Location Estimation of Wireless Sensor Networks Using Spring-Relaxation Technique with Confident Update

Thanakorn Prasansri and Chatchai Khunboa
Department of Computer Engineering, Faculty of Engineering, Khon Kaen University, 40002, Thailand
Email: imissyou27@hotmail.com, chatchai@kku.ac.th

Abstract**—Self-localization becomes the main issue for wireless sensor network (WSNs) because WSNs is widely used in various applications that adapt on industries, domestic animal raising and so on. For the low-cost localization and suitable in a real deployment solution, the extra hardware equipment is unsuitable due to its size, power requirement and memory constrain sensor nodes. The Spring-Relaxation localization is a method which can support the requirement of localization. In this paper, we propose the use of a confident value to indicate the correctness of a node's location. Our study shows we can improve the original spring-relaxation distance error by using 40 confidence values.**

Index Terms**— wireless sensor network, spring relaxation technique, confident update**

I. INTRODUCTION

Wireless Sensor Network [1] can be effectively applied in different tasks in order to increase productivity, decrease costs, and upgrade product standards. Wireless sensor network is an efficient technology with its outstanding minute size, low power consumption and long and continuous operating hours owing to its small batteries. It allows short-length communication or the dubbed wireless personal area network. This network is capable of both high and low speed data sending and receiving. Our research applies the IEEE 802.15.4 [2] standard – a low-speed short-range sensor network of the frequency of 2.4 GHz, with a capacity of 250 Kbps [3].

Localization s in one widely used different application in order to track or locate interested objects. Thought the Global Positioning System (GPS) is a well-known commercial use, energy consumption makes it not suitable in WSN applications. Therefore, in WSNs, the received signal strength indicator (RSSI) is widely applied because there is no extra equipment needed

Practically, we wish to simplify deployment WSNs. Nodes are randomly placed with minimum efforts. Thus, the multi-hop WSN eases to fix node's location by minimum the number of reference nodes. In this paper, we present the deployment of sensor nodes in real environment using Spring-Relaxation technique [4] with our proposed *confident value*. Also, we reduce the computation phase to decrease the power consumption.

The rest of this paper is organized as follows. Section 2 presents related work on multi-hop location systems. Section 3 presents our system set-up and methodology. Section 4 our experiment results and finally our conclusion is described in Section 5.

II. RELATE WORKS

Spring-Relaxation Technique is a method used to locate a node based on particle-moving behavior under the force of spring. Naturally, the length of spring is measured when the spring is at its rest state. If a spring length is shorter than usual, it means that a pressure is exerted on it. If a spring length is longer than usual, it means that the spring is stretched. The force occurs at both ends, and at the particle there is a set of force the spring receives when it is pressed or stretched. Therefore the resultant force of the particle is the sum of total vector the particle receives. When this parameter of the resultant force is not equal to 0, the particle will move towards a new direction of the resultant force. It will continuously move until the resultant force is zero. The final point is the location of particle or node obtained from calculation. In the real deployment [5] the nodes were placed at different places on a building and refer converted RSSI to ranging from [6].The study found that on average, the calculated location had an error of three meters.

In order to take a common ranging be able to use for many types of sensor nodes, we choose path loss equation that will be descries in the next section.

III. METHODOLOGY

A. Spring Relaxation with Confident Value

The original of Spring-Relaxation Technique divide its operation to 2 phases. At the first phase, all sensor nodes randomly select their locations. Each node relies on RSSI to find its distance from all beacon nodes which locations are known. This distance is used for indicating the location by the spring-relaxation technique. Since the number of nodes is small and there is discrepancy of RSSI, precision of localization is low. The second phase is used to refine node's location again except beacon

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nodes. The location and distance of each node is exchanged with neighbors in order to accurately calculate the location of that node.

As we have seen in the original version, each nodes re-computes its location as soon as received a location from its neighbors. However, there are no indicators that describe the accuracy of each node's location. Thus, in order to allow each node to filter from only trustful nodes, we proposed a metric called a *confident value* (CV).

$$CV = \sum_{i=0}^{n} \left(\frac{x_i}{n} * 100 \right) \quad (1)$$

where *n* is the number of neighbors of a node and x_i is a confident value of each node between zero to 100.

Initially, each node has a CV of zero and each reference node has a CV of 100. When a node receives a CVs from its neighbors, if the received value is higher than a expected value called *confidence threshold*, nodes use the received value to compute its new CV before propagating to its neighbor nodes every 10 seconds.

