International Journal on Wireless, Networking & Mobile Communication Innovations
http://eurekajournals.com/wireless.html
ISSN: 2581-5113

Analysis of Energy Saving Parameters and Open Loop Scheme in Mobile Communication Network

Tanveer Singh Gaga[1], B. Manikumar[2], Dr. C. Ram Singla[3], V Narasiman[4], Jestin Joseph[5]

[1]Research Scholar, Department of Electronics and Communication, Madhav University, Rajasthan, India.
[2]Associate Professor, Madhav University, Rajasthan, India.
[3] Professor, Madhav University, Rajasthan, India.
[4]Professor, Madhav University, Rajasthan, India.
[5]AssociateProfessor, AEC, Salem, India.

Abstract

Background: In cellular wireless networks, power control refers to regulating the output power levels of transmitters, referred to as eNodeB in the downlink and user equipment (UEs) in the uplink. LTE employs two different techniques for uplink power management: Open Loop Power Control (OLPC) and Closed Loop Power Control (CLPC) (CLPC). Uplink OLPC is performed by the UE in line with the eNodeB configuration, and it may compensate for long-term channel changes such as path loss and shadowing. The uplink CLPC technique seeks to improve power control performance by compensating for fast channel changes caused by multipath fading. To regulate the transmit power of the UE, the eNodeB sends Transmit Power Control (TPC) signals to the UE in CLPC.

Methods: In order to reduce UE energy consumption, the Okumura-Hata propagation path loss model is utilised to calculate the User Equipment (UE) uplink transmit power management parameters in this research. Because the UE requires more power to connect to far base stations than to local base stations, this thesis examines the required power levels using the Okumura-Hata propagation, COST 231 path loss model.

Findings: Comparison between Hata and COST 231 Model, Path loss for different values of alpha, User Equipment (UE) with different height of base station for Rural, Urban and Suburban**.**

Novelty and Application: This study brings us one step closer to developing “green” cellular networks.

Keywords: Open Loop Power Control (OLPC) and Closed Loop Power Control (CLPC) (CLPC), Receiver antenna height (h_{bs} , Path loss compensation factors (α , eNodeB sensitivity(P_o).

Introduction

Power control in cellular wireless networks refers to managing the output power levels of transmitters, also known as user equipment (UEs) in the uplink and eNodeB in the downlink. Open Loop Power Control (OLPC) and Closed Loop Power Control (CLPC) are two alternative uplink power control strategies used by LTE (CLPC). The UE performs uplink OLPC in accordance with the eNodeB setup, and it has the ability to account for long-term channel changes such path loss and shadowing. By adjusting for quick channel changes brought on by multipath fading, the uplink CLPC approach aims to enhance power control performance. The eNodeB transmits Transmit Power Control (TPC) signals to the UE in CLPC to control its transmit power.

In this study, the User Equipment (UE) uplink transmit power management parameters are calculated using the Okumura-Hata propagation path loss model to reduce UE energy consumption. The Okumura-Hata propagation path loss model is used in this thesis to investigate the necessary power levels since the UE needs more power to connect to distant base stations than to local base stations.

Background Related Work

[5] Many users share the same radio resources in a multi-user scenario. As a result of the restricted selection the same channel must be played on each of the network's radio stations be given to several users. Consequently, a signal meant for a certain user will interact with other users and cause disruption for them decrease the quality of the connection. Due of this, the Power

A crucial problem is control functionality. Reduced power control is necessary while achieving a necessary inter-cell interference level SINR score. A closed loop component that revolves around an open loop point of operation makes up the LTE power regulation mechanism. The open loop component allows for a trade-off between cell edge throughput and mean cell throughput by compensating route loss and shadowing through fractional power regulation. By accounting for quick channel fluctuations, the closed loop component enables additional system performance improvement. The performance study of LTE power control techniques is presented in this research. According to the simulation results, in terms of mean cell throughput, fractional power management is preferable to the more common open loop power control.

[6]Transmit Power regulation is crucial for preserving the quality of service (QoS) of cellular radio systems, limiting the near-far effect, and reducing co-channel interference. This study analyses several closed loop uplink power control strategies for various mobile user speeds in cellular radio systems. Our goal is to provide a solution to the trade-off between competing limitations on the upper and lower limits of the two important cellular system variables, uplink power and signal-to-interference plus noise ratio (SINR), which is to maintain the SINR at a high value with a low power. This research focuses on performance comparisons of several feedback controllers used in uplink power control for pedestrian and high-speed mobile users,

including relay control, PID control, self-predictive and fuzzy based controllers. Three separate methods are used to compare the SINR responses, MSE responses, and compute the outage probability for the various feedback uplink power management systems. These methods use simulation in MATLAB Simulink models. Following thorough study and analysis, it is projected that employing fuzzy based uplink power regulation technique in both low-speed and high-speed mobile situation would result in the major performance improvement.

[7] Wireless communication systems that employ various multiple access approaches need to manage their radio resources carefully. Given how quickly the propagation channel changes, this viewpoint is crucial. The capacity of the cellular system degrades as a result of its complexity's periodic contribution to various interference levels, whether high or low.

