBm

Our required Fade Margin is 10 dBm. If the Fade Margin is less than 10dBm then the received signal is not acceptable. Here the Fade Margin is greater than 10 dBm. So, the received signal strength is good and acceptable. Directional antennas increase the fade margin by adding more gain when the service operates under significant NLOS fading. This increases the link availability as shown by K-factor comparisons between directional and omni-directional antennas [12].

Signal to Noise Ratio (SNR)
The Signal to Noise Ratio (SNR) is the power ratio between the signal and the background noise. SNR will give a better indication of the actual system conditions because interference and noise is revealed. SNR and RSSI are measured at all locations and should be closely correlated, and a plot of RSSI versus SNR should by definition give a linear graph if the interference and background noise is absent.

The example below is based on the following assumptions:

- Frequency: 3.5 GHz
- Length of Path: 15 km or 9.32 mile
- Transmitter Power: 24 dBm
- Number of Connectors Used: 4 (~ 0.5 dB loss per connector)
- Antenna Gain: 15 dBi transmit, 15 dBi receive
- Receiver Threshold: –88 dBm
- Required Fade Margin: 10 dB (minimum)
- Antenna Height for 60% Fresnel zone clearance:

$H = 43.3\sqrt{\frac{D}{4F}}$ Here, D=9.32 mile and F=3.5GHz

Gives, H=35.32 meter or 115 ft from ground level and it is longer than 7 mile so we have to calculate earth bulge $H = \frac{D^2}{8}$. Which gives, H =10.85 ft

Minimum Antenna height: $H = \sqrt{\frac{D}{4F}} + \frac{D^2}{8}$

So, H =125.85 ft from ground level

Free-Space Path Loss:

$L_P = (92.4 + 20\log_{10} F) + (20\log_{10} D)$

Here, F=3.5 GHz

D=15 km

Lp =Free space path loss in db

So, Lp = 126.8 db

Performance Monitor from Software for Client B

From this study we observe that theoretical Receive signal strength is -76.8 dBm and practically we have -72.2 dBm. Actually the value is fluctuating. We see in the performance monitor graph that the RSSI value in between -77dBm to 65 dBm. Here fade margin is 11.2 dBm which is greater than our required fade margin (10 dBm). So, we can say that this is a good link.