B. *Distance error*

Regarding distance error (E), we measure a location error of each node by measuring distance from its location and estimated location using the Euclidean distance equation[7]

$$E = \sqrt{X_e - X_t{}^2 + (Y_e - Y_t)^2} \quad (2)$$

where $(X_e,\ Y_e)$ is the estimated location and $(X_t,\ Y_t)$ is a node's location.

IV. EXPERIMENT AND RESULTS

Our sensor nodes used in this experiment are CC2530 from Texas Instruments. Nodes function at 2.4 GHz over 6LoWPAN (IPv6 over Low power WPAN) [2] by using a ContikiOS [8] platform. Our spring-relaxation algorithm with an extended confident value is installed to all nodes. Each node is put into a 1.2-meter station height as shown in Fig. 1.

Figure 1. A Sensor node installed over station

A. *RSSI Limitation Testing*

To make the estimation accuracy as possible, we bound the RSSI values used in our environment. Therefore, we compare the RSSI value and path loss equation [9] (Equation 3.)

$$\log_{10}(d) = \frac{1}{10_n}(P_{TX} - P_{RX} + G_{TX} + G_{RX} - X_a + 20\log_{10}\lambda - 20\log_{10}(4\pi)) \quad (3)$$

where

d = distance between nodes (m)

P_{TX} = sending power at sender (dBm)

P_{RX} = sending power at receiver (dBm)

G_{TX} = amplifying power of transmitter at sender (dBi)

G_{RX} = amplifying power of transmitter at receiver (dBi)

λ = wavelength (m)

n = Path Loss Exponent

X_a = Gaussian random variable with a standard deviation of α

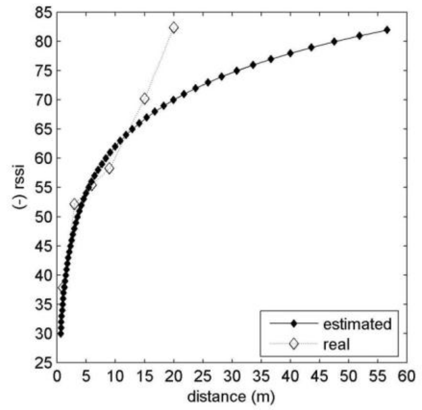

Figure 2. RSSI vs. distance by estimated and real environment

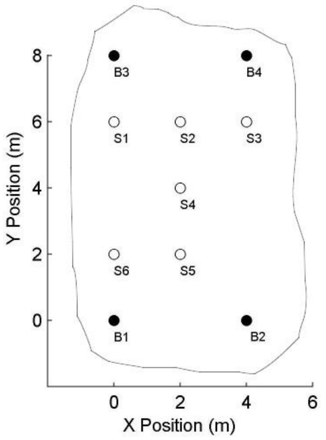

Figure 3. Actual locations of Beacon and Sensor node on

From our environment, we send one hundred packets from a sender to a receiver with two seconds interval. The receiver node is placed at 1, 3, 6, 9, 15, 20 meters from the sender node in order to compute the average RSSI value at each position. The comparison of the values from Equation 2 and real measurement is shown in Fig. 2. We found that at lower -60 dBm RSSIs of both have the same tendencies. However, when a RSSI value is higher than -60 dBm, they trend to move away from each other. Using values at higher than -60 dBm will cause the location estimation error. Hence, in our environment, we limit RSSI value to -45 dBm for Equation 3.

B. Confident Theshold Testing

Fig. 3 shows our test environment for different confident values. All sensor nodes are placed in an open field with 4x8 meter^2 as shown in Fig. 3.

At the initial state, all nodes are randomly pick their position. Then, each sensor node will propagate its position and (CV) to other nodes in specific interval called *update timer*, which is set to every 10 seconds.

