

A Development of Distance Measurement Scheme for Localization System in Wireless Personal Area Network

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Abstract

As the development of the computer and communication technologies, the ubiquitous society can be realized to the world early in the future. Thus, the localization system in Wireless Personal Area Network (WPAN) is required for many users of ubiquitous society to provide the ubiquitous computing based applications in respective of anytime and anywhere. In this paper, we propose the distance measurement scheme that is based on the distance measurement using RSSI (Received Signal Strength Indicator) of sensor module considering of two distance conditions for the localization system using Zigbee in WPAN. Also, the localization errors of the proposed scheme are analyzed in the three scenarios that the mobile module tracks in the in $6m \times 6m$ scaled experimentation area. In addition to this, the monitoring subsystem is developed using GUI (Graphical User Interface) in order to monitor the location of the moving objects accurately and user-friendly.

Keywords: USN, WPAN, RSSI, Zigbee, Localization

I. Introduction

The wireless sensor modules in the Ubiquitous Sensor Network (USN) have a major role of implementing ‘invisible technology’ and carry out an agent between human and computer in the WPAN (Wireless Personal Area Network) of ubiquitous computing society. The localization services using Zigbee, UWB, ultrasonic, IrDA and Wi-Fi technologies in WPAN are attractive research fields at many industries and research centers in the world due to the GPS oriented LBS (Location Based Services) cannot provide a precise localization quality in the practical environment.[1]-[4] As the localization services using Zigbee in WPAN can realize the higher location accuracy than GPS based LBS, it can be seen that localization service is key technology to realize ubiquitous computing society.[5]-[7]

II. Distance Measurement Scheme Design

The proposed distance measurement scheme meas-

ures the distance between the moving and beacon modules ($Distance_{MB}$) by receiving the RSSI (Received Signal Strength Indicator) values from the beacon modules to the moving module in sensor network. There are two types of the measuring $Distance_{MB}$, 1st type is the $Distance_{MB}$ is less then 1m type, and 2nd type is the $Distance_{MB}$ is greater than 1m and less than 5m type. In 1st type, the interval space between beacon modules is planned to 10cm each, the beacon modules are launched to 10cm, 20cm, 30cm, ..., 100 cm positions. In 2nd type ($1m < Distance_{MB} < 5m$), the interval space between beacon modules is planned to 10cm each, the beacon modules are launched to 1m, 2m, ..., 5cm positions. The RSSI values are transferred from the moving module to the monitoring subsystem through the sink module.[8]-[9]

Equation (1) is adapted to the 1st type and equation (2) is to the 2nd type measuring $Distance_{MB}$. In equation (1) and (2), Ed is the classes of the estimated distance the moving module located. If $Distance_{MB}$ is less than 1m (1st type), it is divided into 4 classes such as 0cm ~ 40cm, 40cm ~ 70cm and 70cm ~ 100 cm. If $1m < Distance_{MB} < 5m$ (2nd type), it is divided into 3 classes such as less than 1m, 1m ~ 3m and 3m ~ 5m.

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Less than 1m (1st type),
 $Ed = rss_i \times sd \times V$ (1)

$1m < Distance_{MB} < 5m$ (2nd type),
 $Ed = rss_i \times Distance_{MB} \times sd / 100$ (2)

In equations (1) and (2), sd is semi-diameter of measuring region (m), V is average variation rate of RSSI value (slope) and rss_i is RSSI value (dBm). The distance measurement function is run in the monitoring subsystem and it receives the RSSI values from the sink module, it calculates the estimated $Distance_{MB}$ using triangulation scheme. The estimated $Distance_{MB}$ is the reliable values obtained by many experimentations of the distance measurement. Thus, the location of the moving module is calculated by triangulation scheme using this $Distance_{MB}$ in the monitoring software of server system.

The Ed calculated from the function (1) and (2) indicates the cellular region that the moving module is located. Using the Ed , the estimated distances per Ed ($Distance_{MB}$) are classified and ordered as shown to <Table 1>. The $Distance_{MB}$ are the statistical and guaranteed values obtained by many experimentations of the distance measurements. Thus, the location of the moving module is calculated by triangulation scheme using this $Distance_{MB}$ in the monitoring software of server system.[10]

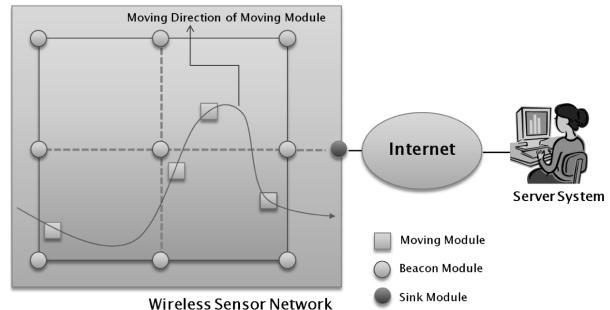
<Table 1> $Distance_{MB}$ in Eq. (1) and Eq. (2).

