Effect of Collision on Movement Tracking Using Active RFID Power Measurement

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***Abstract*— This paper reports preliminary work with an RFID based real time location system (RTLS) designed for location and guidance of people in welfare facilities like the sanatorium which has the both of indoor and out door environment. The system consists of a number of fixed RF readers and a number of active RFID tags carried by the target object, or senior people. We compare the performance of several RTLS schemes which use the received signal strength indication (RSSI) values emitted by the moving active RFID tags. Traditional trilateration, fingerprinting, and well-known LANDMARC approaches are evaluated and compared using the SystemC-based computer simulation. Results show a mean estimated error (MEE) performance of 3m with the 130 tags according to the position updated frequency in our simulation environment.**

Keywords — Active RFID, Positioning system, RTLS, RSSI

I. Introduction

The issue of the Real Time Location System (RTLS) in limited size areas, such as indoor environments or small outdoor spaces, has gained large attention in the last few years. As it's well known, the GPS system was designed for outdoor localization, and will not usually work indoors. However, a much varied set of alternative local position system have been developed over the years, based in technologies like artificial vision, ultrasonic or sonic signals[1],[2], infrared, and a growing importance, Radio Frequency (RF) signals [5-14]. Belonging to this last category, many different possibilities have been explored: Wi-Fi, Bluetooth, Ultra-Wideband (UWB), Radio Frequency Identification (RFID), etc.

Real time location system has general procedure such as beacon transmission, beacon measurement, and position determination as shown in Fig. 1. Measuring is a process to measure metric in order to obtain distance information. The measured metric can be one or more than among RSSI (received signal strength), TOA (Time of Arrival), TDOA(Time Difference of Arrival), and AOA (Angel of Arrival). In the case of RSSI, distance is extracted from RSSI based on the fact that transmitted power reduces regularly with respect to distance. While the RTLS scheme based on RSSI is easily implemented, measured RSSI is seriously fluctuated due to wireless channel characteristics such as multi-path and shadowing.

RTLS based on TOA/TDOA measures the transmission time and have better performance than that of RSSI. This scheme need to synchronization between AP or between

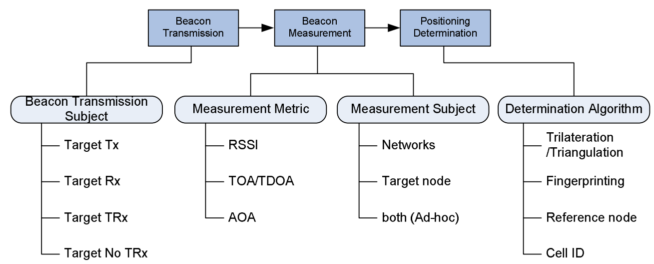

Figure 1. Categorization of real time location system

network node and target node. While RTLS based on AOA has a strong point that target's location can be calculated by using only two sensor nodes. This scheme needs multiple antennas such as antenna array or directional antenna, and is sensitive to the reflected and scattered signals, or NLOS environment.

RTLS can be also categorized as Client-based scheme and Network-based scheme according to the subject device to determine location or position [3]. While the target or mobile station calculate and determine the location by itself in Client-based scheme, target does not be involved in the process of determination in Network-bases system. Network-based scheme can be categorized again according to the subject to measure the metric as shown in Fig. 2.

There are several schemes for determining the target's position from the 'Determination Algorithm'. The triangulation scheme is widely used in determination technology, traditionally. Fingerprinting [4] is a kind of empirical schemes. RSSIs from the all beacon signal transmitter in all candidate position are measured in offline-phase and these information are converted as the fingerprint, or radio-map. Fingerprinting scheme determine the location by using the radio-map. In [9], the authors use hybrid scheme

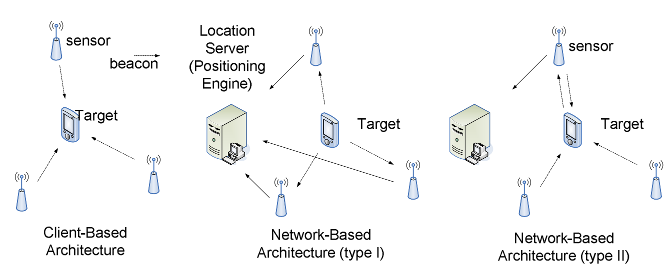

Figure 2. Categorization according to measurement subject

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based on TOA and RSSI. Because location calculation to use TOA is ambiguous in NLOS (non-line of sight) environments, they use RSSI to compensate uncertainty of location and increase accuracy of location in NLOS environments. The schemes with flight time related metric like TOA/TDOA are hard to apply to WLAN system because of its time resolution according to its signal bandwidth and inter-AP synchronization requirement. LANMARC [12] scheme is operated based on active RFID, and calculate the weighting factor from RSSI of reference Tags, and determine the location of target tag by using weighting factor.

