Introduction

- Ad-Hoc & Sensor Networks
  - Data can relay through nodes
  - New concept of connectivity

Problem...
Existing propagation models??

Propagation Models for Short-Range Communications

New way of treating data
Less power needed
Range of communications decreased

Propagation Models for Short-Range Communications

- 'UWB Channel Characterization in Indoor Office Environments'
- 'UWB Channel Characterization in Outdoor Environments'
- 'Indoor Propagation Modeling at 2.4GHz for IEEE 802.11 Networks'

- Path Loss Propagation Model
- Shadowing Propagation Model

Contents

- Introduction
- Propagation Models for Short-Range Communications
- Equipment
- Measurements
- Conclusions and Recommendations
Propagation Models for Short-Range Communications

- Indoor Propagation Modeling at 2.4GHz for IEEE 802.11 Networks

<table>
<thead>
<tr>
<th>Environment</th>
<th>AP1</th>
<th>AP2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Closed Corridor</td>
<td>3.264</td>
<td>3.186</td>
</tr>
<tr>
<td>Indoor Office</td>
<td>3.414</td>
<td>3.368</td>
</tr>
<tr>
<td>Open Corridor</td>
<td>3.846</td>
<td>3.704</td>
</tr>
<tr>
<td>Computer Lab</td>
<td>3.264</td>
<td>3.208</td>
</tr>
</tbody>
</table>

- Path Loss Propagation Model

\[ L[dB] = L_0 + 10 \log_{10} \left( \frac{d}{d_0} \right) \]

- Shadowing Propagation Model

\[ L[dB] = L_0 + 10 \log_{10} \left( \frac{d}{d_0} \right) + \sigma_n \]

Equipment

- Tmote Sky
- Disto Meter
- Matlab

Measurements

- Processing method
- Measurement environments
  - Indoor Office
  - Indoor Corridor
  - Indoor Lecture/Conference room
  - Outdoor urban
Processing Method

- Lost messages
  - Sensitivity [dBm]:
    - Typical: -94 dBm
    - Nominal: -90 dBm
  - Probability of messages lost:
    - p = 10%: -90 dBm
    - p = 90%: -100 dBm

Measurements

- Measurement Environments:
  - Indoor Office
  - Corridor
  - Lecture/Conference Room
  - Outdoor Urban

Indoor Office

Indoor Office
**Indoor Office**

Comparison between measured and predicted for Indoor Office.

- Path Loss (predicted): 98 dB
- Measured Path Loss: 110 dB
- Standard deviation: 5.63 dB

**Corridor**

Shadowing

- RMS Error: 3.52
- Lo [dB]*

**Corridor**

N-Ray Model

<table>
<thead>
<tr>
<th>2D Model</th>
<th>Ground Ceiling</th>
</tr>
</thead>
<tbody>
<tr>
<td>3D Model</td>
<td>Ground Ceiling</td>
</tr>
<tr>
<td></td>
<td>Walls</td>
</tr>
</tbody>
</table>

*Note: The * symbol indicates a measured value.*
**Corridor**

Path Loss Model approximations, Three-Ray Model & Five-Ray Model for Corridor

- Path Loss Approximation
- Three-Ray Model (3RM)
- Five-Ray Model (5RM)

\[ \sigma = 3.12 \text{ dB} \]

\[ \mu = 6.34 \text{ dB} \]

\[ \sigma = 3.12 \text{ dB} \]

**Corridor**

Shadowing

- Path Loss Approximation
- Three-Ray Model (3RM)
- Five-Ray Model (5RM)

\[ \mu = 6.34 \text{ dB} \]

\[ \sigma = 3.12 \text{ dB} \]

**Lecture/Conference Room**

- Path Loss Approximation
- Three-Ray Model (3RM)
- Five-Ray Model (5RM)

\[ \rho = 5.95 \text{ dB} \]

\[ \sigma = 1.49 \text{ dB} \]

**Lecture/Conference Room**

- Path Loss Approximation
- Three-Ray Model (3RM)
- Five-Ray Model (5RM)

\[ \rho = 5.95 \text{ dB} \]

\[ \sigma = 1.49 \text{ dB} \]

**Outdoor Urban**
Conclusions

• Free Space & N-Ray Propagation Models do not give good predictions

• Path Loss Propagation Model

• Shadowing Normally distributed ... ?? ...

Recommendations

• Extend outdoor measurements

• Signal Strength indicator
  ➢ Higher accuracy
  ➢ Greater detection range
  ➢ Omnidirectional radiation pattern

Thank you for your attention

Questions?