The effect of various parameters of large scale radio propagation models on improving performance mobile communications

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Abstract. One technique for ensuring continuity of wireless communication services and keeping a smooth transition on mobile communication networks is the soft handover technique. In the Soft Handover (SHO) technique the inclusion and reduction of Base Station from the set of active sets is determined by initiation triggers. One of the initiation triggers is based on the strong reception signal. In this paper we observed the influence of parameters of large-scale radio propagation models to improve the performance of mobile communications. The observation parameters for characterizing the performance of the specified mobile system are Drop Call, Radio Link Degradation Rate and Average Size of Active Set (AS). The simulated results show that the increase in altitude of Base Station (BS) Antenna and Mobile Station (MS) Antenna contributes to the improvement of signal power reception level so as to improve Radio Link quality and increase the average size of Active Set and reduce the average Drop Call rate. It was also found that Hata's propagation model contributed significantly to improvements in system performance parameters compared to Okumura's propagation model and Lee's propagation model.

1. Introduction

Code Division Multiple Access (CDMA) is one of the communication technologies for 3G standards in mobile communications. 3G is an international technology standard that aims to improve efficiency and improve mobile network performance. 3G offers improved service quality (QoS) [1]. One facility in a cellular system to ensure continuity of communication when a customer moves from one cell to another is a handover. CDMA-based cellular networks are capable of supporting soft handover, which makes smoother transitions and improves communication quality. With Soft handover, some radio links can operate in parallel, so the MS (mobile station) connection with several base station transceivers can be done simultaneously [2].

   Soft handover is often associated with active set and its size. Active set is a set of all stations that communicate with MS. The input / discharge of a base station to / from the active set is determined by the initiation trigger that has been determined. Initiation can be done with strong signal measurements from the existing BTS set. One of the initiating initiatives set up on signal strength measurement is the Hysteresis-threshold method [3].

   Due to the high mobility of MS moving from one cell to another, it is difficult to predict the signal propagation and affect the signal strength of the reception. The strong signal levels received by MS are

influenced by path loss, Shadow fading and Fast fading, as a result of propagation attenuation and irregular environmental conditions [4][5]. The accumulation of MS mobility, propagation damping and environmental conditions will affect soft handover performance on CDMA systems.

In this paper, the propagation channel used as a signal transmission channel connecting base stations with MS is a large-scale propagation model, i.e. Lee, Okumura and Hata models. These propagation models predict signal strength at any distance on the MS receiver against the base station. Furthermore, the signal strength of the prediction results of these propagation models is used as the signal strength for the initiation trigger to activate the soft handover. So we get the relationship between the height of BS antenna and MS antenna on the improvement of system performance, namely Drop Call, Radio Link Decrease Rate and the average size of Active Set.

