Project	IEEE 802.16 Broadband Wireless Access Working Group <**http://ieee802.org/16**>
Title	Text Proposal for the Path Loss Models
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Re:	Response to a call for contributions for the Relay TG 80216j-06/006.pdf
Abstract	This document captures several path loss models for IEEE802.16j
Purpose	Text proposal for IEEE C802.16j-06/040
Notice	
Release	
Patent Policy and Procedures	

Multi-hop System Evaluation Methodology

Introduction

In this contribution, we present the text proposal to C802.16j-06/040, section 2.1 for the path loss models for IEEE802.16j. The path-loss models proposed are based on the comparison study of the modified 802.16d models and models developed by WiNNER.

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2.1 Path-Loss Model

2.1.1 BS ↔ RS, LOS (rooftop-to-rooftop) pathloss model

This scenario is shown in Figure 0-1, where both the BS and RS antennas are mounted above the rooftops and they have a LOS between them.

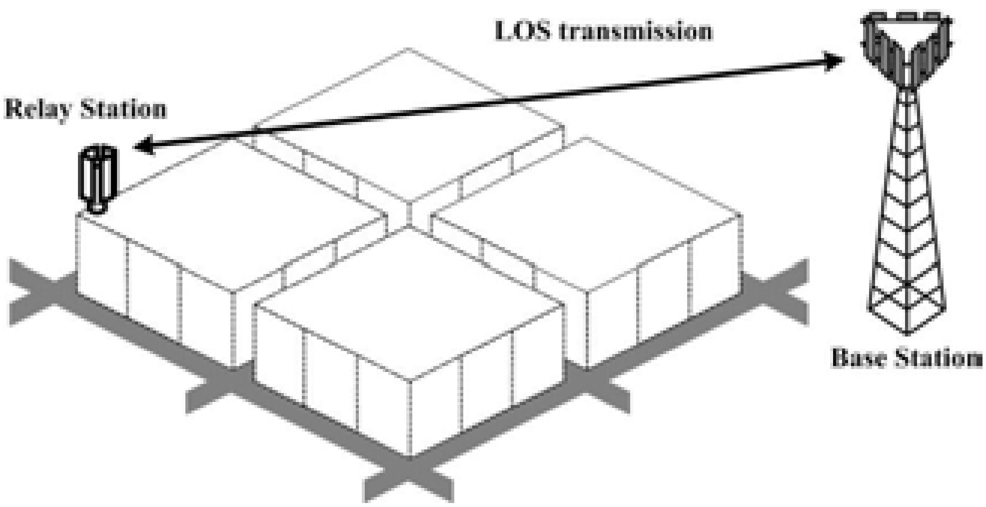


Figure 0-1 – BS-RS link with LOS

For this link a modified IEEE 802.16d channel model is recommended [1]. There are three categories for this model, where each category represents a different environment. The most benign category (category C) is chosen for this scenario to allow for the fact that the relays in this case are assumed to have been deployed with a good LOS back to the BS. The model is equal to the free space path loss up to a breakpoint, which is determined by the transmission frequency and the relay antenna height. Beyond the breakpoint, the path loss exponent increases, and this is to account for the fact that LOS probability will decrease with distance from the BS. This factor is also important for multicell simulations for interference calculations. The relay will only be deployed to try to give LOS back to the 'wanted' BS. Interfering BSs (at greater distance) will most likely not have a LOS back to the BS, and the path loss model will account for this.

