International Journal of Applied Engineering Research
ISSN 0973-4562 Volume 10, Number 10 (2015) pp. 25789-25800

http://www.ripublication.com

Analysis of Pathloss Models For 3g Mobile Signals Inurban, Suburban and Rural Environment

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Abstract

Third generation telecommunication technology, which is the successor of EDGE and GPRS technologies provides better data rates and better signal quality than the pre-existing technologies. This paper presents a method to measure 3G received and measuring a parameter comparable to the field strength is sufficient to evaluate coverage to variance of Received Signal Code Power (RSCP) and to the distance between the signal receiving unit and the mobile base station. A comparative study with real time RSCP measurements are obtainedfrom Bharat sanchar nigam limited (BSNL) in and around Vijayawada , Andhra Pradesh, India to estimate the path loss models such as Hata, Cost-231 and Ecc-33 path loss estimation models.

Index Terms: 3G, Received signal code power (RSCP), Energy per chip over noise(Ec/N0),

Introduction

The 3G has the following enhanced features over the 2G,GSM and EDGE such as higher data speed, video conferencing support, enhanced audio, video streaming, and web browsing at high speed and watch High Definition videos, datatransfers, games and much more. The 3G network services provide datatransfer rate at 200 Kbit/s. 3G also provides mobile broadband access to several Mbit/s for smart phones and mobile modems in laptops. The speed of data transmission for 3G network is 384 kbps to 2 Mbps. The 3G is currently the world’s best connection method when it is connected with mobile phones and especially for internet.

The launch of 3G mobile communication services has made use of mobile multimedia services with the increase of data rates. The 3G fulfils the need of higher data rates required for multimedia and higher bit rate services which is adopted by many regions. However coverage area is one of the challenging problems for 3G technology implementation in India. To improve the coverage area estimation, path loss analysis is carried out to represent the optimal behavior of mobile environment under rural, sub-urban and urban areas.

Propagation Model

Path loss for Hata model

Frequency: 50–1500 MHz
Mobile station antenna height: 1–10 m
Base station antenna height: 30–200 m
Link distance: 1–10 km

For Urban areas, the path loss can be calculated as [4],

$$PL_u = 69.55 + 26.16\log_{10}(f_{tr}) - 13.82\log_{10}(h_b) + (44.9 - 6.55\log_{10}(h_b))\log_{10}(d) + s - a(h_m)) \quad (1)$$

For sub urban areas, the path loss can be calculated as,

$$PL_{su} = PL_u - 2(\log_{10}(f_{tr}/28))^2 - 5.4 \quad (2)$$

For rural areas, the path loss can be calculated as,

$$PL_r = PL_u - 4.78(\log_{10}(f_{tr})^2) + 18.33\log_{10}(f_{tr}) - 40.98 \quad (3)$$

Main Station antenna correction factor for all areas is [8]

$$a(h_m) = (1.11\log_{10}(f) - 0.7h_m - (1.56\log_{10}(f) - 0.8 \quad (4)$$

Where PL_u = Path loss in urban areas. Unit: decibel (dB),
h_B = Base station antenna height. Unit: meter (m),
h_M = Mobile station antennaheight. Unit: meter (m)
f_{tr} = Transmitter frequency Unit: Megahertz (MHz).
d = Distance between the base and mobile stations. Unit: kilometer (km).

Path loss for Cost-231 model

For Urban areas, the path loss can be calculated as,

$$PL_u = 46.3 + 33.9\log_{10}(f_{tr}) - 13.82\log_{10}(h_b) + (44.9 - 6.55\log_{10}(h_b))\log_{10}(d) + s - a(h_m) \quad (5)$$

For suburban areas, the path loss can be calculated as

$$PL_{su} = PL_{urban} - 2*(\log_{10}(f_{tr}/28))^2 - 5.4 \quad (6)$$

For Rural areas, the path loss can be calculated as,

$$PL_r = PL_{urban} - 4.78(\log_{10}(f_{tr})^2) + 18.33\log_{10}(f_{tr}) - 40.98$$

