RFID Localization Estimation Techniques for Indoor Environment

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Abstract— *The purpose of wireless sensor network (WSN) has made real time tracking of objects through the use of a radio frequency identification (RFID) system possible. Localization techniques in an RFID system affect on accurate estimation of the reading range between the sensor node and the tags. The tags consist of a chip and an antenna which receives from and transmits information to the sensor node. This paper aims to get the more accurate object location estimator within a complicated noisy propagation environment using RFID technology based on real time locating system (RTLS). The location estimate is based on the reading range using a time difference of arrival (TDOA) approach. In order to obtain the location information, a multilateration technique is employed. The TDOA value is investigated in order to get the estimated tag position. Different numbers of readers are simulated to compare the mean error and the standard deviation in multilateration techniques. As the simulation results, we get the high performance when the number of readers in the network is increased.*

Keywords: wireless sensor network (WSN), radio frequency identification system (RFID), time difference of arrival (TDOA), multilateration, non line-of sight (NLOS)

I. INTRODUCTION

Among developing wireless sensor network technology radio frequency identification technology is gaining more ground by the day due to its ease of use, security, cost effectiveness and ease of deployment. Radio frequency identification technology becomes one of the main means to construct a real time locating system that monitors and identifies the location of objects in the real time. The architecture of the system is made up of inexpensive tags attached or embedded in the object or item to be tracked, the readers that transmits and receives the radio signals to and from the tags and associated computing equipment for automatic identification and information retrieval. The estimation accuracy of the reading range (distance between the tag and the reader) depends on RFID technology and localization methods. Customarily, the read range information is determined from the received signal strength indication. However, due to the nature and characteristics of the different environment, short-falls were discovered in the accuracy of this measure metric (Feifei Guo, 2008).

II. PROBLEM STATEMENT AND OBJECTIVES

This paper aims to get the rattling object location estimator within a complicated propagation environment using RFID technology based on RTLS. In order to obtain the distance or location information, a multilateration technique is employed. During the work, the error in distance estimated due to the multipath fading is investigated in a non-line of sight (NLOS) environment using TDOA measure metrics in the multilateration technique. Keeping the number of tags in the network we increase the number of readers in order to compare the mean errors and the standard deviations of the positioning estimates.

III. RFID SYSTEM OVERVIEW

A. RFID Reader

An RFID reader transmits or reads information from RFID tags in vicinity. The system parameters, i.e., size, reading range, and the type are dependent of applications. The information communicating between an RFID tag and RFID reader is carried out through the reader's antenna using electromagnetic radio waves. Signals detected by the reader are decoded and usually saved in the middleware (Feifei Guo, 2008).

B. RFID Tag

A tag is the component used as the sensor in a wireless network. Types of RFID tags can be mainly classified into a passive tag and an active tag. The difference between them is that the active tag has its internal power source. (Feifei Guo, 2008).

As shown in Figure 1, an RFID system basically consists of four elements. The RFID tag element consists of an antenna integrated with a microchip. The RFID reader with an antenna transmit RF signals. This signal is received by the RFID tag via the tag's antenna. The computer system serves two main functions. First, it receives data from the readers and performs data processing, such as filtering. Then it serves as a device monitor, making sure the reader functions properly, securely, and with up to date instructions.

A. Radio Frequency Identification Active Tags

The only difference between an active tag and a passive tag is that an active tag has its internal power source whereas a passive one has not. This is as a result of its continuous communication with its environment, it continuously transmits its radio signals even if it receives no query from an interrogator (Feifei Guo, 2008).