$$PL(dB) = \begin{cases} 20\log\left(\frac{4\pi d}{\lambda}\right) & \text{for } d \le d_0 \\ A + 10\gamma\log\left(\frac{d}{d_0}\right) + PL_f + PL_{ht} & \text{for } d > d_0 \end{cases}$$

where,

$$A = 20\log\left(\frac{4\pi d_0'}{\lambda}\right)$$

$$d_0 = 100m$$

$$d_0' = d_0 10^{-\left(\frac{PL_f + PL_{ht}}{10\gamma}\right)}$$

$$\gamma = a - bh_b + \frac{c}{h_b}$$

$$PL_f = 6\log\left(\frac{f(MHz)}{2000}\right)$$

$$PL_{ht} = \begin{cases} -10\log\left(\frac{h_t}{3}\right) & \text{for } h_t \le 3m \\ -20\log\left(\frac{h_t}{3}\right) & \text{for } h_t > 3m \end{cases}$$

d = distance between basestation and terminal

h_b = height of basestation

h_t = height of terminal

$a = 3.6$

$b = 0.005$

$c = 20$

Note that the MS height correction factor is Okumura's correction factor (see [2], for example).

2.1.2 BS ↔ RS, NLOS (rooftop-to-below rooftop) pathloss model

This scenario is shown illustrated in Figure 0-2, where in this case the BS antenna is mounted above the rooftops and the relay antenna is mounted below the rooftop.

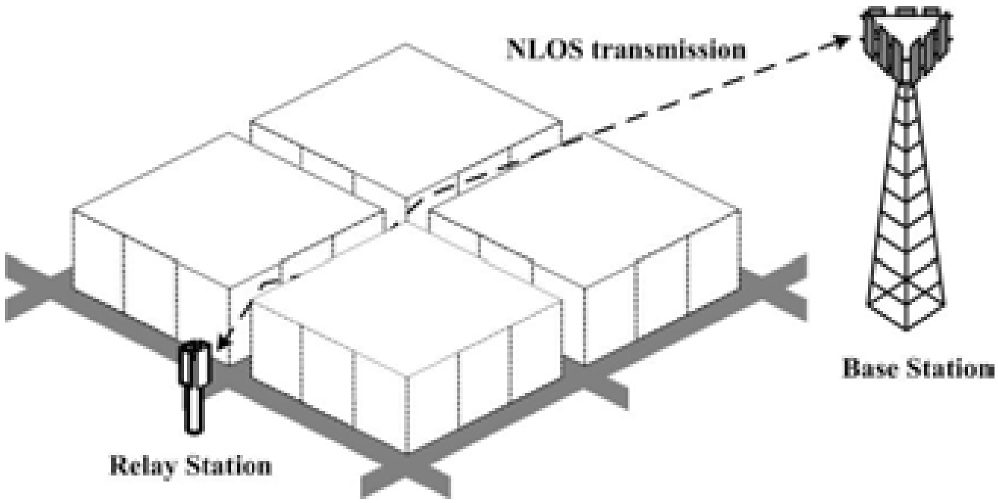


Figure 0-2 – BS-RS NLOS (rooftop-to-below rooftop)

For this case the link is like a standard macrocellular link, except that the relay antenna height is likely to be higher than the height of a typical MS. Consequently, the modified IEEE 802.16d model is a good model for this case, where all three categories (A, B, and C) are now applicable to cover different environments. The model includes a MS antenna height correction factor, and it includes a frequency correction factor.

The model is identical to that given in section 1.1.1 except for the following changes to allow for three different environment types:-

Category A:- Hilly terrain with moderate-to-heavy tree densities
Category B:- Mostly flat terrain with moderate-to-heavy tree densities, or hilly terrain with light tree densities
Category C:- Flat terrain with light tree densities

$$PL_{ht} \quad \begin{cases} 10.8 \log \dfrac{h_t}{2} & \text{Categories A \& B} \\ 10 \log \dfrac{h_t}{3} & \text{Category C}, h_t \quad 3 \\ 20 \log \dfrac{h_t}{3} & \text{Category C}, h_t \quad 3 \end{cases}$$

Model Parameter	Terrain type A	Terrain type B	Terrain type C
a	4.6	4.0	3.6
b	0.0075	0.0065	0.005
c	12.6	17.1	20.0

Table 1 – Model parameters for different terrain categories

2.1.3 BS ↔ MS, LOS pathloss model

Median path loss models for the BS-MS link include LOS and NLOS paths, where the LOS locations are included in the shadowing distribution. Therefore, there is no specific path loss model for the LOS case.

