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Text Proposal for the Path Loss Models

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### Abstract
This document captures several path loss models for IEEE802.16j

### Purpose
Text proposal for IEEE C802.16j-06/040

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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 WiINNER.

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.

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.
\[ 20 \log \frac{d}{d_0} \quad \text{for} \quad d > d_0 \]

\[ PL_{dB} = 10 \log \frac{d}{d_0} + PL_f + PL_h \quad \text{for} \quad d > d_0 \]

where,

\[ A = 20 \log \frac{d_0}{d_0} \]

\[ d_0 = 100m \]

\[ d' = \frac{d_0}{10^{\frac{PL_f + PL_h}{10}}} \]

\[ a = b \left( \frac{c}{h_b} \right) \]

\[ PL_f = 6 \log \left( \frac{f \text{ MHz}}{2000} \right) \]

\[ 10 \log \frac{h_t}{3} \quad \text{for} \quad h_t < 3m \]

\[ PL_h = 20 \log \frac{h_t}{3} \quad \text{for} \quad h_t = 3m \]

\[ d \quad \text{distance between basestation and terminal} \]

\[ h_b \quad \text{height of basestation} \]

\[ h_t \quad \text{height of terminal} \]

\[ a = 3.6 \]

\[ b = 0.005 \]

\[ c = 20 \]

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)](image)

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

\[
P_L^{ht} = 10 \log_2 \left( \frac{h_t}{3} \right)
\]

<table>
<thead>
<tr>
<th>Model Parameter</th>
<th>Terrain type A</th>
<th>Terrain type B</th>
<th>Terrain type C</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>4.6</td>
<td>4.0</td>
<td>3.6</td>
</tr>
<tr>
<td>b</td>
<td>0.0075</td>
<td>0.0065</td>
<td>0.005</td>
</tr>
<tr>
<td>c</td>
<td>12.6</td>
<td>17.1</td>
<td>20.0</td>
</tr>
</tbody>
</table>

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)](image)

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](image)

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:

\[
PL \ dB = 20\log \left( \frac{e^{sr}}{4\pi D} \cdot \frac{rD}{r} \right)
\]

where,

- \( r \) distance between Tx and Rx
- \( e^{sr} \) Visibility factor \( s = 0.002 \)
- \( Wavelengt \)
- \( 1 \) \( r \) \( r_{bp} \)
- \( D \) \( r \) \( r \) \( r_{bp} \)
- \( r_{bp} \) \( 4 \) \( h_t \) \( h_0 \) \( h_r \) \( h_0 \)

\( h_t \) 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](image)

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:

\[ Tx \quad d_1 \quad q_1 \quad j=0 \]
\[ r_0 \quad i=1 \]
\[ q_1 \quad d_2 \quad r_1 \]
\[ j=1 \]
\[ r_1 \quad d_2 \quad q_2 \]
\[ i=2 \]
\[ d_3 \quad j=3 \]

Figure 0-7 – Geometry of street sections used for Berg model
\[ PL_{\text{Berg}} \, dB \quad 20 \log \frac{4 \, d_n \, D^n \, r_j^n \, e^{\nu_{j,1}}}{j^1 \, j^1} \]

\( R \quad r_j \quad j_1 \quad \text{Distance along streets between Tx and Rx} \)

\( r_j \quad \text{Length of the street between nodes } j \text{ and } j_1 \quad (\text{there are } n \quad 1 \text{ nodes in total}) \)

\( r_0 \quad \text{if } R \quad \frac{4 \, h_j \, h_0 \, h_r \, h_0}{r_0} \)

\( r_{bp} \quad 4 \, h_j \, h_0 \, h_r \, h_0 \quad \text{if } R \quad \frac{4 \, h_j \, h_0 \, h_r \, h_0}{r_{bp}} \)

\( D \quad R \quad R \quad r_{bp} \quad \text{if } R \quad r_{bp} \)

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

\[ \begin{align*}
  k_j & \quad k_{j_1} \quad d_{j_1} \quad q_{j_1}^1 \\
  d_j & \quad k_j \quad r_j \quad d_{j_1} \\
  \text{with } k_0 & \quad 1 \quad \text{and } d_0 = 0 \\
 q_j & \quad q_{j_0}^1 \quad 90 \\
 \end{align*} \]

\( j \quad \text{Angle between streets at junction } j \)

\( q_{j_0} 0.5, \quad \text{and } 1.5 \)

\[ PL_{\text{over the rooftop}} \, dB \quad 24 \quad 45 \log r_{Eu} \]

\( r_{Eu} \quad \text{Euclidean distance between Tx and Rx} \)

\[ PL \, dB \quad \min \, PL_{\text{Berg}} \, dB, \quad PL_{\text{over the rooftop}} \, dB \]

### 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
2.1.9.2 RS-MS below rooftop case

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

Given \( d \), uniform generate \( d_1 (0, d) \)
References