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2. Model System

2.1. Network configuration

For simplification, the system configuration consists of two BSs. Each BS has the same and separate transmit power at distance D and MS moves on a straight path with a regulated speed as shown in Figureure1. During movement, MS receives signals with descending power. This decrease is due to the increase of distance and obstacle from the surrounding nature that spread between transmitter base station with MS. In this paper the decrease in power due to surrounding natural obstacles is determined by large-scale propagation model. MS samples the received signal strength (RSS) at a fixed interval distance (d = kds), where ds is the sampling distance. The ds value used is 1meter. The variable k is an integer with the value $k \in [0, D / ds]$.
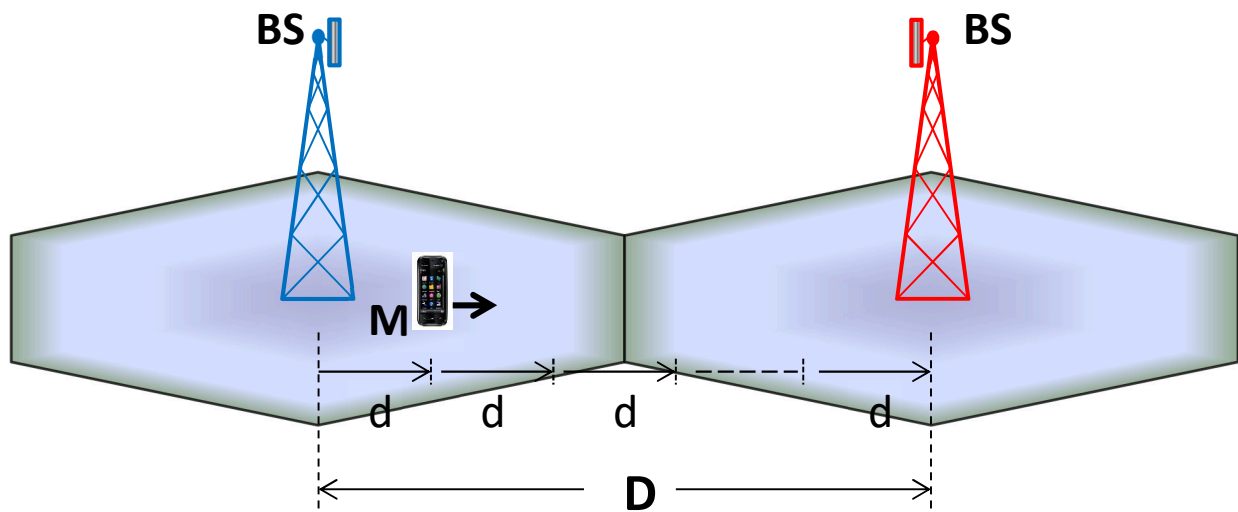
Figure. 1 Network model

2.2. The propagation Channel Model

The propagation model describes the average propagation of signals in an area. The magnitude of these propagation losses varies according to the spectrum and the nature and the environment. Estimating the losses to be signaled is very important. One of them is the losses generated by signal propagation. Loss of propagation are fairly difficult to predict. This loss is directly affected by the state of the environment surrounding the signal. Experts have produced some mathematical models that can provide good enough value to approach real-world circumstances. Among the radio signal propagation channel models are large-scale propagation models. In this research, the propagation

channel model is determined based on large-scale propagation models for urban areas ie Model Lee, Okumura and Hata.

2.2.1. Okumura model

To determine the damping of the path with the Okumura model, we must first calculate the free path loss, then the Amu (f, d) value of the Okumura curve that is added to the correction factor to determine the type of area. The path loss of Okumura model (PL (dB)) can be written in Equation (1) [6] [7].

$$PL (dB) = L_F + A_{mu}(f,d) - G(h_{te}) - G(h_{re}) - G_{AREA} \qquad (1)$$

Where; L_F , A_{mu}, G (h_{te}), G (h_{re}) and G_{AREA} are respectively free path losses (dB), average attenuation relative to free path loss (dB), gain of antenna BS (dB), gain of MS antenna (dB) and gain area (dB).

The gain of antenna BS (G (h_{te})) is calculate by Equation (2)

$$G (h_{te}) = 20\log (h_{te} / 200), \text{ for; } 100 \text{ m} > h_{te} > 10 \text{ m} \qquad (2)$$

The gain of antenna MS (G (h_{re})) is calculate by Equation (3) and (4)

$$G (h_{re}) = 20\log (h_{re} / 3), \text{ for; } 10 \text{ m} > h_{re} > 3 \text{ m} \qquad (3)$$

$$G (h_{re}) = 10 \log (h_{re} / 3), \text{ for; } h_{re} \leq 3 \text{ m} \qquad (4)$$

with h_{te} and h_{re} are high antenna BS (m) and high antenna MS (m) respectively. The Okumura model is a simple model but provides good accuracy for predicting track attenuation on mobile radio communication systems for irregular areas.

