Study on Attenuation Law of Wireless Sensor Network Signal Transmission in a Plantation Based on Bp Neural Network

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Abstract: Deployment of wireless sensor network nodes is the key problem in the application of the field of forestry and to determine the max effective communication range of network nodes is the key to solve the problem. However, forest environment is complex, the trunks, branches and leaves are playing a big role on signal scattering. What is more, Radio frequency, distance, height, gain and polarization mode of transmitting and receiving antenna are all having a certain effect on wave propagation. Therefore, a multivariate composite model, which takes tree species, height of transmitting antenna, height of receiving antenna and the distance between transmitting antenna and receiving antenna as the independent variables, is established based on the BP neural network in this paper. The experimental site has a typical temperate continental monsoon climate, so for the same climatic conditions of the plantation, the composite model can be used to estimate the wireless signal propagation loss in the plantation. Furthermore, it provides an important basis for determining the max effective communication distance and rational distribution of communication nodes.

Key words: Wireless sensor network, mechanism of signal transmission, attenuation loss model, BP neural network

INTRODUCTION

Wireless Sensor Network (WSN) technology has large-scale, self-organizing, dynamics, reliability and other characteristics (Gan, 2006). Because of the advantage of data centric in data collection, researches on forest fire monitoring ecological diversity monitoring, detection of plant diseases and insect pests, wood detection and precision forestry have attracted more and more attentions of workers and experts in forestry science and technology (Porter et al., 2005; Gay-Fernandez et al., 2010). Deployment of wireless sensor network nodes is the key problem in the application of the field of forestry, but forest environment is complex, the trunks, branches and leaves are playing a big role on signal scattering. What is more, Radio frequency, distance, height, gain and polarization mode of transmitting and receiving antenna are all having a certain effect on wave propagation.

In view of the 2.4GHz WSN radio frequency signal attenuation phenomena in the process of transmission in the forest, relevant researches have been carried out by a large number of domestic and foreign scholars. And signal attenuation loss theoretical simulation analysis models and empirical statistical models have also been, respectively established (Li et al., 2007; Richter et al., 2005; Meng et al., 2008-2010; Xu and Li, 2011; Zhang and Zhou, 2011). Empirical statistical models are more accurate than theoretical simulation analysis models, but considering the modeling process and the models’ complexity, the existing empirical statistical models are usually obtained in certain conditions, without fully considering the factors influencing the models’ accuracy, such as antenna gain, the effect of depolarization, the density of trees, tree species, crown density, environmental temperature, air relative humidity and so on. Based on the BP neural network, a method for establishing the multivariate composite transmission attenuation model is presented in this paper.

The experiment site and environment, experimental equipments and experimental measurement are briefly introduced in Section 2. Section 3 makes an overview of the processing of the experimental data, including the calculation of field strength value at receiving point and the calculation of attenuation values. In Section 4, the modeling procedure, model establishment and prediction results are described in turn. Finally, Section 5 summarizes the full text, points out that the composite model has a
high accuracy and it will promote the application of wireless sensor network in plantation ecological monitoring field.

EXPERIMENT

Experiment site and environment: Experimental data is obtained from the plantation at the bank of Wenyu River in Changping District, Beijing, whose climate is a typical warm temperate continental monsoon climate. The main species is poplar and willow. The poplar trees’ diameter is from 15 to 25 cm, plant spacing is from 3 to 3.5 m, average height is from 7 to 10 m. And the willow trees’ diameter is from 8 to 10 cm, height is about 8.5 m, plant spacing is about 1.5 m, line spacing is about 2 m. The experiment scene is shown in Fig. 1.

Experimental equipments: In this experiment, the field strength meter is the portable, multi-functional Protek 3290N produced by company GSI in Korea, which is used to measure the field strength. The transmitter module is antenna produced by company TP-LINK in America, which is used to amplify the radio signal and then the signal is transmitted to the field strength meter. The schematic diagram of field strength measurements is shown in Fig. 2.

Experimental measurement: The way of experimental measurement is as follows: First of all, the position of nodes, the height of nodes and the height of receiving antenna should be fixed. Then the receiving antenna should be moved in a fixed direction along the transmitting module. Finally, the data of field strength can be measured. Figure 3 shows the schematic diagram of transmitter module and receiving antenna.

PROCESSING OF THE EXPERIMENTAL DATA

Calculation of field strength value at receiving point: The expression on relationship between field strength value at receiving point and the reading data of field strength meter is shown in (1):

\[ E_t = E_r - G_a - 20 \log \lambda + L_f + 6K \]  

(1)

where, \( E_t \) is field strength value at receiving point (dBμV/m). \( E_r \) is the reading data of field strength meter (dBm). \( K \) is antenna correction factor (dB). \( G_a \) is receiving antenna gain (dB). \( L_f \) is the effective length of receiving antenna (m), \( L_f = \lambda/\pi \). \( L_f \) is receiving feed line loss (dB). \( 6 \) is the correction value from terminating-value to open-value. Because the feed line in experiment is coaxial cable and also very short, \( L_f \) is neglected. \( G_a \) HG2458-09P antenna gain, is \( 9 \) (Zhang and Zhou, 2011).

So the expression on relationship between actual field strength and measured field strength is shown in (2):

\[ E_t = E_r - 9 + 28 + 6 + 74.75 = E_r - 9 + 108.75 = E_t + 99.75 \]  

(2)
Calculation of attenuation values: The power of the transmitter is measured in watts (W) and the calculation method which converts the power into the corresponding field strength (dBμV/m) is shown in (3):

\[ E_t = V + h_t = P_0 + 120 + 10 \log R + 20 \log h_t \]  

(3)

where, \( E_t \) is the size of the electrical signal induced at a point in space, that is, the value of field strength (dBμV/m). \( P_0 \) is decibel value of the power of transmitter (dBW). \( V \) is level value of the electrical signal which is engendered by transmitting device at a point in space (dBμV). \( P_0 \) is the effective length of transmitting antenna and in order to achieve the maximum transmit power, the value is in a quarter of wavelength, 0.03125 m (Li et al., 2007).