2.1.4 BS ↔ MS, NLOS pathloss model

For this case, the path loss model given in section 1.1.2. can be used.

2.1.5 RS ↔ RS, LOS pathloss model

For this scenario we assume that both relays are deployed above the rooftops, and they are deployed such that a LOS exists between them. Note that interfering relays at greater distances will not necessarily have a LOS path, and so the model proposed in 1.1.1. can be used.

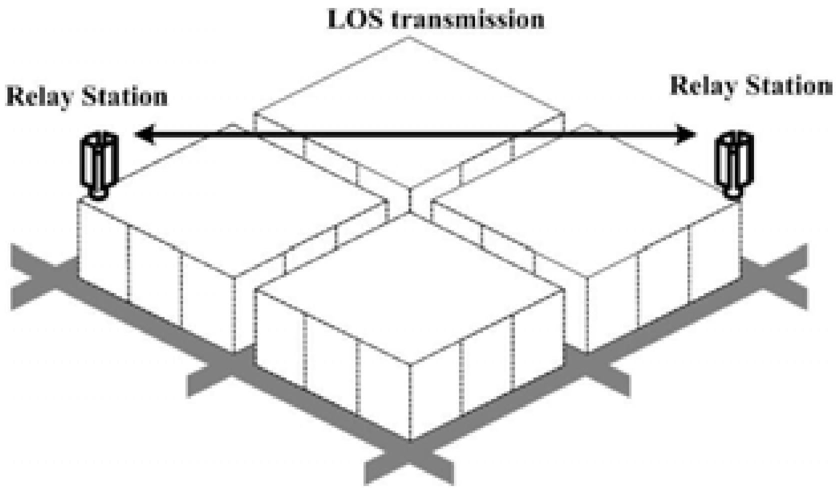


Figure 0-3 – RS-RS LOS link (rooftop-to-rooftop)

2.1.6 RS ↔ RS, NLOS pathloss model

This scenario is similar to the BS-MS link, where it is assumed that one relay is mounted above the rooftop and one relay is mounted below the rooftop. Therefore, the model proposed in section 1.1.2. can be used.

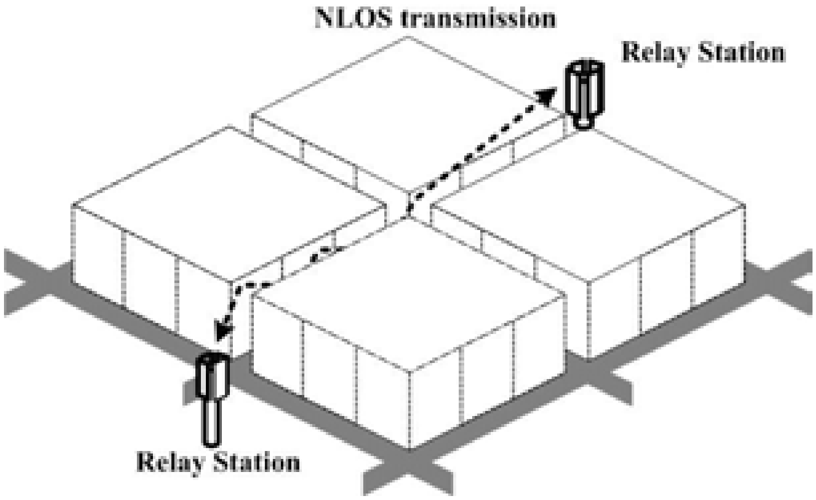


Figure 0-4 – RS-RS NLOS (rooftop-to-below rooftop)

2.1.7 RS ↔ MS, LOS pathloss model

For this scenario we assume that both the relay antenna and the MS antenna are located below the rooftop, and that they are located on the same street.

