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Power Loss Analysis of Zigbee Propagation Models on the Landslide of Heifang platform

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Abstract. Landslide frequently occurred in Heifang platform of Gansu province which have brought great loss to local villagers. Filed monitoring and warning system based on wireless sensor network with Zigbee technology for landslide is a good choice for landslide monitoring. The prediction of energy loss through propagation models is important for deployment of sensor nodes in Heifang platform environment. The objective of this paper is to find the best propagation model in Heifang platform to predict signal attenuation, in which we analyze the signal strength of different receiver height by measuring RSSI value, optimize parameters of Log-norm shadowing model by simulated annealing algorithm, and make comparison with different models to show the best model in this place.

Introduction

Over the past few decades, landslides occurred frequently in China especially in Heifang platform of Gansu province. The disasters have caused great damage to the lives and property, as well as the highways, railways, houses etc simultaneously. So many papers have made many studies about landslides, such as research of Heifangtai landslide distribution and characteristics [1], selection of control measures for landslide disaster [9]. Filed monitoring and warning system for landslide geological disaster has been proposed in recent years which is used for monitoring and early-warning of landslide environment [16]. Wireless communication among sensor module nodes adopts Zigbee technology. The data collected by the sensor module nodes is transmitted to the data processing center by the base station through the 3G cellular communication technology, athen the data processing and analysis are carried out.

Deployment of wireless sensor network is important for transmitted data accuracy and channel quality. A good sensor network will help to decrease the costs of devices and to find the best positions to cover the entire area of interest. So many researchers rely on signal propagation path loss models to know how to allow the deployment of sensor nodes since the propagation models have traditionally focused on predicting the average of the received signal strength at a given distance from the transmitter. Many addressed literature have a study on propagation path loss models in outdoor environment. For example, Tewari proposes a model applied to rain forests of India [13], the authors of [10] carry out studies about near ground path loss model in a forest with free space model, ITU-R model, COST-235 model and their proposed model, and paper [5] focuses on signal propagation in a vineyard with Friis model, log-distance model considering the angle between the transmission path and the crop rows.

The objective of this study is to obtain the most optimized parameters of Log-norm shadowing model called Optimized Log-norm by simulated annealing algorithm which is nearest to the real measurements of true environment in Heifang platform. We have also made a comparison between other models, different parameters of Log-norm shadowing model and Optimized Log-norm model.

The best model for the Heifang environment called Optimized Log-norm could help estimate the signal strength more accurately and deploy sensor nodes more expediently.

Measured Theory, Tools and Methodology

There are many kinds of wireless technologies for a sensor network, such as Zigbee, Wi-fi, and Bluetooth. We choose Zigbee as our option because of its low power, low latency communication and other advantages. The CC2530 is the Zigbee RF modules, and RSSI serves as measurement between the two network nodes. The Zigbee protocal, CC2530, RSSI and the detailed procedure of experiment will be described in this section.

Zigbee is a wireless communication technology based on IEEE802.15.4 standard with the characteristics of low rate, close range, low power consumption, low complexity, low cost, reliable communication and high network capacity. Zigbee works in ISM frequency band and operation frequency channels fall into three bands: 868 MHz in Europe, 915 MHZ in the United States, 2.4 GHz on the rest of world [12]. In the 2.4 GHz band there are 16 Zigbee channels with the data transmission rate of 250kps. Zigbee supports three main self-organization wireless networks (see Fig. 1), star topology, net topology and clusters topology [4].

