

Mobile WiMAX Coverage Evaluation for Rural Areas of India

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Abstract - Measurement of propagation parameters are essential for coverage and quality prediction. Commercially available planning tools are not customised for local geographical conditions, thus leading to inadequate service and unnecessary expenditure. Mobile WiMAX is under rapid installation throughout the globe. Present study made at rural areas of Rajasthan establishes lower path loss than the coverage prediction models recommended by WiMAX forum.

Keywords: WiMAX, IEEE 802.16, path loss exponent, Rayleigh fading, RSSI, CINR

I. INTRODUCTION

Mobile services for voice have been implemented in urban areas in redundant and many parts of the rural areas are still not covered. The economics of extending mobile services in a cost effective manner is a challenge to the network designers.

Measurement of propagation parameters are essential for coverage and quality prediction. Cell edge probability and area coverage probability are calculated based on parameters like initial path loss, path loss exponent (γ) and Rayleigh fading factor (σ). Jakes graph is usually deployed for prediction of cell radius. Now, Commercially available planning tools are deployed for estimation of coverage which includes clutter diagram and a suitable prediction model. Base transceiver station locations are plotted on the predicted coverage map plot.

The studies were carried out at dense city like Kolkata and medium to small towns like Raipur, Jabalpur, Katni, Jagdalpur etc of India during 2006 to 2009[1]. Measurements on GSM carried out revealed that Okumura-Hata model customised for typical geographical conditions matches receive signal level to a reasonable extent as per prediction only beyond half of Fresnel Zone distance and signal quality is adequate. Receive signal quality is very poor in near region of base station together with much higher signal strength than calculated free space signal strength leading to un-predictable communication. For CDMA, the signal strength variation with distance is observed regular throughout; signal quality is nearly flat upto two times the Fresnel Zone distance after which signal quality drops sharply which makes communication to fail. Observation similar to CDMA is found in case of WCDMA also but the range is numerically less than CDMA due deployment of higher frequency band of operation in WCDMA.

Evolution of data service through voice channels has limitations in deployment of time-slots in GSM and code-channels in CDMA. Extension of mobile data services to rural areas needs thorough planning with greater importance to extend larger coverage than capacity and with compromising throughput. A study was conducted in 2007 to estimate the coverage of WiMAX based on IEEE 802.16 D at Kalyani, a suburban area of Kolkata City. Measurements were taken for rooftop antennas on line of sight (LoS) condition upto 4 km and backhaul throughput capacity of 2 mbps due to practical limitations. The throughput was observed full and signal quality was found adequate. For on road measurements involving both LOS and Non-LoS condition, the communication was found limited to 2 Km zone only[2].

Present study on WiMAX based on IEEE 802.16 E recommendation was conducted at two rural locations of Rajasthan during the months of November 2009 to February 2010 when cold wave flows and temperature reaches near freezing point of water. Morning time is full of fog, however, sky was almost clear during the period when observations were taken. The area covers light green vegetation with low height hills scattered here and there, otherwise mostly plain. The study measured all the three components for effective service and leads to estimate values of various communication parameters essential for estimation of coverage. As the two base stations used were far off and no other WiMAX system was in use, no cell concept was used neither the handover issue was taken into consideration.

Section II discusses various propagation models based on which WiMAX coverage is predicted and a statistical approach for gross estimation of pathloss exponent and fading component. The various studies already conducted on several mobile communication technologies and results obtained has been stated in Section III. Base station setup, Subscriber Station location arrangements and methodology of data collection has been elaborated in section IV. Processing of data and results obtained has been given in section V followed by discussions and conclusion has been drawn in section VI.

II. PROPAGATION MODELS

Okumura Hata model is widely used for voice coverage in below 1500 MHz range and the same has been deployed with modification for prediction of WiMAX coverage

which works in 2500 MHz and 3500 MHz band. The COST 231 model has been used for calculation of pathloss with correction factor $C_m=0$ as applicable for sub-urban centres with medium tree density [3]. SUI type C terrain model has also been used with a, b and c parameters for flat terrain and light tree density. σ , the fading standard deviation factor varies from 8.2 dB to 10.6 dB depending on trees and clutter value and was taken as 9.4 for comparison with experimental results [4]. A more general model which includes pathloss exponent and shadow fading factor is given as

$$PL=PL(d_0)+10 \gamma \log(d/d_0) + \sigma \quad (1)$$

Where $PL(d_0)$ the intercept and γ is the slope [5]. Losses are measured in dBm and d is in meters.

