

# Improving Localization Accuracy Using Signal Attenuation due to Neighbour Signal Interference in Wireless Sensor Networks

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**Abstract**— In wireless sensor networks, estimating location of node is important for routing efficiency and location-based services. Traditional Localization techniques are using by distance, hop-count, connectivity, and etc. But the accuracy of these algorithms is highly dependent on the environment and quality of the transmission equipment and they have not only the localization errors but also high energy consumption caused by packet retransmission. In this paper, we propose a improving localization accuracy algorithm by using a signal attenuation due to neighbour signal interference that is designed to reduce the location error in wireless sensor networks. We compared with The simulation results illustrate our algorithm has improved the communication-cost and accuracy of localization.

**Keywords**— Localization, Accuracy, RSSI, SIR, Wireless Sensor Network

## I. INTRODUCTION

Wireless Sensor Networks(WSN) has been used in various industries according to the international standards and active working of related organizations. Localization in WSN is important since many applications depend on knowing the locations of sensor nodes. Especially, in order to maintain consistency and to provide accurate information to clients in location-based services, location information of node is one of the most important issues.

In research[1][2][3], many localization techniques and algorithms have been proposed. To obtain position of node, an each node uses a special device such as a GPS module, which leads to high unit price and high energy consumption. But sensor node should be small in size, consume extremely low energy, operate in high density area, the utilization of GPS within sensor node is not a feasible solution in WSN.

Some techniques have been proposed the use of range-based localization[2] schemes that depend on the node-to-anchor distance estimates. There are several ways of obtaining an estimate for the distance between two nodes as like Received Signal Strength Indicator (RSSI), Time of Arrival(TOA), Time Difference of Arrival (TDOA), Angle of Arrival(AOA). But these scheme are typically dependent on some form of distance estimates, the accuracy of the estimate will be highly dependent on the environment and quality of the transmission equipment. Also location accuracy is reduced

by the noisy and imperfection measurements, primarily caused by the signal interference and propagation effects.

To overcome the inherent difficulty of accurately determining exact inter-node distances in sensor networks, some techniques have been proposed the use of range-free localization schemes[3] that depend on the hop-based or connectivity-based localization. There are several ways of obtaining an estimate for the location of nodes as like DV-hop, Amorphous Positioning Algorithm(APA), APIT. These schemes are more cost-effective because they do not require sensors to be equipped with any special hardware, but operation is complicated and is less accurate than the range-based algorithms.

In this paper, we propose a improving localization accuracy scheme by using a signal attenuation due to neighbour signal interference that is designed to reduce the location error in wireless sensor networks. The proposed scheme provides both low-cost and accuracy than the previous localization scheme.

The rest of the paper is organized as follows: Section II outline the fundamental concept of the distance based localization. Section III describes our proposed localization scheme. Section IV evaluates the algorithmic performance. Finally, Section V concludes this paper.

## II. FUNDAMENTAL CONCEPTS OF THE LOCALIZATION

### A. Received Signal Strength

Lots of localization algorithms require a distance to estimate the position of unknown devices. One possibility to acquire a distance is measuring the RSS(Received Signal Strength) of the incoming radio signal.

RSS is closely related to the distance and RSS value is different by the arrival distance between two nodes. The idea behind RSS is that the configured transmission power at the transmitting device directly affects the receiving power at the receiving device. According to Friis' free space transmission equation[4][5], Given two antennas, the ratio of power received by the receiving antenna,  $P_r$ , to power input to the transmitting antenna,  $P_t$ , is given by.

$$L_{\theta} = \frac{P_r}{P_t} = G_t \cdot G_r \left( \frac{\lambda}{4\pi d} \right)^2 \quad (1)$$

where  $G_t$  and  $G_r$  are the antenna gain of the transmitting and receiving antennas, respectively,  $\lambda$  is the wavelength, and  $d$  is the distance between sender and receiver.

The inverse of the factor in parentheses is the so-called free-space path loss. The antenna gains are with respect to isotropic (and not in decibels), and the wavelength and distance units must be the same. If network environment changes to development field from freedom space, path gains value is changed by 2 to 4.

Through the above formula, distance between two nodes is as following.

$$d = \frac{\lambda}{4\pi} \cdot 10^{\frac{L_p}{20}} \quad (2)$$

In the formula (2), the detected signal strength decreases with the distance to the sender.

