# *Research on the Signal Random Attenuation Coefficient Based on RSSI in WSN Localization Technology*

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***Abstract*—Localization technology is the important supporting technology in wireless sensor networks. Positioning precision is largely determined by ranging precision in the localization technology based on the distance. Traditional RSSI ranging method exists some problems of path loss model complex, serious signal concussion caused by environmental changes, which leads to ranging error and so on. According to the above problems, the RSSI ranging method which uses anchor nodes to aided ranging based on signal random attenuation coefficient is proposed. In this ranging method, path loss model need not to be established, furthermore, attenuation coefficient is in using when needs, and the ranging error caused by serious signal concussion as a result of environmental change is reduced, thus the ranging method has good environment adaptability.**

***Keywords- wireless sensor network; localization technology; RSSI ranging method; signal random attenuation coefficient***

## I. INTRODUCTION

Wireless Sensor Networks technology is a product of the combination of three pillars of the information industry (computer, communication and sensor) in the 21st century, which is widely used in military, environmental monitoring, agriculture, health and many other fields.

Localization technology is an important supporting technology of wireless sensor networks. Determine the position of incident or lock node position of received message is the premise of the oriented practical application of wireless sensor network. Meanwhile, node position information plays an important role in the target tracking, aided routing, network management and many other aspects [1].

In range-based localization technology, the ranging is premise of localization and is to get actual distance between nodes by means of specific methods. Ranging process is divided into two stages which are ranging stage and localization calculation stage, among them, ranging stage need be calculated by signal propagation velocity, signal attenuation and auxiliary hardware facilities. At this stage, it is easy to generate ranging error. It can be calculated directly by triangular method, triangulation and maximum likelihood estimation method in localization stage, and is difficult to generate error. Therefore, ranging accuracy becomes a research focus for ranging accuracy deciding the localization accuracy at a large extent. RSSI is Received Signal Strength Indicator method, it is a typical ranging method, without adding any additional hardware, compared to other ranging method, and it has a great advantage. However, different environments need the different path loss model, thus causing that model is complex and different to be set up. When the environment changes, there would be a oscillation in received signal strength value, which can result in 50% of the ranging error in the maximum [2]. In this paper, it proposes RSSI ranging method based on signal random attenuation coefficient to solve above problems.

## II. WSN LOCALIZATION TECHNOLOGY SUMMARY

Regarding whether measuring the actual distance between nodes in the process of positioning process, at present, the localization algorithm is divided into range-based localization algorithm and range-free localization algorithm [3].

### *A. Range-Based Localization*

In range-based localization mechanism, the distance among nodes or the angular information is required to be measured, then calculating node location by trilateration, triangulation and maximum likelihood estimation localization method.

In the range-based localization method, localization accuracy depends on the ranging accuracy; therefore there are the following introductions to the ranging method.

TOA [4] (Time of Arrival) ranging method calculates the distance by use of signal propagation velocity and propagation time. There is very high localization accuracy, but precise time synchronization is needed, so hardware costs are relatively high. The most typical use of localization system of TOA technology is GPS. GPS system requires expensive equipment and great energy consumption to achieve precise synchronization with the satellite, which is incompatible with simple hardware-required and limited energy consumption in wireless sensor network.

TDOA[5] (Time Difference of Arrival) localization method, directly transforms the time difference into distance by recording two different signal arrival time differences according to the propagation velocity of two known signals. It needs precise clock to record the arrival time interval between

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two signals, meanwhile the nodes need to have the capacity to perceive two different kinds of signals, and they are affected by distance restrictions of ultrasonic propagation and non line of sight to the impact of ultrasonic signal propagation.

AOA[6](Angle of Arrival) localization method gets the signal direction send by adjacent node through the combination of array antenna and multiple receivers, then calculates the location of node by triangulation method. AOA ranging technique is easily affected by external environment, such as noise and so on, thus making it unsuitable to large-scale wireless sensor networks due to the cost of its additional localization equipment.