III RELATED WORKS

A project had been initiated by Ofcom U.K. for comparative study of propagation pathloss models for Cambridge U.K. at 3.5 GHz band during the period September to December 2003 [6]. Similar measurements for statistical pathloss were also done at London, Birmingham, Liverpool and Manchester at 3.5 GHz by Marcus C. Laden and Frank J. Rowsell during the period December 2003 to June 2004 [7]. Propagation study for pathloss at further higher frequency viz. 5.3 GHz was carried out during summer of 1998 at Ottawa, Ontario and the recommendation was submitted by IEEE 802.16 wireless access working group during November 2000 [8]. A study to measure TCP and UDP based throughput along with RSSI and CNR was conducted in 2006 after release of WiMAX certified equipment in sub-urban areas of Oslo, Norway for fixed WiMAX ranging upto 15 Km at plain and rising slope upto a height of 251m above sea level [9]. Similar study was conducted at the sub-urban area of Kalyani, Kolkata for LOS and NLOS conditions where terrain is mostly flat and building height is averaged at 7m [2]. VoIP and Audio-video streaming performance was measured over fixed WiMAX test bed in Oulu, Finland comprising of one BS and two SS [10]. In addition to RSSI, CNR and throughput, network performance e.g. throughput, latency and jitter was also measured for fixed WiMAX system in sub-urban areas of Ghent (Belgium) by Dept of Information Technology, Ghent University [11] during 2008. Pathloss measurements for fixed WiMAX were carried out at rural areas of Italy on a system installed in 2006 [12]. SUI (Scalable, Ultra-fast and Interoperable Interactive Television) conducted field trial at Aveiro-Portugal for mobile WiMAX over 10 MHz bandwidth and at speed upto 140 kmph and measured throughput in sub-urban city environment for both unicast and multicast mode [13]. A pilot project is being conducted at the IRT (Institut fur Rundfunk technik) to test the digital video broadcasting ability of both fixed and mobile WiMAX at Munich city during 2009 [14]. Measurements for mobile WiMAX system in rural areas of Japan viz. Yamaguchi district of Akaiwa city in the Okayama prefecture where the residential and agricultural field areas are surrounded by

mountains. A hybrid approach of 802.11 b/g LAN has been deployed in it. Performance concluded for need of improved throughput [15].

The studies related to fixed and mobile WiMAX are mostly located at upper hemisphere of the globe where habitation and greeneries are different whereas propagation parameters are heavily dependent on them. Furthermore, the trends for measurements are more in urban areas than rural areas. Particularly in India, no study on mobile WiMAX coverage has been noticed. The present study is timely and relevant.

IV STUDY SETUP

A. Base Station-

Two WiMAX systems were installed at a separation of about 45 Kms at Sikrai and Bassi in Rajasthan province of India.

Sikari is located around 85 KM in east from province capital Jaipur. It is situated on Jaipur -Agra National Highway. Sikari tower is just 2 KM from National Highway in east direction shown in fig 1. The tower shares other Antenna assemblies also and locations of WiMAX antenna assembly (left) and Radio Resource Unit (RRU) (right) are shown as inset. The antenna assembly is located at a height of 40m. The output power at antenna connector is set at 40 dbm and antenna used has dual element system (2 Rx/2 Tx) with gain of 17 dBi. The antenna orientations are set at 0° - 120° - 240° respectively. The frequencies used are in of 5 MHz bandwidth each and from 2.6375 GHz to 2.6525 GHz. The system uses Time Division Duplexing, convolution turbo code and Adaptive Multiple Antenna. Depending upon coding schemes, the throughput is supposed to vary from 3.57 Mbps to 16.07 Mbps, however limited to backhaul capacity of 8 Mbps.

Bassi is located around 45 KM in east from Jaipur. It comes on Jaipur Agra National Highway. Bassi is located just 3 KM away from National Highway in east direction. Other parameters remaining same, orientation of antenna assembly was at 20° - 120° - 300° respectively.

B. Measurement environment-

Sikrai Direction A:

The way of direction which is marked as A goes towards hilly area. This landscape of this way has full farms up to around 6 KM and few populated area comprising of maximum three story building (10 m height), but this population is quite thick causes poor LOS. As its route goes toward hills, there is some ups and downs in the way, which causes some time poor LOS. At the end of way 8 to 10 KM in range it is slope of Hills and having very large area covered with high and big trees. At around 10 KM this way cross the hills and cause complete NLOS region.

Sikrai Direction B:

The way of direction which is marked as B goes on national highway towards Agra. As it is national highway the road was plane but having very heavy high speed traffic. This landscape of this way towards BTS site has

full farms with few populated area comprising of maximum three story building (30m Height) and large no of big trees. At around 8 to 10 KM towards Agra site some heavy populated villages comes in between the LOS.

Route trace of Sikrai base station is shown in fig 1.