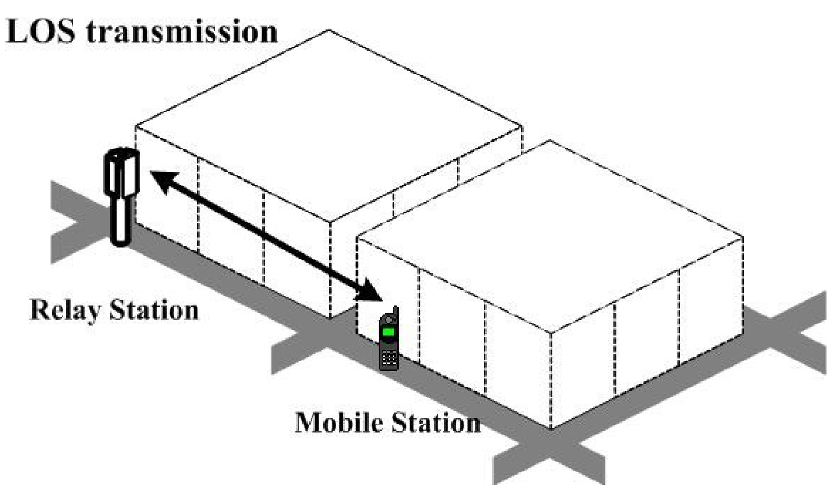


Figure 0-5 – RS-MS LOS scenario

For this case an advanced LOS model is proposed [3], [4]. This model essentially behaves like a two-slope model, where the breakpoint is dependant on the relay and MS antenna heights. However, the effect of traffic is taken into account by defining an effective road height, which reduces the relay and MS heights. In addition, a visibility factor is included which reduces the path loss further as distance increases, and this factor accounts for the fact that LOS decreases with distance along a street. The model is given below:-

$$PL\ dB \quad 20\log \frac{e^{sr} 4\ rD\ r}{}$$

where,

r distance between Tx and Rx

e^{sr} Visibility factor s 0.002

Wavelength

$$D\ r \quad \begin{matrix} 1 & r & r_{bp} \\ \frac{r}{r_{bp}} & r & r_{bp} \end{matrix}$$

$$r_{bp} \quad \frac{4\ h_t \quad h_0\ h_r \quad h_0}{}$$

h_t Height of transmitter above ground

h_r Height of receiver above ground

h_0 Effective road height $1.0m$

2.1.8 RS ↔ MS, NLOS pathloss model

For this scenario the RS and MS antenna heights are below rooftop and they are located on different streets.

