Research on the Received Signal Strength Indication Location Algorithm for RFID System

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***Abstract*— Received signal Strength Indication (RSSI) location algorithm is studied in this paper. Simulation platform of Radio Frequency Identification (RFID) location system is also constructed. The affection by different number of reference tags with detection power-level is studied. Tracing location information of mobile tags and the layout of simulation area to effect location error are also investigated. The simulation results illustrate that RSSI algorithm based on RFID with active tag is a viable and cost-effective candidate for indoor location sensing.**
***Keywords*—RSSI; location technique; RFID; active tag**

I. INTRODUCTION

Various positioning systems have been proposed for use in ubiquitous computing. As an essential prerequisite for ubiquitous computing, mobile positioning techniques, linked with wireless networks, have increasingly provided mobile users with opportunities to access personal information, corporate data, and shared resources anytime, anywhere. Some techniques are already available to gather location data, foremost GPS or cells networks [1]. Most of those are usable only outside of buildings and require complex hardware. The most popular and feasible technique for indoor application is the measurement of time of flight of signals (TOF) while this need a great amount of installed hardware also and need timing information.

Different indoor location algorithm based on RFID have been proposed in [2][3][4]. The most common approach is to locate the objects with RFID tag, and then to have a variety of RFID readers at known locations scan for nearby chips. When a tag is scanned, it is known that this tag is in the location of the reader. Such systems tend to only resolve the location of the object to somewhere within the read range of the scanner. A more precise system employs RFID triangulation. When an object is scanned by multiple scanners with measurable delay times in signal response to an emitted radio wave, then comparison of the delay times for multiple scanners can be used to triangulate the position of the object being scanned. One drawback of this system is accurate timing information are needed between active tags which is not easy available and sensitive in system.

The objective of the paper is to evaluate an easily accessible wireless indoor location-sensing system based on RFID using Received Signal Strength Indication (RSSI) location algorithm.

The remainder of this paper is organized as follows. In Section II, we survey the system model of the RFID location system and RSSI location algorithm. Since RFID is not designed for location sensing, the purpose of our simulation is to investigate whether the RFID technology is suitable for locating objects with accuracy and cost-effectiveness. In Section III, simulation results illustrate the application of RSSI algorithm for RFID location. The last section concludes some problems and discussions.

II. SYSTEM MODEL

A. RFID Premier

RFID systems are composed of two main elements, the RFID tag, which usually carries a serial number and potentially other data and the RFID reader, which detects tags and reads from and writes to the tags [5].

RFID tags, which are attached to objects that need to be identified or tracked, consist of an antenna that is used to communicate with the reader, and a microchip which stores, among other things. The RFID reader interrogates tags for their data using wireless communication. The reader contains the RF interface to the tags, internal storage, processing power and an interface to a host computer system to transfer the data sensed. RFID readers and tags use a defined radio frequency and protocol to transmit and receive data. RFID tags are categorized as either passive or active. Passive RFID tags operate without a battery. They reflect the RF signal transmitted to them from a reader and add information by modulating the reflected signal. Passive tags are mainly used to replace the traditional barcode technology and are much lighter and less expensive than active tags, offering a virtually unlimited operational lifetime. However, their read ranges are very limited. Active tags contain both a radio transceiver and a button-cell battery to power the

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transceiver. Since there is an onboard radio on the tag, active tags have more range than passive tags.

Active tags are ideally suited for the identification of high-unit-value products moving through a tough assembly process. They also offer the durability essential for permanent identification of captive product carriers.

B. Received Power

In backward link, the Effective isotropic Radiated Power (*EIRP*) of active-tag is P_{EIRP} .The typical maximum output power is 500mW, 2W (*ERP, CEPT*) and 4W (*EIRP, FCC*).Converted to dBm, the permitted maximum values are about 29dBm (500mW *ERP*, 825mW *EIRP*), 35dBm (2W *ERP*, 3.3W *EIRP*) and 36dBm (4W *EIRP*). G_{reader} is the gain of the reader antenna. The typical value is assumed to be 6dBi, therefore, the maximum output power from power amplifier should be 23dBm, 29dBm and 30dBm, respectively [6].

The power transmitted from tag to reader can be expressed as [7], also called Friss formula/equation.

$$P_{rec} = P_{EIRP} G_{reader} \left(\frac{\lambda}{4\pi d} \right)^2$$

λ is the wavelength of the carrier and d is the distance between reader and tag.