RSSI[7] (Received Signal Strength Indirection) ranging method measures received power by receiving node, calculates propagation loss, transform propagation loss to distance by theoretical or empirical signal path loss mode, without any additional hardware so as to reduce input cost. However, the establishment of path loss model is complex; Radio-frequency signal is easily affected by environment such as multipath fading and non line of sight, which leads to severe concussion strength of received signal and is difficult to make a ranging accurately.

### *B. Range-Free Localization Algorithms*

Centroid algorithm estimates location by the polygonal geometric centroid which is overlapped by communication zones that are composed of all the anchor nodes in communication zones of unknown nodes. The characteristics of centroid algorithm is easy realization and without additional supporting hardware, but with low accuracy.

DV-Hop[8]algorithm is that unknown node measures the minimum hop with anchor node by routing method, and calculates the mean distance of each hop, makes the product of minimum hops and mean distance as the distance reckon between unknown node and anchor node. Finally it makes use of triangular measuring method or maximum likelihood estimation method to calculate unknown node coordinate. DV-Hop algorithm accuracy is higher than centroid algorithm, and the node dose not request with additional hardware support.

Amorphous algorithm is similar to DV—Hop algorithm, the difference is that, it assumes that the average network connectivity is known, Pre-deployment at the network off-line calculates the average jump distance.

APIT algorithm, the basic thought is that the any numbers of the triangular region composed by all anchor nodes in communication range of unknown nodes, overlapping regions of these triangles is the unknown node location by testing the unknown nodes is in which the inside triangle. Its communication overhead is small and has high precision, but needs enough anchor nodes in the communication range.

Convex programming algorithm treats the communication connection between nodes as the geometric constraint of node location, it transfers the entire network model into a convex set, therefore, node localization problem is transformed into a convex constrained optimization problem, and makes the use of linear programming and semi-definite programming approach to achieve a global optimization solution and determine the node location[9].

DV-distance localization algorithm is similar to DV-Hop, the difference is that adjacent nodes using the RSSI measurement of the distance between nodes, then makes use of method of similar distance vector routing to disseminate the accumulated distance with anchor nodes, uses trilateration positioning after the unknown nodes achieving the distance with three or more anchor nodes[3].

The theoretical basis of MAP algorithm is that the intersection point of two perpendicular bisectors of random two different strings of a circle namely is the circle center.

In the localization mechanism of range-free, they all use the connectivity between nodes to localization, without additional hardware, with small influence by environmental factors, but with larger localization errors, requirement with node density, so it is suitable for large-scale application environments with less demanded localization accuracy.

## III. **RSSI RANGING METHOD**

In the localization mechanism based on RSSI ranging method, the localization accuracy depends on the ranging accuracy. The basic thought of RSSI ranging method is that, because the signal will attenuate in the propagation process, utilizes the specific signal pass loss model in specific environment to calculate certain signal attenuation corresponding to signal propagation distance based this environment, namely the distance between two nodes.

### *A. RSSI Ranging principle*

In localization mechanism based on RSSI ranging method, signal strength of launch node is known, receiving node records the received signal strength, calculates the signal propagation loss, reuses path loss model to transform transmission loss into distance, the path loss model is followed:

$$P_r(d) = P_t G_t G_r \lambda^2 /(4\pi)^2 d^2 L \qquad (1)$$

Pt and $P_r(d)$ separately are node transmission power and node receive power which is apart from the launch node d, $G_r$ and $G_t$ separately are gain of transmitting antenna and receiving antennas. d is distance, L is system loss factor which is nothing to do with the transmission, $\lambda$ is wavelength. From the formulation of (1), it gets:

$$d = \frac{\lambda}{4\pi}\sqrt{\frac{P_t G_t G_r}{P_r L}} \qquad (2)$$

It can be seen that, in the free space, receiver power attenuate with the square of distance between transmitter and receiver, makes use of formulation of (2) by measuring the received signal strength to calculate the distance between transmit node and receive node.