2.2.2. Hata Model

Hata model is a form of empirical equation of curved track curve made by Okumura, therefore this model is more commonly referred to as Okumura-Hata model. Hata creates a standard equation to calculate the path attenuation in the urban area, whereas to calculate the path attenuation in other types of regions (suburbs, open areas, etc.), Hata gives the correction equation. To determine the loss of Hata model for urban (L(*urban*)(dB)) area using Equation (5), [6] [8].

$$L(urban)(dB) = 69{,}55 + 26{,}16\log(f_c) - 13{,}82\log(h_{te}) - a(h_{re}) + (44{,}9 - 6{,}55\log(h_{re})) \log(d) \qquad (5)$$

where; f_c, h_{te}, h_{re} and d are working frequency (150-1500 MHz), high effective antenna transmitter BS (30-200 m), high effective antenna receiver MS (1-10 m) and distance between Tx-Rx (km). a(h_{re}) is correction factor for the effective height of the MS antenna as a function of the area served.

For small towns to medium cities, the correction factors a (h_{re}) are given by Equation (6).

$$a(h_{re}) = (1.1\log (f_c) - 0.7) h_{re} - (1.56\log(f_c) - 0.8)dB \qquad (6)$$

while for big cities, the correction factors a (h_{re}) are given by Equation (7) and (8).

$$a(h_{re}) = 8.29 (\log 1.54 h_{re})^2 - 1{,}1 \text{ dB, for; } f_c < 300 \text{ MHz} \qquad (7)$$

$$a(h_{re}) = 3.2 (\log(11{,}75 hre))^2 - 4{,}97 \text{ dB for } fc > 300 \text{ MHz} \qquad (8)$$

Although the Hata model has no specific track correction as the Okumura model provides, but the above equations are very practical to use and have excellent accuracy

2.2.3.Lee Model
Lee's propagation model is derived from experimental data in several major cities in the world. The reference parameter is 900 MHz, at antenna height 30.5 m, with power transmission 10 W. Lee's model propagation loss PL_{so} is shown at Equation (9), [6] [8].

$$PL_{so} = L_0 + \gamma \log d - F_0 \qquad (9)$$

where; L_0, γ, d and F_0 are transmission losses at a distance of 1 km (dB), slope of path loss (dB / decade), distance from base station (m) and adjustment factor. The values of L0 and γ are obtained from the experimental data [5].

While the value of F_0 is given by equation (10),

$$F0 = F1\ F2\ F3\ F4\ F5 \qquad (10)$$

with;

$$F_1 = \frac{[actual\ base\ station\ antenna\ height\ (m)]^2}{(30.5\ m)^2} \qquad (11)$$

$$F_2 = \frac{[actual\ transmitter\ power\ (W)]}{10\ W} \qquad (12)$$

$$F_3 = \frac{[actual\ gain\ of\ bus\ station\ antenna]}{4} \qquad (13)$$

$$F_4 = \frac{[actual\ mobile\ antenna\ height\ (m)]^2}{(3\ m)^2} \qquad (14)$$

$$F_5 = \frac{[f_c]^2}{[f_0]^2} \quad \text{where } f_0 = 900\ \text{MHz} \qquad (15)$$

MS measures the strength of the received signal (RSS) of each BS. The measured RSS (dBm) value represents the difference between the transmitted power of the BS and the attenuation of the PL radio wave propagation model (dB) [3].

Suppose d_i indicating the distance between MS with BSi. If the power transmitted by the BTS is P_t, then the signal strength of the BSi is denoted by Xi (d), and is written with Equation (16)

$$X_{i(r)}(d) = P_t - P_L \qquad (16)$$

where; $X_{i(r)}$ (d), P_t and P_L respectively are the signal strength of the i-th BS received by the MS at a distance d (dBm), power transmitted BTS (dBm) and path loss of the radio wave propagation model (dB). Then, the result of signal strength measurement, is averaged to eliminate the effect of rapid variation of the received signal. The method used in averaging is the window method. The Equation model of the window method can be written with Equation 17.

$$\hat{X}_{i(r)}(k) = \frac{1}{N_W} \sum_{n=0}^{N-1} X_{i(r)}(k-n) W_n \qquad (17)$$