In this paper, we focus on the RFID system for sanatorium for senior people because the tags are set of small device attached to or incorporated into a product, animal, or person whose location and identification are desired. The contribution of this paper is the evaluation of moving RFID tags' positioning performance in terms of the number of tags for capacity, while literature does not concerned the mobility and capacity of RFID system. This paper in structured as follows. In section II, we provide the requirement of RTLS for monitoring system of senior people in the sanatorium. In section III, we describe the simulator based on SystemC used in this study. The simulation results are shown in Section IV. Finally, in section V, we draw conclusion of the work.

II. Requirement of RTLS for Monitoring System in The Sanatorium

3m accuracy with 50% CDF (Cumulative Density Function) probability is needed. Accuracy of RTLS depends on service type. Generally, people tracking service requires higher accuracy than other tracking service for the vehicles and products. The exact number for high accuracy can be know through commercialized service. LEGOLAND Billund in Demark applied RTLS system to kids position monitoring in their amusement park in order to protect a missing child and use to manage customer information [15]. They provide electronic map to parents. The map is divided by grid or zone and location of kid is display as □ mark. Zones can vary in size from 20m x 20m down to a minimum zone size of 3m x 3m, depending on the density of the area. RTLS service for senior is similar with that of missing kid's service and needs the same accuracy.

III. Simulation Environment

We assume that the area size of sanatorium is 150m x 150m. This simulation field includes indoor areas (buildings, 40m x 55m, 65mx50m) and outdoor area as shown in Fig. 3. RFID readers are installed every 50m distance and the location of them is fixed. The tags are always moving for the whole simulation time with Johnson and Maltz's 'Random Waypoint' mobility model[17]. The maximum speed of tag is 4m/s.

The transmission power of target and reference tag is 10dBm and target moves according to the random way-point movement model. When simulation starts, all target and reference tag turns on randomly between 0 and 1sec and start to transmit blink frame according to the ISO/IEC 24730-2 protocol [15]. The protocol parameters used in simulation are as follows: Begin of blink interval is randomly selected by ±638ms. Begin of sub-blink interval is randomly selected by 125±15ms. Blink interval is 1.8sec and number of sub-blink is 4. The sensitivity of the received signal from the tags is -72dBm as described in the standard.

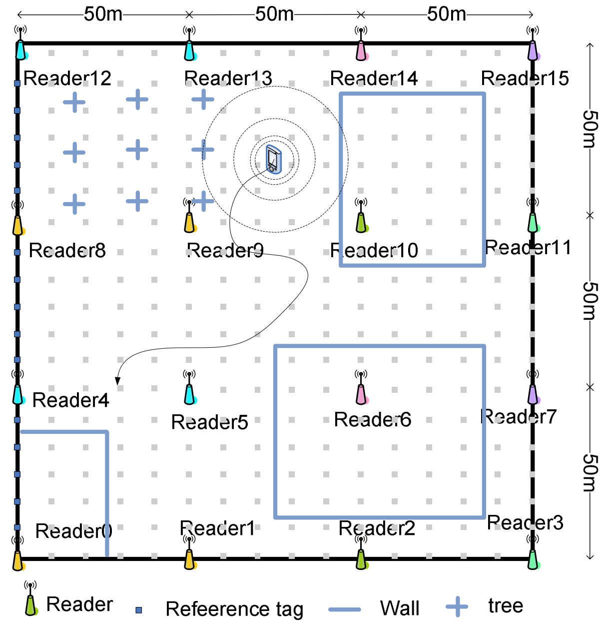

Figure 3. RTLS simulation environments for Active RFID

The path loss model is described by,

$$p(d)[dBm] = p(d_0)[dBm] - 10n\log(d/d_0) - m*WAF \quad (2)$$

where n indicates the rate at which the path loss increases with distance, $p(d_0)$ is the signal power at some reference distance d_0, d is the separation distance between transmitter and receiver, and m is the number obstacles like the walls and trees.