C. Indoor Wireless channel

The wireless channel is modeled by the Friis transmission equation. The Palomar project introduced power shadow by reflections from the walls [8].

RFID system is a LOS (Line of Sight) communication system. The influence of reflection by the environment should be considered. The radio propagation model can be expressed as

$$P_r = P_t \left(\frac{\lambda}{4\pi} \right)^2 \left| G_0^{1/2} \frac{1}{r_0} \exp(-jkr_0) + G_i^{1/2} \sum_{i=1}^{n} \Gamma(\alpha_i) \frac{1}{r_i} \exp(-jkr_i) \right|^2$$

P_r is the received power. P_t is the transmitted power. The antenna gain of transmitter is different in different direction. G_0 is the antenna gain of the direct path. G_i is the antenna gain of the propagation way numbered *i*. $\Gamma(\alpha_i)$ is the reflection coefficient of each ray. When tag is close to reader, power level changes smaller than the far regions. When the distance gets larger, the reflections become more important. When the tag is close to the wall that reader faced, the received power by tag changes rapidly and deeply and the maximal amplitude may exceed 10dB. Friis transmission equation is a good approximation for simplicity the analysis and simulation.

D. RSSI Location Algorithm

In detection range, the tags provide character ID to read for identification. RFID reader has several different power levels. The reader will report distance information, there power level 1 has the shortest range based on the signal strength received by the RFID reader. In order to increase accuracy without placing more readers, our system employs the idea of having extra fixed location reference tags to help location calibration. These reference tags serve as reference points in the system (like landmarks in our daily life).This approach has three major advantages:

Firstly, extra cheaper active RFID tags instead of large number of expensive RFID readers. Secondly, the environment dynamics can easily be accommodated, the environment factors that contribute to the variations in detected range because the reference tags are subject to the same effect in the environment as the tags to be located. Thirdly, the location information is more accurate and reliable. Obviously, the placement of readers and reference tags is the key to the overall accuracy of the system. So we might do a preliminary measurement to know which power level corresponds to what distance, but the power level distribution is dynamic in a complicated indoor environment. Thus, the physical distance cannot be computed accurately by using power levels directly. Ref. [8] presents an algorithm to reflect the relations of signal strengths by power levels.

Suppose that *n* RF readers along with *m* tags as reference tags. The readers are continuous reporting the tags that are within the specified range and scan the detection-rang. The signal strength vector of a tracking tag is defined as $\vec{S} = (S_1, S_2, \cdots, S_n)$, where S_i denotes the signal strength of the tracking tag received on reader *i,* where $i \in (1, n)$. The Signal Strength vector of the reference tags is defined as $\vec{\theta} = (\theta_1, \theta_2, \cdots, \theta_n)$, where θ_i denotes the signal strength. The Euclidian distance is introduced in signal strengths. $E_j = \sqrt{\sum_{i=1}^{n} (\theta_i - S_i)^2}$, $j \in (1, m)$ is defined as the Euclidian distance in signal strength between a tracking tag and a reference tag r_j for each individual tracking tag. Let *E* denotes the location relationship between the reference tags and the tracking tag, i.e., the nearer reference tag to the tracking tag is supposed to have a smaller *E* value. When there are *m* reference tags, a tracking tag has its *E* vector as $\vec{E} = (E_1, E_2, \cdots, E_m)$.

The unknown tracking tag nearest neighbors is found by comparing different *E* values. Since these *E* values are only used to reflect the relations of the tags, we use the reported value of the power level to take the place of the value of signal strength in the equation. The simplest way to find the nearest reference tag to the tracking tag is to use the coordinate of the reference tag with the smallest *E* value as the unknown tag's coordinate. This called as 1-nearest neighbor algorithm. Or, we can choose a tracking tag's two nearest neighbors and call it 2-nearest neighbor algorithm. When k nearest reference tags coordinates to locate one unknown tag is used, it is called as k-nearest neighbor algorithm. The unknown tracking tag's coordinate (x, y) is obtained by:

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

where w_i is the weighting factor to the i-th neighboring reference tag. The choice of these weighting factors is another design parameter. Giving all k nearest neighbors with the same weight (i.e., $w_i = 1/k$) would make a lot of errors. Empirically, weight used here is given by:

$$w_j=\frac{\frac{1}{E_i^2}}{\sum_{i=1}^{k}\frac{1}{E_i^2}}$$

III. SIMULATION RESULTS AND EVALUATION

We conduct a series of experiments to evaluate performance of the positioning of our system. Firstly, the simulation environment is presented as follows: Assume that the effective distance of RFID signals is 10 meter. The readers are all in continuous mode (continuously reporting the tags within the specified range) and a detection-power level of 8 and 12 which means the reader will specify 8 and 12 different range.5 readers are used in location. The location precision is evaluated by using different numbers of reference Tag and detection-power level. The layout of location system using 8 and 12 reference tag is illustrated by Fig.1 and Fig.2.