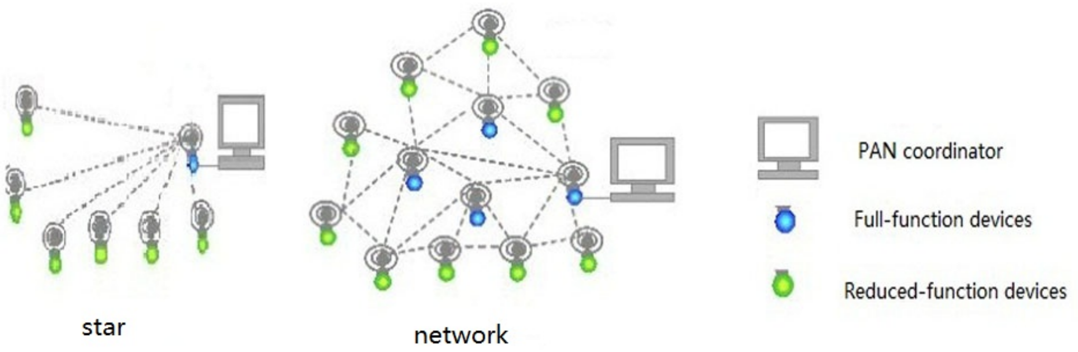

Fig.1. Topologies of Zigbee

RSSI stands for Received Signal Strength Indicator, and is used as a metric to estimate the receiving signal strength between two nodes according to their relative distance. It is conformed to the wide applied 802.11 standard [2]. We can measure the distance between one fixed point and another moved point by the received signal strength, then make the position calculation according to the data, such as the positioning engine based on CC2431 chip of Zigbee wireless sensor network by this technology. Electromagnetic wave will attenuate when transmit from one place to another because of the ground reflection, obstacles reflection, refraction and diffraction. RSSI is importance of the severity of fading effects on wireless communications, making their existence directly affect the performance of wireless communications systems [3].

Hardware: We use the CC2530F256 (see Fig. 2) included ZB502 expansion board as well as core2530 antenna chip in our experiment. CC2530 is a true system-on-chip solution for IEEE 802.15.4 of 2.4 GHz, Zigbee and RF4CE application. It supports establishing a powerful network nodes with very low total cost of materials [7]. The CC2530 has various operating modes, making it highly suited for systems where ultra low power consumption is required. Short transition times between operating modes further guarantee low energy consumption. Moreover, the reliable communication distance is more than 250 meters in the empty area.

Software: The received data is displayed on PC with serial debugging assistant called SComAssistant v2.2. Receiver get a RSSI value every one second and display on the software in the Fig. 3. The PC we have used is Lenovo 405-ASI with Windows Professional Edition 32 bit operating system, CPU: AMD Trinity APU A8-4555M, Main frequency: 1.6GHz, Memory Capacity: 2GB DDR3, Hard drive capacity: 500GB, and Power consumption: 17W.

Fig.2. CC2530 Eval Kit

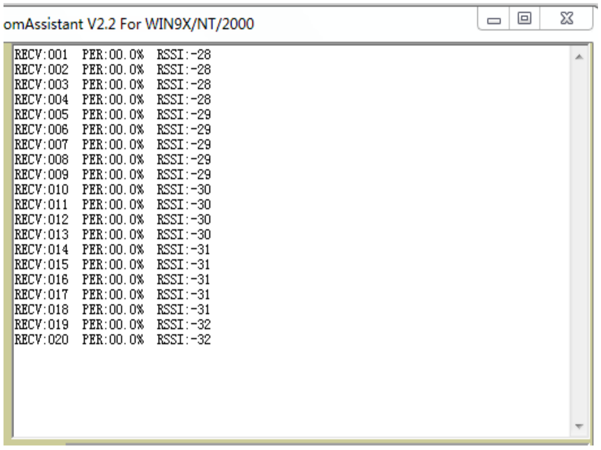

Fig.3. Data Display

The selection of location and measurement steps are very important to our experimental result. Huangci landslide, located at the town of YanGuoXia, village of JiaoJia with large scale, poor stability, and heavy damage, is a typical one of Heifang Platform landslide groups. The local villagers told us that there have been several landslides over the last twenty years, which have caused tremendous losses to villages, farmland, roads, and enterprises. The probability of landslides remains high in the future. So we select Huangci landslide to the experiment (see Fig 4).

