Distance Measurement and Error Estimation Scheme for RSSI Based Localization in Wireless Sensor Networks

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Abstract

With the advent of Wireless Sensor Networks (WSN's) covering a whole gamut of applications which is getting broader by the day and it is indeed necessary to study the nuances in WSN out of which aforementioned is one. WSN's consists of large number of deployed sensor nodes and a base node for aggregating data from deployed sensor nodes. Wireless Sensor Network's (WSN) are attribute based and they are not concerned about the location of deployed sensor node from which the base node is receiving the data. In certain specific applications like health monitoring systems, tracking systems and dynamic networks, the location of transmitting node is essential.

Location of the deployed sensor nodes can be found either by TOA, TDOA or Received Signal Strength (RSS) measurements. In this paper we tried to estimate the approximated distances of deployed sensor nodes using RSS measurements. The estimated distances can be further used for locating the position of deployed sensor nodes. The working model has been realised in TinyOs and RSS measurements are made using Telosb nodes.

Keywords— Wireless Sensor Network (WSN), Received Signal Strength (RSS), Localization, CC2420, TinyOs, Telosb.

I. Introduction

Wireless Sensor Network's (WSN) constitutes of large number of deployed sensor nodes and base nodes. Base nodes collect the data from deployed sensor nodes. Each deployed sensor node is equipped with a battery device and in general they are deployed randomly. Hence the location of each deployed node is unknown. Ergo, algorithms are developed to realize the working of WSN's without knowing the exact location of transmitting node. Following are the some of applications where localization is essential.

- In wild life monitoring systems where sensor nodes are attached to each animal to track its motion.
- In dynamic sensor actuator networks, to take the preventive measures at malfunctioning location, the accurate location of sensing node is essential.
- In highway traffic monitoring systems to locate the position of vehicle moving at high speed.
- In industrial observatory systems, to locate the fractures of a large functioning body.

Hence localization in WSN's is very much essential for specific applications [1, 2].

The position of deployed sensor nodes can be located using either of Time of Arrival (TOA), Time Difference of Arrival (TDOA) or Received Signal Strength (RSS) algorithms [1, 3, and 4]. In this paper we tried to estimate the approximate distances of deployed sensor nodes using mean RSS measurements, from which the position of deployed sensor node can be found.

Although literature survey states that, in practical WSN's Localization measurements using RSS values will deviate maximum from the accurate location. In spite of that many researchers follow RSS based localization methods because of its easiness in working and cost efficiency. In this paper we tried to measure the distances of deployed sensor nodes providing ideal conditions.

The organisation of this paper is as follows: Section 2 describes about the related work. Section 3 presents the localization model. Section 4 depicts about the simulation results. Finally in Section 5 we concluded the paper with future work.

II. Related Work

We made an extensive study about RSSI based distance measurement models using CC2420 radio. Under practical conditions, depending on the environmental conditions measured distances deviate from the actual value. In practical sensor networks providing Line of Sight (LOS) communication between all the deployed sensor nodes and base station is impossible [4].

The measured RSSI values will vary a lot for two deployed senor nodes at equal distance from base

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node, but located on opposite directions to the antenna of base node. The node present in the direction of antenna will receive higher RSSI value compared to the node present in the opposite direction to the antenna of base node [4].

For localization using approximated distances of a deployed node from different base stations, the location is approximated as centroid of the triangle formed by interception of three circles; which is not always true in practical WSN's [1, 2, 4].

None of the localization schemes tried to estimate the mean error in RSSI based distance measurements under ideal conditions. Hence it is important to estimate the mean error deviation of distance measurements under ideal conditions. We tried to estimate the mean error deviation in RSSI based distance measurements; which further can be used for approximating the location of deployed sensor nodes.

III. LOCALIZATION MODEL

(A) RSSI Model

In our localization model we used Telosb motes for measuring RSSI values. Each Telosb mote has an inbuilt IEEE 802.15.4 radio (CC2420) with an integrated 2.4 GHz- 2.4835 GHz antenna. CC2420 chip has an inbuilt RSSI register and its value is RSSI.RSSI_VAL [6, 7, 8]. The RSS at RF pins:

$$RSS = RSSI\_VAL + RSSI\_OFFSET[dBm] \qquad (1)$$

The empirical value of RSSI_OFFSET is approximately -45[6]. Hence the Received Signal Strength (RSS):

$$RSS = RSSI\_VAL - 45[dBm] \qquad (2)$$

The relation between RSS values and distance are derived as follows:

$$RSS = 10 \log (P/P_{ref}) \qquad (3)$$

Here 'P' is the power of received signal and P_{ref} is the reference power. Hence:

$$RSS \; \alpha \; \log (p) \qquad (4)$$

The received signal power is inversely related to distance as:

$$P \; \alpha \; 1/ D^n \qquad (5)$$

Here D is the distance of deployed sensor node from base node and 'n' is the path loss exponent factor. Hence from equations 3, 4, 5:

$$RSS \; \alpha \; 10 \log (1/D^n)$$

$$RSS = -10n \log (D) + C \qquad (6)$$

From equation 6, it is clear that RSS has a linear relationship with logarithm of distance, where C is some fixed constant. In more compact form RSS can be represented as:

$$RSS = -m \log (D) + C \qquad (7)$$

Here 'm' is the slope of linear equation between RSS and log (D). From equations 6, 7 the path loss exponent factor is given as:

$$n = m/10 \qquad (8)$$

(B) Experimental Setup

The entire experiment has been carried out in an indoor environment. The RSS measurements are prone to noise and interference, which leads to error in localization. Hence to provide ideal environment we have taken the following precautions:

- All the deployed nodes are kept at same altitude from surface of floor.
- Each Telosb mote is supplied with USB power supply, so as to ensure that the battery power is same at all the nodes.
- All the deployed nodes are in line of sight with the base node and no obstacle is present in between them.
- Since the antenna of base node is not isotropic, we have deployed the sensor nodes only in the antenna direction of base node.
- To avoid interference, we have taken measures to see that no other device working in range of 2.4 GHz is present in the vicinity of experimental location.