In embedded devices, the received signal strength is converted to a RSSI (Received Signal Strength Indicator) which is defined as ratio of the received power to the reference power ( $P_{ref}$ ). Typically, the reference power represents an absolute value of  $P_{ref}=1\text{mW}$ .

$$RSSI = 10 \cdot \log \frac{P_r}{P_{ref}} \quad (3)$$

An increasing received power results a rising RSSI. Figure 1b illustrates the relation between RSSI and the received signal power. Plotting RSSI versus distance  $d$  results in a graph, which is in principle axis-symmetric to the abscissa. Thus, distance  $d$  is indirect proportional to RSSI.

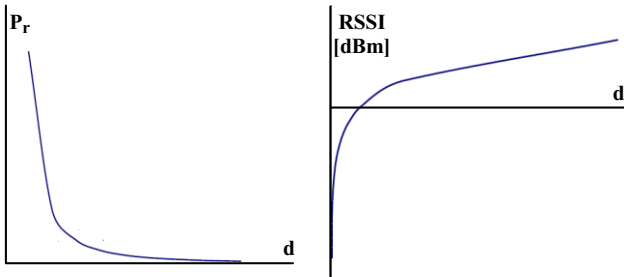


Figure 1. a) Received power( $P_r$ ) versus distance( $d$ ) to the transmitter  
b) RSSI as quality identifier of the received signal power( $P_r$ )

This simple form applies only under the following ideal conditions:

- The antennas are in unobstructed free space, with no multipath.
- $P_r$  is understood to be the available power at the receive antenna terminals. There is loss introduced by both the cable running to the antenna and the connectors. Furthermore, the power at the output of the antenna will only be fully delivered into the transmission line if the antenna and transmission line are conjugate matched.
- $P_t$  is understood to be the power delivered to the transmit antenna. There is loss introduced by both the cable running to the antenna and the connectors. Furthermore, the power at the input of the antenna will

only be fully delivered into free space if the antenna and transmission line are conjugate matched.

- The antennas are correctly aligned and polarized.
- The bandwidth is narrow enough that a single value for the wavelength can be assumed.

The ideal conditions are almost never achieved in ordinary terrestrial communications, due to obstructions such as noisy, fading, reflection, signal interference and so on. These obstructions have a high residual error value in the distances for measured RSSI values. Therefore, in order to accurate position measurement of node, we consider a lot of effects that influence in signal.

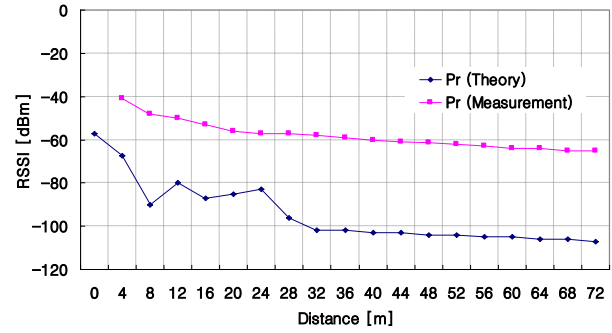


Figure 2. Received Signal Strength of a Chipcon CC1010 sensor node

## B. Attenuation due to Signal Interference

Attenuation affects the propagation of waves and signals in radio waves[4][6][7]. The signal-to-interference ratio(SIR) is the quotient between the average received modulated carrier power  $S$  and the average received co-channel interference power  $I$  from other transmitters than the useful signal.

$$SIR = \frac{S}{I} = \left( \frac{f_b}{B} \right) \cdot \frac{E_b}{N_0} \quad (4)$$

where  $B$  is the channel data rate,  $f_b$  is the channel bandwidth. The effect of the interfering signal on the desired signal is assumed to be similar to Additive White Gaussian Noise in the same bandwidth.

If the signal and the noise are measured across the same impedance, then the SIR can be obtained by calculating the square of the amplitude ratio:

$$SIR = \frac{P_{signal}}{P_{interference}} = \left( \frac{A_{signal}}{A_{interference}} \right)^2 \quad (5)$$

where  $A$  is root mean square amplitude. Because many signals have a very wide dynamic range, SIR is often expressed using the logarithmic decibel scale. In decibels, the SIR is defined as:

$$SIR_{dB} = 10 \log_{10} \left( \frac{E_b}{N_0} \right)^2 + 10 \log_{10} \left( \frac{f_b}{B} \right) \quad (6)$$

Sometimes, the noise power is denoted by  $N_0/2$  when negative frequencies and complex-valued equivalent baseband signals are considered, and in that case, there will be a 3 dB difference.

If all nodes use uniformity frequency and reception power level is equal, all signals act interference except itself. So,  $I$  value is  $(n-1)S$ .

$$\frac{S}{I} = \frac{S}{(n-1)S} = \frac{1}{(n-1)} \quad (7)$$

Where,  $n$  is the nodes numbers in cluster area.

