Performance Analysis of Location Estimation Algorithm Using an Enhanced Decision Scheme for RTLS

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ABSTRACT

In this paper, we proposed a high precision location estimation algorithm using an enhanced decision scheme for RTLS and analyzed its performance in point of an average estimation error distance at 2D coordinates searching area, 300m×300m and LOS propagation environments. Also the performance was compared with that of conventional TDOA algorithm according to the number of available reader and received sub-blink. From the results, we confirmed that the proposed location estimation algorithm using an enhanced decision scheme was able to improve an estimation accuracy even in boundary region of searching area. Moreover, effectively reduced an error distance in entire searching area so that increased the stability of location estimation in RTLS. Therefore, we verified that the proposed algorithm provided a more higher estimation accuracy and stability than conventional TDOA.

Keywords
RTLS, TDOA, RFID, Location Estimation, Enhanced Decision

Ⅰ. Introduction

The RFID (Radio Frequency IDentification) technologies attach electronic tag at thing serve to various services which can be remote processing and information exchange between management and thing, etc. The RFID can also recognize physical location and condition for user[1]. These RFID technologies have greatly extended our ability to monitor and control the physical world and have been proposed for various applications including search and rescue, disaster relief, target tracking, and smart environments. The inherent characteristics of these applications make a thing's location an important part of their state. Therefore, recent growth of interest in pervasive computing and location aware system provides a strong motivation to develop the techniques for accurate estimating the location of devices in both outdoor and indoor environments[2],[3].

Thus, in this paper we propose a high precision location estimation algorithm adopting an enhanced decision scheme for RTLS (Real Time Location System) and analyze its performance at 2D searching area, 300m×300m and LOS environments. This paper is organized as follows. Section II discusses related work in RFID and introduces the overview of RTLS. In section III we present the location estimation algorithm with an enhanced decision rule proposed in this paper. Section IV describes the simulation results and analyzes the performance with detailed performance comparison. Finally, we conclude in section V.

Ⅱ. The Overview of RTLS

RTLS is real time location estimation system with RFID technology in 2.45GHz that also provides robust wireless telemetry capabilities. It operates in conformance with the INCITS 371 RTLS standard.

RTLS employs DSSS RF technology to determine the location of transmitting blinks. The system's blink devices, called Tags. These tags shall transmit at a power level that can facilitate reception at ranges of at least 300 meters open field separation between the tag and reader. These blink transmissions are extremely low power, only about 2mW. This low power signal is spread over a large portion of the 2.40-2.483 ISM band of the RF frequency spectrum. In spreading the signal over this wide band, the system employs 511 chips. Because of this large amount of processing gain, the transmissions can be received at long distances. Each reader shall be capable of receiving and processing data from a minimum of 120 tags per second. RTLS enables the user to locate, track and manage assets within the infrastructure of the system on a real-time basis. The nominal location data provided by the RTLS shall be within a 3-meter radius of the actual location of the transmitting RTLS tags. The structure of tag signal designed sub-blink and blink. 1 blink is consisting of sub-blink as 1 to 8. The elements of RTLS infrastructure constitute the RTLS transmitters (Tags), RTLS server (Reader), and RTLS application program interface[4].

III. TDOA with an Enhanced Decision Scheme

Location estimation algorithms are commonly used as a method to obtain the high precision location information of tags or objects. Generally speaking, the location estimation approaches divided to four subsections: Time of Arrival (TOA), Time Difference of Arrival (TDOA), Angle of Arrival (AOA) and RSSI.

AOA technique estimates the angle at which signals are received and uses geometric relationships to calculate node positions. AOA has several problems in hardware constraints and energy consumptions. RSSI technique measures the power of the signal at the receiver. The main advantage of RSSI method is its low communication overhead and no additional hardware requirement. However, problems such as multi-path fading, background interference and irregular signal propagation characteristics make range estimates inaccurate. Furthermore, RSSI method needs considerable efforts to obtain an empirical radio propagation model beforehand.