In order to reduce interference under fading conditions, solve the NearFar issue, and prolong battery life, transmitter power regulation is an effective strategy. As a result, the Quality of Service (QoS) for all users may be significantly enhanced by the efficient application of various power control algorithms in cellular radio communication systems. The selection of a suitable power control algorithm is crucial since it should work to improve the system's overall effectiveness. In this article, several distributed power control algorithms that may be used with various cellular technologies were thoroughly examined. On the basis of performance measures like Carrier to Interference Ratio (CIR) and Outage for the downlink situation, three distributed power control techniques are specifically evaluated through simulations.

[8] An extensive lesson on power control problems in all cellular system generations is offered here. Power control is a crucial design option for cellular systems, providing significant advantages for the efficient and equitable running of the system, particularly in energy-efficient designs. Additionally, it offers several features across all cellular system stages, including as QoS, bit error rate optimization, and energy-efficient designs. Performance of various power management algorithms has been examined as a function of transmitted power, taking energy efficiency into consideration, with some intriguing findings.

[9] A new 3GPP standard called Long Term Evolution (LTE) is intended to boost capacity and enhance service performance. The multiple access method employed in the uplink is known as single carrier FDMA; it avoids the intra-cell interference that CDMA systems are prone to, but it is vulnerable to inter-cell interference. This makes the ability to manage electricity a crucial concern. Power regulation must decrease inter-cell interference while achieving the necessary SINR level. The combined open-closed loop algorithm component that is suggested in this work improves uplink power control and intelligently sets the power for the user. In the combined method, the traditional closed loop technique is used in the closed loop and the fractional power control algorithm is used in the open loop. The combined algorithm outperformed both the open and closed loop algorithms in this study's analysis of uplink power control schemes because it includes a cell autonomous mechanism that manages interference and instructs the UEs to transmit with a psd in accordance with the gain in throughput it would produce. It also gives the option for customers to adjust their transmission power to a minimal SINR.

[10] Many users share the same radio resources in a multi-user scenario. Shared channels result in the signal meant for one user reaching another, introducing interference into their route, and lowering the signal quality. Power regulation must decrease inter-cell interference while achieving the necessary SINR level. The UE transmits Power Head Room (PHR), indicating how much more it can broadcast before reaching maximum power, and the eNodeB sends Transmit Power Control (TPC) Command in Downlink in PDCCH to accomplish this SINR level. The PUSCH Power Control, LTE Power Control Mechanism, TPC Command, and Power Headroom Reporting have all been addressed by the authors in this research. Additionally, they discovered the Path Loss Compensation Factor's "α". ideal value.

Controlling the uplink power in LTE cellular networks

The transmit power of the UE, P_{Tx}, for uplink transmission in a subframe of the Physical Uplink Shared Channel is configured as follows, The setting of the UE transmit power for PUSCH is determined by the following equation according to 3GPP standard 36.213.[9]:

$$P_{Tx} = min(P_{max}, P_o + 10log_{10}(M) + \alpha_L + \delta_{mcs} + f(\Delta)_i) \quad (1)$$

Where:

Open loop parameters

The highest permitted UE transmit power (class 3) is $Pmax$, which is 23 dBm. [9].

P_o is a cell/UE-specific parameter signalled by Radio Resource Control (RRC).

However, we assume that P_o is cell specific.

P_o is the eNodeB sensitivity.

M is the bandwidth of the UE uplink resource assignment, expressed in number of PRB for each TTI.

α is the path loss compensation factor.It is a three-bit cell specific parameter in the LTE standard, α belongs to the set 0, 0.4:0.1:1 signalled by the RRC.

P_L is downlink path loss estimated and calculated in the UE which is used to compensate the received power at eNodeB in uplink power control.

Closed loop parameters

δ_{mcs} is a cell/UE-specific Modulation and Coding Scheme (MCS) parameter defined in 3GPP specification for LTE and has been set to 0 in this work.

$f(\Delta)_i)$ is a correction value provided by the Transmit Power Control (TPC) command.

The TPC commands are sent from an eNodeB after the OLPC has set the initial transmit power using the desired α and P_o values to adjust the target SINR for different UEs. In CLPC, $f(\Delta)_i)$ can be used to improve system performance controlled from eNodeB. Since in this paper discusses OLPC, $f(\Delta)_i$ is set to 0 in this work. The expression of UE transmit power assigned by a particular user to a PRB is simplified in this study since it solely focuses on open loop power control. [9]

$$P_{Tx} = min(P_{max}, P_o + 10log_{10}(M) + \alpha_L) \quad (2)$$

There is no power control when $\alpha = 0$ (i.e. no compensation for path loss), and all users will utilise the maximum allowable transmit power. The UE power is set to $P_{TX} = P_{max}$ when $\alpha = 1$ (complete compensation of path loss). Full functional power control is therefore accomplished with $\alpha = (0<\alpha<1)$ (functional compensation of path loss). As a result, the management of $alpha$ is crucial in this project.

The LTE uplink power regulation for physical uplink shared channel was described in this chapter using a model analysis. It has explored several power control applications and assessed its performance for various parameter settings such as base station height (h_{bs}), path loss compensation factor (α), and eNodeB sensitivity (P_o).

Research Methodology

Here Open and closed schemes for Power Saving are analyzed with diagram and calculations in MATLAB and graphs are plotted for the same indicating the values.