Fig.4. Huangci Landslide

The experiment was taken on a sunny day with a temperature of 36°Cand it was taken in the following three steps:

1. We wrote the C-program language of sender and receiver in IAR Embedded Workbench for Evaluation environment, then we loaded the entire C-program on the host and slave, host represents sender and slave stands for receiver. The host was fixed at a point of the top, and the slave was moved to test the RSSI value with different distance.
2. The receiver was placed at a height of 0 m above ground and was measured with intervals of 1 meter. In order to evaluate the samples collected, we processed the samples with 25 measuring points collected 20 samples, in total of 500 samples of RSSI values. Then, respectively, repeat the above steps by setting the height of slave to 1 meter, 2 meter, etc.
3. Then the collected data have been preprocessed, and the processed data was analyzed by using MATLAB tools. Finally, different models were compared with each other.

The Path Loss Models in Outdoor Environment

The empirical path loss models were constructed based on the result which was measured in multiply similar environment, then we get the average result at a given distance *d* in specific circumstances. Both theoretical and measured values based propagation models indicate that the average of received signal power decreases with distance. Empirical models help to reduce computational complexity and increase the accuracy of the predictions. So far, there are many empirical models used in the various environments to predict the average signal strength between two nodes of wireless communication system. We will discuss the widely used models in the outdoor environment. In every model, PL(Path Loss), whose unit is dBm, represents the losses of the model, *d*, whose unit is meter, represents the distance , and *f* stands for the frequency.

A. Free Space Model [10]

$$PL_{(dB)} = -27.56 + 20 * \log(f) + 20 * \log(d) \quad (1)$$

Where the unit of *f* is MHz.

B. Cost 235 Model [6]

$$PL_{(dB)} = 15.6 * f^{-0.009} * d^{0.26} \text{ - With leaf}$$

$$PL_{(dB)} = 15.6 * f^{-0.2} * d^{0.5} \text{ - Without leaf} \quad (2)$$

Where the unit of *f* is MHz. In the COST235 model, measurements were performed over two seasons, when the trees are in-leaf and when they are out-of-leaf. Similarly, this model is applicable for frequencies between 200 MHz to 95 GHz.

C. ITU-R Model [15]

$$PL_{(dB)} = 0.2 * f^{0.3} * d^{0.6} \quad (3)$$

Where the unit of *f* is MHz and this model is applicable for frequencies between 200 MHz to 95 GHz.

D. Log-norm Shadowing Model [14]

$$PL_{(dB)} = PL(d_0) + 10 * n * \log(\frac{d}{d_0}) + X_\sigma \quad (4)$$

Where, X_σ is a zero-mean Gaussian distributed random variable with standard deviation σ, d_0 is close-in reference distance , n is the path loss exponent ,The parameter n is different in the different environment.

Table 1. Path Loss Exponents n for Different Environments

Environment	Path Loss Exponent, n
Free Space	2
Urban area cellular radio	2.7 to 3.5
Shadowed urban cellular radio	3 to 5
In building line-of sight	1.6 to 1.8
Obstructed in building	4 to 6
Obstructed in factories	2 to 3

Analysis Based on the Experimental Data

We conducted experiments in Huangci landslide several times and recorded data of different receiver height and different transmission distance. We collected the values of RSSI in different receiver height, which is analyzed by MATLAB tools. Fig. 5 shows the graph of measured data. From the picture we can draw a conclusion that signal quality of 1 meter is strong. Table.2 presents the average value of RSSI of 0m, 1m and 2m. For 1m, the average value of RSSI is the maximal of the three heights,from which we get the same conclusion that signal quality of 1 meter is strongest. So we will use the data of 1m to analyze in the future work.

From the above analysis we know that the height of the receiving antenna influences on signal energy and signal quality of 1m is better than 0m, 2m. So the next analysis of the measured data by SAA will use the data of 1m.

SAA (Simulated Annealing Algorithm) is firstly designed by Kirkpatrick etal (1983) to combinatorial optimization based on probability theory. Gradually, this algorithm becomes one of the most popular metaheuristics for real world problems due to easy utilization and high performance [8]. The algorithm derives from solid annealing process, internal energy of solid increases with the temperature rising, while temperature *T* influences on the internal energy.