TOA and TDOA methods both compute signal propagation time to obtain range information. The difference between them is that the former records the time of arrival and transmission of the same signal while the latter uses two signals with different propagation speeds such as RF signals[5]. Thus, TDOA technique is the most suitable method for a RTLS specification without synchronization between all of tags and readers and without accurate GPS time.

As mentioned above, the TDOA works by measuring the difference in the arrival time of a signal among a minimum of three fixed-position Readers. In this system the Tags transmit their blink signal every fixed period of time. By comparing the difference in the time of arrival of the beacon signal at each of readers the system can determine the location of the transmitting Tag. Therefore, we used the time information which received signal to available reader given by equation (1). Where X and Y are unknown actual tag position, Xi and Yi are available reader position and C is speed of light respectively. $R(i,j)$ is the time difference i-th reader's arrival time of a signal form a tag and j-th reader's arrival time of a signal form a tag. Afterward, this time differences have included measurement error time, which is uniformly distributed random error time within 32.76nsec which is spreading code's one chip duration[6],[7].

$$R(i,j) = \frac{\sqrt{(X - X_i)^2 + (Y - Y_i)^2}}{C} - \frac{\sqrt{(X - X_j)^2 + (Y - Y_j)^2}}{C} . \quad (1)$$

Using the time difference R(i,j), we can draw a hyperbolic curve. Figure 1 shows the intersection position of hyperbolic curve using arrival time t1, t2, t3. Through this curve we can extract two equation as follows

$$y = mx + b . \quad (2)$$

$$Ax^2 + Bx + C = 0 . \quad (3)$$

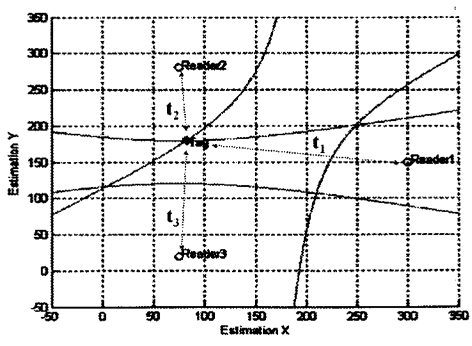

Figure 1. Locating a tag through Trilateration.

Finally, we can get two estimated locations for the virtual tag location are given by the

$$x = \{-B \pm \sqrt{B^2 - 4AC}\}. / 2A \, . \quad (4)$$

$$y = mx + b \, . \quad (5)$$

We propose location estimation algorithm with an enhanced decision scheme executing each step as follows:

Step 1 : Get arrival time from each reader

RTLS server has received signal's arrival time (t1, t2, t3) from tag to available each reader. Though transmitted time is same at tag, available each reader's positions are different separately. Therefore, arrival time (t1, t2, t3) is normally different respectively. And then calculate time differences with each arrival time and stores the time difference at database.

Step 2 : Calculate time difference between each arrival time

RTLS application program interface express intersection position of hyperbolic curve using measured t1, t2, t3. And then set virtual tag to valid intersection position. (Ref. locating a tag through trilateration in figure 1, and equation (1))

Step 3 : Virtual tag's location estimation

Through the equation (4), (5) acquired virtual tag's paired location repeats Step 1, and produces the intersection position among hyperbolic curve as 2 to 4 with 3 readers for intelligent coordination scheme. (We assume that t1=t1', t2=t2' and t3=t3', respectively. Normally, we have two virtual tag positions.)

Step 4 : Location decision with an enhanced decision scheme

The location estimation algorithm with an enhanced decision scheme which compare time difference information (t1', t2', t3' and t1'', t2'', t3'') of virtual tags and measured time difference information (t1, t2, t3) in database of RTLS, respectively. And then select the estimation position of the unknown tag. At this time, we use an enhanced decision scheme and environmental exception rules. For example, when the virtual tag's position has an imagination root, multiple root or exception case by second order equation's determinant, eliminate that case's estimated location.

Through this kind of algorithm and process, we can estimate location of tag in real time, and improves accuracy of location estimation. Also, we can manage each tag's information efficiently as reusing database.

