

# SDS-TWR based Location Compensation Mechanism for Localization System in Wireless Sensor Network

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## Abstract

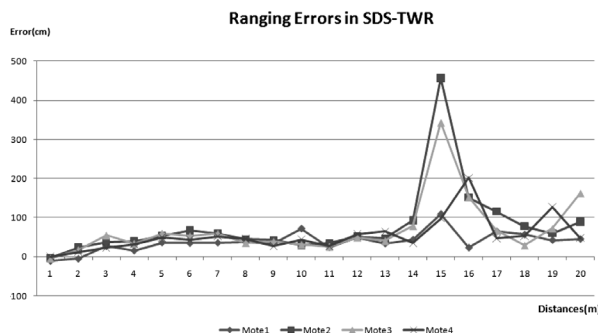
In this paper, the Location Compensation Mechanism using equivalent distance rate ( $LCM_{edr}$ ) for localization system based on SDS-TWR (Symmetric Double-Sided Two-Way Ranging) in wireless sensor network is proposed. The performance of the mechanism is experimented in terms of two types of the localization tracking scenarios of indoor and outdoor environments in university campus. From the experimentations, the compensation ratio in the  $LCM_{edr}$  is better than that in SDS-TWR about 90% in indoor/outdoor environments in scenario 1 but also is better than that of SDS-TWR about 91.7% in indoor environment and about 100% in outdoor environment in scenario 2 respectively.

**Keywords:** SDS-TWR, Localization, Ranging Error, Compensation Algorithm, WSN

## I. Introduction

SDS-TWR (Symmetric Double-Sided Two-Way Ranging) ranging errors are occurred due to the crystal oscillator synchronization[1]-[5], and most of all ranging errors are less than 1m and above 3m in the specific region.[6] The ranging errors are different from each other according to the experimental environments.

But the ranging errors of SDS-TWR in some distance points, for example 15, 16, 17, 19 and 20, are



[Fig. 1] Ranging errors in SDS-TWR.

above 100cm, though most of the ranging errors are measured to below 100cm by ranging experimentation as shown to [Fig. 1].

## II. SDS-TWR based Location Compensation Mechanism

### 1. $LCM_{edr}$ design concepts

The Location Compensation Mechanism using equivalent distance rate ( $LCM_{edr}$ ) for localization system in wireless sensor network is designed by adapting the equivalent distance rate concept. Let a regular square that has width 10m \* height 10m each. 4 edges  $W, X, Y, Z$  and random vertex  $P(3,3)$  are also in the regular square. It is assumed that distance  $WP$  be  $a$ ,  $XP$  be  $b$ ,  $YP$  be  $c$  and  $ZP$  be  $d$ . Then the eq. (1) is satisfied in each distance of  $a, b, c, d$  about  $P(3,3)$ . [7]-[8]

$$W^2 + X^2 = Y^2 + Z^2 \quad (1)$$

### 2. Location compensation mechanism

#### a. Above 3m ranging error case

If the above 3m ranging error is occurred to the interface between sensor modules, for example, there is 3m ranging error in  $c$ , the eq. (2) is satisfied in

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each distance of  $a, b, c, d$  about  $P(3,3)$ .

$$W^2 + Y^2 > X^2 + Z^2 \quad (2)$$

If the eq. (2) is satisfied, it is necessary to decide the ranging error is occurred to a or c. Then if eq. (3) is satisfied, it is assume that the ranging error is occurred to a. If the eq. (4) is satisfied, it is assume that the ranging error is occurred to c. In two cases of the eq. (3) or (4), the SDS-TWR based location compensation mechanism using equivalent distance rate is used for error compensation to satisfy eq. (1).

$$W^2 > X^2 + Z^2 \quad (3)$$

$$Y^2 > X^2 + Z^2 \quad (4)$$

#### b. Below 1m ranging error case

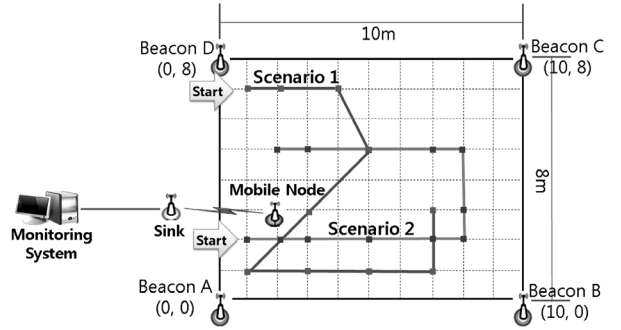
If the below 1m ranging error is occurred to the interface between sensor modules, for example, if 0.5m ranging errors occurred to all of  $a, b, d$ , and if 1m ranging error is occurred to  $c$ , the eq. (2) is satisfied in each distance of  $a, b, c, d$  about  $P(3,3)$ . In the case of the eq. (2), the SDS-TWR based location compensation mechanism using equivalent distance rate is used for error compensation to satisfy eq. (1) and not to satisfy the eq. (3) and (4).