The error distance is used as the benchmark for the accuracy of different configuration of RSSI algorithm. The Mean Estimation Error is defined as

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

MEE is the linear distance between the tracking tags real coordinates (x_0, y_0) and computed coordinates (x, y), M is the number of simulations.

A. Effect of the Number of detection-power levels

The key issue is to find the best number of detection-power levels in algorithm. The 8 and 12 level is chosen to computes the coordinates of the tracking tags, respectively. Figure 3 shows the mean results of using 12 reference tags, 12 power level by 20 stochastic cycles. All reference tags are considered in compute tracked tag information. The average location error is 0.5386m for 20 simulation cycles. When using 12 reference tags, 8 power level by 10 stochastic simulation which given in Figure 4, All reference tag are considered in compute tracked tag information also, the average location error is 1.0971m.

We can see that using 12 levels can get the better location information, while as the power level of distinct of received power increase, the power-level detect maybe more sensitive to errors.

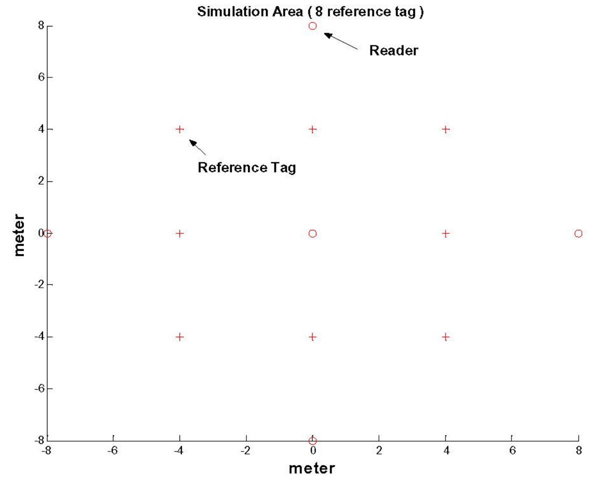

Figure 1. The layout of simulation area by using 8 reference tags and 5 readers

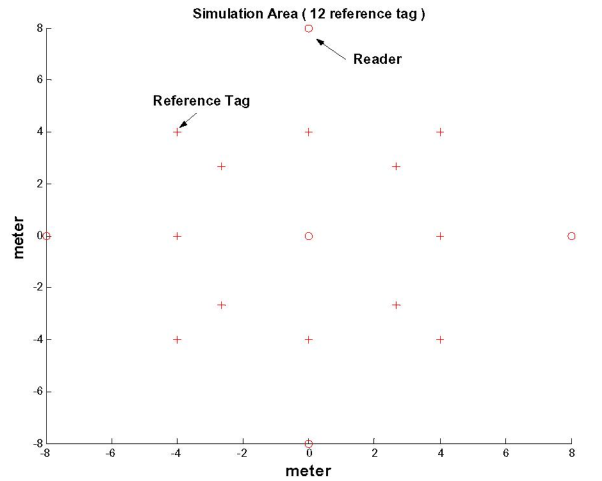

Figure 2. The layout of simulation area by using 12 reference tags and 5 readers

B. Effect of the different number of reference tag

The affection of using different numbers of tag is considered by weighting. TABLE I gives MEE results by using 12 power level and different numbers of reference tags. The precision increased as adding more reference tag as the number of tags increased from 6 to 8. There is minimal mean error as number of reference tag is 8 and meanwhile using 12 reference tags can also get another minimum for the layout of using 8 and 12 reference Tags are symmetry. When all reference tags are considered, some far reference tags can leading more error as weighting, leading the main trend of location precious decrease as the number large than 8. Circle denotes for tracked Tag and square denotes for estimated coordinate in the following figures.