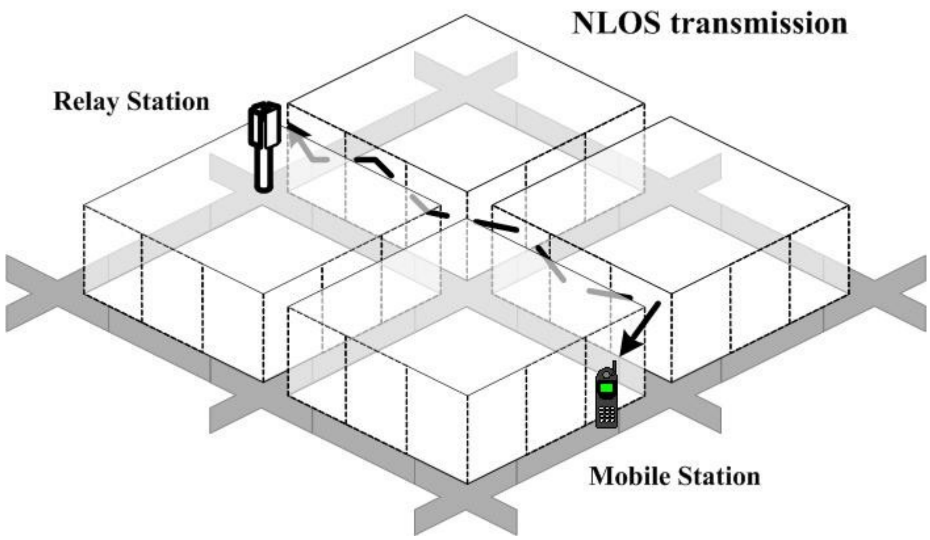


Figure 0-6 – RS-MS NLOS scenario

For this case a model proposed by ETSI [5] is employed where this takes the minimum of an over-the-rooftop component and a round-the streets component. The round-the-streets component is based on a model by Berg [6], although this has been modified to be compatible with the advanced LOS model, such that the visibility is included, and the effective road height to give the correct breakpoint in the first street section. The full model is given in [4] and is repeated below:-

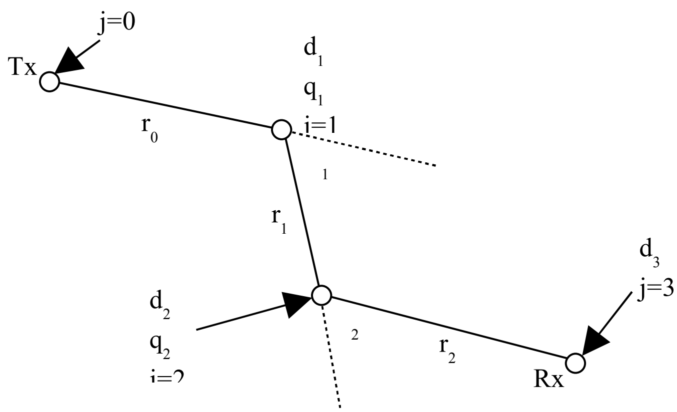


Figure 0-7 – Geometry of street sections used for Berg model

$$PL_{Berg}\ dB \quad 20\log \frac{4\ d_n D \ \overset{n}{\underset{j\ 1}{}}\ r_{j\ 1} \ \overset{n}{\underset{j\ 1}{}}\ e^{sr_{j\ 1}}}{}$$

$R \quad \overset{n}{\underset{j\ 1}{}} r_{j\ 1}$ Distance along streets between Tx and Rx

r_j Length of the street between nodes j and $j \quad 1$ (there are $n \quad 1$ nodes in total)

$$r_{bp} \quad \begin{matrix} r_0 \text{ if } r_0 \quad \frac{4\ h_t \quad h_0 \quad h_r \quad h_0}{} \\ \frac{4\ h_t \quad h_0 \quad h_r \quad h_0}{} \text{ if } r_0 \quad \frac{4\ h_t \quad h_0 \quad h_r \quad h_0}{} \end{matrix}$$

$$D\ R \quad \begin{matrix} 1 \text{ if } R \quad r_{bp} \\ \frac{R}{r_{bp}} \text{ if } R \quad r_{bp} \end{matrix}$$

The distance d_n is the illusory distance and is defined by the recursive expression,