### III. Results Analysis and Evaluation

#### 1. Experimental sensor network

The sensor network for experimentation of the  $LCM_{edr}$  is consisted of 1 mobile node, 4 beacon nodes, 1 sink node, and monitoring server. The CSS based PHY/MAC protocols that is recommended to IEEE 802.15.4a standard ported chipset is included in the sensor nodes.

In the sensor network, beacon nodes  $W, X, Y, Z$  are arranged to the axis of coordinates  $(0,0), (10,0), (10,8), (0,8)$  in  $10m \times 8m$  experimental region. The experimentation are executed using 2 localization tracking scenarios in the indoor/outdoor Line Of Sight (LOS) of the Tongmyong University where at the corridor and the open space each. The axes of coordinates of the localization tracking in two scenarios are indicated in the [Fig. 2].

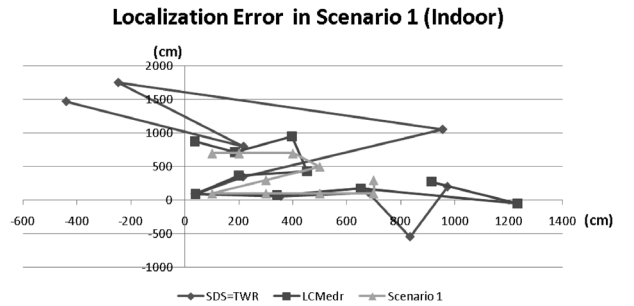


[Fig. 2] Experimental sensor network.

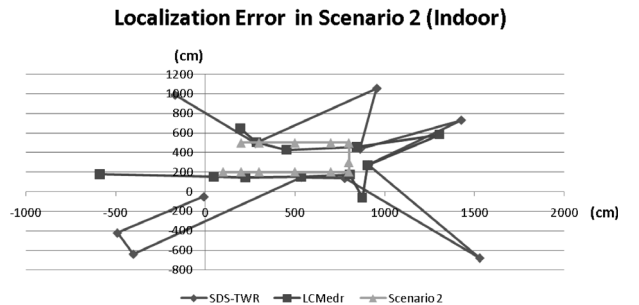
#### 2. Results analysis and evaluation

The location measurements about scenario1 and 2 using the  $LCM_{edr}$  and SDS-TWR in indoor environment are shown to [Fig. 4] and [Fig. 5]. The localization error comparisons with the  $LCM_{edr}$  and SDS-TWR about scenario 1 and 2 in indoor environment based on [Fig. 3] and [Fig. 4] are also measured and shown to <Table 1> and <Table 2> respectively.

It can be seen that the localization error of the  $LCM_{edr}$  is considerably reduced than that of SDS-TWR in the scenario 1 and 2 generally as shown to <Table 1> and <Table 2>. In particular, the localization



[Fig. 3] Localization error comparisons in scenario 1 (indoor).



[Fig. 4] Localization error comparisons in scenario 2 (indoor).

<Table 1> Localization error comparisons in scenario 1 (indoor).

Axis of Coordinates	SDS-TWR (cm)	$LCM_{edr}$ (Cm)
1, 7	943.6	185.0
2, 7	101.1	21.2
4, 7	1,239.1	249.0
5, 5	718.4	84.9
3, 3	95.9	119.7
1, 1	63.3	60.8
3, 1	69.9	47.5
5, 1	181.2	168.7
7, 1	661.9	553.9
7, 3	291.2	215.5

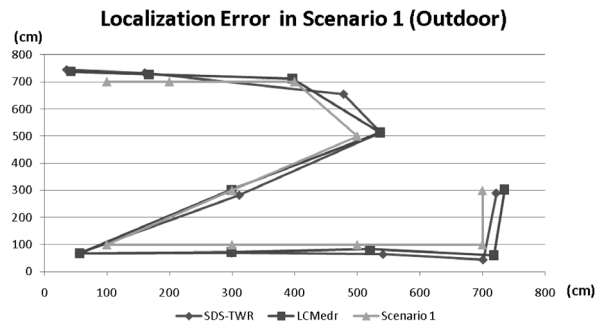
<Table 2> Localization error comparisons in scenario 2 (indoor).

Axis of Coordinates	SDS-TWR (cm)	$LCM_{edr}$ (Cm)
1, 2	274.2	70.4
2, 2	929.4	789.0
3, 2	1,092.3	93.0
5, 2	61.4	57.6
7, 2	98.7	109.4
8, 2	1,140.1	272.7
8, 3	110.9	107.9
8, 5	666.6	512.6
7, 5	174.1	151.2
5, 5	718.4	84.9
3, 5	21.8	15.8
2, 5	611.3	147.9

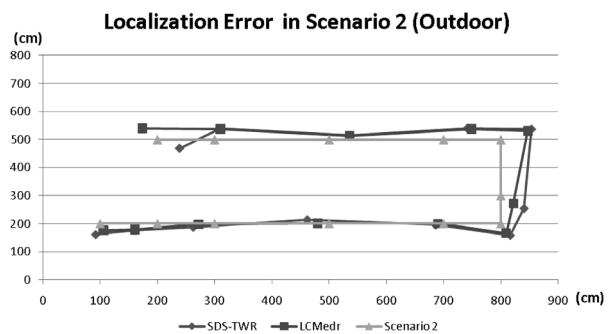
error of the  $LCM_{edr}$  in the axis of coordinates (5, 5) is largely lower than that of SDS-TWR in the scenario 1 from 718.4cm to 84.9cm as shown to <Table 1> in the case of scenario 1.

