Project	IEEE 802.16 Broadband Wireless Access Working Group <**http://ieee802.org/16**>
Title	Text Proposal for Shadowing Modeling
Date Submitted	2006-07-12
Source(s)	Dean Kitchener , Mark Naden, Gamini Senarath, Wen Tong, Peiying Zhu, Hang Zhang, David Steer, Derek Yu Nortel 3500 Carling Avenue Ottawa, On, K2H 8E9 Canada wentong@nortel.com Voice: 1-163-763-1316
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
Notice	
Release	
Patent Policy and Procedures	

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].

++++++++++++++++++++Start Text Proposal ++++++++++++++++++++++++++++

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 additions 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 ofBSs, 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 modelled. 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 modelled.

2.1.11.1.1 Correlation between MSs

For modelling 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

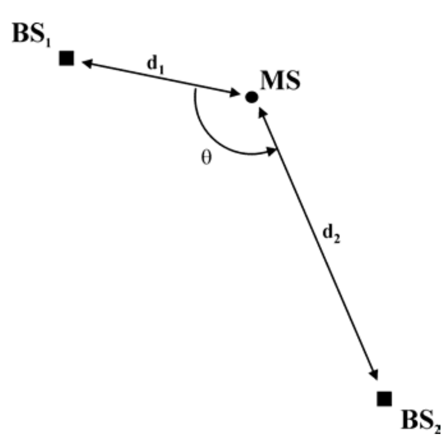

Figure 1-1 – Geometry for correlation between two BSs

The correlation is then calculated using the following equations:-

$$\frac{d_1}{d_2} \qquad \text{for } 0^{\circ} \qquad {}_{T} \text{ and } d_1 \quad \frac{d_c}{2}$$

$$\frac{\ \ _T}{} \quad \sqrt{\frac{d_1}{d_2}} \qquad \text{for} \quad {}_{T} \qquad \text{and } d_1 \quad \frac{d_c}{2}$$

$$\sqrt{\frac{d_c}{2d_2}} \qquad \text{for } d_1 \quad \frac{d_c}{2}$$

where,

Correlation

$d_c \quad \frac{1}{e}$ decorrelation distance

$$_{T} \quad 2\sin^{\ 1} \frac{d_c}{2d_1}$$

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, $\mathbf{R}_{xx}$, 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 $\mathbf{R}_{xx}$.

$$\mathbf{y} \quad \mathbf{Tx}$$

where,

x Vector of independent lognormal samples

y Vector of correlated lognormal samples

T Transformation matrix

To calculate T : -

$$\mathbf{R}_{xx} \quad E\ \mathbf{yy}^{\mathbf{H}} \qquad E\ \mathbf{Tx}\ \mathbf{Tx}^{\ \mathbf{H}}$$

$$\mathbf{T}E\ \mathbf{xx}^{\mathbf{H}}\ \mathbf{T}^{\mathbf{H}}$$

$$\mathbf{TIT}^{\mathbf{H}}$$

$$\mathbf{TT}^{\mathbf{H}}$$

where **I** is the identity matrix

$$\mathbf{R}_{xx} = \mathbf{UDU}^{\mathbf{H}}$$
$$\mathbf{D} = \mathbf{D}^{1/2}\mathbf{D}^{1/2}$$
$$\mathbf{R}_{xx} = \left(\mathbf{UD}^{1/2}\right)\left(\mathbf{D}^{1/2}\mathbf{U}^{\mathbf{H}}\right)$$
$$= \left(\mathbf{UD}^{1/2}\right)\left(\mathbf{UD}^{1/2}\right)^{\mathbf{H}}$$
$$= \mathbf{TT}^{\mathbf{H}}$$

where : -

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

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:

$$L(dB) = \sum_{n=1}^{N} a\cos\left(k_{n\_1}x \quad _n\right)\cos\left(k_{n\_2}y \quad _n\right)$$

$$a = \sqrt{\frac{4 \quad ^2}{N}}$$

$_n$ 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.

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.

2.1.11.2.1 Correlation between RSss

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

2.1.11.2.2 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.

2.1.11.2.3 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.

$$(r) \qquad 1 \quad e^{\frac{|P(r)\ \ P_{fs}(r)|}{4}} \qquad 1.5$$

Where,

is the maximum standard devation

$P(r)$ 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 ($_u$+*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=1.9dB
For neighbouring BS's, no guarantee of LOS so shadowing will be greater. s_u=4.5dB
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=6.5dBOkumura's frequency dependant equation for the BS-MS link is given below [3]:-

$$0.65 \log f \ \ MHz^{\ \ 2} \ \ 1.3\log f \ \ MHz \qquad A$$

$$A \quad 5.2dB \text{ (urban) or } 6.6dB \text{ (suburban)}$$

+++++++++++++++++++*End of Text Proposal* +++++++++++++++++++++

References

[1] S.R. Saunders, "Antennas and Propagation for Wireless Communication Systems", John Wiley & Sons, pp. 190-198, 1999.
[2] IEEE C802.16j-06/009, 'Correlated Lognormal Shadowing Model', D.Kitchener et al, 2nd May, 2006
[3] 'Field strength and its variability in VHF and UHF land-mobile radio service', Y.Okumura et al., Rev. Elec. Comm. Lab., pp.825-873, 1968