Ed	0	1	2
$Distance_{MB}$ in Eq.(1)	100cm	70cm	40cm
$Distance_{MB}$ in Eq.(2)	100m	300cm	500cm

III. Wireless Personal Sensor Network Design

The wireless personal sensor network for experimentations and evaluation of the proposed distance measurement scheme is organized into moving module, beacon modules and sink modules that are connected into each other by IEEE 802.15.4 standard (Zigbee), and the server system is connected to the sink module by Internet as shown to [Fig. 1].[11]

The hardware of the sensor modules is the CC2420 chipset based NANO-24 and they are communicated with other sensor modules by radio interface and in-



[Fig. 1] Wireless Sensor Network Architecture.

ternet controlled by ATMega128L micro controller. The sink module sends the distance measurement data to the server system after it collects the distance measurement data from the moving module. The server system calculates the estimated localization the moving module located and indicates the location by Graphical User Interface (GUI).

In the organized personal wireless sensor network, 9 beacon modules are arranged into 6m by 6m geographic regular space, and the interval space among beacon modules is uniformly maintained to 3m. The moving module can be moved to horizontal and vertical directions by 30cm and the localization data of moving module is indicated and obtained from 21 by 21 horizontal and vertical lines in the space.

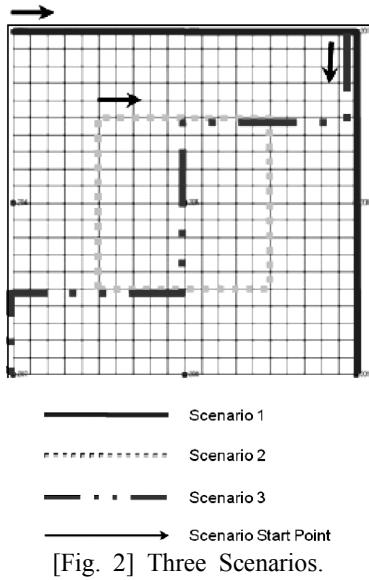
IV. Experimentations and Analysis

1. Experimentation Environments

The experimentations for estimating the performance of the proposed scheme are tried in the open spaces such as the rooftop of the university buildings and building lounges. The 9 beacon modules are arranged in the experimentation area as 3 modules per vertical and horizontal in $6m \times 6m$ scaled experimentation area.

2. Scenarios for Experimentation

The performance of the scheme is measured by running three scenarios as shown to [Fig. 2]. Scenario 1 is the outer side track, scenario 2 is the center oriented track and scenario 3 is the cross side track. In order to estimate the localization errors of the proposed scheme, the moving module is moved to the horizontal and vertical directions to 30cm each.



[Fig. 2] Three Scenarios.

3. Localization Error Patterns

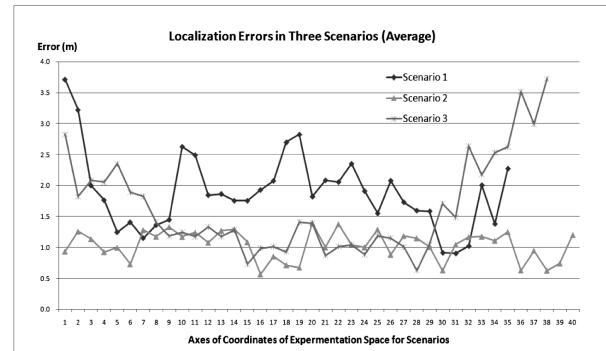
The average localization error patterns in three scenarios are shown to [Fig. 3]. In [Fig. 3], the localization error of the scenario 1 is higher than that of other two scenarios entirely. The localization error of the scenario 2 is lower than other two scenarios, and the error distribution is lower than other two scenarios in all axes of coordinates of experimentation space of 21 by 21 horizontal and vertical lines.

The localization error of the scenario 3 is better than that of the scenario 1 and lower than that of the scenario 2, and the appearance of the error pattern is similar to the hemisphere. It is inferred that the moving node in the scenario 2 can be more communicated to beacon nodes than other two scenarios in respect of the location of the mobile node in each scenario because the scenario 2 is center oriented track, and it may be affected to the localization error as good.