IV. Simulation and Discussions

The effectiveness of our approach for enhancement of location estimation accuracy in RTLS is validated through a simulation. This section describes the simulation results and performance analysis in point of an average estimation error distance. In simulation, we assume that searching area is 300m×300m and propagation path is LOS (Line-Of-Sight) environments. Besides, each RFID tag is located every 3m in searching area and each reader is located with equal distance. At this condition, we evaluate an average error distance of proposed algorithm and it is compared with that of conventional TDOA algorithm according to the number of available reader and sub-blink.

Figure 2 shows an average error distance of conventional TDOA versus the number of available reader. At a certain available reader an average error distance reduces as the number of sub-blink increases, but it not agree with expectation when the sub-blink number increases. This is due to relatively low accuracy at searching boundary area. In boundary area, the arrival time difference between readers is much less or nearly same, so estimated tag position has relatively low accuracy. For improving this problem, we propose a location estimation algorithm using an enhanced decision algorithm and the results are shown in figure 3. In figure 3, different from figure 2, an average error distance is linearly decreased when the number of reader and sub-blink increases.

From the results, proposed algorithm satisfies the RTLS specification requirement, 3m radius accuracy when the number of available reader is more than 4 and the received sub-blink number exceeds 1. However, conventional TDOA meets the same RTLS requirement when the number of available reader and received sub-blink is more than 4 and 2, respectively. Therefore, we confirm that proposed algorithm is accurately operated at searching boundary area.

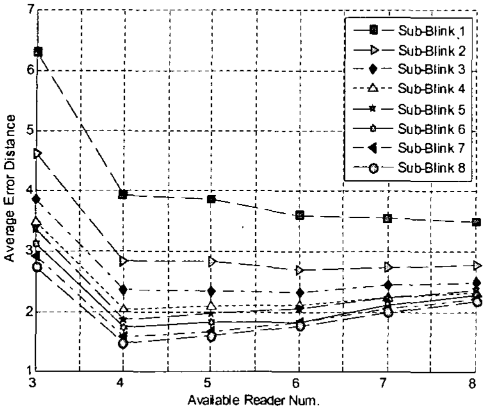

Figure 2. Average error distance of conventional TDOA according to the available reader number.

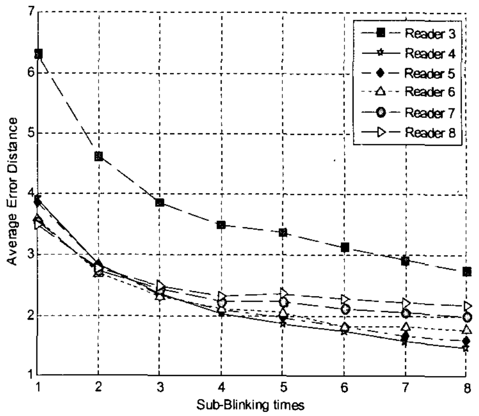

Figure 4. Average error distance of conventional TDOA according to the number of sub-blink.

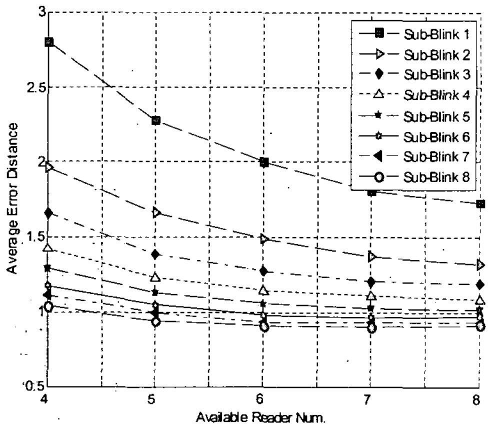

Figure 3. Average error distance of proposed algorithm according to the available reader number.