The path loss exponent of one wall is 3dB [4], and path loss of one tree is varied from 0.5 to 2dB.

IV. Simulation Results

We simulate and compare the performance of trilateration, Fingerprint, and LANDMARC schemes for determination. The performance is varied according to the exponents of path loss in trilateration scheme. Fig. 4 shows MEE (mean estimation error) performance according to the exponents of path loss. MEE value is defined by the following equation 3,

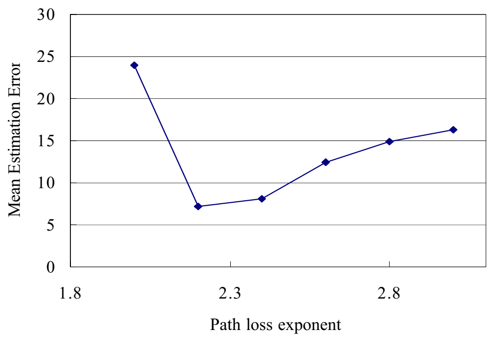

Figure 4. MEE in trilateration scheme versus path loss exponent method

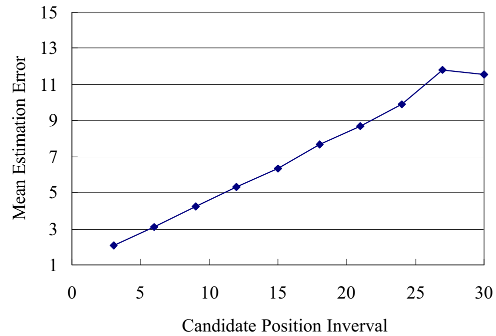

Figure 5. MEE in Fingerprinting scheme versus Candidate position interval or resolution of radio-map

$$MEE = \frac{1}{M}\sum^{M}\sqrt{(x-x_0)^2+(y-y_0)^2} \quad (3)$$

(x_0, y_0) : real coordinates

(x, y) : estimated coordinates

When the exponent of path loss is 2.2, distance error is minimized. And we can see that trilateration can not meet the accuracy constraint, 3m. Fig. 5 shows the MEE performance according to the interval of fingerprinting candidate position, or resolution of off-line radio-map. As candidate position resolution become larger, MEE increase. We can see that the interval of RFID readers should be less than 6m in order to satisfy the accuracy, 3m.

Fig. 6 shows the MEE performance in regard of number of nearest neighbor reference tag and interval of reference tag in the LANDMARC algorithm. LANDMARC location performance depends on the two parameters, reference tags' distance and the *k* value for *k*-nearest neighbor algorithm [12]. The unknown tag's coordinate (x, y) is obtained by :

$$(x, y) = \sum_{i=1}^{k} w_i(x_i, y_i) \quad (4)$$

where w_i is weighting factor to the *i*-th neighboring reference tag. In the case of 10m interval of RFID reference tags, we can see that the number of neighboring reference tags is three to eight in order to satisfy required accuracy, 3m.

According to the simulation, we find optimal parameter value such as exponents of path loss and the number of neighbor reference tag. When using these values, accuracy value with 50th percentile value of error distance is 4.5ms, 3ms, 1.9m in trilateration, fingerprint, and LANDMARC scheme, respectively, as shown in Fig. 7.

Above simulation focus on MEE performance in case of one station (user) exists. In order to analyze the effects of number of user stations, we simulate MEE performance when the number of user stations increase concerning various updating periods. Figs. 8, 9, and 10 show the MEE performance of trilateration, fingerprinting, and LANDMARC, respectively. T3 stands for the blink emission interval in the standard ISO 24730-2 protocol. As the number of user stations increase, the MEE performance becomes worse due to collision. As the updating period increase, the MEE performance also becomes worse because the target go wide of the estimated position for the updating duration. Faster updating period does not always guarantee better performance. However, it is worthwhile noting that short updating period does not always guarantee better performance. As shown in Figs. 9 and 10, the performance with updating period of 0.5 sec is worse than others when the number of tags is larger than