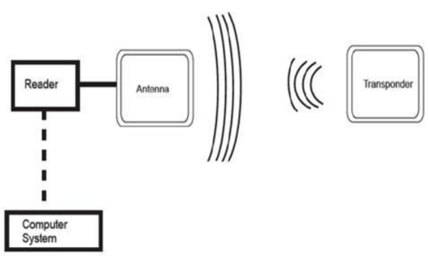

Figure 1: RFID System

IV. SYSTEM MODELING

According to the hyperbolic location theory shown in Figure 2, the reader R_A is at position A, this also can applies for the readers R_B, R_C and R_D. A tag is positioned in 3-D co-ordinate (x, y, and z). A location estimate is the intersection of all hyperbolas. *N* readers provide *N*-1 hyperboloids intersecting on a single point of the location of the tag. The readers R_A and R_B are at known locations, a tag can be located onto a hyperboloid. The readers not necessary know the absolute time of a transmission, only the time difference is required using the third reader R_C at the third location. This provides the second TDOA measurement and hence locates the tag on the second hyperboloid. The intersection of these two hyperboloids represents a curve on which the tag lies. In addition, the fourth reader R_D makes possible third TDOA measurement and the intersection of the resulting third hyperboloid with the curve already found with the other three readers defines a relevant point in the space. The tag's location is therefore determined in three dimensions (3D) as shown in Figure 2. The unknown location of the tag determined is in (x, y, z) coordinate. A multilateration algorithm comprising of four readers at known location A, B, C and D, the time of arrival (TOA) *T* of the pulses from the tag at (x, y, z) to each of the reader locations is the distance divided by the speed of light *c*. (Guowei Shen and Thom, 1994).

The corresponding TOA at each reader is given by

$$T_{\mathrm{A}} = \frac{1}{c}\sqrt{(x - x_{\mathrm{A}})^2 + (y - y_{\mathrm{A}})^2 + (z - z_{\mathrm{A}})^2}, \quad (1)$$

where T_{A} denotes the TOA value for the reader A. Similarly, the TOA values for the readers B, C, and D are T_{B}, T_{C}, and T_{D}, respectively. The multilateration technique is used to estimate the unknown target (*x, y, z*) in real time with respect to the reader *A* in the network.

$$\begin{aligned}\tau_{\mathrm{B}} &= T_{\mathrm{B}} - T_{\mathrm{A}} \\ &= \frac{1}{c}\Big(\sqrt{(x - x_{\mathrm{B}})^2 + (y - y_{\mathrm{B}})^2 + (z - z_{\mathrm{B}})^2} \\ &- \sqrt{x^2 + y^2 + z^2}\,\Big) \\ &+ measurement\ noise, \qquad (2)\end{aligned}$$

where x'_{B}, y'_{B}, z'_{B} is the coordinate of the reader B with respect to the origin located at the reader A as shown in Figure 2. Finally, the TDOA τ_{B} of the reader B is calculated. This is also applied for τ_C andτ_D.

Since the number of equations out-numbers the number of the unknowns, also that the system be a nonlinear least square minimization problem, the Levenberg-Marquardt (LM) algorithm was adopted to find an optimization solution to the systems (He and Feng, 2011).

$$S(\beta) = \sum_{i=1}^{m}\big[y_i - f\big(x_{i,}\,\beta\big)\big]^2, \quad (3)$$

where β is the parameter vector, x_{i} and y_{i} are the independent and the dependent variables, S(β) is the summation of the squares of the deviations.

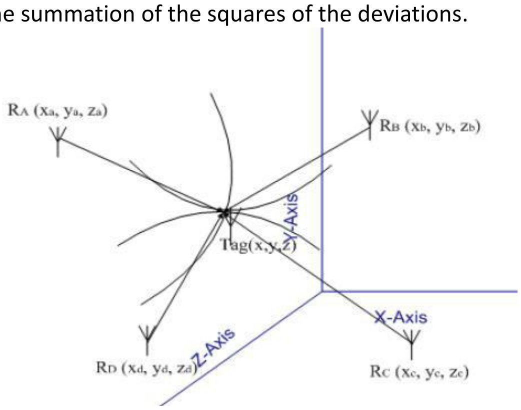

Figure 2: Hyperbolic location theory

V. SIMULATION

We consider a small room with the size of 5m X 5m X 5m for the MATLAB simulations. Seven readers and ten thousand tags are placed at random positions in order to statistically analyze the performances. Multilateration algorithm was implemented by using; TOA of signals calculated from different readers T_A in (1) likewise T_B, T_C and T_D the calculated time delay (TDOA), τ_B in (2) likewise τ_C and τ_D of paired readers. Pre defined MATLAB template used for the Levenberg-Marquardt (LM) algorithm.