In decibels, the  $n$  is defined as:

$$n = \frac{B}{f_b} \frac{E_b}{N_0} + 1 \quad (8)$$

Figure 3 illustrates the relationship between bit-per-error-rate (BER) and SNR in IEEE 802.1x standards[9][10][11][12].

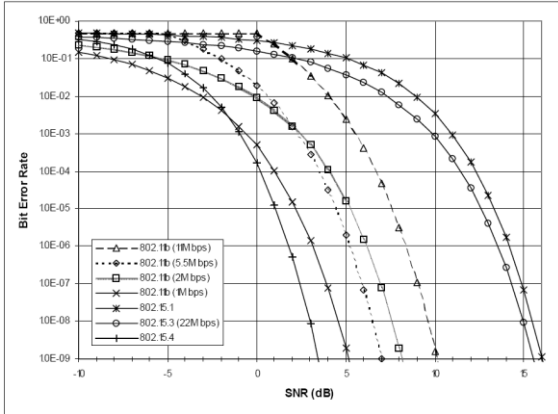


Figure 3. Relation between BER and SNR

### III. PROPOSED LOCALIZATION SCHEME

We describe two fundamental concepts of the localization in Section 2. In this section, we describe a proposed localization scheme. The basic idea is that an unlocated sensor can localize itself by signal attenuation due to neighbour signal interference in range. Our localization algorithm can be divided into three steps: 1) In the first phase, neighbour discovery, each sink node selects member node based on the strength of the received signal. 2) In the second phase, one-hop distance estimation, a sink node estimate one-hop distance using the RSSI. 3) In the last phase, distance refinement, a sink node refine the distance using signal attenuation due to neighbour signal interference in own cluster that is mentioned in section II.

In the following subsections, the procedure of the proposed localization scheme is discussed in detail. We also present an improving the localization accuracy.

#### A. Assumption

We design a RSSI-based location system of wireless is given by. Our algorithms can handle heterogeneity in radio transmission range, but we assume for ease of exposition that each sensor has the same ideal radio range,  $r$ . Sensor nodes are developed by using 2.4GHz microwave as communication frequency and the RSSI range model is obtained from the data measured at site. The objective of establish RSSI range model is to obtain the corresponding relation in RSSI received and distance between the transmitter and the receiver.

#### B. Proposed Localization Algorithm

1) **Neighbour node Discovery:** In the first phase, neighbour discovery, a cluster head broadcasts its location to all neighbour nodes in the communication radius. These neighbour nodes advertise their ID and location through Hello messages. This message contains node's unique ID and its current location information. Upon receiving those Hello messages, each cluster head selects member node based on the strength of the received signal. Up to now, each sensor belongs to only one cluster.

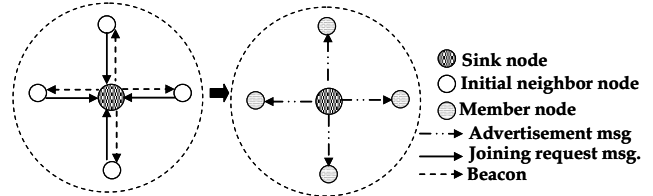


Figure 4. Neighbour node discovery phase

2) **One-hop Distance Estimation using RSSI:** In the second phase, a sink node estimate one-hop distance using the RSSI. Figure 5 illustrates the one-hop distance estimation using RSSI. If a transmitting device send the signal that power is 45dBm, a receiving device receive the signal that power is -43dBm. Through the above Friis's formula[4][5], the distance between two nodes is 7.94m using pass loss that is 58dBm.

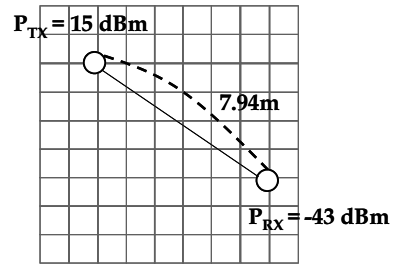


Figure 5. One-hop distance estimation using RSSI phase

3) **Distance Refinement using Signal Attenuation:** In the last phase, a sink node refines the distance using signal attenuation due to neighbour signal interference in own cluster. Figure 6 illustrates the signal attenuation due to neighbour signal interference.