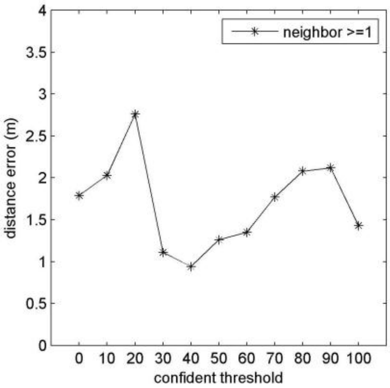

Figure 4. Average distance error of all nodes in each confident threshold

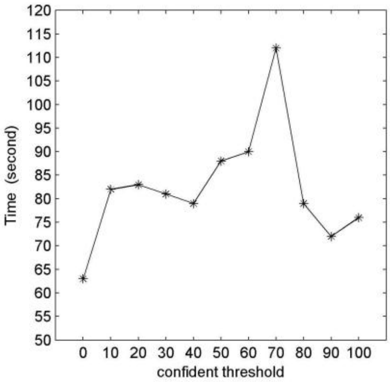

Figure 5. Average convergent time when neighbor>=1 in each confident threshold

Fig. 4 shows the effect of different confident threshold. The minimum distance error is when the confident threshold is set to 40 where the original spring relation is set at the zero confidence threshold. Therefore, our CV can improve a distance error from the original one approximately 0.5 meter.

C. Estimated Location's Time

From the previous test, we have seen the improvement of location error based on CV assignment. However, a convergence time is also an important parameter. Fig. 5 presents a convergence time of different threshold. The zero confident threshold as the original relaxation algorithm shows the minimum convergen time.

D. The Number of Neigbor Nodes

Because we perform the multihop location, each node believes its neighbors as reference nodes. In normal localization, there are minimum three reference nodes for triangulate algorithms. In this case, we compare two cases. First, there is at least one node neighbor with CV; Second, the minimum of three neighbors with CV. Fig. 6 shows that there are no significant difference in both cases and the 40 confident threshold is the minimum distance error in both cases.

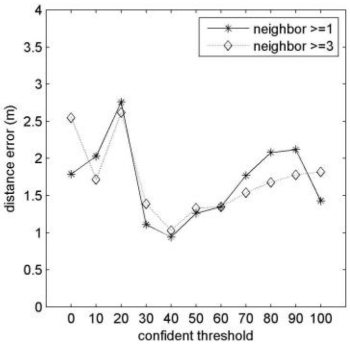

Figure 6. Average distance error of all nodes when neighbor>=1 and neighbor>=3 in each confident threshold

Fig. 7 presents the average time used before nodes can find their estimated locations. The use of three neighbors reduces delay to find a location. The reason of delay is shown in Fig. 8 where the one neighbor nodes needs more movement than that of three neighbor nodes.

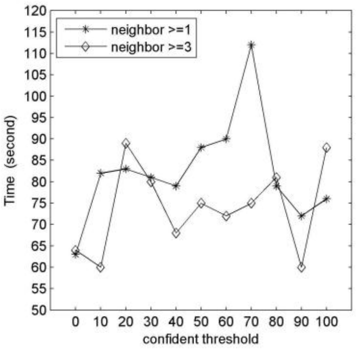

Figure 7. Average convergent time when neighbor>=1 and neighbor>=3 in each confident threshold

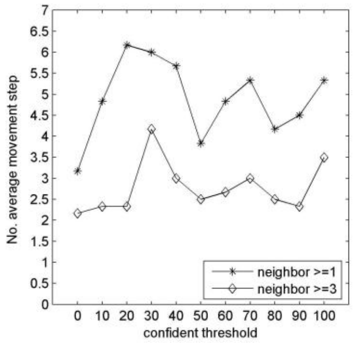

Figure 8. Average movement step of sensor nodes in each confident threshold.

E. Movement Step

Fig. 8, this is the average times of the movement. We found that a node will have significant reduction of movement if they wait until at least three CV collected.

V. CONCLUSION

To estimate location of a sensor node, the extension version of Spring-Relaxation by confidence value (CV) benefits to reduce the distance error from the original version. We found that the 40 confidence threshold has lowest average distance error. Also, the incensement of neighbor nodes has not significant reducing of distance error but nodes have to wait more time before approximating distance errors.

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Thanakorn Prasansri, received his B.Eng. degree in Computer Engineering from Kasetsart University (Siracha campus), Thailand, in 2008. After spending two years in industry, he joined the graduate program in Computer Engineering at the Khonkhen University until now. His research focuses on wireless sensor network, 6LowPAN, and contiki operating system.

Chatchai Khunboa, received his B.Eng. degree in electronics engineering from Khon Kaen University, Thailand. He received his, M.S. degree in Telecommunications from University of Pittsburgh in 2000 and his Ph.D. degree in Information Technology from George Mason University in 2005. His research interests in wireless communications and sensor networks. He is currently an assistant professor with the Department of Computer Engineering, Khon Kean University, Thailand.