### B. The Advantages and Disadvantages of RSSI Ranging Method and Error Analysis

Radio transceiver is existing resources of sensor node, without additional hardware, so it is a low-power and low-cost ranging technology.

In the practical use of RSSI ranging method, it is liable to the effects of humidity, temperature and obstacles, thus generating multipath propagation, reflection, antenna gain and non line of sight and so on, therefore, even at the fixed location, it also can lead to changes in the rate of signal attenuation due to the changing topography weather, they would have a significant different propagation loss with the same distance. However, the path loss model is aiming at the relationship between signal attenuation and distance based on certain environment, can not be stochastic changes, thus causing path loss model not meeting the environment and generating ranging error, Maximum ranging error is even up to 50%, so RSSI-based localization technology in distance-based localization technology areas usually belongs to a kind of rough localization.

## IV. RSSI RANGING METHOD BASED ON SIGNAL RANDOM ATTENUATION COEFFICIENT

### A. The Improved Idea

According to the exiting deficiencies of traditional RSSI ranging method, the paper proposes to improve the signal random attenuation coefficient. The basic idea is that calculating the signal random attenuation coefficient by means of signal propagation loss between two anchor nodes, which then be used to calculate the distance between known nodes and unknown nodes.

Ranging process such as Figure 1, node A is the anchor node, node C is the unknown node, A and C can communicate with each other in the same visual ranging environment, the distance from A to C needs to be measured. The traditional RSSI ranging method needs use the path loss model, however, when the external environment changes, the same distance will bring about different propagation loss, the different ranging results and larger error. At this time it can use the idea of signal random attenuation coefficient, if there is an anchor node B in the communication range of node A, so the node A ,B and C are neighbor nodes, the communication area of general node is within 100 meters, when the environment changes with irregular attenuation in the range of this small area, the signal propagation velocity from A to C and from A to B will be subject to the same impact, namely signal from A to C and from A to B would have the same attenuation regular. Therefore, makes use of anchor node A and B to obtain the relation between signal attenuation regular and distance, and then calculates the distance between A and C by signal random attenuation coefficient, based on this idea, the paper will combine the situation with the increasing distance but quickly attenuation change, thus deduced the signal random attenuation coefficient.

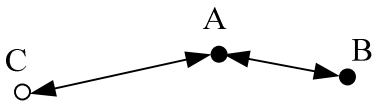


Figure 1: Node-aided positioning diagram

In the localization process of RSSI-based ranging method, it need at least three anchor node for localization in the communication range of unknown node, so when calculating the random attenuation coefficient, it can make use of these anchor nodes without additional increasing nodes.

### B. The Derivation of Signal Random Attenuation Coefficient and the Algorithm Described

Such as figure 2, at the same line-of-sight environment, there are two anchor nodes A, B and unknown node C. A and B, A and C can communicate with each other, the distance between A and B is $d_1$, the signal strength launched by A is $P_A$, when propagating to B, the strength is down to $P_B$, the strength from A to C is down to Pc, so it should measure the distance d from A to B.

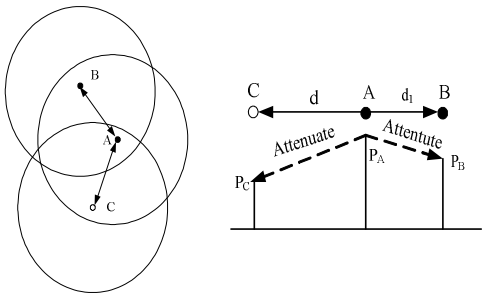


Figure 2: node-aide ranging schematic diagram

Derived as follows:

Relation between radio signals energy loss E and distance d:

$$E=kd^n \tag{3}$$

It can be seen that signal attenuation value is direct proportional to the n-th power of signal propagation distance, signal attenuation change quickly with distance increases (generally n is equal to 2 in the free space)