We have carried out the experiment with nine Telosb nodes within our lab environment. The nodes are deployed at fixed distances from base node and the Localization error is estimated by comparing the distances calculated by mean RSS values.

IV. SIMULATION RESULTS

The RSSI values measured from the deployed sensor nodes are discrete in nature and are not constant. First we deployed an addressed Telosb node at five meters away from the base node; the corresponding measured RSSI values are shown in figure 1.

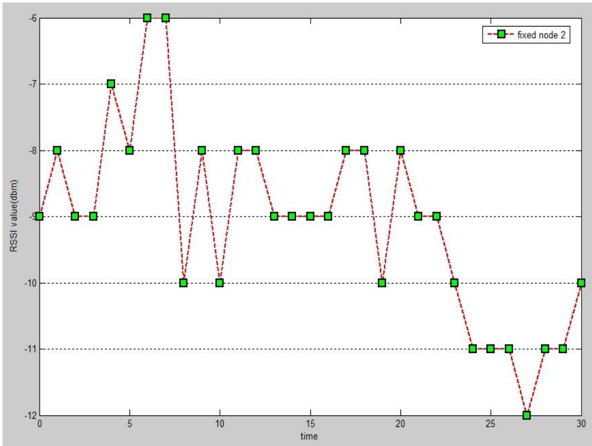

Figure 1: RSSI values measured from a fixed node 2

Since the measured RSSI values are randomly varying with time, we have considered mean RSSI values for calculating the distances of deployed sensor nodes. We have varied the distance of a deployed node from 3 -8 meters. The corresponding measured RSSI values of moving node at each particular distance are plotted in figure 2.

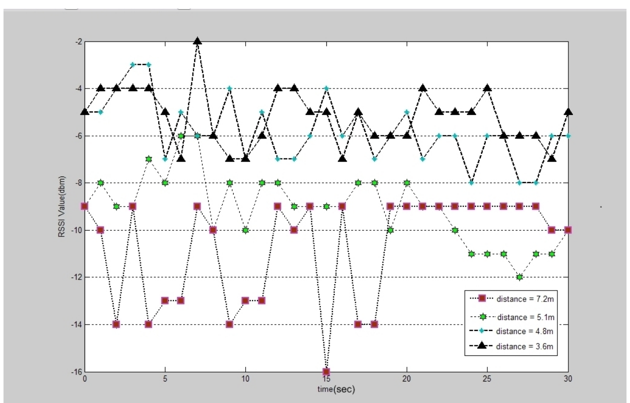

Figure 2. Measured RSSI values at different distances

The experimentally measured mean RSSI values and corresponding distances are used to find the coefficients in the linear equation 6, 7, 8. The evaluated linear coefficients are as follows:

$$m=26.4432 \tag{9}$$
$$C = -35.289 \tag{10}$$
$$n = 2.6 \tag{11}$$
$$RSS= -26.4432 \log (D) -35.289 \tag{12}$$

Equation 12 is the linear relation derived from experimental RSS values. The path loss exponent factor has been found to be 2.6 for indoor environment in which we have conducted the experiment.

All the nodes are deployed at fixed locations in the range of nine meters from base node. The corresponding measured RSS values are compared with the theoretical RSS values in equation 12. The comparison plot is shown in figure 3.

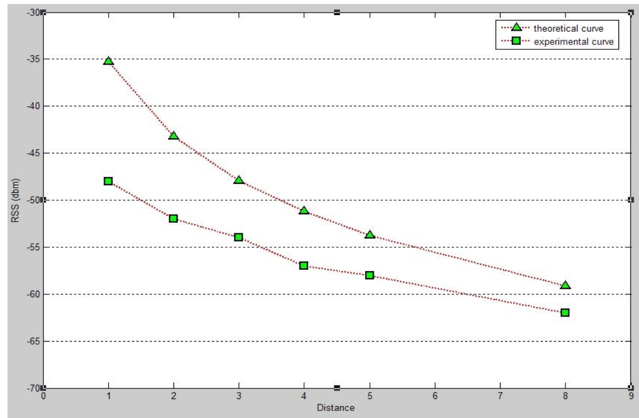

Figure 3: Comparison between theoretical and measured RSS values

The error in measuring the distance of deployed sensor nodes from base node is estimated by comparing the theoretical and experimental results. The estimated error in distance measurement of each node deployed at different locations is tabulated in table 1.

Distance of Deployed Node (D)(meter)	Measured RSS Value(dBm)	Measured Distance (Dm)(meter)	Error(e)=Dm-D
1	-48	3.0252	2.0252
2	-52	4.2858	2.2858
3	-54	5.1013	2.1013
4	-57	6.6243	2.6243
5	-58	7.2271	2.2271
8	-62	10.2359	2.2359

Table 1: Estimated errors in RSS based measurements

The mean error estimated from the error measurements in table 1 is:

$$\text{Mean Error } (E_{mean}) = 2.2498 \text{ m} \tag{13}$$

Table 1 shows that the error is all most uniform in RSS based distance measurements in an indoor environment under ideal conditions applied.

V. CONCLUSION AND FUTURE WORK

The estimated error in distance measurements for RSSI based localization in WSN's is almost uniform under ideal conditions. Hence we conclude that, under ideal conditions by using sophisticated approximation algorithms, efficient localization can be achieved through RSSI measurements.

In the future we will try to localize the deployed sensor nodes on two dimensional and three dimension plane using mean RSSI values

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