Open Loop Scheme and Closed Loop Scheme

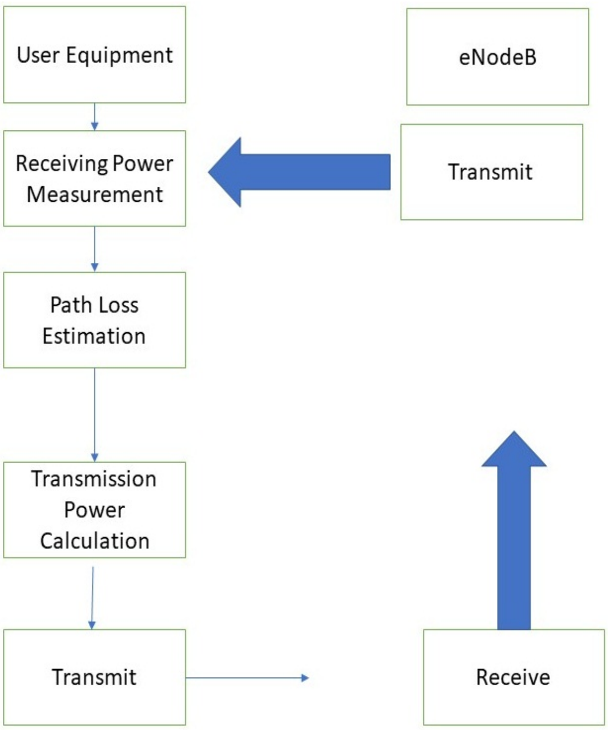

Figure 1.Open Loop Scheme

The figure shows how open loop schemes works, here the Transmitter sends, receiver measures the power, then path loss is estimated, then Transmission Power calculation is done, there is no feedback mechanism.

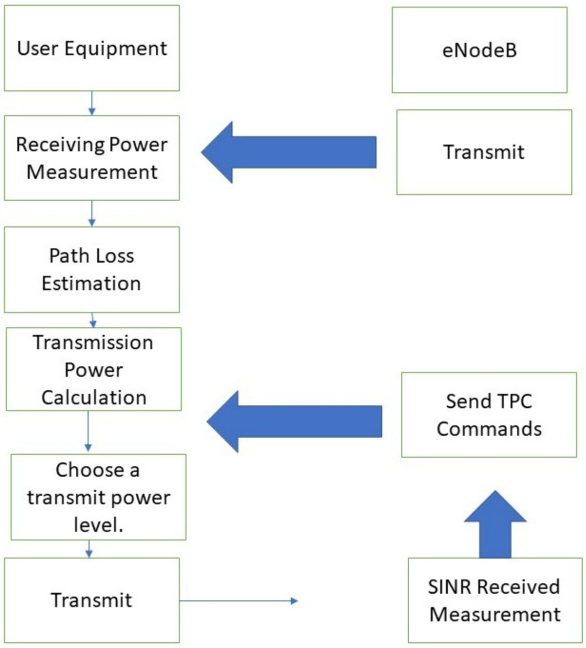

Figure 2.Closed Loop Scheme

The figure shows how closed loop schemes works, here the Transmitter sends TPC commands, receiver measures the power, then path loss is estimated, then Transmission Power calculation is done, after that a transmit power level is chosen. SINR measurement is also done. There is feedback mechanism.

Simulation Setup and Results

In the Simulation setup Power density, User Equipment with different height of base station for Rural, UE with different height of base station for urban, UE with different height of base station for Suburban area for different height of Base station i.e. 10m, 35m,50m,75m. and Analysis of Path Loss Model like Okumura Modes, COST 231 Model and Hata Model.

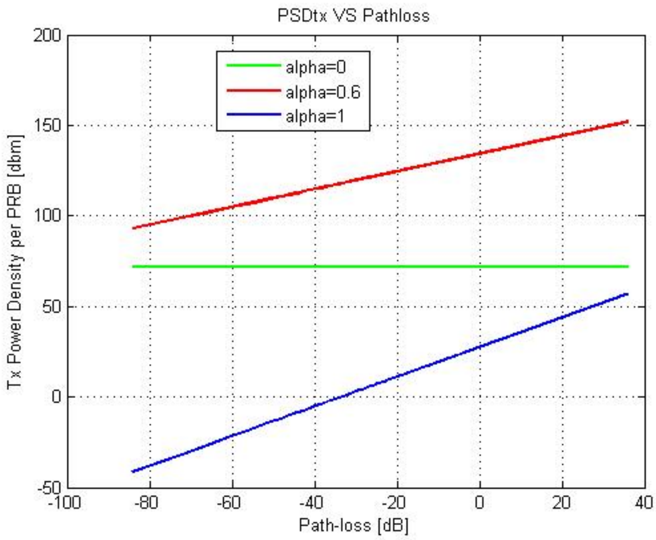

Figure 3.PSD (Tx)[dbm] v/s Path Loss (PL)[dB] for different Alpha Values

The figure 3 indicates the Transmit Power density of Physical Resource Block and Path Loss measurement for different values of alpha factor like 0, 0.6 & 1.The graph shows that for alpha =0, the graph is almost a straight line, and for alpha =0.6, is increasing slope and more Transmit Power density and for alpha =1, is increasing slope but with lower Transmit Power density.