MS antenna correction factor

$$A(h_m) = (1.11\log_{10}(f_{tr}) - 0.7)h_m - (1.56\log_{10}(f_{tr}) - 0.8 \quad (8)$$

The path loss exponent

$$\alpha = (44.9 - 6.55\log_{10}(h_b))/10) \quad (9)$$

Path loss for Ecc-33 model

$$PL = PL_{fs} + PL_{hm} - G_b - G_m \quad (10)$$

$$PL_{fs} = 92.4 + 20\log_{10}(d) + 20\log_{10}(f) \quad (11)$$

$$PL_{hm} = 20.41 + 9.83\log_{10}(d) + 7.894\log_{10}(f) + 9.56(\log_{10}(f)^2 \quad (12)$$

$$G_b = \log_{10}(h_b / 200)\{13.98 + 5.8[\log_{10}(d)\}^2 \quad (13)$$

$$G_b = [42.57 + 13.7\log_{10}(f_{tr}) * [\log_{10}(h_m) - 0.585 \quad (14)$$

Where

PL_{fs} and PL_{fm} are the free space path loss and the basic median path loss.

The above propagation models are plotted together with experimental results to see which one estimate the path loss more accurately.

PL = Path loss

f = Frequency of transmission. Unit: Megahertz (MHz).

d =distance

h_b = Height of base station antenna

MS antenna correction factor a (h_m) = (1.11 $\log_{10}$ (f) -0.7) hm - (1.56 $\log_{10}$ (f) - 0.8)

PL_{fs} = path loss for free space

PL_{bm} =path loss for basic medium

G_b =gain at base station

G_m =gain at main station

In this paper, different path loss models such as Hata presented the real time measurement of the 3G signal by measuring the Ec/No from different locations. We have compared the measured values with the theoretical values. A model that is used widely for calculating path loss in mobile wireless system is the COST 231-Hata model [4]. COST -231 is designed to use in the frequency band range from 500 MHz to 2.1 GHz 2000MHz models due to 3G data and Hata model is valid to 2.4GHz. The basic equation for path loss in dB is

$$PL = 46.3 + 33.9\log_{10}(f_{tr}) - 13.821\log_{10}(h_b) - X(h_m) + 44.9 - 6.55\log_{10}(h_b)\log_{10}(d) + cm \quad (15)$$

$$X(h_{m)} = 3.20(\log_{10}(11.75))^2 - 4.97 \; for \; f{>}400MHz \quad (16)$$

Where f = frequency in MHz, d = distance between AP and CPE antennas in km, hub is the AP (point scale) antenna height above ground level in meters.

$$n_{\cos t} = 44.9 - 6.55\log_{10}(h_b)/10 \quad (17)$$

The cm = 0 dB 3dB parameter to the suburbs to urban areas When he is the CPE (Customer Premises Equipment) antenna height above the ground. Observation of (7) to (9) reveals that the path loss exponent of the predictions made by the COST-231 Hata model is given by, [4]