Based on formula (3), it gets:

$$P_A-P_B=kd_1^2,\ P_A-P_C=kd^2 \tag{4}$$

So it achieves that $\frac{P_A-P_B}{kd_1^{\ 2}}=\frac{P_A-P_C}{kd^2}$

then：

$$d=\sqrt{(P_A-P_C)\frac{d_1^{\ 2}}{P_A-P_B}}=\sqrt{P_A-P_C}\,\frac{d_1}{\sqrt{P_A-P_B}} \tag{5}$$

$\frac{d_1}{\sqrt{P_A - P_B}}$ is obtained by auxiliary node B and node A, supposed $\frac{d_1}{\sqrt{P_A - P_B}} = \eta$ , $\eta$ namely is signal random attenuation coefficient arrived by node A and B, the different environment has the different $\eta$ value, it has

$$d = \sqrt{P_A - P_C}\,\frac{d_1}{\sqrt{P_A - P_B}} = \eta\sqrt{P_A - P_C} \qquad (6)$$

It can be seen that, RSSI ranging method based on signal random attenuation coefficient and the traditional RSSI ranging method all use the received signal strength indirection method, but the ranging method has essential differences, in the RSSI ranging method based on signal random attenuation coefficient, makes anchor node aided with localization. This ranging method does not need establish complicated path loss model, and makes use of signal random attenuation coefficient for distance measurement.

## V. SIMULATIONS AND ANALYSIS OF ALGORITHMS

In order to test the performance of RSSI ranging method based on signal random attenuation coefficient, put out the simulation diagram about the algorithm to analyze, namely in the condition of fixed $P_A$, $P_B$, $d_1$ to get the relationship between $P_C$ and d.

The algorithm $d = \sqrt{P_A - P_C}\,\frac{d_1}{\sqrt{P_A - P_B}}$ , among, $\frac{d_1}{\sqrt{P_A - P_B}} = \eta$ , that is, signal random attenuation coefficient. It is got by two anchor nodes A and B, and $\eta$ changes with the environment. It can set a group of values, $d_1$=30m, $P_A$=25w, $P_B$=15w, namely $\eta$≈9.49, then do simulation of the algorithm to get the relationship image about d and $P_C$.

Simulation result:

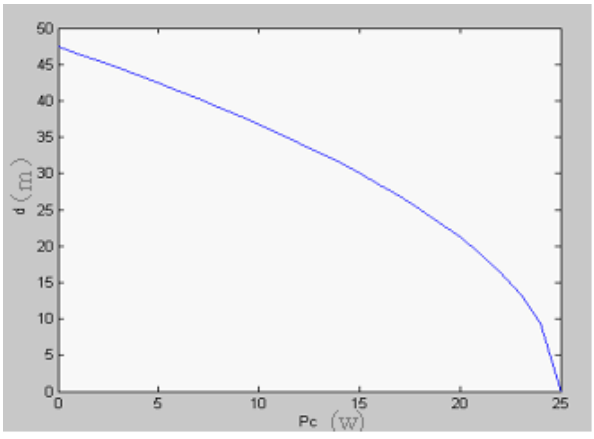


Figure3: algorithm simulation

The curve in the picture shows the relationship between the signal strength and distance of the node C which is got by the use of signal random attenuation coefficient method. The attenuation of signal strength is speeding with the distance increasing, and the rate of attenuation is homogeneous with non-shock situation.

## VI. CONCLUSIONS

In the distance-based localization technology, the localization accuracy depends on the ranging accuracy. In this paper, the idea of using the anchor node to aided ranging has been proposed, then not only explained the ranging principle but also deduced the signal random attenuation coefficient. Compare with the traditional RSSI ranging method, this ranging method does not need to set up complex path loss model, but to calculate the current signal random attenuation coefficient for the range acquisition. Attenuation coefficient is "in using when needs", which can effectively reduce the ranging error bought by the signal strength shaken due to the environment change and has good environmental adaptability.

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