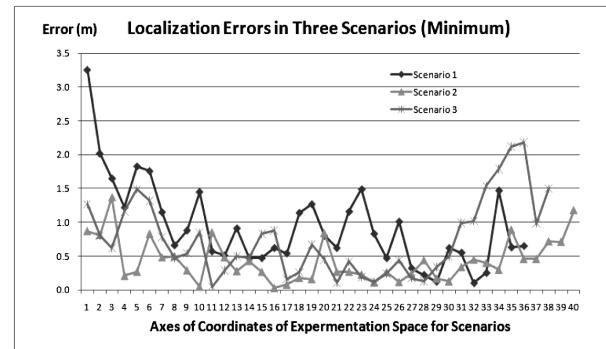
The minimum and maximum localization error patterns in three scenarios are also shown to [Fig. 4] and [Fig. 5] respectively. The pattern of measured data of minimum and maximum localization errors in these scenarios are similar to each other except the difference of error levels.

4. Measured Localization Error in Scenarios

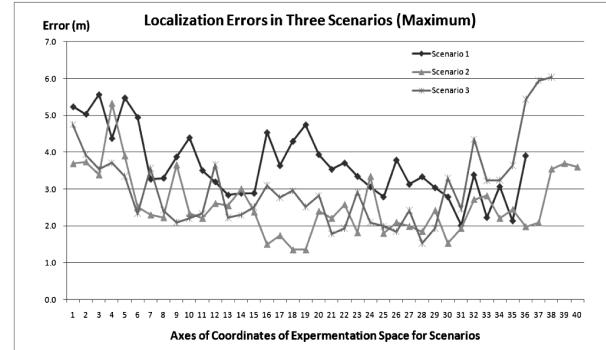
The localization errors in three scenarios are measured and indicated to minimum / maximum / average



[Fig. 3] Localization Error Patterns in Three Scenarios (Average).



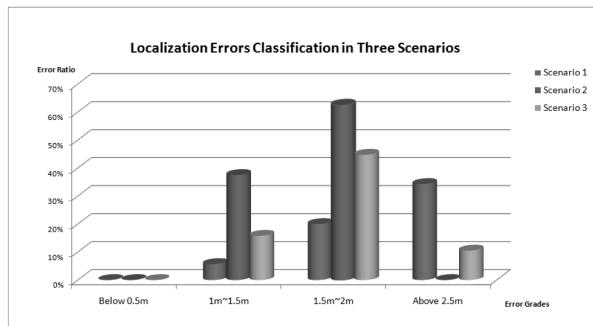
[Fig. 4] Localization Error Patterns in Three Scenarios (Minimum).



[Fig. 5] Localization Error Patterns in Three Scenarios (Maximum).

<Table 2> Measured Localization Errors in Three Scenarios (Minimum, Maximum and Average).

Scenarios	Minimum Errors	Maximum Errors	Average Errors
Scenario 1	0.90m	3.72m	1.90m
Scenario 2	0.57m	1.40m	1.04m
Scenario 3	0.63m	3.71m	1.64m



[Fig. 6] Localization Errors Classification in Three Scenarios.

errors that are summarized to <Table 2>. In scenario 1, all the errors are higher than other scenarios cases. But in scenario 2, all the errors are lower than any other scenarios. From the above results, the localization errors are tended to decrease if moving module is moved to the center area.

5. Localization Errors Classification

The localization errors ratio per error grades in three scenarios are classified in [Fig. 6]. About 32% and 18% of the localization error in the scenario 1 are measured to above 2.5m and 1.5m~2m errors respectively. About 60% and 35% of the localization error in scenario 2 and about 42% and 12% of the localization error in scenario 3 are measured to above 1.5m~2m and 1m~1.5m errors respectively. It is inference that the localization error of ranging 1.5m~2m in the scenarios 2 and 3 are 42%~60% and the error of ranging above 2.5m is 32%.

V. Conclusions

In this paper, we propose the distance measurement scheme that is based on the distance measurement using RSSI of sensor module considering of two distance conditions for the localization system using Zigbee in WPAN.

From the experimentations, we can see that the localization error in scenario 2 (center oriented track) is lower than other scenarios, and the localization error in scenario 1 (outer side track) is higher than other scenarios. Also, it is inference that the localization error of ranging 1.5m~2m in the scenarios 2 and 3 are 42%~60% and the error of ranging above

2.5m is 32%. In the future, the errors may be greatly improved if the scheme that guarantees the multiple broadcast signals from the beacon module is adapted to the localization system.

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