Environmental Description

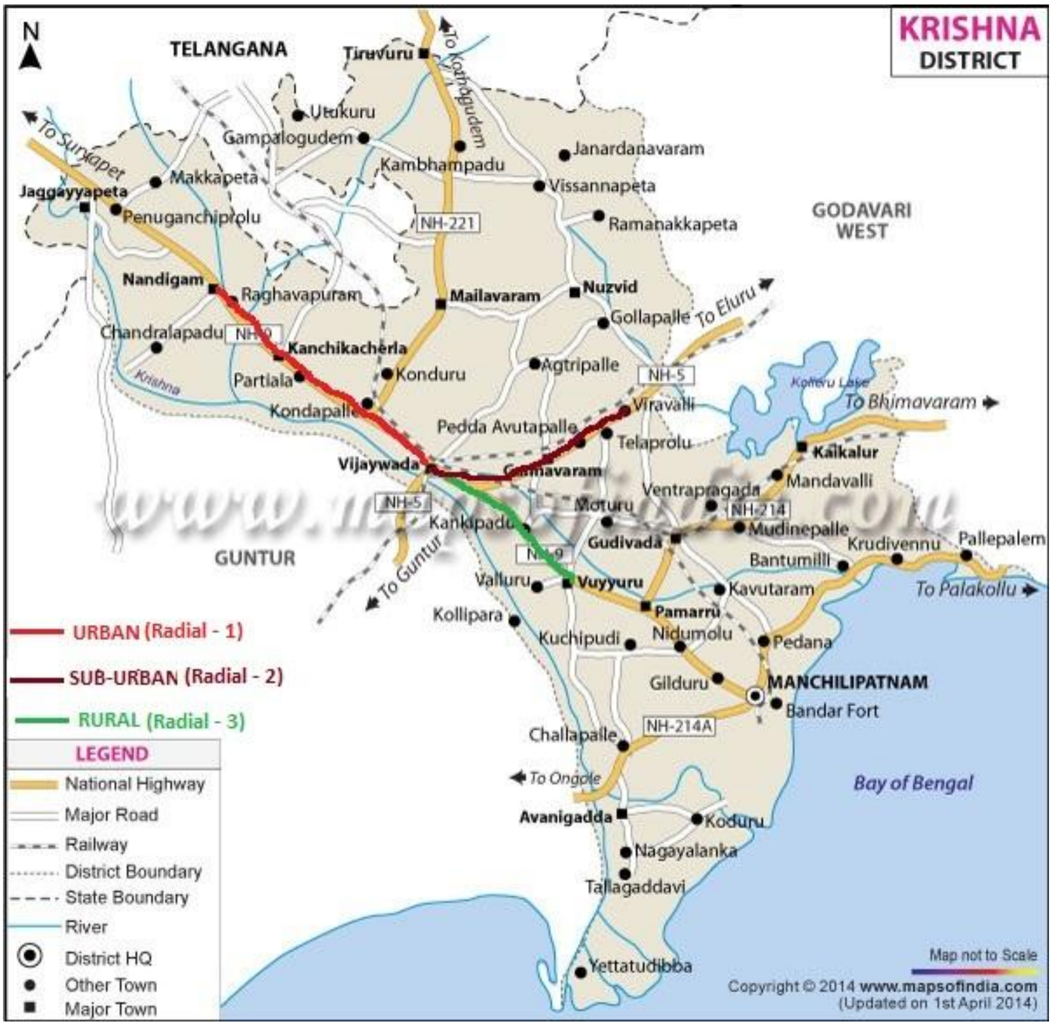

Figure 1: District map with Radial areas (courtesy: mapsofindia.com)

In the present study different path loss models presented the real time measurements of 3G signal at Vijayawada is monitored in different environments and a map of Vijayawada as shown in Figure1 and the cell tower transmitter is located in a thickly populated zone surrounded by congested multi-stored buildings like 5 story buildings like Apartments, Multiplex theaters,markets and somewhat narrow roads. The characteristics of the transmitter are as shown in Table 1

Table 1: comparison of areas with transmitting frequency, W, dB,m.

Place	Vijayawada(Urban)	Nandigama(Suburban)	Vuyyuru(Rural)
Transmitting frequency	2.4GHz	2.4GHz	2.4GHz
Transmitting power(W)	20	20	20
Transmitting Antenna gain(dB)	17	17	17
Transmitting Antenna height(m)	30	35-40	24-30

The measurements were conducted radially from the transmitter in urban areas by three different routes which are designated as Radial1 and Radial 2 and Radial 3.Radial1 started from

BSNL Office, M.G.Road and ending at N.T.R Health University via Benz circle. In this case the measurements were taken up to a distance of 10km from the transmitter. The first 4km is densely populated with 5storied buildings and road width is 100 feet denoting urban conditions and the zone is between2-4km from the transmitter and less populated conditions are changes tosuburban conditions and few tall trees like Banyan trees of 20 feet in height which was located nearer to the road. (I.e. Andhra Loyola college) and the measurements were taken in the month of September to October.

