A Measurement-Based Path Loss Model for Mobile-to-Mobile Link Reliability Estimation

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Abstract. This paper shows results of narrowband path loss measurements in a typical urban mobile-to-mobile radio environment at 900 MHz band. The path loss exponent and the variance of the random variable modeling the effects of shadowing and fading are derived from real world measurements performed in an urban and rural area. These parameters can be used with a simple power law path loss model to predict reliable communication link for communication systems operating in a mobile-to-mobile environment, such as a cross-layer routing protocol design of mobile ad-hoc networks. The proposed method can be also used for path evaluation of multipath routing.

Keywords: path loss measurements; mobile-to-mobile; path loss exponent; shadow fading

1 Introduction

Characteristics of a mobile-to-mobile radio channel are quite different compared with the traditional stationary base station to mobile radio channel. Mobile to mobile radio channels can be found in ad-hoc networks, delay tolerant networks and vehicle-to-vehicle communications. The wireless radio channel poses a severe challenge as a medium for reliable communication. Not only is it susceptible to noise and channel impediments, but these impediments change over time as a result of user movement and environment dynamics [1, 2].

The radio propagation effect on signal strength will lead to signal attenuation and yield a large fluctuation of signal strength with the propagation range. However, it has not been well considered in mobile-to-mobile network environment for developing most of the routing protocol.

During the recent years, statistical properties of mobile-to-mobile channels have been investigated by many researchers concentrating on small-scale characteristic of the mobile-to-mobile radio channels [3-9]. These parameters of the derived model should be determined by carrying out measurements in the area for mobile-to-mobile
system operation. For the practice of routing protocol of mobile-to-mobile communication system, some profiles with different parameters should be set up for the environment [10, 11].

In this paper, path loss exponent and shadowing parameters are derived for a simple power law path loss model based on measurement in urban rural environments with low elevation antennas for a transmitter and a receiver at 900 MHz band.

Kinds of methods could be used to estimate these parameters for practical of routing protocol. However, it is difficult for a node to estimate these parameters by considering received signal properties from its neighbors and their locations (due to noise, channel impediment, change over time, node calculating ability.). It is practical to preset path loss exponent for a routing algorithm for mobile-to-mobile networks. In this paper, we set up there profiles with different parameters for the outdoor urban and rural environment of xi’an city. This facilitates to design and optimize the wireless system in specific environment [1].

The remainder of this paper is organized as follows. In Section 2, the measurement configurations are described. The empirical propagation model that is tuned with measured data is shown. The measurement results are presented in Section 3. Conclusion is in Section 4.

2 Measurement Configuration

2.1 Measurement Parameters

To validate that the model works well for mobile-to-mobile channels, experiments were carried out in spring at an urban and rural area. Table 1 summarizes the measurement parameters.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transmitter</td>
<td>PCS-20</td>
</tr>
<tr>
<td>Receiver</td>
<td>FSL6 Spectrum Analyzer</td>
</tr>
<tr>
<td>TX Antenna</td>
<td>Omni-directional (3.0 dBi)</td>
</tr>
<tr>
<td>RX Antenna</td>
<td>Omni-directional (3.0 dBi)</td>
</tr>
<tr>
<td>Frequency</td>
<td>914MHz</td>
</tr>
<tr>
<td>TX Antenna Height</td>
<td>1.5m</td>
</tr>
<tr>
<td>RX Antenna Height</td>
<td>1.5m</td>
</tr>
<tr>
<td>Feeder Loss</td>
<td>2.9 dB</td>
</tr>
<tr>
<td>Cable Loss</td>
<td>2.0 dB</td>
</tr>
</tbody>
</table>
2.2 Reference Mobile-to-Mobile Path Loss Model

A base-to-mobile power law path loss model was used for predicting the distance of reliable communication between two mobiles [2].

\[
PL(d) = PL(d_0) + 10n \log\left(\frac{d}{d_0}\right) + N(0, \sigma)
\]  

(1)

Where \(d\) is the distance from the transmitter. \(PL(d_0)\) is the reference path loss at distance \(d_0\). \(PL(d)\) is the mean path loss value. \(n\) is the path loss exponent. Where \(N(0, \sigma)\) reflects effects of shadowing and fading that follows a zero-mean Gaussian distribution with a variance \(\sigma\).

3 Measurement Results and Application Analysis

3.1 Measurement Results

The measurement environment consisted of two slightly different propagation environments. The first measurement survey was performed in urban region. The second measurement survey was performed in rural region.

Fig. 1. The measured pat loss (dB) is curve-fitted by a normal distribution with a given standard deviation \(\sigma\) value 5.48 in urban area.
The measured path loss in urban area is showed in Fig. 1. The solid curve shows the normal distribution with standard deviation. The measured Probability Distribution Function (PDF) is showed in dashed line. We observed that the measured n is 4.3, and a zero-mean normal distribution with a given standard deviation $\sigma$ 5.48 can fit the curve of measured data well.

In rural area, the measured n is 3.6, and a zero-mean normal distribution with a given standard deviation $\sigma$ 3.47 can fit the curve of measured data well as shown in Fig.2. The measured results are similar to the results measured in other urban and rural mobile-to-mobile scenarios [7-9].

### 3.2 Estimation of Link Reliability

For application, there is a target minimum received power level $P_{\text{min}}$ below which performance becomes unacceptable in wireless systems [1].

For application, the link reliability $LR_i$ for a radio link $i$ is defined to be the probability that the received power at a given distance $d_i, Pr(d_i)$, falls above $P_{\text{min}}$:

$$LR_i = p(P_r(d_i) \geq P_{\text{min}})$$  \hspace{1cm} (2)

With Eq.(2) and some derivations [1][9], $LR_i$ is given by

$$LR_i = Q \left( \frac{P_{\text{max}} - (P_i - PL(d_i) - 10n \log(d_i/d_0))}{\sigma} \right)$$  \hspace{1cm} (3)

where $Q(z)$ is a complementary error function and is defined as:
A radio link with a higher $LR_i$ value can be considered better than others for data routing. Path consists of mobile nodes with highly link reliability should be used to forward packets. A link reliability-awareed method can be used to evaluate path stability for multipath routing design.

For application, the path loss exponent $n$ and the variance $\sigma$ can be configured by doing field-test in the propagation environment. [9][13]. The transmission power and target minimum received power can be used for parameters $P_t$ and $P_{\text{min}}$ respectively.

### 4 Conclusion

This paper provides field-test values for path loss models of mobile-to-mobile wireless systems at 900 MHz band. These parameters were derived from a base-to-mobile path loss model by measurement in urban and rural mobile-to-mobile environment. These can be used with a simple power law path loss model to predict reliable links for mobile-to-mobile communication systems.

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### References