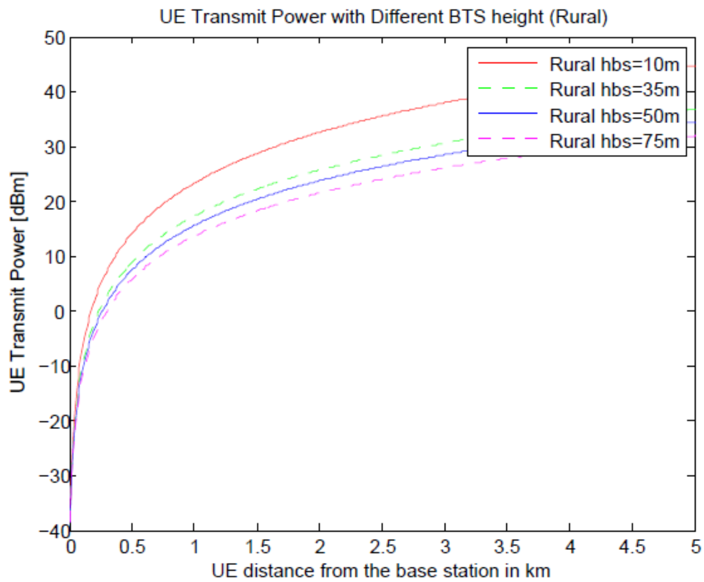

Figure 4.User Equipment (UE) with different height of base station for Rural

The figure 4 shows User equipment Transmit Power [dBm] and User equipment distance from base Station in km relation for different height of Base station i.e. 10m, 35m,50m,75m in Rural Region. For base station height = 10m, the graph shows the maximum value and for base station height = 75m, the graph shows the minimum value. base station height = 35m has less value than base station height = 10m but more than base station height = 75m.

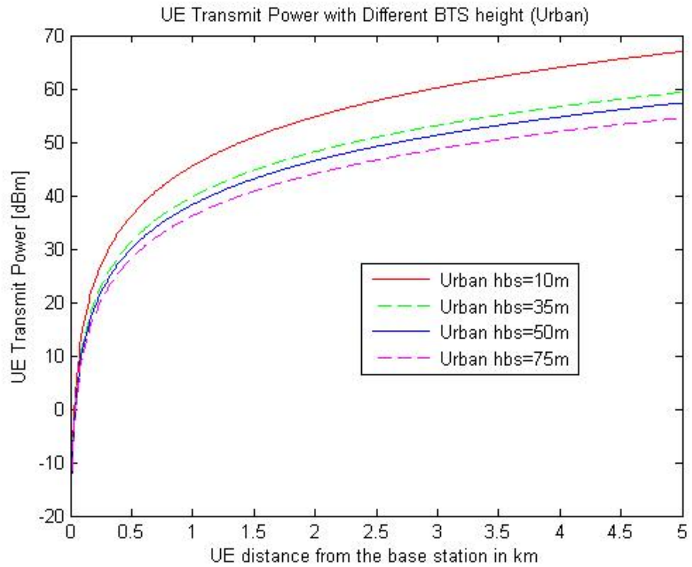

Figure 5.User Equipment (UE) with different height of base station for urban

The figure 5 shows User equipment Transmit Power [dBm] and User equipment distance from base Station in km relation for different height of Base station i.e. 10m, 35m, 50m, 75m in

Urban region. For base station height = 10m, the graph shows the maximum value and for base station height = 75m, the graph shows the minimum value. base station height = 35m has less value than base station height = 10m but more than base station height = 75m.

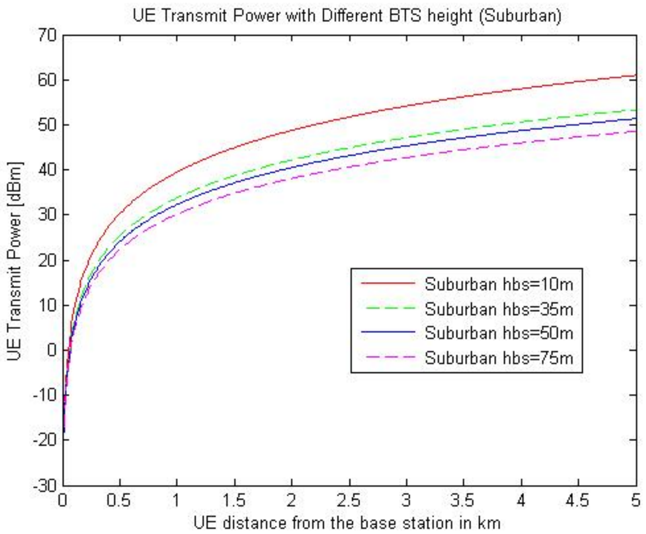

Figure 6.User Equipment (UE) with different height of base station for Suburban

The figure 6 shows User equipment Transmit Power [dBm] and User equipment distance from base Station in km relation for different height of Base station i.e. 10m, 35m,50m,75m in Urban region. For base station height = 10m, the graph shows the maximum value and for base station height = 75m, the graph shows the minimum value. base station height = 35m has less value than base station height = 10m but more than base station height = 75m.