Radial 2 started from Gollapudi and ending at Nandigama of a distance of 20 km.The distance of 4km from the transmitter tower is densely populated, denoting urban conditions and Beyond 4km ,conditions changed to suburban and after 5km the environment is resembled quasi open There are some open lands with trees of 10feet in height having leaves. Around 4km some palm trees are also seen. Beyond 5km Agriculture land are seen near Mic engineering college and beyond that the area looked like open.

Radial3 started around the transmitter tower and followed the road is known as Kannur and ended At another village called Vuyyuru covering a distance of 10km as in this case the region up to 3km distance represented urban conditions with single multi stored buildings and shopping complex and during the time of measurements the nearby roads are filled with heavy traffic after 3 -5km the area looked like suburban area with road width of 40feet and some agriculture land is seen with no obstructions near kankipadu which as a small population single story buildings denoting suburban conditions. After 4-5km the area looked like rural area and they are open lands and the measurements ended at Vuyyuru.

Results and Discussions

In this paper, different path loss models such as Hata,cost-231 and ecc-33 presented the real time measurement of the 3G signal by measuring the Ec/N0 from different locations. The measured and theoretical values are compared. TEMS software is used to collect data at BSNL. (The instruments used in the measurement and the way of doing the experiment and the period in which the experiment was conducted by using test drive to cover 40 KM from Vijayawada .The drive test measurements provide additional more precise values of Ec/No information along the route that are driven and the propagation models are plotted with experimental results to see which is the model that estimate the path loss more accurately.

In this as distance is taken along x-axis and pathloss is taken along y-axis.The theoretical path losses for different models are made for different distances from the base station are as follows:

Tabel 2: Distance and Calculated Path Loss Values For Different Path Loss Models

Distance(m)	Hata model(dB)	Cost-231(dB)	Ecc-233(dB)
36191.79433	133.9459617	282.13414	265.15839
36192.18727	133.5859395	282.13425	265.162222
36193.48847	133.58643	282.134832	265.16278
36194.46227	133.5883685	282.135228	265.163134
36195.57156	133.5887655	282.13567	265.163586
36196.70209	133.58917019	282.13646	265.163941
36221.31015	133.5979741	282.146144	265.1727
36223.08525	133.59860894	282.14686	265.1733
36224.745	133.59920250	282.14754	265.173968
36232.14243	133.60184762	282.15054	265.17658