In addition to this, the localization error of the  $LCM_{edr}$  in the axis of coordinates (3, 2) is also remarkably lower than that of SDS-TWR in the scenario 2 from 1,092.3cm to 93.0cm as shown to <Table 2> in the case of scenario 2.

The location measurements about scenario1 and 2 using the  $LCM_{edr}$  and SDS-TWR in outdoor environment are shown to [Fig. 5] and [Fig. 6]. The localization error comparisons with the  $LCM_{edr}$  and SDS-TWR about scenario 1 and 2 in outdoor environment based on [Fig. 5] and [Fig. 6] are also measured and shown



[Fig. 5] Localization error comparisons in scenario 1 (outdoor).



[Fig. 6] Localization error comparisons in scenario 2 (outdoor).

to <Table 3> and <Table 4> respectively.

It can be seen that the localization error of the  $LCM_{edr}$  is reduced than that of SDS-TWR in the scenario 1 and 2 generally though not so much in case of indoor environment as shown to <Table 3> and <Table 4>. In particular, the localization error of the  $LCM_{edr}$  in the axis of coordinates (4, 7) is largely lower than that of SDS-TWR in the scenario 1 from 89.7cm to 13.4cm as shown to <Table 3> in the case of scenario 1. In addition to this, the localization error of the  $LCM_{edr}$  in the axis of coordinates (8, 3) is also largely lower than that of SDS-TWR in the scenario 2 from 60.5cm to 35.2cm as shown to <Table 4> in the case of scenario 2.

The compensation ratio of the  $LCM_{edr}$  and SDS-TWR in Scenario 1 and 2 is analyzed based on the [Fig. 3]~[Fig. 6] and <Table 1>~<Table 4>.

It can be known that the compensation ratio in the  $LCM_{edr}$  is better than that in SDS-TWR about 90% in indoor/outdoor environments in scenario 1 but also is better than that of SDS-TWR about 91.7% in indoor environment and about 100% in outdoor environment in scenario 2 respectively as shown to <Table 5> and

<Table 3> Localization error comparisons in scenario 1 (outdoor).

Axis of Coordinates	SDS-TWR (cm)	$LCM_{edr}$ (Cm)
1, 7	79.1	69.4
2, 7	51.7	42.6
4, 7	89.7	13.4
5, 5	40.3	2.6
3, 3	21.1	119.7
1, 1	54.7	54.7
3, 1	30.6	27.2
5, 1	54.3	25.8
7, 1	55.1	42.1
7, 3	24.2	35.5

<Table 4> Localization error comparisons in scenario 2 (outdoor).

Axis of Coordinates	SDS-TWR (cm)	$LCM_{edr}$ (Cm)
1, 2	37.6	24.7
2, 2	45.6	44.8
3, 2	38.6	27.9
5, 2	39.8	19.9
7, 2	14.1	10.0
8, 2	43.5	34.6
8, 3	60.5	35.2
8, 5	65.7	57.3
7, 5	58.4	55.2
5, 5	40.3	39.0
3, 5	41.2	40.1
2, 5	50.4	47.5

<Table 5> Compensation ratio of  $LCM_{edr}$  and SDS-TWR in scenario 1.

Spaces	Scenario 1		Remarks
	SDS-TWR	LCMedr	
Indoor	1/10 (10.0%)	9/10 (90.0%)	# of axis of coordinates (ratio)
Outdoor	1/10 (10.0%)	9/10 (90.0%)	

<Table 6> Compensation ratio of  $LCM_{edr}$  and SDS-TWR in scenario 2.

Spaces	Scenario 2		Remarks
	SDS-TWR	LCMedr	
Indoor	1/12 (8.3%)	11/12 (91.7%)	# of axis of coordinates (ratio)
Outdoor	0/12 (0%)	12/12 (100%)	

<Table 6>. Thus, the compensation capability of the proposed mechanism, the  $LCM_{edr}$ , is very superior than that of SDS-TWR above 90% in two scenarios.

#### IV. Conclusions

In this paper, the  $LCM_{edr}$  for localization system based on SDS-TWR in wireless sensor network is proposed and the performance of the proposed mechanism is evaluated. In scenario 1, the compensation ratio in the  $LCM_{edr}$  is better than that in SDS-TWR about 90% in indoor/outdoor of the university. In scenario 2, it is also better than that of SDS-TWR about 91.7% in indoor and about 100% in outdoor respectively.

The evaluation of the  $LCM_{edr}$  in the NLOS (Non LOS) environment is required to adapt this mechanism to commercial localization system. In the future study, it is necessary to develop the compensation mechanism that can be adapted to various environments and some ubiquitous city in Korea.

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