Path Loss Models

Okumura model

The formula for Okumura model is given as[4]:

$$P_{L(dB)} = L_f(d) + A_{mu}(f,d) - G_{(h_{te})} - G_{(h_{re})} - G_{AREA} \quad (4)$$

Where:

$P_{L(dB)}$ = median path loss (dB)

a = free space propagation path loss (dB)

A_{mu}(f,d) = Free space path loss (dB)

(h_{te}) = base station antenna height gain factor

(h_{re})= mobile antenna height gain factor

$AREA$ = gain in urban, suburban, or open regions matching to a certain environment and characteristics

f = Frequency (MHz)

h_{te} = Transmitter antenna height (m)

h_{re} = Receiver antenna height (m)

d = distance between transmitter and receiver antenna (km)

$$G_{(h_{te})} = \begin{Bmatrix} 20log_{10}\left(\frac{h_{re}}{200}\right), & \text{if} 100 > h_{re} > 10 \\ 10log_{10}\frac{h_{re}}{3}, & \text{if} h_{re} \leq 3 \\ 20log_{10}\frac{h_{re}}{3}, & \text{if} 10 > h_{re} > 3 \end{Bmatrix} \tag{5}$$

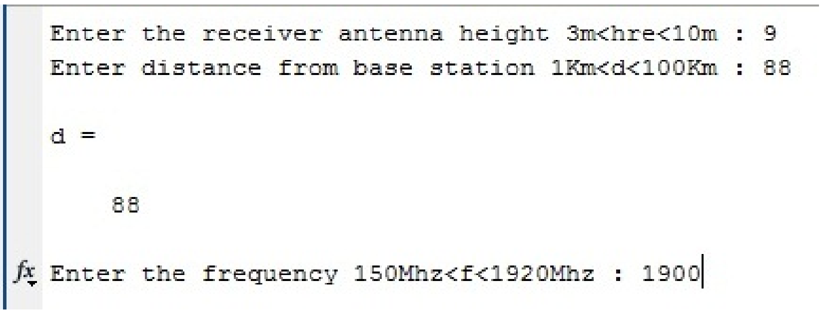

Figure 7.Okumura Model Values

Here in figure 7 Okumura Model values are given, the receiver antenna height is 9m and distance from base station is 88 km. The frequency used for calculation is 1900 MHz. All values are taken within the range of Okumura Model values

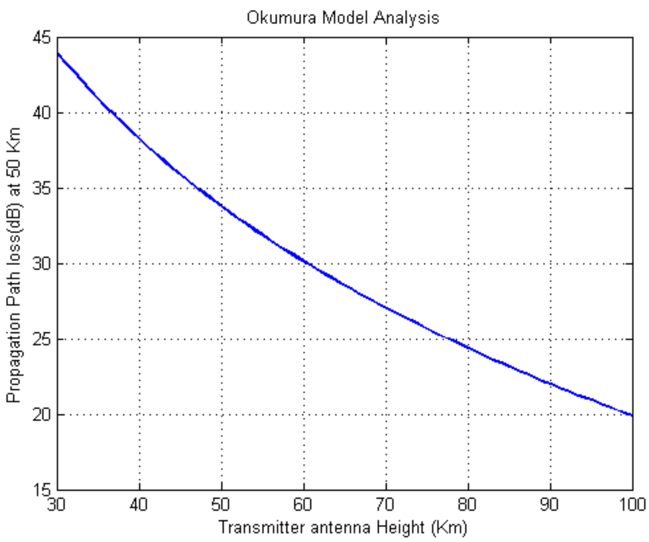

Figure 8.Okumura Model Result

Here in figure 8, the graph indicates the Okumura Model analysis in terms of Path Loss and Transmitter antenna height. It shows that with increasing Transmitter antenna height, the path loss decreases. The range of graph is 100 on x- axis and 45 on y-axis.

Hata model

The Equations used in this model are as follow[3]:

$$PL_{HataModel}(urban) = 69.55 + 26.16log_{10}f_c - 13.82log_{10}h_{te} - a(h_{re}) + (44.9 - 6.55log_{10}(d)) \quad (6)$$

where

Hata Path Loss in dB, $PL_{HataModel}$,

f_c: carrier frequency in MHz (150-1500),

h_{te} (effective base station height), 30-200m,

h_{re}: Height in m for mobile antenna (1-10),

d: the distance between the receiver and the emitter in kilometres

$a(h_{re})$: Factor for adjusting the height of mobile antennas (function of the service area or city).

for cities of a modest to medium size

$$a(h_{re}) = (1.11log_{10}f_c - 0.7)h_{re} - (1.56log_{10}f_c - 0.8)dB$$

for a big city,

$$a(h_{re}) = (8.29(log_{10}1.54h_re)-^2 - 1.1)dB$$

$$(f_c \leq 300Mhz)$$

$$a(h_{re}) = (3.2(log_{10}11.75h_re)-^2 - 4.97)dB$$

$$(f_c > 300Mhz)$$

The path loss in a suburban area is given by

$$L - T(HataModel) = L_{T(HataModel)}(urban) - 2[log_{10}\left(\frac{f_c}{28}\right)^2 - 5.4\Big)]dB \quad (7)$$

For open areas (rural), the formula is modified as

$$L - T(HataModel) = L_{T(HataModel)}(urban) -4.78(log_{10}f_c)^2 + 18.33log_{10}f_c - 40.98dB \quad (8)$$

For higher carrier frequencies of 1500 – 2000 MHz, the following modification of Hata model for urban area is given

$$L_T(HataModel)(urban) = 46.33 + 33.9log_{10}f(Mhz) - 13.82log_{10}h_{te} - a(h_{re}) + 44.9 - 6.55log_{10}d) + C \quad (9)$$

C = 0 dB for medium-sized cities

and C = 3 dB for metropolitan centres is an additional correction factor.