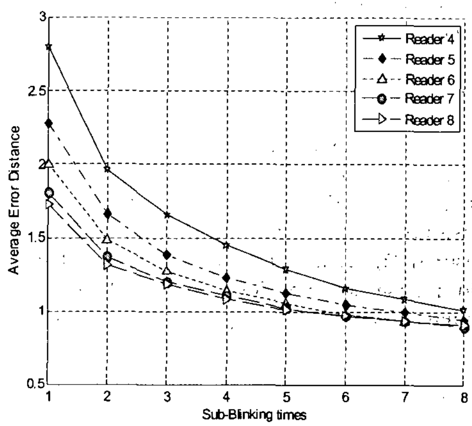

Figure 5. Average error distance of proposed algorithm according to the number of sub-blink.

Figure 4 and figure 5 show an average error distance of conventional TDOA and proposed algorithm according to the number of sub-blink, respectively. From the results, in proposed algorithm an average error distance is linearly decreased according to the number of available reader and sub-blink.

Figure 6 - figure 9 show an error distance distribution and percentage when the number of reader and sub-blink is 8 and 4, respectively. In proposed algorithm, the probability of 3m accuracy is 94% and 2.348m accuracy is 92% when the number of reader and sub-blink is 8 and 4, respectively. However, in conventional TDOA the 3m accuracy and 2.348m accuracy is 78% and 72%, respectively at the same conditions. The 2.348m distance is based on the fact that the international specification of container width is 2.348m.

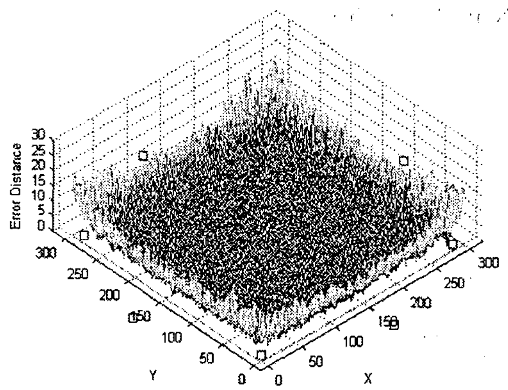

Figure 6. Error distance distribution of conventional TDOA.

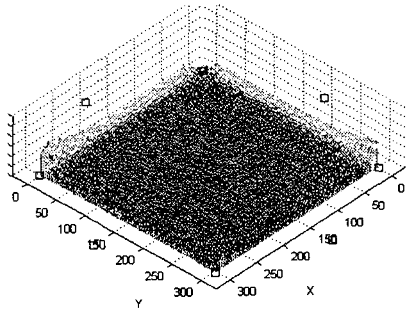

Figure 7. Error distance distribution of proposed algorithm.

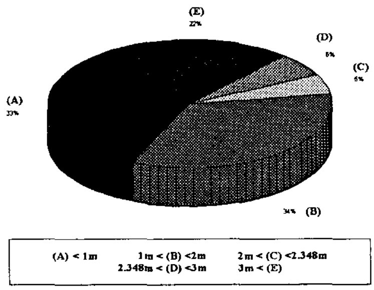

Figure 8. Error distance percentage of conventional TDOA.

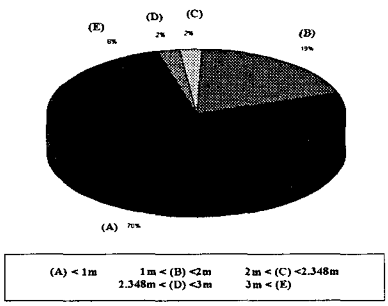

Figure 9. Error distance percentage of proposed algorithm.

V. Conclusions

In this paper, we proposed a high precision location estimation algorithm using an enhanced decision scheme for RTLS and analyzed its performance in point of an average estimation error distance at 2D coordinates searching-area, 300m×300m and LOS propagation environments. Also the performance was compared with that of conventional TDOA according to the number of available reader and received sub-blink.

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From the results, we confirmed that the proposed location estimation algorithm using an enhanced decision scheme was able to improve an estimation accuracy even in boundary region of searching area. Moreover, effectively reduced an error distance in entire searching area so that increased the stability of location estimation in RTLS.

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