Where; $\hat{X}_{i(r)}$ is an averaged signal power gain and $X_{i(r)}$ is the signal strength before the smoothing process. N is the number of samples and Wn is the large window used for sampling. The value of Wn is unity for all n if the method used is a rectangular method. The averaged signal strength $\hat{X}_{i(r)}$ of the whole BS is the quantity to calculate the probability of radio link decrease and as the initiator trigger for soft handoff. The link degradation rate (λ_{LD}) is calculated by Equation (18)

$$\lambda_{LD}(\Phi, S) = E\left[\frac{1}{N} \sum_{k=1}^{N} \mathbb{I}_{\{Degradasi\ Link\ at\ time\ k\}}\right] \qquad (18)$$

λ_{LD} measures the signal quality at time k on link that is in a descending state. $\mathbb{I}$ is an indicator function, worth 1 or 0 depending on whether the argument is true or false. The state of link degradation (LD) occurs when RSS ($\hat{X}_{k,i(r)}$) is below the threshold Δ, as shown in (19).

$$\max_{i \in A_k}(\hat{X}_{k,i(r)}) < \Delta \qquad (19)$$

3. Initiation of SHO Algorithm

The reference parameter used in initiating handoff is the strong signal received from the pilot signal. The soft handover algorithm used is a model of threshold with hysteresis. Threshold is a strong value of the minimum receive signal that must be achieved to maintain a call. If the signal strength falls below the threshold value, then the call will be dropped. As for hysteresis, it is an additional value to the algorithm. This value is useful to improve the performance of the soft handover algorithm.

The type of initiation used is MACHO / MAHO, with algorithm parameters are Threshold, HYST_ADD, and HYST_DROP. The way the soft handover algorithm is described as follows [3]

1. If the active set contains BS1 and $\hat{X}_1(d)$ dan > Δ and the absolute difference of $\hat{X}_1(d)$ and $\hat{X}_2(d)$ is greater than HYST_ADD then active set still contains BS1
2. If $\hat{X}_1(d)$ and $\hat{X}_2(d)$ > Δ and the absolute difference of $\hat{X}_1(d)$ and $\hat{X}_2(d)$ is smaller than HYST_ADD then active set contains BS1 and BS2.
3. If $\hat{X}_1(d)$ and $\hat{X}_2(d)$ > Δ and the absolute difference of $\hat{X}_1(d)$ and $\hat{X}_2(d)$ is greater than HYST_DROP then active set contains BS2 (Soft handoff occurs).
4. If $\hat{X}_1(d)$ and $\hat{X}_2(d)$ < Δ then active set does not contain BS1 or BS2. MS will not have connection with BS1 and BS2. This condition is called a drop call.

The size of the active set for two BS can be modeled with the state diagram as illustrated in Figure 2.
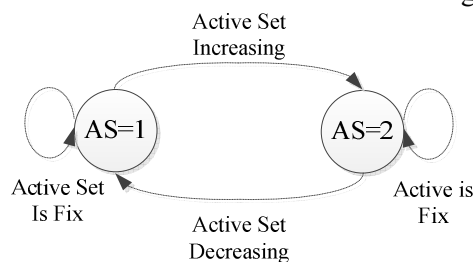

Figure 2. State diagram of Active Set for two BSs

The system parameters used in the simulation are shown in Table 1

Table 1 The system parameter

Symbol	Description	Value
d	Distance between BS	2000 m
P_i	Power transmission	23 dBm
Δ	Minimum Signal Level	-90 dBm
f	Frequency	900 MHz
σ	Standard Deviation	8 dB
M	Large Window	20
h_{re}	High Antenna MS	1,5- 11 m
h_{te}	High Antenna BS	20-120 m
Hist_Add	Hysteresis ADD	10 dBm

Hist_Drop	Hysteresis DROP	10 dBm

Based on the parameter values in Table 1, the discussion emphasizes the observation of the high value changes of BS Antenna and the height of the MS Antenna. For the changing of the high antenna BS, the height of the BS Antenna is varied from a height of 20 meters up to 120 meters with a space of each addition being 5 meters. Minimum signal reception power level is -90 dBm and Hysteresis Add and drop value is 10 dBm. For the changing of the high antenna MS, the height of the BS Antenna is varied from a height of 1.0 meters up to 11.0 meters with a space of each addition being o.5 meters. Minimum signal reception power level is -90 dBm and Hysteresis Add and drop value is 10 dBm. The height variations of antenna BS and MS above is observed its effect on mobile network performance parameters namely; Drop Call Rate, Decreasing of Radio Link, Average Size Active Set.