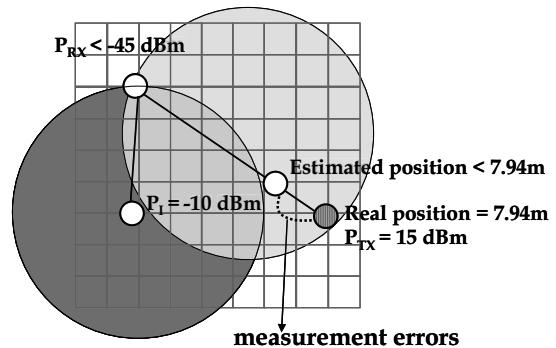


Figure 6. The signal attenuation due to neighbour signal interference

In network that number of neighbour node is  $N$ , probability that neighbour node communicates at the same time is  $P$ , signal interference can appear by  $P$ . The signal interference will generate a distance estimation error using RSSI. Therefore, to improve accuracy of localization in network that distributed large number of nodes with a narrow range, each node must be able to regulate transmission power according to own signal interference degree. Through the above SIR formula in section II, the number of neighbour is proportional to its neighbour signal interference.

When some node will calculate the distance, it apply revision coefficient in distance value. A formula that calculates the revision coefficient of node  $u_i$  as following.

$$RC_{u_i} = \sqrt{\frac{RSSI_{u_i}}{d_{\max}}} \quad (9)$$

when  $RSSI_{u_i}$  is a RSSI of node  $u_i$  and  $d_{\max}$  is a maximum communication distance by signal power from free space. Some node  $u_i$  calculates the average value of RSSI that is received from neighbour node of own communication radius, and then calculates the revision coefficient ( $RC$ ) by the RSSI and the number of neighbour nodes.

If cluster member nodes  $N_k$  ( $k = 1..n$ ) be in the communication range of  $R$ ,  $RC$  of  $R$  as following.

$$RC = \sqrt{\frac{\sum_{i=1}^n (RSSI_{u_i} - \overline{RSSI_u})}{(n-1)}} \quad (10)$$

A  $RC$  means a standard deviation that measures how many difference RSSI in own neighbour node. If  $RC$  value is big, it shows that interference of neighbour node is erratic.

#### IV. PERFORMANCE ANALYSIS

In this section, we show that proposed algorithm improves localization accuracy through simulation experiments. First we assume that cluster member nodes  $N_k$  ( $k = 1..n$ ) be in the communication range of  $R$  in which there are no packet loss by attacks from inside or outside network. The channel model is based on the IEEE 802.11 specification used.

##### A. Evaluation Metrics

We simulated the performance metrics with the parameters of the system and network parameter listed in Table 1.

TABLE 1. THE SYSTEM AND NETWORK PARAMETERS

|                         |                       |
|-------------------------|-----------------------|
| Receiver sensitivity    | -85 dBm               |
| Transmit power          | 0 dBm                 |
| Receiver bandwidth      | 2 MHz                 |
| Transmit spectral masks |                       |
| Carrier Frequency       | $ f - f_c  > 3.5$ MHz |
| Relative limit          | -20 dBm               |
| Absolute limit          | -30 dBm               |
| Frequency               | 2.4 GHz               |
| packet lengths          | 22 bytes              |
| Channel data rate       | Max 1Mbps             |

##### B. Path Loss Exponent

In this subsection we evaluate path loss exponent according to the distance. The coexistence methodology uses a variant of the path loss model described in [8], which stipulates a two-segment function with a path loss exponent of 2.0 for the first 8 meters and then a path loss model of 3.3 thereafter. The formula given in [8] is:

$$pl(d) = \begin{cases} 40.2 + 20\text{Log}_{10}(d) & d \leq 8m \\ 58.5 + 33\text{Log}_{10}\left(\frac{d}{8}\right) & d > 8m \end{cases} \quad (11)$$

where  $pl(d)$  is the path loss at distance  $d$ .

Figure 7 shows the path loss exponent according to the distance when the node transmits data.

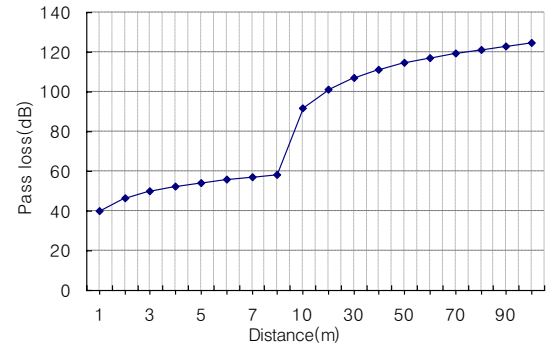


Figure 7. The result of path loss exponent according the distance

##### C. Packet Error Rate

In this subsection we compare the packet error rate (PER) of the proposed localization scheme with the basic characteristics of the IEEE 802.15.4 communication channel. In Figure 8, when the distance increases gradually, the packet error rate in the proposed and IEEE 802.15.4 standard are as follows:

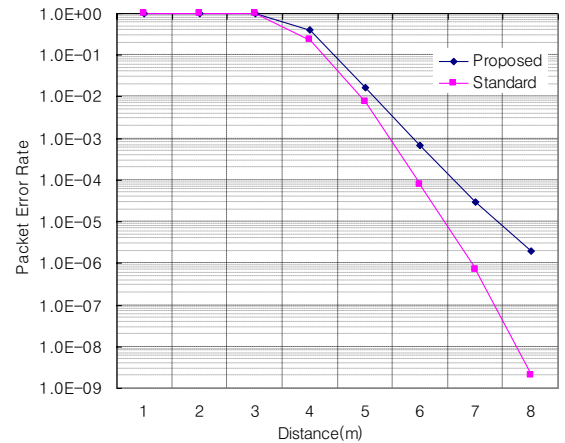


Figure 8. The result of packet error rate

The simulation output shows the PER versus separation distance. When comparing the results, the PER is similar within 3m distance, but the distance is increasing, proposal can certainly reduce packet error rate more than standards.

#### D. Packet Error Rate versus Signal-to-Interference Ratio

In this subsection we compare the packet error rate versus signal-to-interference ratio of the proposed localization scheme with the basic characteristics of the IEEE 802.15.4 communication channel. Figure 9 shows the packet error rate according to the effect of interference between neighbour nodes by increasing the number of nodes.

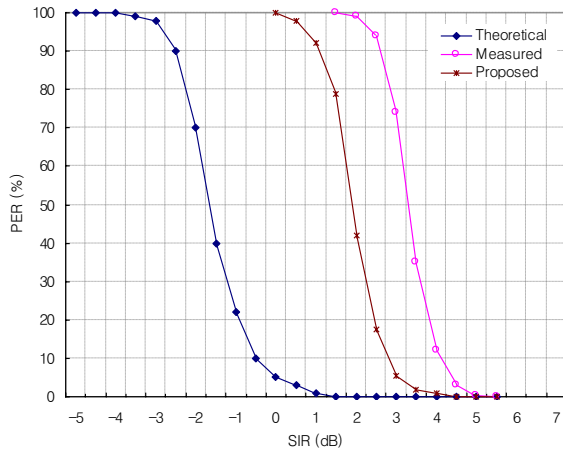


Figure 9. The result of Packet Error Rate versus Signal-to-Interference Ratio

Increasing the number of neighbour nodes, the signal interference due to neighbour increased. Signal interference occurs when two or more signals are received at the same time over the same frequency range. So high density in radius  $R$  should increase the probability that neighbour node communicates at the same time. In this case, signal attenuation and distance measurement error occurs. Therefore, to improve accuracy of localization in network, each node must be able to regulate transmission power according to own signal interference degree.

#### E. Energy Consumption

In this subsection we evaluate the energy consumption versus separation distance and packet lengths. Figure 9 shows the energy consumption of proposal according to the distance and packet size.

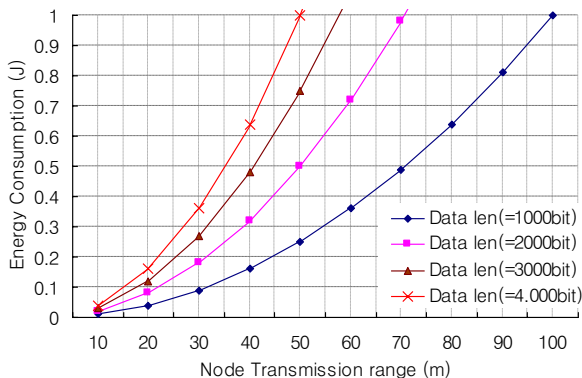


Figure 10 . The result of energy consumption

According to the increase of the transmission range and packet length, the energy consumption increases by exponentially. In transmission range is 50m, the energy consumption of 4Kbyte packet length greater about four times than 1Kbyte.

#### V. CONCLUSION

In this paper, we propose a localization scheme which improving the accuracy. The proposed scheme estimate the distance of unknown node in cluster area using RSSI, and then refine the distance value by the signal attenuation due to neighbour signal interference in own cluster.

In order to evaluating the performance of proposed scheme, we have compared the path loss exponent, packet error rate, bit error rate and energy consumption. Through the simulation experiments, we showed that our algorithm has improved the communication-cost and accuracy of localization.

#### ACKNOWLEDGMENT

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