In this experiment, the transmitting power of wireless sensor nodes is 3dBm. So the field strength of transmitting terminal can be obtained from formula (4), the unit is dBμV/m:

\[ E_t = -27 + 120 + 16.98973 - 30.1030 - 79.8867 \]  

(4)

where, the calculation method of attenuation is shown in formula (5), the unit is dB:

\[ L_p = E_t - E_r \]  

(5)

**MODEL ESTABLISHMENT**

**Modeling procedure:** BP neural network is a kind of multilayer feedforward neural networks (Peng and Wen, 1999; Zhao et al., 2004). Its characteristic is signal forward transmission and error back propagation. Neural network training process is shown in Fig. 4.

**Model establishment:** A total of 54 experimental data are used to establish the composite model. Among them, there are two species: willow and poplar. The heights of transmitting and receiving antenna are divided into 0.5, 1.0, 1.32 and 1.5 m. And the distance between transmitting antenna and receiving antenna is not fixed. In this modeling, 44 groups of data are randomly selected as the training data and the other 10 groups as the prediction data. This model is a single hidden layer model, the number of hidden layer nodes is 5, the number of network parameter configuration iterations is 100, the learning rate is 0.1 and the target is 0.00002.

**Prediction results:** After the model establishment, the prediction results of 10 groups of data are shown in Table 1 and Fig. 5.

The average error of this model is 1.40%, the accuracy is 98.60% and the MSE is 1.5855. Thus, BP neural network model has a high accuracy in the modeling process of four variables, including tree species, height of transmitting antenna, height of receiving antenna and the distance between transmitting antenna and receiving antenna. It provides a new way to build a composite

Fig. 4: Neural network training process

<table>
<thead>
<tr>
<th>Tree species</th>
<th>Height of receiving antenna (m)</th>
<th>Height of transmitting antenna (m)</th>
<th>Distance (m)</th>
<th>( E_t ) (dBm)</th>
<th>Prediction ( L_p ) (dB)</th>
<th>Accuracy values (dB)</th>
<th>rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>willow</td>
<td>1.32</td>
<td>1.32</td>
<td>8</td>
<td>-87.92053</td>
<td>66.19333</td>
<td>66.30082</td>
<td>99.84</td>
</tr>
<tr>
<td>willow</td>
<td>1.32</td>
<td>1.32</td>
<td>23</td>
<td>-97.98679</td>
<td>69.61334</td>
<td>70.23553</td>
<td>99.11</td>
</tr>
<tr>
<td>willow</td>
<td>1.32</td>
<td>1.32</td>
<td>40</td>
<td>-85.10207</td>
<td>72.81915</td>
<td>73.45119</td>
<td>99.14</td>
</tr>
<tr>
<td>poplar</td>
<td>1.32</td>
<td>1.32</td>
<td>5</td>
<td>-86.05663</td>
<td>65.23877</td>
<td>64.69571</td>
<td>99.16</td>
</tr>
<tr>
<td>poplar</td>
<td>1.32</td>
<td>1.32</td>
<td>18</td>
<td>-81.48450</td>
<td>70.57964</td>
<td>70.83212</td>
<td>99.64</td>
</tr>
<tr>
<td>poplar</td>
<td>1.32</td>
<td>1.32</td>
<td>25</td>
<td>-96.95214</td>
<td>74.84579</td>
<td>73.03959</td>
<td>97.53</td>
</tr>
<tr>
<td>willow</td>
<td>1.50</td>
<td>1.50</td>
<td>10</td>
<td>-87.18321</td>
<td>68.56277</td>
<td>66.73119</td>
<td>97.26</td>
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<tr>
<td>willow</td>
<td>1.50</td>
<td>1.50</td>
<td>35</td>
<td>-89.67286</td>
<td>74.37813</td>
<td>72.30520</td>
<td>97.13</td>
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<tr>
<td>willow</td>
<td>1.00</td>
<td>1.00</td>
<td>15</td>
<td>-91.60746</td>
<td>73.47642</td>
<td>73.44306</td>
<td>99.95</td>
</tr>
<tr>
<td>willow</td>
<td>0.50</td>
<td>0.50</td>
<td>20</td>
<td>-88.71071</td>
<td>71.84808</td>
<td>69.90306</td>
<td>97.22</td>
</tr>
</tbody>
</table>
model for attenuation of 2.4GHz wireless sensor network signal transmission in a plantation and also has some important application value.

CONCLUSION

This study focuses on four variables, including tree species (poplar, willow), height of transmitting and receiving antenna (0.5, 1, 1.32 and 1.5 m) and distance, to establish the signal attenuation composite model, which is based on BP neural network. It has a high accuracy and can not only provide a scientific basis for estimating the max effective communication distance between nodes, but also provide an important theoretical support for determining the rational distribution of nodes in wireless sensor network. It will certainly promote the application of wireless sensor network in plantation ecological monitoring field.

ACKNOWLEDGEMENTS

This study was supported in part by project supported by Beijing Municipal Natural Science Foundation (Grant No.6133032), project supported by National Natural Science Foundation of China (Grant No.31300470) and project supported by the Fundamental Research Funds for the Central Universities (Grant No.TD2013-3).

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