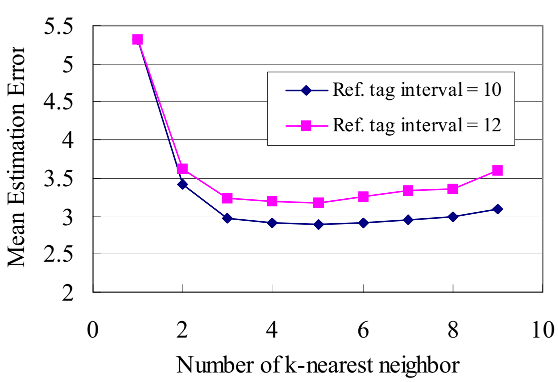

Figure 6. MEE in LANDMARC scheme versus Candidate position interval, or resolution of radio-map

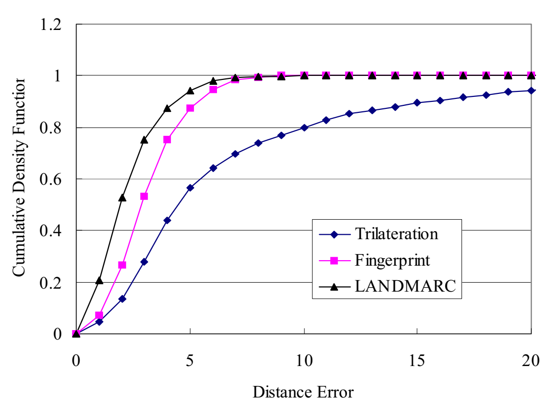

Figure 7. Distance error performance of three active RFID-based RTLS

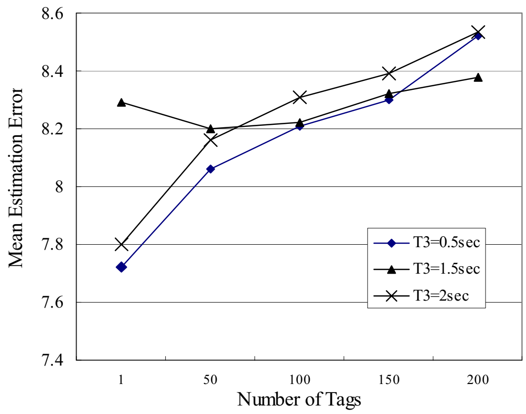

Figure 8. MEE performance of trilateraion scheme versus the number of tags

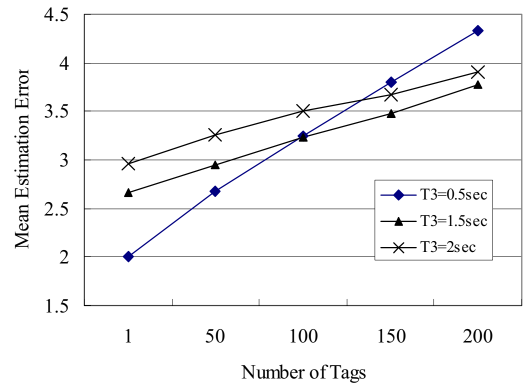

Figure 9. MEE performance of fingerprint scheme versus the number of tags

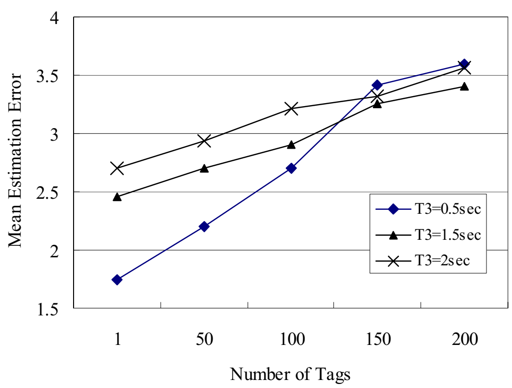

Figure. 10. MEE performance of LANDMARC scheme versus the number of tags

100 and 120 because of increased collision from the dense tags. When the number of station is more than 60, fingerprinting scheme does not satisfy the accuracy requirement. In case of LANDMARC, the MEE performance of LANDMARC satisfy accuracy requirement until the number of stations is 120~130.

V. Conclusion

In this paper we assess the performance of location algorithms based on RSSI measures in active RFID systems, namely the traditional trilateration, fingerprinting and LANDMARC scheme. We simulate these schemes in the SystemC-based simulation field which has the both of indoor and outdoor environment. The trilateration scheme can not meet the requirement of error distance 3m, and the fingerprinting and LANDMARC algorithms meet the accuracy requirement according to the position update frequency. And we can see that the MEE performance with low frequent update the position is better if the number of tags is larger then about 100.

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