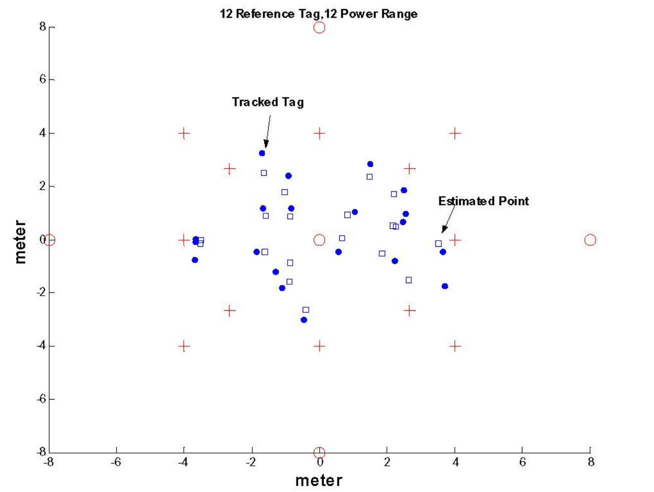

Figure 3. Simulation results of 20 cycles by using 12 reference Tags, 12 power level, all reference tag are considered in weighting.

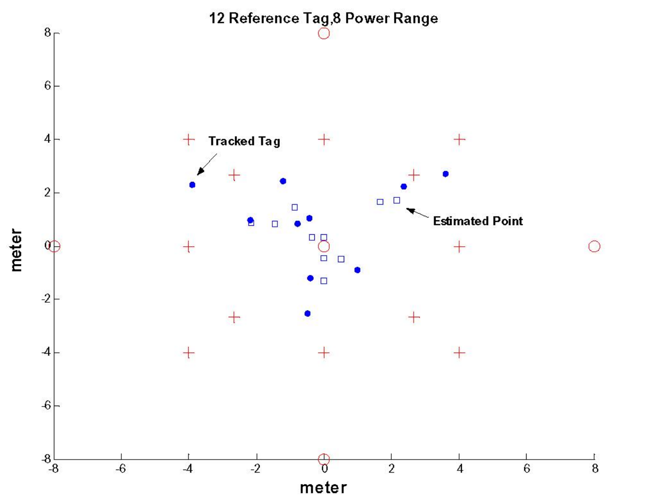

Figure 4. Simulation results of 20 cycles by using 12 reference Tags with 8 power levels, all reference tag are considered in weighting.

TABLE I

The result of Mean Estimation Error by using 12 power level and different numbers of reference tags

Number of reference tags	MEE(m) averaged by 100 realization
6	0.8393
7	0.8132
8	0.5637
9	0.7243
10	0.7379
11	0.6569
12	0.6132
13	0.7315
14	0.8117
15	0.8429

TABLE II

The simulation result of Mean Estimation Error by using 16 reference tag and different number of nearest neighbor algorithm

The number of nearest neighbor	MEE(m) averaged by 100 simulation cycles
k=14	0.683
k=12	0.641
k=10	0.6098
k=9	0.552
k=8	0.526
k=7	0.6071
k=6	0.6279

TABLE III

The simulation result of Mean Estimation Error by using 12 reference tag and different number of nearest neighbor algorithm

Number of nearest neighbor	MEE(m) averaged by 100 simulation cycles
k=10	0.618
k=9	0.541
k=8	0.566
k=7	0.638
k=6	0.737

TABLE II and III summarize the Mean Estimation Error (MEE) by using different nearest neighbor on 12 and 16 reference tags. According to TABLE II, k=8 can get the minimal error as reference tag is 16, the mean error is 0.526m. Using 12 reference tag and k=9 can get the minimal error and MEE is 0.541m by 100 simulation cycles.

C. *Tracing Mobile tag*

The location error of mobile traced tag is considered in the following simulation. assumed that the position of traced tag changed 0.2m at a time. The simulation results are given in fig. 5, 6, 7, 8 by using different number of tag and detection-power levels. The best tracing performance is by using 12 reference tags with 12 power levels.

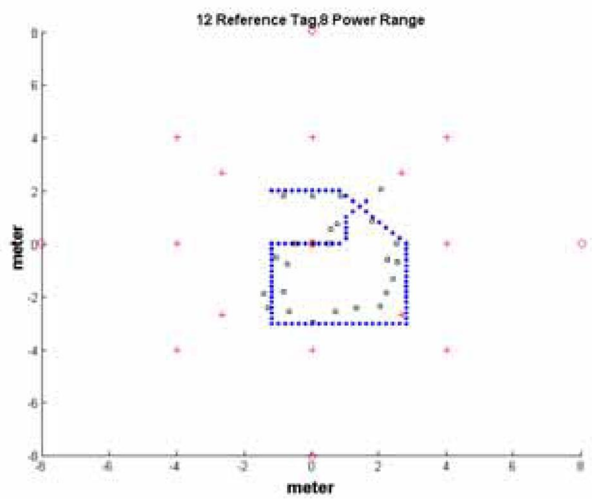

Figure 5. Simulation result of tracing mobile tags by using 12 reference Tags with 8 power levels.