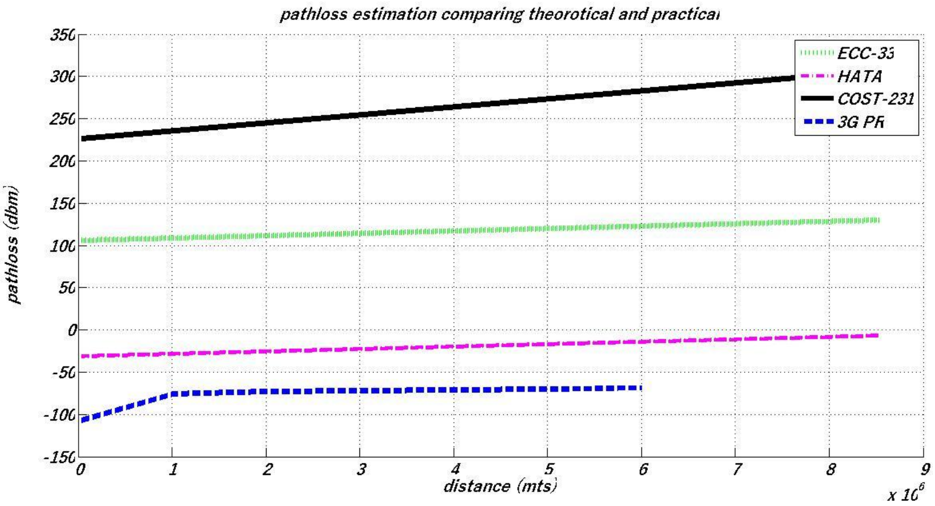

Figure 2: path loss estimation for urban areas

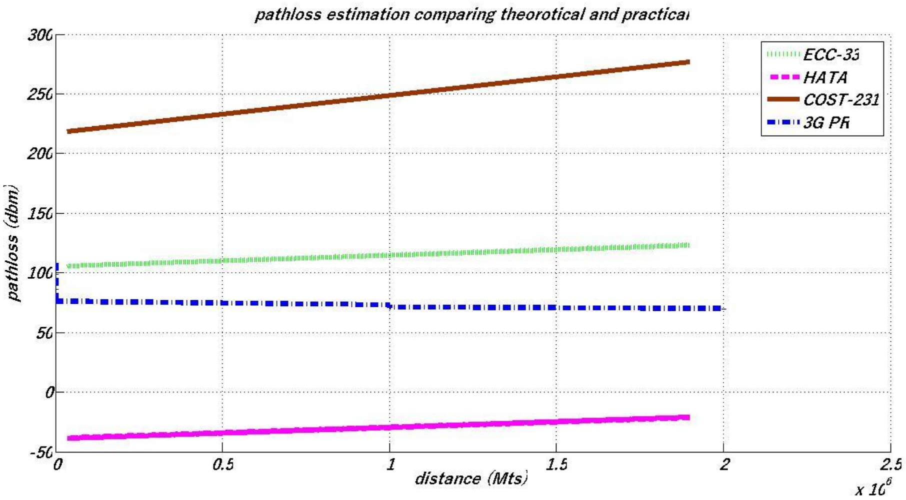

Figure 3: Path loss estimation for suburban Region

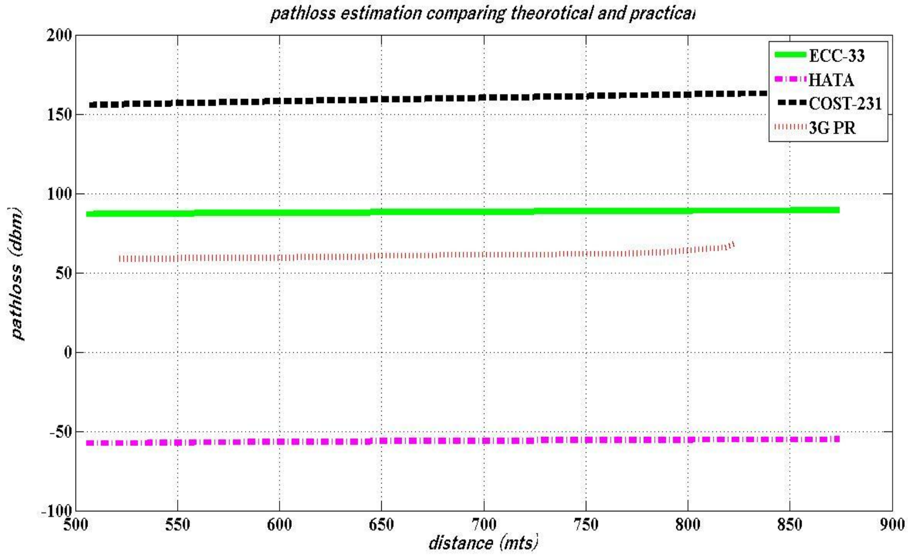

Figure 4: Path loss for Rural Region

The **Figure 2** shows path loss at urban region of Vijayawada, A.P. In this the distance is taken along X-axis and path loss is taken along Y-axis. This show the comparison of observed path loss with those predicted by above prediction methods either function of distance. Hata model is better agreement than other methods up to 10kms. The urban conditions exists up to maximum distance of 10kms, beyond this condition resembles those of sub urban. The maximum deviation observed by Hata method are -50dbm a 10kms. The **Figure 3** shows the graph of sub-urban region like Nandigama which is nearer to Vijayawada (40kms) and Ecc-33 gives good agreement with observed valuesand follows the same trend as observed path loss. The maximum deviation is observed around of 75dbm at 15kms distance. The agreement is good up to distance of 15kmsand there after the observed path loss shows increasing tendency. **Figure 4** shows the path loss at rural area like Vuyyuru which is located 25kms from Vijayawada.Here the Cost 231 shows the highest path loss of the order of 151dbm respectively.The maximum deviation is observed at 25kms and can be considered up to 40kms and there after it shows a raise in pathloss.The **figure 5** shows that the graph between mobile distance vs RSCP. Mobile distance is taken along X-axis and RSCP (Received signal code power) is along the Y-axis. As pathloss is related to RSCP by Path loss= Transmitted channel power (dbm) –RSCP (dbm)**.** This graph shows that RSCP falls off as base mobile distance increases. The **figure 6** shows the relation between distance vs Ec/Io. The **figure 7**shows the relation between logarithmic distance vs RSCP. With the help of this figure we can also test how our data fit to a logarithmic model such as log-distance model. The logarithmic pathloss is calculated by $L=P_{t\,(dbm)}–RSCP_{\,(dbm)} =L_0+10\log_{10} (d/d_0)$. The RSCP value is -96dB and is constant up to 6KM. The figure shows the linear regression line and dots which are spreading by the side of regression line shows collected data from the test drive.**Figure 8**shows the practical and theoretical path loss for urban area. The theoretical path loss for the urban was calculated using P=42.6+26*log$_{10}$ (d) +20*log (900). Here (d) is replaced by the distance values calculated from the collected data. There is a gradual increase in theoretical path loss from 450dbm to 600dbm.**Figure 9**shows the comparison of theoretical and practical path loss in rural areas. The path loss values vary from 320dbm to 390dbm and practical path loss values decreases with increase in distance.**Figure 10**compares the theoretical and practical path loss of sub-urban areas. The theoretical path loss varies from 450dbm to 650dbm in a short rage of distance.