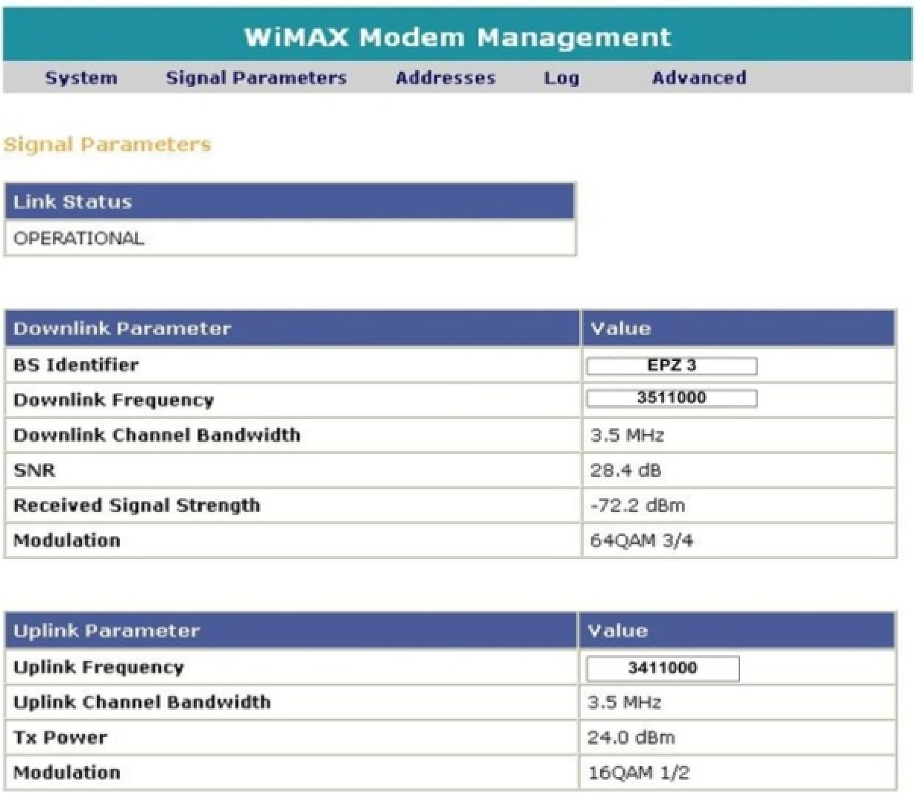


Figure 4: Signal Parameters from software

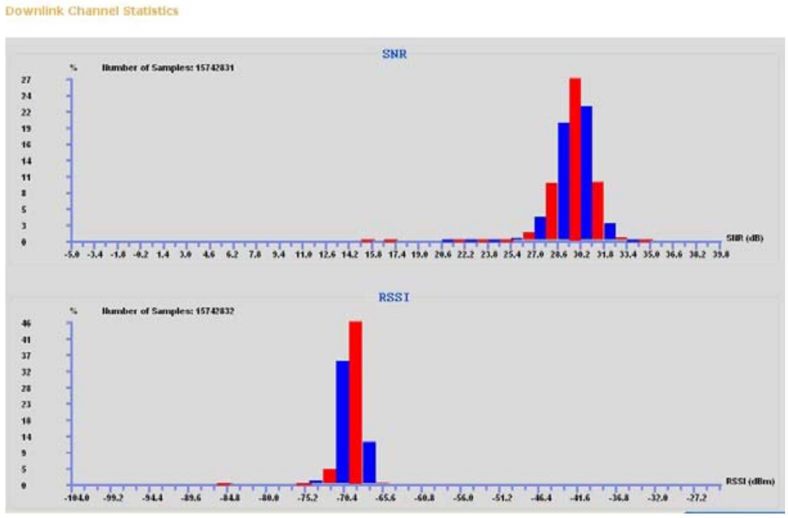
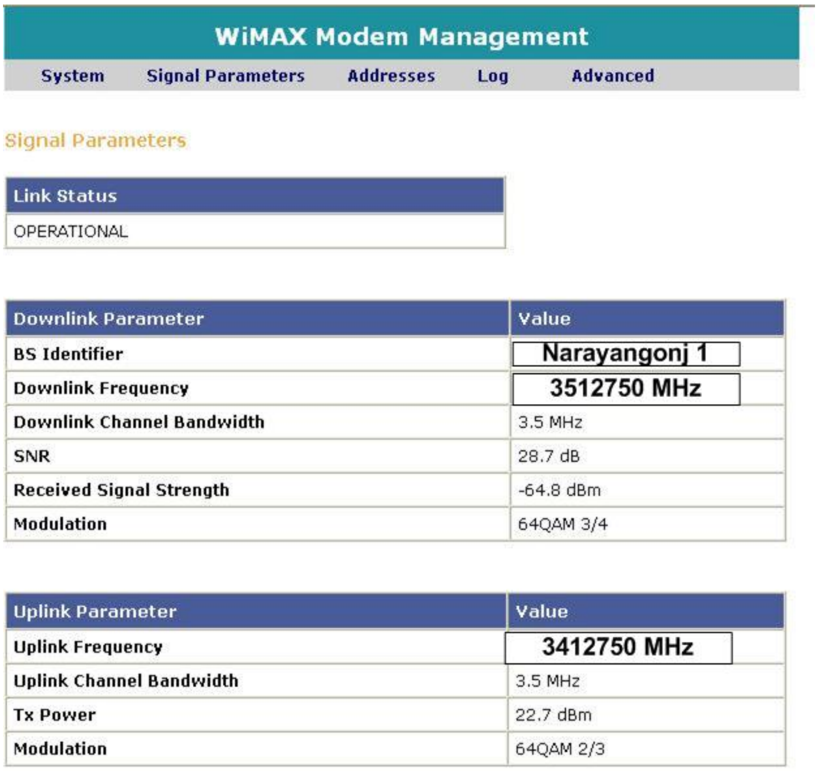


Figure 5: Performance Characteristics showing for SNR and RSSI for SU B.