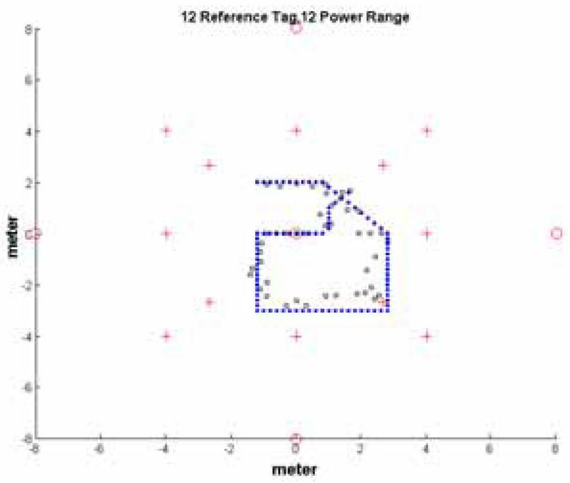

Figure 6. Simulation results of tracing mobile tags by using 12 reference Tags with 12 power levels.

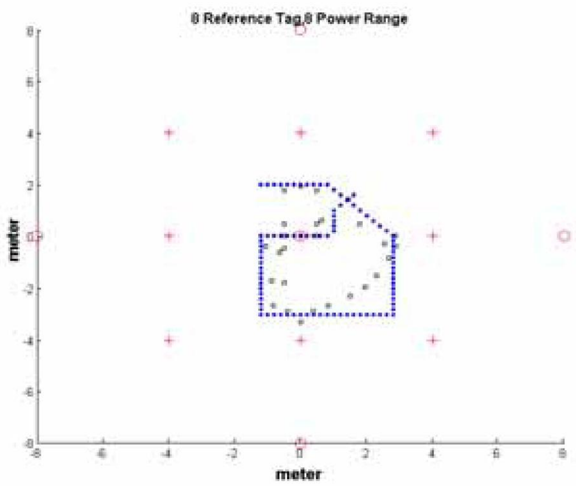

Figure 7. Simulation results of tracing mobile tags by using 8 reference Tags with 8 power levels.

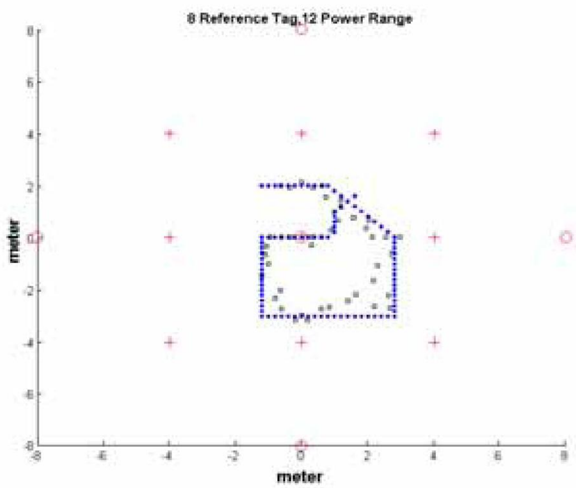

Figure 8. Simulation results of tracing mobile tags by using 8 reference Tags with 8 power levels

IV. CONCLUSIONS AND DISCUSSIONS

This paper has presented a simulation platform based on RSSI location algorithm for RFID location system. Simulation results show that adopting active RFID tag is a viable cost-effective candidate for indoor location.

The basic assumption for simulation is that all tags have roughly the same signal strength in emitting the RF signal, while the power level detected by the same reader from two tags in an identical location may be different. For example, the difference may be due to the variation of the chips and circuits, as well as batteries. Another simulation assumption is that all signals are not collisions (perfect collision avoided algorithm by MAC layer), the power level can be detectable for every realization. However, the error due to the dynamics change of environment can hardly be realization which may increase measurement errors, as we can never guarantee all the nearest neighbors and the tracking tag itself are always influenced equally. For practical application, a person standing in front of a tracking tag may greatly increase the error distance of locating this tag and this is often unpredictable. All reference tags are organized in symmetrical grid in simulations may explain why using 8 nearest neighbors can get better location accuracy. The research results should be validated not only via simulation but also with real experiments. All these will be left for future research.

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