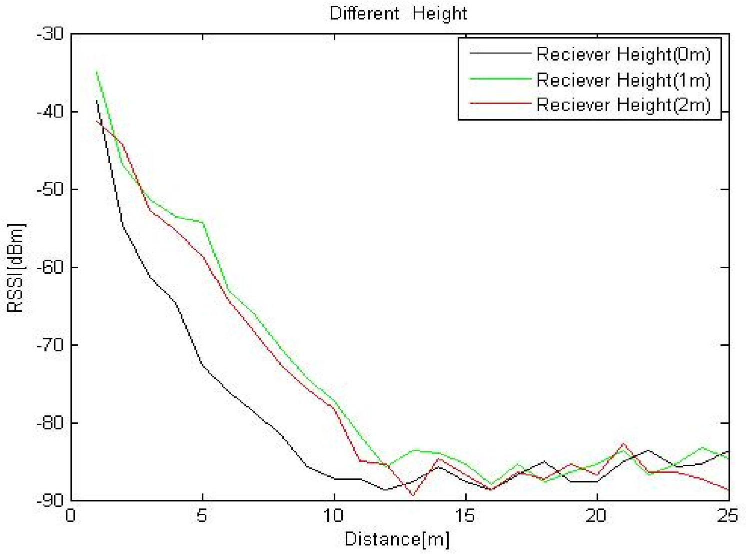

Fig.5. RSSI Value of Different Receiver Height

Table 2. AVG For Different Receiver Height

Receiver Height	0m	1m	2m
Average RSSI	-79.90	-74.77	-76.34

The probability of particles trending to balance is $e^{-\Delta E/(kT)}$ according to Metropolis standard when *T*, where *E* is the internal energy at *T*, ΔE is variation, k is Metropolis constant, at the temperature of *T*, the molecules remain in the state r to meet the Boltzmann probability distribution, the equation is as follows:

$$P\{\overline{E} = E(r)\} = 1/Z(T) * e^{-E(r)/kT} \quad (5)$$

where $\overline{E}$ presents a random variable of molecule energy, E(r) is the energy of state r, Z(T) stands for the standard factor of Boltzmann probability distribution, k >0. Internal energy e is simulated as the objective function value *f*, temperature *T* corresponding to the control parameter t in SAA. The algorithm starts with initial solution i and an initial value of control parameter initial value t, then t is gradually attenuated until the approximate optimal solution is found. The flow chart of SAA is seen in Fig. 6 [11].

In our experiment, we gain the optimal values of parameters n and X_σ in Log-norm Shadowing model will be found by this algorithm. Every founded parameters math a smallest RMSE (Root Mean Square Error). The objective function is $f = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(y-y_1)^2}$, where n is the data dimension, y presents measured data, y_1 stands for predict data of different propagation models.

The Log-norm Shadowing Model has presented in section 3, parameter n and X_σ influences on attenuation of channel model, and this model is designed for computer simulation to provide received power levels for random locations communication system. The predicted RSSI of different n and settled X_σ are shown in Fig. 7 (a) while different X_σ and settled n are presented in Fig. 7 (b) which is compared with the measured data.