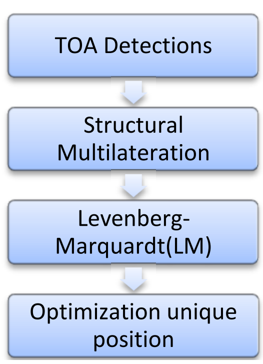

Figure 3: Block diagram of localization algorithm

The positions of the readers are given as a matrix, for an example, three reader positions are given in the matrix **xyz** in (4). Seven readers are placed in the different positions represented with the black squares shown in Figure 4.

$$xyz= \begin{bmatrix} 0 & 5 & 5 \\ 0 & 0 & 0 \\ 0 & 0 & 5 \end{bmatrix}. \qquad (4)$$

VI. RESULT AND DISCUSSION

Table 1 shows the absolute mean error of multilateration technique (Abs Mean Error_Multi(m)) and the standard deviation error of the multilateration (Standard deviation Error_Multi(m)). An example of the simulation results with some actual (blue squares) tag positions are shown in Figure 4. The estimated tag positions are represented by the green squares. Next, the number of tags is fixed to 50, and the number of readers is varied in the network. Then, the number of tags is increased up to ten thousand tags. In this case, we can see that the numerical values of both mean error and standard deviation error decrease as the number of readers increase. Figures 5 and 6 show the trends of both type of errors with the number of readers. This result gives a good hint for designing and implementing of large RFID networks.

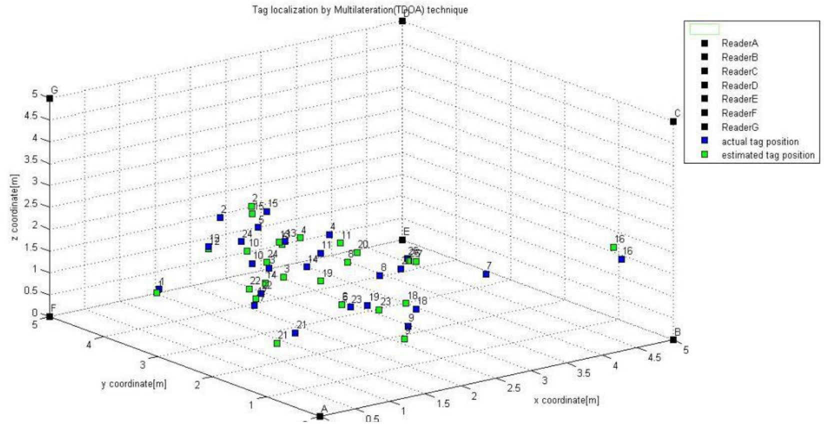

Figure 4: Simulation of the multilateration algorithm showing the actual (blue squares) and estimated (green suares) tag positions

Number of Readers	Abs Mean Error_Multi(m)	Standard deviation Error_Multi(m)
4	0.0888	0.2177
5	0.0891	0.2414
6	0.1008	0.2504
7	0.0868	0.2104
8	0.0623	0.2001
9	0.0611	0.1983
10	0.0389	0.0891

Table 1: Absolute mean error and standard deviation for the multilateration technique with different number of readers

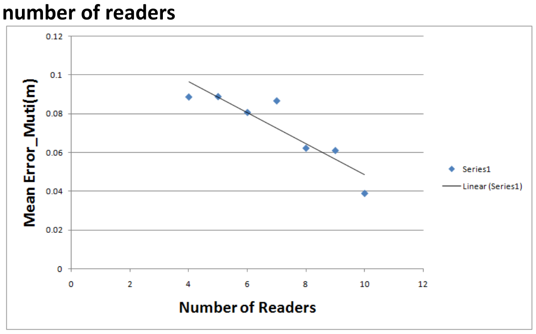

Figure 5: Absolute mean error versus the number of readers

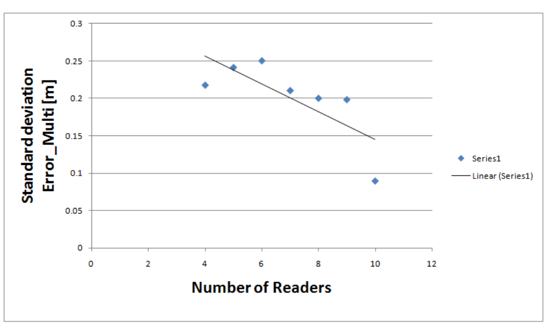

Figure 6: Standard deviation error versus the number of readers

VII. CONCLUSION

This paper aimed to improve the indoor localization estimation techniques using the RFID technology with multilateration technique. The multilateration technique provides the geometrical approach on estimating the unknown positions of points. The results showed that the multilateration technique can be applied on the position estimation. We observed that by increasing the number of readers in an RFID network the errors of the position estimates can be reduced.

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