4. Results And Discussion

The graph of the relationship between each BS Antenna High and MS Antenna with Drop Call Rate is shown in Figure 3 and 4. It can be observed that with the increase of BS Antenna and MS Antenna, the Drop Call rate decrease.

For Lee's model, almost at all BS altitudes, the mobile network has Drop Call, except starting at a height of 120 meters. As for the Okumura model, the mobile network is free from Drop Call when the BS antenna is at a height of 60 meters. The average value of Drop Call Rate against the increase of antenna height BS, ie from 20 meters to 120 meters for each Lee and Okumura model is 0.2304 and 0.0897. Meanwhile for the Hata model, at all altitudes the BS Antenna does not experience Drop Call. This is due to the fulfillment of signal reception level from BS above the threshold value of the network system provision.
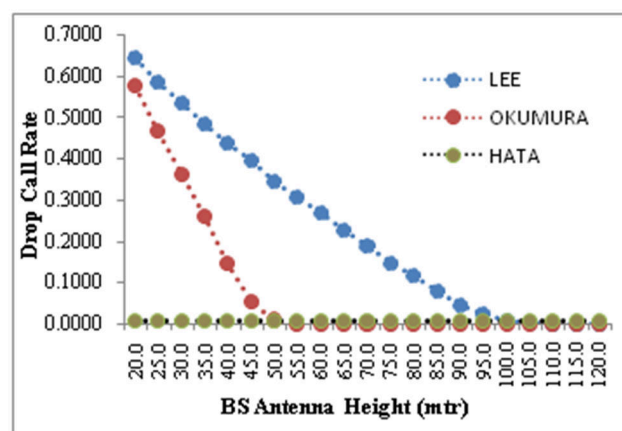
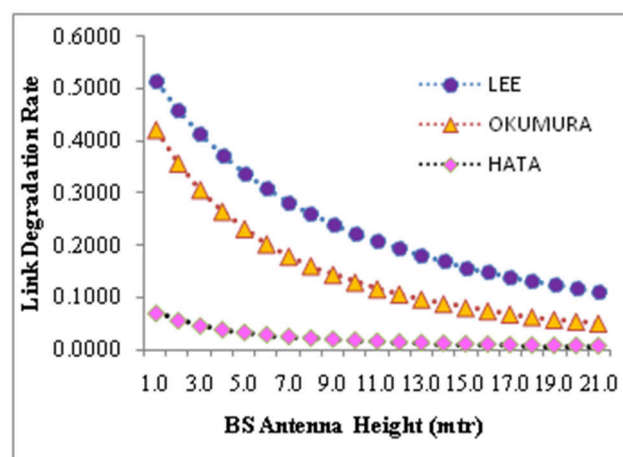**Figure 3.** Drop Call Rate Against the increase of BS antenna height

Similarly to the increase in the height of the Antenna MS, the mobile network is free from Drop Call when the height of the MS antenna for each Lee and Okumura model is 8.5 meters and 4.5 meters. The average value of Drop Call Rate against the increase of antenna height MS, ie 1.0 meter to 11.0 meters for each Lee and Hata model is 0.1808 and 0.0667. Meanwhile for the Hata model, as well as the increase of BS antenna height, which is at all altitude Antenna MS mobile network does not experience Drop Call.
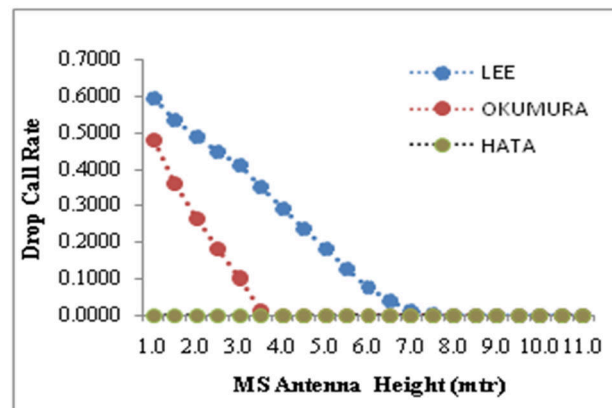
Figure 4. Drop Call Rate Against the increase of MS antenna height