COST-231 Hata Propagation Model

The COST-231 Hata model equations used are as follows[6]:

$$L_p(dB) = A + Blog_{10}(d) + C \quad (10)$$

Where:

$A = 46.3 + 33.9log_{10}(f_c) - 13.82log_{10}(h_{bs}) - ah_m$

$B = 44.9 - 6.55log_{10}(h_{bs})$

$C = 0$ for medium city and suburban areas

$C = 3$ for metropolitan areas

The function ah_m for urban area is defined as:

$$ah_m = 3.2(log(11.75h_{ue}))^2 - 4.97 \quad (11)$$

and for rural and suburban areas it is as follows:

$$ah_m = (1.1log(f_c) - 0.7)(1.56.log(f_c) - 0.8) \quad (12)$$

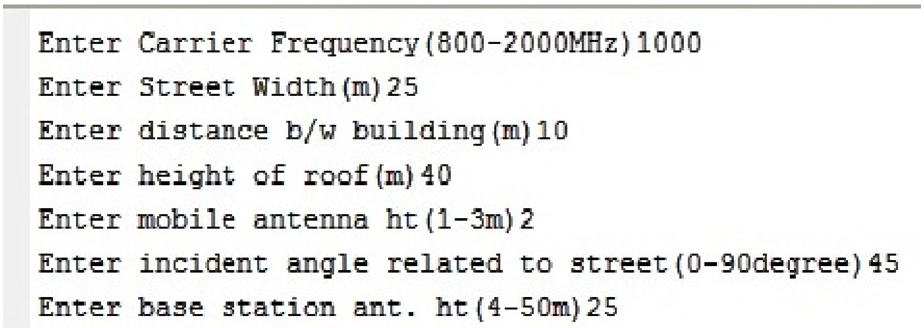
```
Enter Carrier Frequency(800-2000MHz)1000
Enter Street Width(m)25
Enter distance b/w building(m)10
Enter height of roof(m)40
Enter mobile antenna ht(1-3m)2
Enter incident angle related to street(0-90degree)45
Enter base station ant. ht(4-50m)25
```

Figure 9.COST 231 Model Value 1

Here in figure 9,values for COST 231 Model is taken for Model analysis, where Frequency is 1000 MHz, Street width is 25m, distance between building is 10 m, height of roof is 40 m, mobile antenna height is 2m, incident angle related to street is 45 degrees and base station height is 25m.

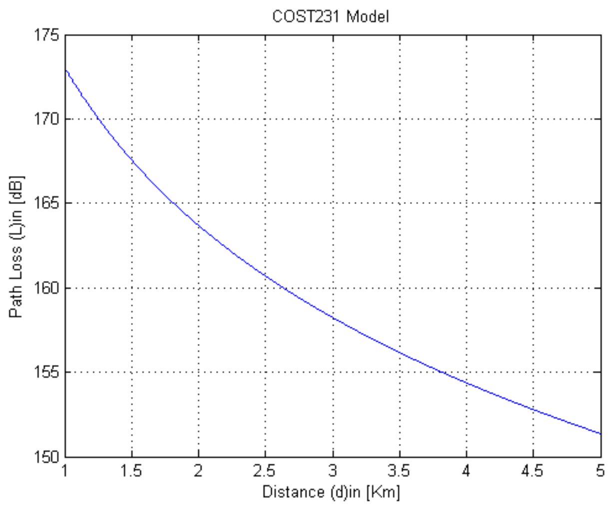

Figure 10.COST 231 Model Value 1 Result

Here in figure 10, graph for COST 231 Model taken for Model analysis is shown, in this as the distance increases, the path loss decreases, indicating a fall in path loss with increasing distance.

```
Enter Carrier Frequency(800-2000MHz)2000
Enter Street Width(m)3
Enter distance b/w building(m)5
Enter height of roof(m)7
Enter mobile antenna ht(1-3m)2
Enter incident angle related to street(0-90degree)30
fx Enter base station ant. ht(4-50m)30
```

Figure 11.COST 231 Model Value 2

Here in figure 11,for COST 231 Model is taken for Model analysis, where Frequency is 2000 MHz, Street width is 3m, distance between building is 5 m, height of roof is 7 m, mobile antenna heightis 2m, incident angle related to street is 30 degrees and base station height is 30m.

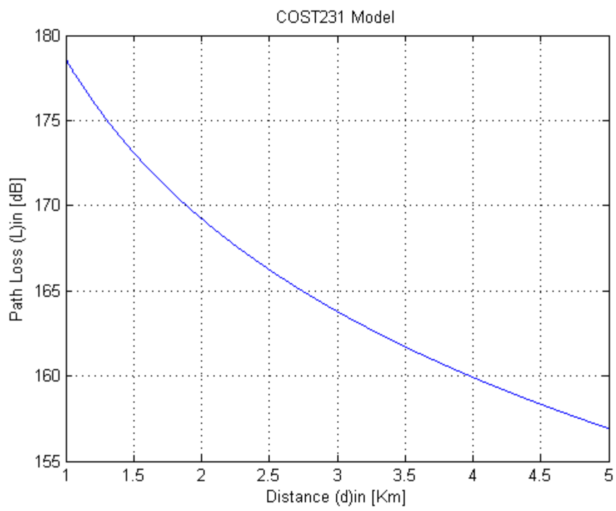

Figure 12.COST 231 Model Value 2 Result

Here in figure 12, graph for COST 231 Model taken for Model analysis is shown, in this as the distance increases, the path loss decreases, indicating a fall in path loss with increasing distance