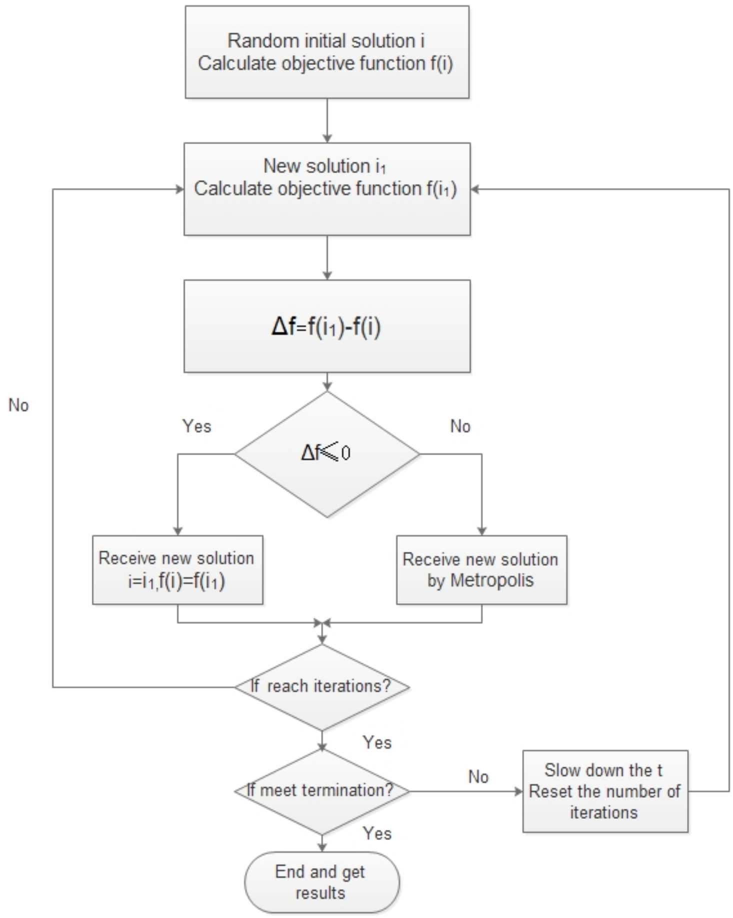

Fig.6. The Flow Chart of SAA

We can see from Fig. 7 that when n = 3 and X_σ is fixed value 9 meanwhile $X_\sigma = 4$ and n is fixed value 3 is most close with the measured value. So the parameters n and X_σ value can be set 3 and 4 approximately. The optimal parameters will be found by SAA which is ran in MATLAB ten times, then ten groups optimal parameters, RMSE value and their average are shown in Table.3. The Log-norm shadowing model of optimal average values n = 3.53, $X_\sigma = 4.02$ will be titled Optimized Log-norm model in future work.

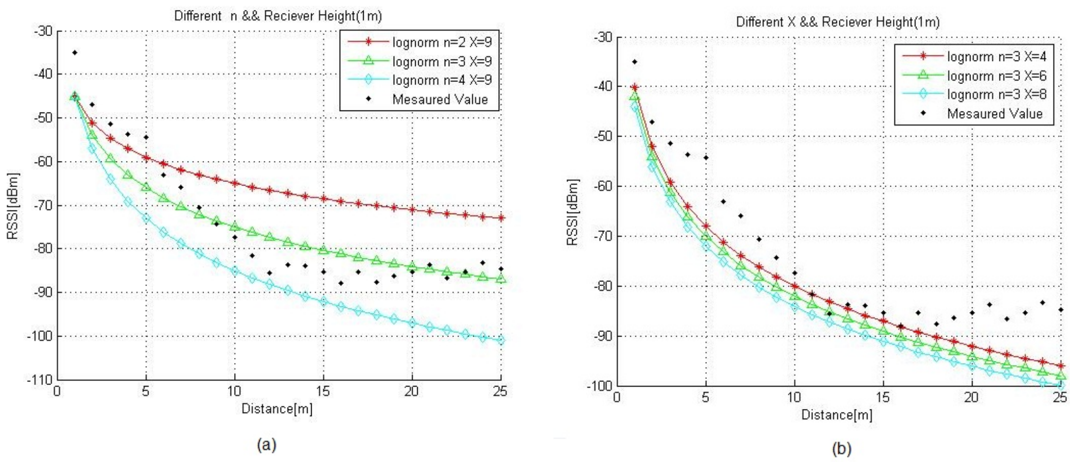

Fig.7. Curves of Different Parameters and Measured Values

Table:3 Average RMSE of Different n and $X\sigma$

times	n	X_σ	RMSE
1	3.52	4.01	0.98
2	3.53	4.01	0.97
3	3.52	4.09	0.93
4	3.56	4.02	0.99
5	3.53	4.01	0.93
6	3.52	4.01	0.92
7	3.51	4.00	0.91
8	3.54	4.00	0.95
9	3.54	4.07	0.96
10	3.52	4.00	0.96
AVG	3.53	4.02	0.95

The different propagation models such as Free Space Model, ITU-R Model, COST235 Model, Log-norm Shadowing Model have been discussed in Section 3. The predicted RSSI values of these models can be drew up by using MATLAB tools. Fig.8 shows the curves which obtained from the measured RSSI values in comparison with the prediction of each propagation model including the Optimized Log-norm model from the Log-norm Shadowing.