The relation graph of each of the height of BS Antenna and MS Antenna on Radio Link decrease is shown in Figure. 5 and 6. From both Figure it can be seen that the trend pattern of improvement of Radio Link decrease with high increment of BS and MS Antenna is close to equal
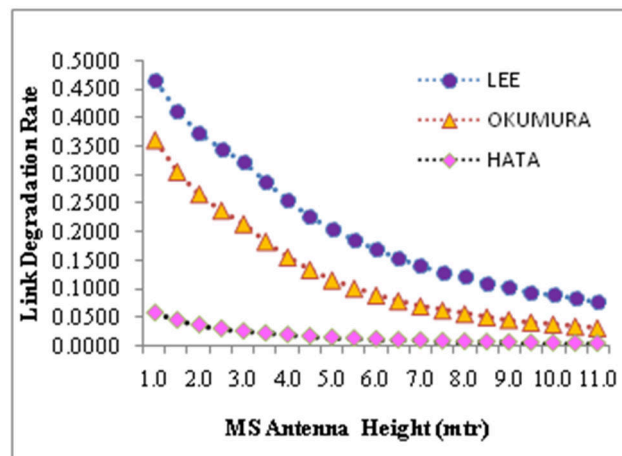
In Figure. 5 it is shown that, for the three propagation models, ie Lee, Okumura and Hata models, repair of mobile network radio links increases with the increase of the BS Antenna height. This is because the increase in antenna height of the BS contributes to the decrease of radio signal path losses, so that the receiving power increases along with the decrease of the propagation losses. It is also shown that, the decrease of the average radio link of the Hata model against the increase of BS antenna height (20 meters to 120 meters) is lower than that of the Okumura and Lee models, which for the Hata model is 0.007, Okumura model is 0.0233 and Lee Of 0.1553.

**Figure 5.** Link Degradation Rate Against the increase of BS antenna height

Similarly to the increase of the height of the Antenna MS (Figure 6), that improvement of mobile network radio links increases with the high increase of MS Antenna for all three propagation models. However, the decrease in the average radio link of the Hata model against the increase in the height of the MS antenna (1.0 meters to 11.0 meters) was lower than the Okumura and Lee models, where for the Hata model is 0.0130, meanwhile for each of Okumura and Lee model's are 0.01185 and 0.1879.

Figure 6. Link Degradation Rata Against the increase of MS antenna height

The average size of Active Set against the high increments of BS and MS Antennas for the three radio propagation models is shown in Figures. 7 and 8. It is shown that the height incremental effects of both BS and MS antennas increase the average number of active sets on mobile networks. Increasing the average number of active sets will improve the service of the continuity of communication, which certainly minimizes the possibility of drop calls.
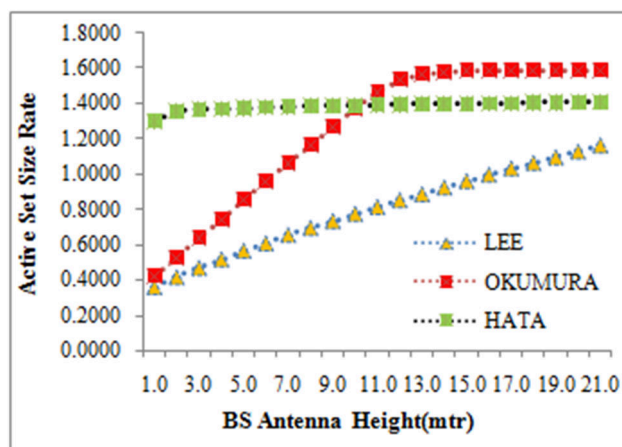
Figure 7. Active Set Size rate Against the increase of BS antenna height