Bassi Direction A:

The way of direction which is marked as A goes on national highway towards Jaipur. As it is national highway the road was plane but having very heavy high speed traffic. This landscape of this way towards BTS site has full farms with some populated area comprising of maximum three story building (10 meter height) and large no of big trees. The road of highway is also having up and down causing poor LOS as antenna height on vehicle is low. The area towards Base Station site also has few low height hills which is further causing poor NLOS signal level.

Bassi Direction B:

The way of direction which is marked as B goes towards villages away from main national highway. The Bassi BS is situated in industrial area and surrounding is having big industries. The landscape also un even and the roads crosses through field area. There is an also big up and down which causes frequent NLOS or poor LOS. The Antenna height during testing was low which further caused Bad LOS and poor downlink.

Route trace of Bassi Base station is shown in fig 2.

C. Subscriber Station (SS) Setup-

An outdoor SS was chosen for the measurements. The SS, laptop and GPS all were mounted inside a vehicle. The outdoor antenna was mounted on a wooden stick and kept outside the vehicle at a height and rotated to get maximum signal strength. The total height of the antenna was at 3 m which, on an average, was equal to height of average buildings in rural areas and line of sight signal was mostly obtained. The output at the antenna connector was 25 dBm and had a gain of 13 dBm. The laptop was loaded with driver software for measurement of signal parameters and attached to a server for measurement of throughput. RF performances were also monitored at Access Service Network (ASN) Gateway for uplink parameters.

V RESULTS AND DISCUSSIONS

- A. All download RSSI, CINR and throughput obtained for Bassi are shown in figs 3,4 and 5 respectively and the corresponding values for Sikrai at figs 6,7 and 8. RSSI values were compared with COST 231 model and SUI type C models and pathloss plotted with parameters applicable for sub-urban and rural areas. It is observed that the pathloss slope is much less compared to other two models. Figs 3 and 6 gives pathloss exponents for Bassi and Sikrai respectively.
- B. For Bassi A side, RSSI was better than -70 dBm upto a distance of 4.5 Km, varied between -70 to -80 dBm upto 9.7 Km after which it improved again to -60 dBm upto 11.84 Km. Signal could be observed upto a distance of 13.62 Km only. CINR varied between 15

and 30 and mostly better than 20. Throughput varied from 4.6 Mbps to 1.1 Mbps upto 7.05 Km, between 1 to 2 Mbps upto 8.9 Km and improved to 4 Mbps again till signal lasts.

- C. In Bassi B side, RSSI varied from -40 dBm to -70 dBm upto 2.33 Km after which it drops to -80 dBm till no signal at 8.22 Km. CINR was fixed at 30 upto 2.33 Km after which it improves to 3 mbps and there after varies between 2.5 Mbps to 4.5 Mbps thereafter.
- D. In Sikrai A side, RSSI mostly varied between -70 dBm to -80 dBm upto 7.48 Km after which there was total drop of signal upto 8.76 Km. The signal was observed to improve upto a distance of 9.83 Km beyond which there was no signal. CINR varied between 25 to 12 before signal dropped. Throughput drops from 6 to 1 Mbps at 3.57 Km after which it improves and varied between 5 and 6 Mbps before signal break. At 8.76 Km, throughput was about 400 kbps which improves to 5 Mbps at 9.83 Km.
- E. In Sikrai B side, RSSI varied between -50 dBm to -80 dBm upto 10.45 Km with slight ups and downs but without break of signal. CINR varied between 30 and 15. Throughput varied between 6.5 Mbps to 2 Mbps at 9.78 Km.
- F. Observation of Bassi A side and Sikrai B side were regular for terrain with slow ups and downs. Bassi B side had bent on road initially. There was near shade in initial observations which may not affect RSSI and CINR but throughput was badly affected. Also, for Sakrai A side, there was a valley from 3.57 Km to 8.76 Km where RSSI and CINR was not affected but throughput was affected badly.
- G. Overall pathloss exponent (γ) for Bassi was 1.8289 and fading (σ) 11.70299; The corresponding values for Sikrai were 1.6814 and 11.68299 respectively.

VI CONCLUSION

RSSI was found to be higher than the value calculated for free space where $\gamma=2$ which lead to overall value of $\gamma<2$. The observation is similar to GSM as obtained in earlier observations. However this situation continued nearly upto 1 Km after which nearly free space propagation was observed. The σ/γ value was observed near 6.662103 where Jakes Graph is nearly flat. The Cell edge and area coverage can be stated with better degree of confidence level. Further, low γ value indicates better coverage than predicted by all models used by planning tools, however throughput was observed to have wide variation mostly due to poor CINR. Also, the throughput could not achieve back haul limit of 8 Mbps even at near region and hence it shall be difficult to establish both way mobile video communication using this system.