The Root Mean Square Error (RMSE) is used as a statistical method to estimate the approximation of the prediction and measured data. Table.4 presents the RMSE of different propagation model. From the curves and table we can draw a conclusion that the Optimized Log-norm shows a greater efficiency which is most close to the true environment, with RMSE 0.95.

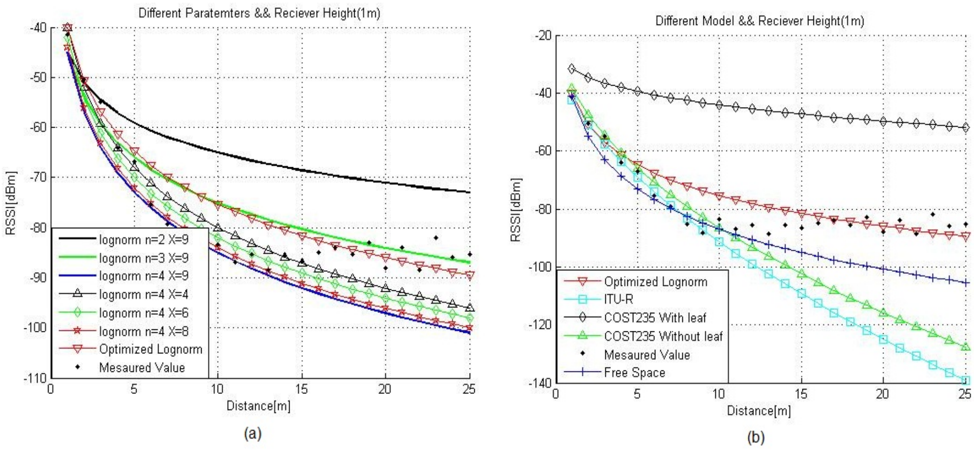

Figure 8: Curves of Different Models and Measured Values

Table 4. RMSE of Different Models

Model	RMSE
Free Space	2.67
ITU-R	5.71
COST235 With leaf	6.30
COST235 Without leaf	5.03
Optimized Model	0.95
Log-norm n=2 $X\sigma$ =9	3.02
Log-norm n=3 $X\sigma$ =9	1.22
Log-norm n=4 $X\sigma$ =9	1.72
Log-norm n=4 $X\sigma$ =4	1.38
Log-norm n=4 $X\sigma$ =6	1.72
Log-norm n=4 $X\sigma$ =8	2.08

Conclusion

We have shown results of measured data of signal strength in Heifang platform by using the CC2530F256. Both the height and distance of the receiver from sender have influence on signal propagation quality. From the picture and average RSSI of different receiving antenna height we gain that when the height is 1 meter, the signal strength is the best. Simultaneously, from the comparison with different prediction models and different parameters of Log-norm shadowing model, we conclude that Optimized Log-norm model is the most optimized one that is most close to the real environment of Heifang platform. RMSE of My Log-norm which is 0.95 is smaller than the free space model which is 2.67, ITU-R model which is 5.71, COST235 model without leaf which is 3.03 and so on.

The study of propagation model helps us find reasonable position of sensor node while doing the real deployment in the Heifang platform. Furthermore, our Optimized Log-norm model could predict signal strength at a given distance more accurate than other models. Then the Optimized Log-norm helps to find the best way of positioning sensor nodes in this landslide field.

However, the experiment was only taken at a sunny day with 25m. In the future, we will conduct experiment at a rainy day with farther distance due to rainfalls have great influence on landslide. Moreover, the future experiment will perform on other landslide groups of Heifang platform, too.

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