Based on Figure 7 and 8, the performance of the three propagation models for the behavior of the active set size against the increase of the antenna height is slightly different. For Hata propagation model, the active set size remains stable on both the increase of BS and MS antenna height with average size of each is 1.3850 and 1.3656. For the Okumura model, the size of the active set rises above the Hata model, starting at height of 70 meter for BS antenna and at height of 5 meter for MS antenna. The average value of the active set size against increasing of BS and MS antenna are 1.2522 and 1.3202, and the average value of these is still below of the average value of the Hata model. Meanwhile for Lee's model, the size of the active set continues to increase in line with the increase of the BS and MS antennas. The average value of Lee's model for the height increase of BS and MS antennas is 0.7942 and 0.9062. However, the average value of the size of the active set Lee model is still far below the size of the Hata and Okumura models.
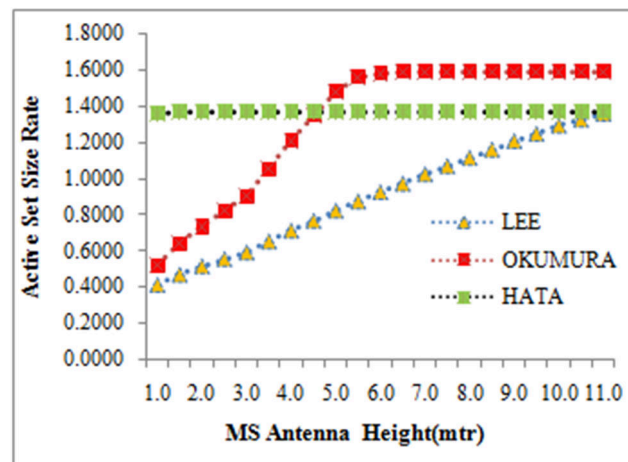
Figure 8. Active Set Size rate Against the increase of MS antenna height

5. Conclusions

In this paper, the effect of changing parameters of large-scale radio propagation models on mobile network performance improvements has been reported, as measured in terms of drop call rates, decreased radio links and active set sizes. An increase in BS and MS antenna altitude, is determined as a model propagation parameter of large scale. The simulation results show that with the increase of BS and MS antenna height improves the performance of the mobile system, where there is an increase of radio link and the size of active size, thereby decreasing the drop call rate. Then from the three large-scale radio propagation models of Lee, Okumura and Hata models, it was found that with the increase of BS and MS antenna altitude, the Hata Model contributed the most in improving the performance of the mobile system compared to both Okumura and Lee models, both in terms of increasing radio links and active set sizes as well as decreasing the rate Drop call

References

[1].   Smith C and Collins D 2002 3G Wireless Networks. McGraw-Hill Companies, Inc
[2].   Singh N P and Singh B 2008 Performance of Soft Handover Algorithm in Varied Propagation Environments. World Academy of Science. Engineering and Technology. **45** 377-381
[3].   Singh N P and Singh B 2010 Performance Enhancement of Cellular Network Using Adaptive Soft Handover Algorithm. Wireless Personal Communications
[4].   Veeravalli V V and Kelly O E 1997 A locally optimal handoff algorithm for cellular communications. *IEEE Trans. Veh. Technol.* **46** 603–610
[5].   Singh N P and Singh B 2010 Effect of Soft Handover Parameters on CDMA Cellular Networks. Journal of Theoretical and Applied Information Technology **110-115**
[6].   Rappaport T S 1995 Wireless Communications: Principles and Practice. 2nd Ed. New Jersey
[7].   Goldsmith A 2005 Wireless Communication. Cambridge University Press
[8].   Lee C Y and William 2006 Wireless and Cellular Telecommunications. 3rd Edition
[9].   Singh N P and Singh B 2007 Effects of Soft Handover Margin under various Radio Propagation Parameters in CDMA Cellular Networks. IEEE Conference on WCSN. **45-50**
[10]. Corraza G E, Giancristofaso D and Santucci F 1994 Characterization of Handover Initiation in Cellular Mobile Radio Networks. IEEE Technology Conference, **1896-1872**