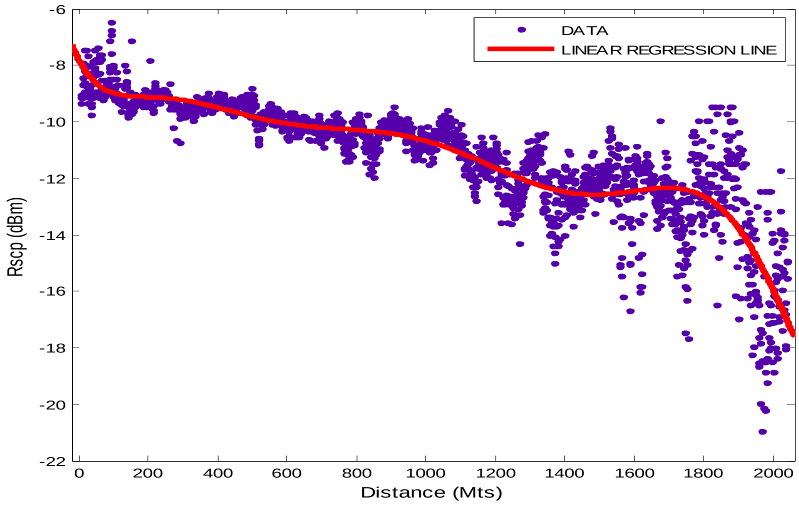

Figure 5: Distance vs RSCP

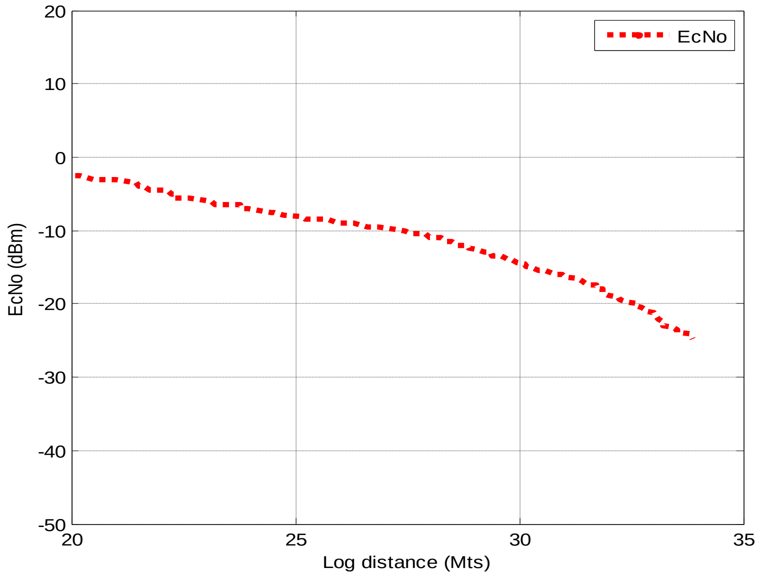

Figure 6: Distance Vs Ec/Io

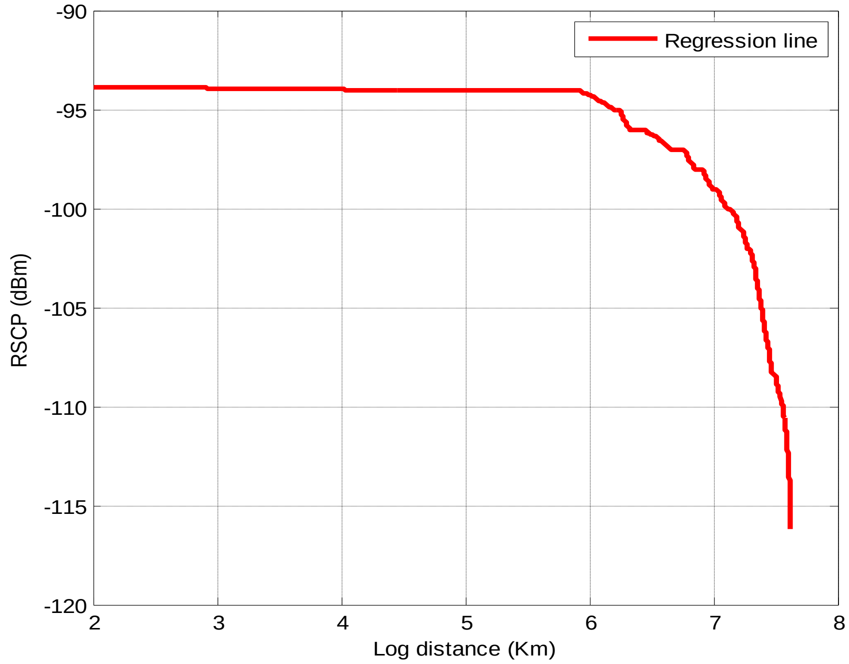

Figure 7: logarithmic distance vs RSCP

Comparison of Theoretical And Practical Pathloss Graphs

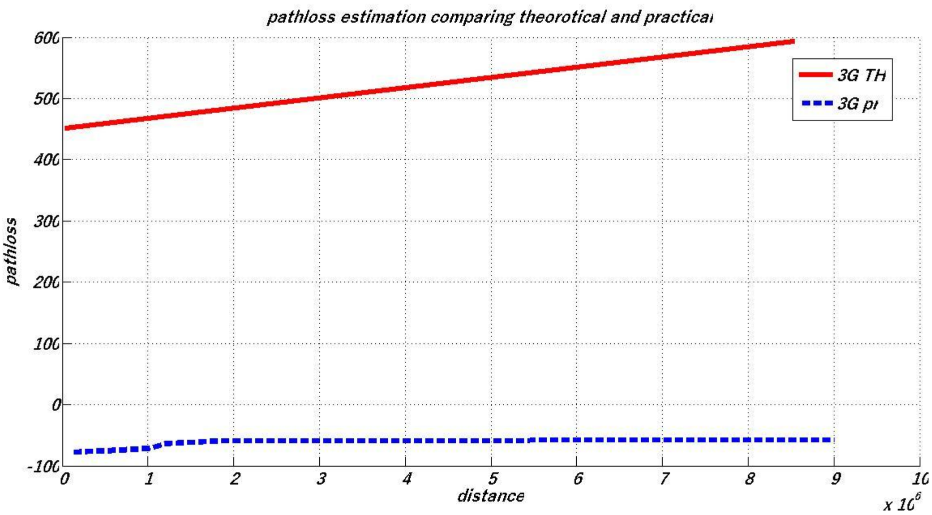

Figure 8: path loss comparision in urban area

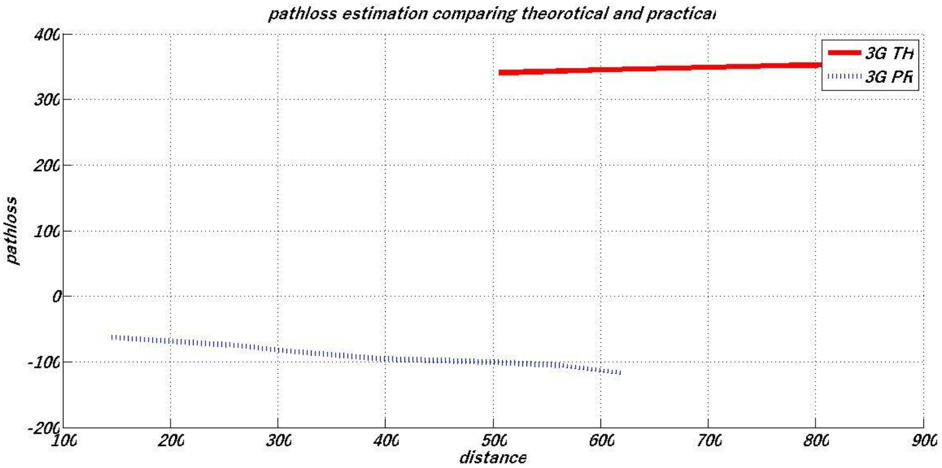

Figure 9: pathloss comparision in rural areas

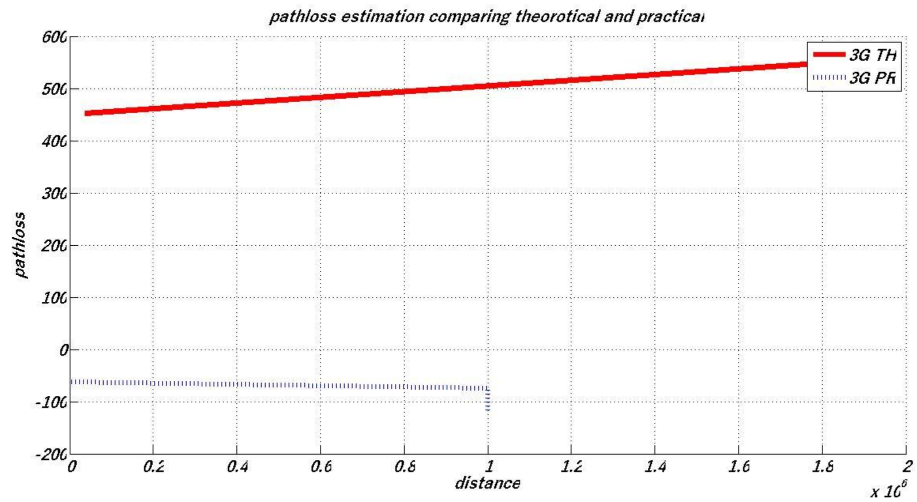

Figure 10: pathloss comparison in sub-urban areas

Conclusion

Thestudy aim's to calculate the path loss for urban, sub-urban and rural regions of Vijayawada and to compare with various empirical models.We conclude this, as mobile distance from the base station increases with decrease in RSCP value. RSCP range declines as mobile distance increases. We also tested that our data fits to logarithmic model. The RSCP has to be measured to the specific code only and it represents the quality of the reception. When the cell has good coverage, RSCP values are obtained would me more otherwise the coverage is poor. We can also estimate pathloss by using different pathloss estimation models such as Hata model, Cost-231 model and Ecc-33 model. We compared these three models in areas where pathloss is low then signal strength will be more. We conclude that COST-231 is best. We can also conclude as the distance increases the Ec/no decreases, it also fits to logarithmic distance. From this as Signal to noise ratio (SNR) increases throughput increases. It also increases the quality of the signal.

Acknowledgement
We profound our deep sense of respect and gratitude to P.Ramachandrarao and MS.Sridhar BSNL, Vijayawada under whose precise orientation and friendly encouragement we had the privilege of working on our project.

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