
Title: Text Proposal for Shadowing Modeling

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Re: Response to a call for contributions for the Relay TG, 80216j-06_006.pdf

Abstract: This document captures correlated shadowing model and path-loss-dependent shadowing model for IEEE802.16j

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

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Text Proposal for Shadowing Modeling

Introduction
In this contribution, a text proposal is presented as input to the C802.16j-06/040, section 2.1.11. Based on the editor’s note, the shadowing model should be adopted from [2].

2.1.11 Correlated Shadowing Model
The correlation for the shadowing effect is modeled between the BSs and RSs for case of BS/RS deployed above the rooftop and for the case of RS below the rooftop. In addition the spatial de-correlation is also modeled for BS-MS and RS-MS links. For RS below the rooftop, the RS-MS link path-loss-dependent shadowing is modeled.

2.1.11.1 BS-MS/RS-MS link (BS/RS above rooftop)
In a network of BSs, the lognormal shadowing from two different base sites at a given MS location will have some level of correlation. In order to correctly model the benefits of relaying this correlation needs to be modeled. In addition, the shadowing from a given base site at two different MS locations will be correlated if they are within the spatial decorrelation distance of the shadowing. Therefore relays need to be beyond the spatial decorrelation distance to have a beneficial effect for a subscriber, and the spatial correlation of the shadowing also needs to be modeled.

2.1.11.1.1 Correlation between MSs
For modeling the shadowing correlation between two BSs at a given MS location a model based on that given by Saunders [1] is proposed. The model is given in [2] and the geometry for the model is shown in Figure 1-1.

Figure 1-1 – Geometry for correlation between two BSs
The correlation is then calculated using the following equations:

\[
\begin{align*}
\frac{d_1}{d_2} & \quad \text{for } 0^\circ \quad \tau \quad \text{and } \quad d_1^* \frac{d_1}{2} \\
\tau & \quad \sqrt{\frac{d_1}{d_2}} \quad \text{for } \quad \tau \quad \text{and } \quad d_1^* \frac{d_1}{2} \\
\sqrt{\frac{d_1^*}{2d_2}} & \quad \text{for } d_1, \quad d_1^* \quad \frac{d_1}{2}
\end{align*}
\]

where,

Correlation

\[d_c = \frac{1}{e}\] decorrelation distance

\[\tau = 2 \sin^{-1} \left( \frac{d_c}{2d_1^*} \right)\]

constant depending on size and height of terrain and clutter, and height of the basestations relative to them. A value of 0.3 is used in [1], based on comparison with measured data.

For a given network of BSs a correlation matrix, \( R_{xx} \), can be calculated using the above model. If a vector of independent lognormal samples, \( x \), are generated at a given MS location, representing the shadowing from each BS, then these samples can be correlated using \( R_{xx} \).

\[
\begin{align*}
y & \quad \mathbf{T} x \\
\text{where,} & \\
x & \quad \text{Vector of independent lognormal samples} \\
y & \quad \text{Vector of correlated lognormal samples} \\
\mathbf{T} & \quad \text{Transformation matrix}
\end{align*}
\]

To calculate \( T \) :-

\[
R_{xx} = E y y^H + E \mathbf{T} x \mathbf{T} x^H \\
TE x x^H \mathbf{T}^H \\
\mathbf{T} I I^H \\
\mathbf{T} T^H \\
\text{where } I \text{ is the identity matrix}
\]
\[
\begin{align*}
\mathbf{R}_{xx} &= \mathbf{UDU}^H \\
\mathbf{D} &= \mathbf{D}^{\frac{1}{2}} \mathbf{D}^{\frac{1}{2}} \\
\mathbf{R}_{xx} &= \mathbf{UD}^{\frac{1}{2}} \mathbf{D}^{\frac{1}{2}} \mathbf{U}^H \\
\mathbf{UD}^{\frac{1}{2}} &= \mathbf{UD}^{\frac{1}{2}} \mathbf{U}^H \\
\mathbf{T}^H &= \mathbf{R}_{xx} \\
\end{align*}
\]

where:

\( \mathbf{A}^H \) complex conjugate transpose of matrix \( \mathbf{A} \)

\subsection*{2.1.11.1.2 Spatial correlation of shadowing}

In order to model spatial correlation of the lognormal shadowing along a route a simple sum of sinusoids approach can be used:

\[
L \ dB = \sum_{n=1}^{N} a \cos k_{n-1}x_n \cos k_{n-2}y_n \\
\] 

\[
a = \sqrt{\frac{4}{N}} \\
\]

\( a \) and \( n \) are random phase terms uniformly distributed between 0 - 2

\( k_{n-1}, k_{n-2} \) wavenumbers of the \( n^{th} \) sinusoids

The maximum values of the wavenumbers determine the decorrelation distance of the shadowing. For the urban environment, if the wavenumbers are randomly distributed between \([0, 2/75]\) then a 0.5 decorrelation distance of 20m results, and the 1/e decorrelation distance is 23m (value of \( d_c \) required for calculating correlation between two BS). A suggested number of sinusoids to use is 100.

\subsection*{2.1.11.2 RS-MS link (RS below rooftop)}

The lognormal shadowing from two different below rooftop RSs at a given MS location will have some level of correlation. In order to correctly model the benefits of relaying this correlation needs to be modelled. In addition, the shadowing from a given RS site at two different MS locations will be correlated if they are within the spatial decorrelation distance of the shadowing.

\subsection*{2.1.11.2.1 Correlation between RSs}

For the below rooftop case, the correlation between RSs is T.B.D.
2.11.2.2 Spatial correlation

For the below rooftop case, the same model can be used as for the BS-MS link. The decorrelation distance for this link is T.B.D.

2.11.2.3 Standard deviation of the shadowing

A model is proposed where the lognormal standard deviation increases with excess path loss over free space loss. This is to prevent excessively large shadowing components when the path loss is equal to (or close to) the free space path loss, which occurs at shorter ranges typically. In particular, when the shadowing component is from the ‘negative’ side of the lognormal distribution, this model prevents the path loss from becoming unrealistically low.

\[
\begin{align*}
\text{\(s_u\)} & = 1.5 \\
\text{\(s_u\)} & = 1.9 \text{dB} \\
\text{\(s_u\)} & = 4.5 \text{dB} \\
\text{\(s_u\)} & = 6.5 \text{dB}
\end{align*}
\]

Where,
- \(s_u\) is the maximum standard deviation
- \(P(r)\) is the mean path loss (dB)
- \(P_{fs}(r)\) is the free space path loss (dB)

For short ranges where the path loss is equal to (or close to) the free space loss the lognormal standard deviation reduces to a lower value of 1.5dB, which accounts for variations due to interference of the direct and ground reflected components. The value of 1.5dB is based on an evaluation of the path loss using a two-ray model.

As the excess path loss increases (with distance) the standard deviation increases to an upper value of \((s_u + 1.5)\). This upper value can be specified for the various multihop links.

For BS-RS with RS above rooftop:-
- For wanted BS, assume RS is deployed with LOS back to BS. \(s_u = 1.9\text{dB}\)
- For neighbouring BS’s, no guarantee of LOS so shadowing will be greater. \(s_u = 4.5\text{dB}\)

For BS-MS/BS-RS with MS/RS below rooftop:-
- Use (Okumura equation – 1.5) for \(s_u\)
- For RS-MS with MS on same or different street:-
  - \(s_u = 6.5\text{dB}\)

Okumura’s frequency dependant equation for the BS-MS link is given below [3]:-

\[
A = 0.65 \log f MHz + 1.3 \log f MHz + 5.2 dB (urban) or 6.6 dB (suburban)
\]

++End of Text Proposal ++++++
References