$k_j \quad k_{j\ 1} \quad d_{j\ 1} q_{j\ 1}$

$d_j \quad k_j r_{j\ 1} \quad d_{j\ 1}$

with $k_0 \quad 1$ and $d_0 \quad 0$

$$q_j \quad _j \qquad _j \frac{q_{90}}{90}$$

$_j$ Angle between streets at junction j

$q_{90} \quad 0.5$, and $\quad 1.5$

$PL_{over\_the\_rooftop}\ dB \quad 24 \quad 45\log\ r_{Eu}$

r_{Eu} Euclidean distance between Tx and Rx

$PL\ dB \quad \min\ PL_{Berg}\ dB\ , PL_{over\_the\_rooftop}\ dB$

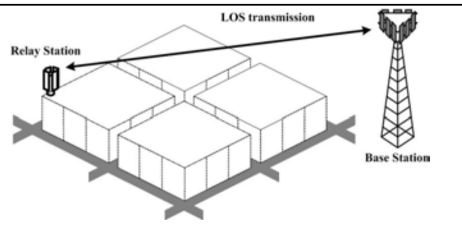
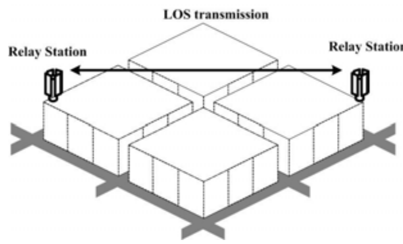
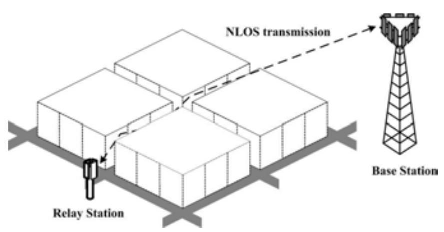
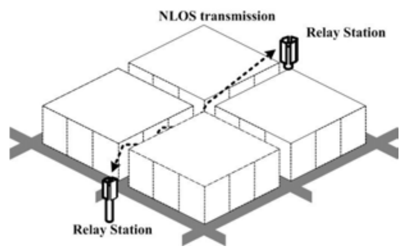
2.1.9 Assignment probabilities

For real world networks, different link models are mixed with a certain percentage. The following link model possibility assignment represents such a mix for their practical deployment

2.1.9.1 BS-RS link

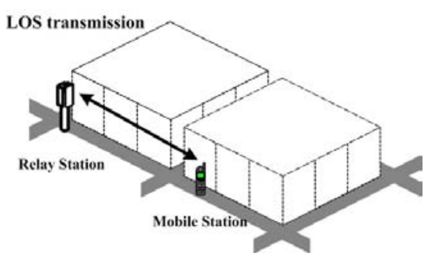
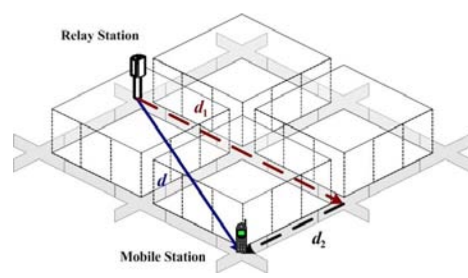
For this case the following probabilities are used for user self-deployed scenarios:-

Probability of RS above rooftop = 0.7
Probability of RS below rooftop = 0.3

	First Hop		K^{th}- Hop
30%		**60%**	
70%		**40%**	

2.1.9.2 RS-MS below rooftop case

For the below rooftop case the following probabilities can be used:-

	Last Hop		
30%		**70%**	 Given d, uniform generate d_1 (0,d)

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References

[1] IEEE C802.16j-06/011, 'Multihop Path Loss Models (Base-to-Relay and Relay-to-MS)', D.Kitchener et al, 2nd May, 2006
[2] 'Wireless Communications. Principles and Practice.', T.S.Rappaport, Chap.3, p.116, Prentice Hall, 1996
[3] 'Advanced LOS path loss model in microcellular mobile communications', Y.Oda, K.Tsunekawa, M.Hata, IEEE VT-49, No.6, Nov 2000, pp.2121-2125
[4] IEEE C802.16j-06/010, 'Below Rooftop Path Loss Model', D.Kitchener et al., 2nd May, 2006
[5] 'Universal Mobile Telecommunications System (UMTS); Selection procedures for the choice of radio transmission technologies of the UMTS', UMTS 30.03 version 3.2.0, Technical Report TR 101 112 v3.2.0, 1998-04
[6] 'A Recursive Method for Street Microcell Path Loss Calculations', J-E.Berg, PIMRC '95, 'Wireless: Merging onto the information superhighway', Vol.1, 27-29 Sept 1995