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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

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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.

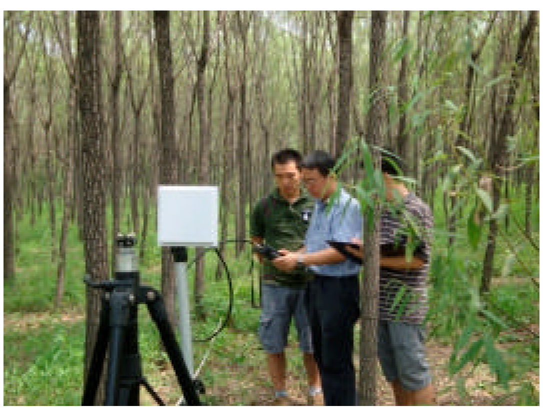

Fig. 1: Experiment scene of plantation environment

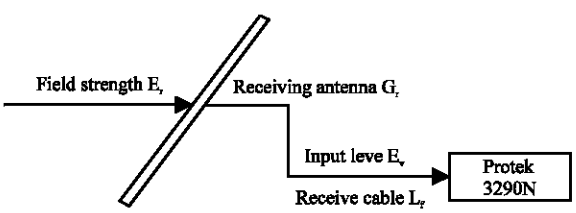

Fig. 2: Schematic diagram of field strength measurements

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):

$$E_r = E_v\text{-}G_d\text{-}20\lg l_e+L_f+6K \tag{1}$$

where, E_r is field strength value at receiving point (dBμV/m). E_v is the reading data of field strength meter (dBm). K is antenna correction factor (dB). G_a is receiving antenna gain (dB). l_e is the effective length of receiving antenna (m), $l_e = \lambda/\pi$. 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):

$$E_{\gamma} = E_V\text{-}\ 9+28+6+74.75 = E_v\text{-}9+108.75 = E_v+99.75 \tag{2}$$

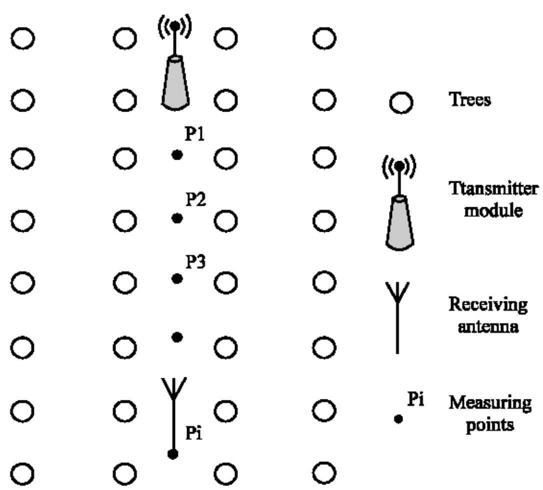

Fig. 3: Schematic diagram of transmitter module and receiving antenna

Calculation of attenuation values: The power of 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):

$$E_t = V+h_e = P_{db}+120+10 \lg R+20\text{gl}h_e \qquad (3)$$

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_{dB} 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). is input impedance of transmitting antenna system (Ω) and it is a standard impedance of 50 Ω. h_e 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:

$$E_t = -27+120+16.9897-30.1030 = 79.8867 \qquad (4)$$

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

$$L_F = E_t - E_Y \qquad (5)$$

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

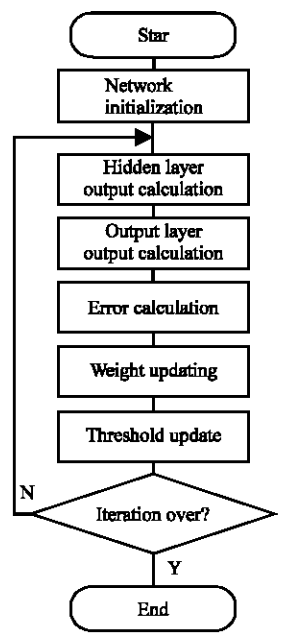

Fig. 4: Neural network training process

Table 1: Predict results of the model

Tree species	Height of receiving antenna (m)	Height of transmitting antenna (m)	Distance (m)	E_Y (dBm)	Prediction L_F (dB)	Accuracy values (dB)	rate (%)
willow	1.32	1.32	8	-87.92053	66.19333	66.30082	99.84
willow	1.32	1.32	23	-97.98679	69.61334	70.23553	99.11
willow	1.32	1.32	40	-85.10207	72.81915	73.45119	99.14
poplar	1.32	1.32	5	-86.05663	65.23877	64.69571	99.16
poplar	1.32	1.32	18	-81.48450	70.57964	70.83212	99.64
poplar	1.32	1.32	25	-90.95214	74.84579	73.03959	97.53
willow	1.50	1.50	10	-87.18321	68.56277	66.73119	97.26
willow	1.50	1.50	35	-89.67286	74.37813	72.30520	97.13
willow	1.00	1.00	15	-91.60746	73.47642	73.44309	99.95
willow	0.50	0.50	20	-88.71071	71.84808	69.90309	97.22

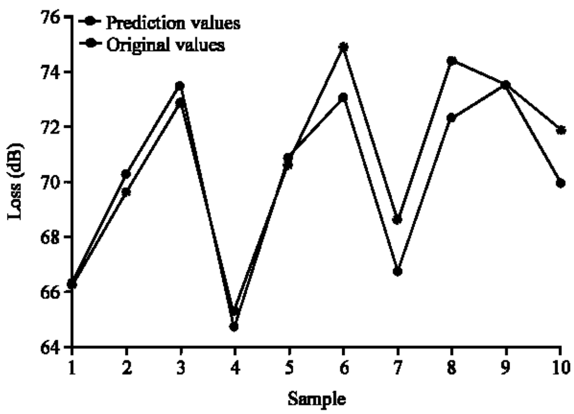

Fig. 5: Modeling results of composite model. BP neural network predicion output

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.

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REFERENCES

Gan, G., 2006. Packet aggregation method in wireless sensor networks. J. Chongq. Univ. Posts Telecommun. (Nat. Sci.), 18: 402-405.

Gay-Fernandez, J.A., M. Garcia Sanchez, I. Cuinas, A.V. Alejos, J.G. Sanchez and J.L. Miranda-Sierra, 2010. Propagation analysis and deployment of a wireless sensor network in a forest. Prog. Electromagnetics Res., 106: 121-145.

Li, W.B., J.M. Zhang, C. Sa, D.M. Wang and K. Gao, 2007. Model for forecasting the electric field intensity of UHF wireless frequency band in plantations. J. Beijing Forestry Univ., 29: 15-19.

Meng, Y.S., Y.H. Lee and B.C. Ng, 2010. Path loss modeling for near-ground VHF radio-wave propagation through forests with tree-canopy reflection effct. Prog. Electromagnetics Res. M, 12: 131-141.

Meng, Y.S., Y.H. Lee and B.C. Ng, 2009. Empirical near ground path loss modeling in a forest at VHF and UHF bands. IEEE Trans. Antennas Propagation, 57: 1461-1468.

Meng, Y.S., Y.H. Lee and B.C. Ng, 2008. Near ground channel characterization and modeling for a tropical forested path. Proceedings of the 29th URSI General Assembly, August 9-16, 2008, Chicago, USA.

Peng, C. and X. Wen, 1999. Recent applications of artificial neural networks in forest resource management: An overview. Proceedings of the AAAI Workshop on Environmental Decision Support System and Artificial Intelligence, July 18, 1999, Menlo Park, CA., pp: 15-22.

Porter, J., P. Arzberger, H.W. Braun, P. Bryant and S. Gage et al., 2005. Wireless sensor networks for ecology. BioSci., 55: 561-572.

Richter, J., R.F.S. Caldeirinha, M.O. Al-Nuaimi, A. Seville, N.C. Rogers and N. Savage, 2005. A generic narrowband model for radiowave propagation through vegetation. Proceedings of the IEEE 61st Vehicular Technology Conference, Volume 1, May 30-June 1, 2005, Stockholm, pp: 39-43.

Xu, Y.J. and W.B. Li, 2011. Propagation path loss prediction model of multi-sensor network in forest. Procedia Eng., 15: 2206-2210.

Zhang, J.G. and F. Zhou, 2011. Study on propagation law of 2.4GHz wireless sensor network signal in plantation environment. Chinese Sci., (Papers Online).

Zhao, M.C., J.Q. Zheng, X.Q. Feng and X.J. Lin, 2004. The application research of artificial neural network and its prospects in forestry. MIE China: Acad. Edn., 32: 99-102.