Hata v/s COST 231 Model Comparison

Following parameters are used for Simulation of the following figure:

Table 1.Hata v/s COST 231 Model Comparison Old Parameters

h_t in (meter)	h_r in(meter)	f in(MHz)
50	2	1500
50	5	1500
50	10	1500
80	2	1500
100	2	1500
150	2	1500
200	5	1500
200	2	1500
200	10	1500
50	2	1800
50	2	2000

.

Table 2.Hata v/s COST 231 Model Comparison New Parameters

h_t in (meter)	h_r in(meter)	f in(MHz)
70	3	1500
110	5	1500
140	6	1500
190	6	1500
100	5	1600
140	4	1600
190	6	1600
140	4	1700
100	5	1800
120	2	1800
150	5	1900
200	5	1900
100	5	2000
90	2	2000
200	10	2000

where

Transmitter Height = ht(in meter)

Receiver Height= hr (in meter)

Frequency= f (in MHz)

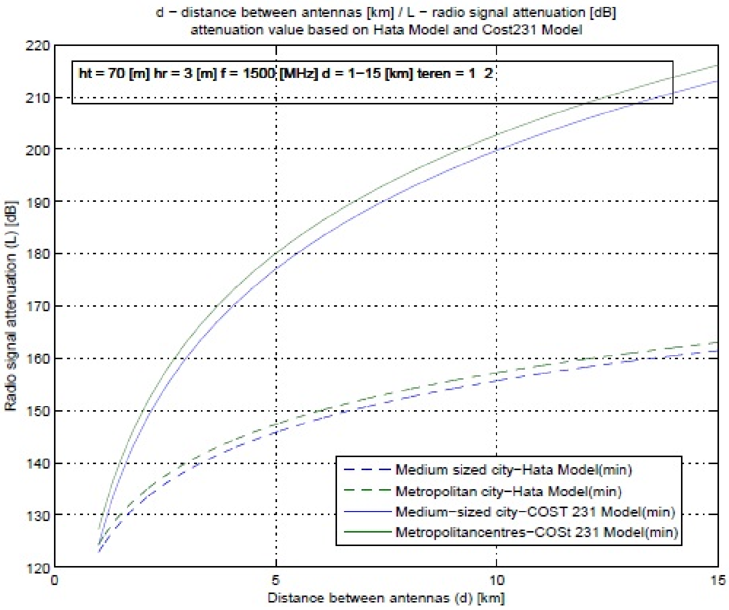

Figure 13.COST 231 V/S Hata Model (minimum Values)

Here in figure 13, The comparison between COST 231 and Hata Model is shown for medium sized city and Metropolian sized city in terms of its minimum values, on x- axis it is the distance between antennas and on y-axis it is the Radio signal attenuation. For medium sized city, hata model has minimum values and for Metropolian sized city COST 231 has minimum values.

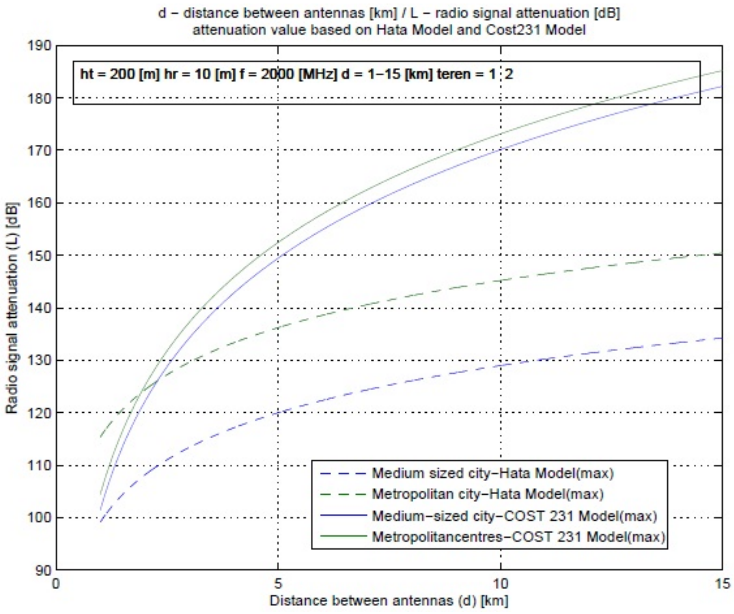

Figure 14.COST 231 V/S Hata Model (maximum Values)

Here in figure 14, The comparison between COST 231 and Hata Model is shown for medium sized city and Metropolian sized city in terms of its maximum values, on x- axis it is the distance between antennas and on y-axis it is the Radio signal attenuation. For medium sized city, hata model has maximum values and for Metropolian sized city COST 231 has maximum values.

Conclusion

The research reported above may therefore be used to determine the uplink transmit power of user equipment (UE). Future research based on this investigation will look at the unexpected changes in the terrain as well as how to apply the findings in other settings.