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Figure 1. Sikrai BS (yellow red) with B route towards north and then east, A route towards South. Hill traces at South East.



Figure 2: Bassi BS(red) with trace route for A routes towards North followed by North West and B route towards South West direction.

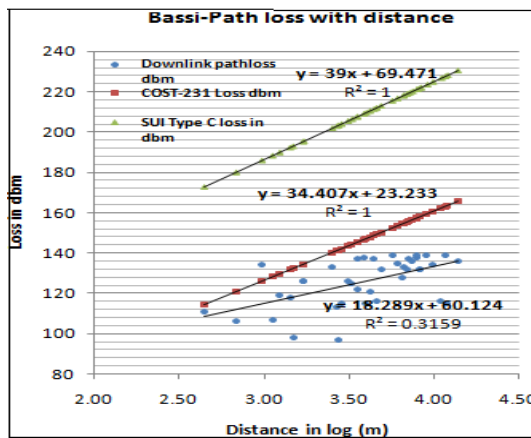


Figure 3 : Bassi Path loss with distance

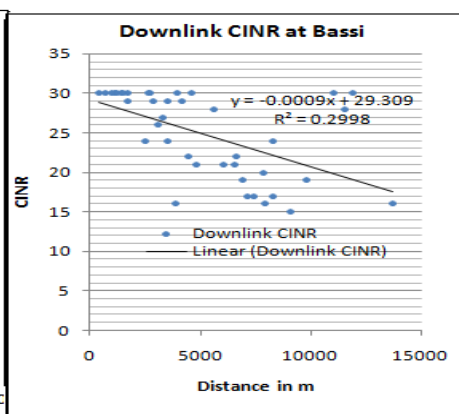


Figure 4 : Bassi downlink CINR

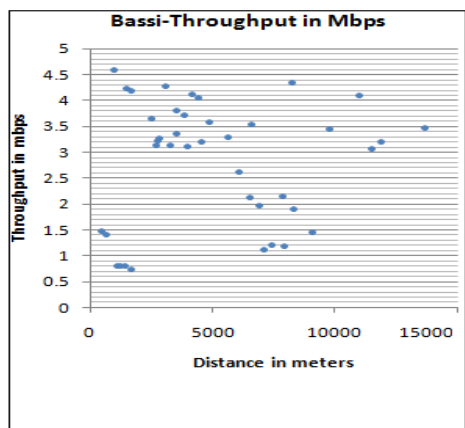


Figure 5 : Bassi throughput in Mbps

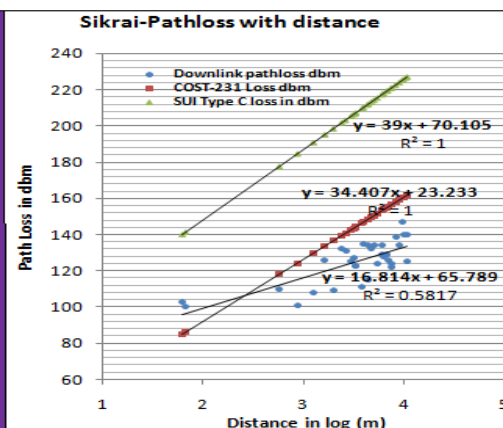


figure 6 : Sikrai Pathloss with distance

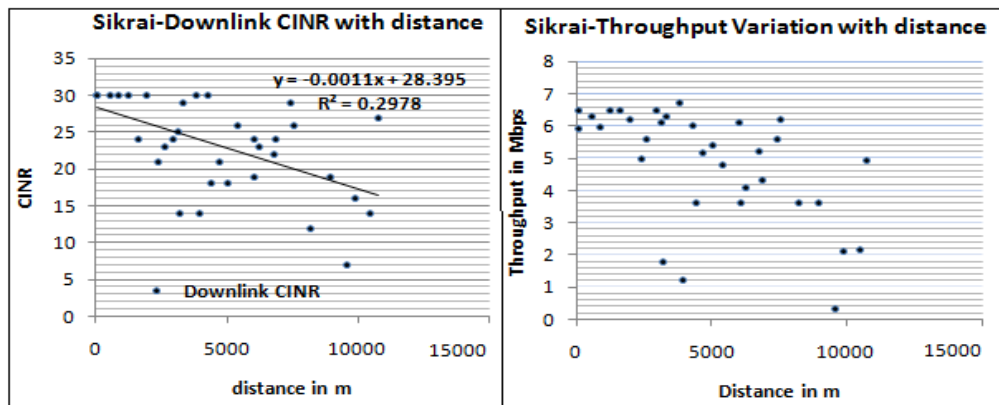


Figure 7: Sikrai downlink CINR

Figure 8 : Sikrai throughput