Performance Monitor from Software for Client C

From the clear view of three BSs we see that the client location is near Mohakhali base station but we can’t select Mohakhali Base station as Base because there is no line of sight.



WiMAX Modem Management

System | Signal Parameters | Addresses | Log | Advanced

Signal Parameters

Link Status
OPERATIONAL

Downlink Parameter	Value
BS Identifier	Narayangonj 1
Downlink Frequency	3512750 MHz
Downlink Channel Bandwidth	3.5 MHz
SNR	28.7 dB
Received Signal Strength	-64.8 dBm
Modulation	64QAM 3/4

Uplink Parameter	Value
Uplink Frequency	3412750 MHz
Uplink Channel Bandwidth	3.5 MHz
Tx Power	22.7 dBm
Modulation	64QAM 2/3

Figure 6: Signal Parameters from software

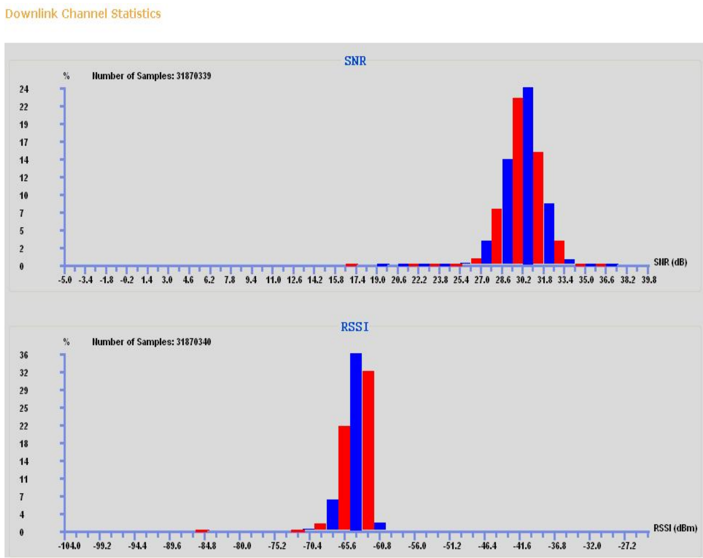


Figure 7: Performance Characteristics showing for SNR and RSSI for SU C

From Narayangonj Base station distance is 10 km but there is a clear line of sight and for this here we have good receive signal. From this study we observe that theoretical Receive signal strength is -64.58 dBm and practically we have -64.8 dBm. Here fade margin is 23.42 dBm. So, we can say that it is an excellent Link.

Results and discussions

We know that the RSSI is related to the distance between the SU and BS gives valuable information related to the power loss in the fixed WiMAX system. From the study if we consider two BSs and SUs, we get RSSI values are -76.8 dBm, -64.58 dBm and the fade margin is 11.2 dBm and 23.42dBm respectively. If the Fade Margin is less than 10dBm then the received signal is not acceptable. Here the Fade Margin is greater than 10 dBm. So, the received signal strength is good and acceptable. Directional antennas can increase the fade margin by adding more gain when the service operates under significant NLOS fading. Again from the performance monitor graph we see that calculated value and the practical value are more similar which gives an excellent link in fixed WiMAX deployment in the metropolitan area. Antenna height and free space path loss has been calculated for different Fresnel zone as well.

Conclusions

A fixed WiMAX deployment has been investigated with focus on the physical parameters. The signal propagation has been analyzed and the signal to noise ratio has been revealed. The main contribution of this paper is to present measurement results from a real life fixed WiMAX deployment and in depth analysis of the physical performance. We also monitor the signal performance from this network management system. At first we calculate required RSSI and finally we find out practically system oriented RSSI. Fixed WiMAX is the initial step of WiMAX but it has a long way to go. The world is looking for the WiMAX Mobility. Based on this report it is clear that WiMAX is a real contender for wireless internet connectivity, not only as a last mile solution but also as a strong backhaul solution. With strengths such as cost effectiveness out weighing few weaknesses, it is hard to see why WiMAX would not be used.

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