For several values of the alpha factor, such as 0, 0.6, and 1, the figure 3 shows the transmit power density of the physical resource block and the path loss measurement. For alpha = 0, the graph is nearly straight; for alpha = 0.6, there is an increase in slope and transmit power density; and for alpha = 1, there is an increase in slope but a decrease in transmit power density.

Figure 4 illustrates the relationship between user equipment transmit power (in dBm) and user equipment distance from base station (in km) for various base station heights, i.e. 10m, 35m, 50m, and 75m in rural region. The graph displays the maximum value when the base station height is 10 metres, and the minimum value when the base station height is 75 metres. Compared to base station heights of 10 and 75 metres, base station heights of 35 metres are more valuable.

Figure 5 illustrates the relationship between user equipment transmit power (in dBm) and user equipment distance from base station (in km) for various base station heights, i.e. 10m, 35m, 50m, and 75m in urban area. The graph displays the maximum value when the base station height is 10 metres, and the minimum value when the base station height is 75 metres. Compared to base station heights of 10 and 75 metres, base station heights of 35 metres are more valuable.

Figure 6 illustrates the relationship between user equipment transmit power (in dBm) and user equipment distance from base station (in km) for various base station heights, i.e. 10m, 35m, 50m, and 75m in SubUrban region. The graph displays the maximum value when the base station height is 10 metres, and the minimum value when the base station height is 75 metres. Compared to base station heights of 10 and 75 metres, base station heights of 35 metres are more valuable.

The reception antenna's height is 9 metres, and its distance from the base station is 88 kilometres, according to Figure 7. The calculation frequency is 1900 MHz. All values are taken from the range of values for the Okumura Model.

The graph for the Okumura Model study of Path Loss and Transmitter Antenna Height is shown here in Figure 8. It demonstrates that the route loss decreases as the height of the transmitter antenna rises. The graph's range is 45 on the y axis and 100 on the x axis..

Figure 9 shows the values for the COST 231 Model that were used for the model analysis. The frequency is 1000 MHz, the street width is 25 metres, the distance between buildings is 10 metres, the height of the roof is 40 metres, the height of the mobile antenna is 2 metres, the incident angle related to the street is 45 degrees, and the base station height is 25 metres.

Figure 10 displays the path loss graph for the COST 231 model used for the model analysis. The graph shows that the path loss falls with increasing distance.

Figure 11 shows the values used for the COST 231 Model analysis. The frequency is 2000 MHz, the street width is 3 metres, the distance between buildings is 5 metres, the height of the roof is 7 metres, the height of the mobile antenna is 2 metres, the incident angle with respect to the street is 30 degrees, and the base station height is 30 metres.

The model study's COST 231 model is shown in Figure 12. Path loss decreases as the distance rises, indicating that path loss decreases as the distance expands.

Figure 13 compares the Hata Model with COST 231 for medium-sized and metropolis-sized cities in terms of their minimum values. On the x-axis, it shows the distance between antennas, and on the y-axis, it shows the attenuation of the radio signal. Hata model includes minimum values for medium-sized cities, and COST 231 has minimum values for Metropolian-sized cities.

Figure 14 compares the maximum values of the COST 231 and Hata Model for medium-sized and metropolis-sized cities, where the x-axis represents the distance between antennas and the y-axis the attenuation of the radio signal. Hata model has maximum values for medium-sized cities, and COST 231 has maximum values for Metropolian-sized cities.

References

Paolo Baracca, Lorenzo Galati Giordano, AdrianvGarcia-Rodriguez, Giovanni Geraci, and David López-Pérez. Downlink performance of uplink fractional power control in 5gmassive mimo systems. In 2018 IEEE Globecom Workshops (GC Wkshps), pages 1-6. IEEE, 2018.

Md Shariful Islam, Md Ashek Raihan Mahmud, Md JashimUddin, and Pallab Kanti Podder. An analytical analysis of pathloss models for mobile cellular wireless communications.

Yoshihisa Okumura. Field strength and its variability in vhfand uhf land-mobile radio service. Rev. Electr. Commun. Lab., 16: 825-873, 1968.

Nestor J Quintero. Advanced power control for utran lte uplink.Master of Science Thesis, Aalborg University, 2008.

Purnachand, S., Prasad, R., Roy, S., & Suresh, A. (2012). Performance analysis of open loop and closed loop power control schemes for LTE uplink. power, 10, 2.

Bankar, N., & Patel, C. (2013, November). Performance analysis of closed loop uplink power control schemes in cellular radio system. In 2013 Nirma University International Conference on Engineering (NUiCONE) (pp. 1-8). IEEE.

Khangura, S. K., Kaur, K., & Uppal, R. S. (2010). Power control algorithms in wireless communication. International Journal of Computer Applications, 1(12), 82-87.

Tondare, S. M., Veeresh, G. K., & Kejkar, A. S. (2015). Review of power control mechanisms in cellular system. Global Journal of Research in Engineering.

George, J. J., & Taha, N. M. A Combined Open-Closed Loop Power Control for LTE Uplink. *vol*, *5*, 234-238.

Sonia, N. M., Malik, N., Rekhi, S., & Malik, S. S. (2014). Uplink power control schemes in long term evolution. International Journal of Engineering and Advanced Technology, 3(3), 260-264.