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Indoor Localization in Wireless Sensor Networks

Farhat M. A. Zargoun[1], Nesreen I. Ziedan[1], and Ibrahim M. Henawy[2], Muamer K. Masoud[3]
[1]*Computer and systems Engineering dept., Faculty of Engineering, Zagazig University*
[2]*Faculty of computer and information, Zagazig University*
[3]*Computer science dept., Faculty of Science, Zaitoona University*

ABSTRACT: *Popularity of ubiquitous computing increases the importance of location-aware applications, which increases the need for finding location of the user. In this paper, we present a novel localization method for indoor environments using Wi-Fi infrastructure.*

While localization using Wi-Fi is cost effective, handling the obstructions which are the main cause of signal propagation error in indoor environments is a challenging task. We address this problem in two levels, resulting in increased accuracy of localization. In the first level, we "localize" the residing area of user node in coarse granularity. Then, we use building layout to find the objects that attenuate the signal between the reference node and the coarse estimate of the location of user node. Using multi-wall propagation model, we apply corrections for all obstructions and find the location of user node. Empirical results based on experiments conducted in lab-scale, shows meter-level accuracy.

I. Introduction

The definition of a localization system among sensor nodes is an important issue for many applications of wireless sensor networks (WSNs). Thus, a localization system is required in order to provide position information to the nodes. The importance of localization information arises from several factors, many of which are related only to WSNs. These factors include the identification and correlation of gathered data, node addressing, management and query of nodes localized in a determined region, evaluation of nodes' coverage, energy map generation, geographic routing, object tracking. All of these factors make localization systems a key technology for the development and operation of WSNs.

To date, a broad variety of positioning techniques has been proposed, the measurement procedures, and their consideration of application-specific requirements.

For the design and maintenance of indoor wireless services the knowledge of the signal propagation in different environments is demanded. Indoor propagation is one of the most complicated propagation topics based on the specific type of the building structure and used materials. Empirical modeling based on statistics seems to be the most efficient approach since there is no need of precise definition of the building interiors. On the other hand, such models can fail in indoor situations where more precise site-specific model should be used.

The major source of error for localization using 802.11x infrastructures in indoor environments is the obstructions that interfere with the signal propagation from the reference node to user node. The attenuation caused is dependent on the number and type of obstructions. The accuracy of the localization method can be increased if these obstructions are identified and necessary corrections are applied to the signal strength during distance estimation. But the actual number and type of obstructions between user node and the reference node depends on the exact location of user node, which is normally unknown. To overcome this problem, a two level system is proposed. The two levels in the proposed system are: Coarse level and Fine level. In Coarse level, the Locality of user node using range-free technique is computed. Then the number and type of obstructions are found using the computed Locality and knowledge of the building layout. In fine level corrections to the signal strength are applied using the obstructions found, which are then fed to range-based technique to find the location of user node.

II. Principles of RSSI ranging

Most widely used propagation model for indoor environments is log distance path loss model, which is given as:

$$RSS(d) = P_t - PL(d_0) - 10\eta \log_{10}(d / d_0)$$

µ is the path loss exponent.

The above equation is best suited for obstruction free environments but not for indoor environments where obstructions are found.

To consider the effect of obstructions on the signal strength, multi-wall propagation model is used; the generalized propagation model can then be given as:

$$RS(d) = P_t - PL(d_0) - TL(d)$$

TL(d) is represent the total transmission loss, which is consists of two components:

- Path transmission loss (PL(d))
- Loss due to obstructions (OL)

Obstruction Loss {OL) depends on the number of obstructions between the transmitter and the receiver and is sum of attenuations which is given as:

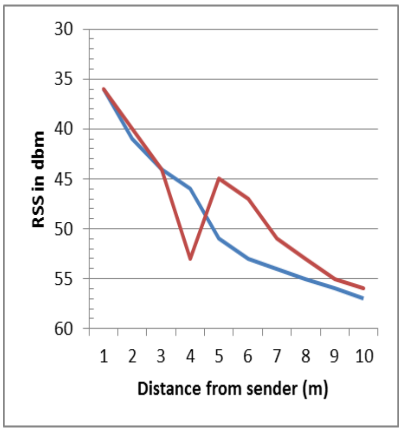
$$OL = \sum_{i=1}^{n} m_i x_i$$

m_i - number of obstructions
x_i – attenuation caused by it.
Note: OL drops to zero when LOS condition exists.
Therefore multi wall propagation model is given as:

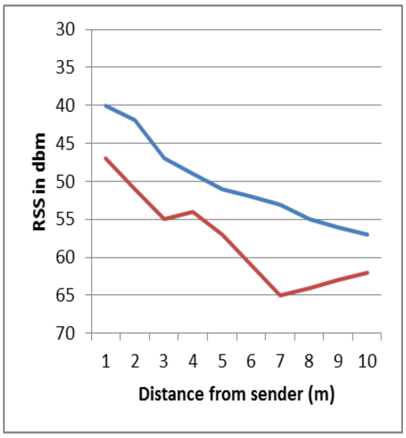
$$RSS(d) = P - PL(d_0) - 10\mu \log_{10}(d/d_0) - \sum_{i=1}^{n} m_i x_i$$

The parameter x_i for each type of obstruction was determined empirically from a series of experiments conducted under controlled conditions.

We conducted two experiments, one to show that log normal propagation model holds good when there is line of sight between sender and receiver and the second one to understand the effect of obstruction on the signal from sender to receiver.



LOS Propagation Model

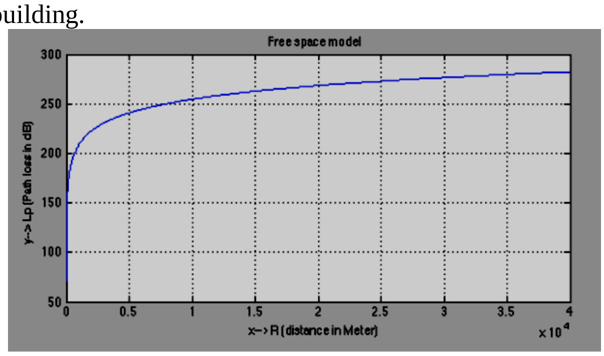


NLOS Propagation Model

The experimental setup for these two experiments is one access point and one laptop were taken, of which access point was the reference node and the laptop was user node. Xirrus Wi-Fi Inspector software was installed in user node which captured the signal strength of the broadcast messages sent by the reference node. The signal strength readings were measured at various distances from the reference node. In LOS experimental setup, Line of Sight condition exists between the reference node and user node, where as in NLOS setup, an obstruction was kept between the reference node and user node to find the attenuation loss of this obstruction.

III. System Model

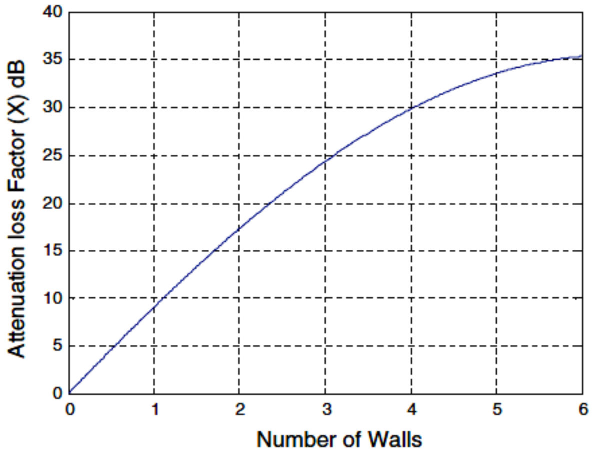
The proposed system requires the storage of the building layout and the attenuation loss of the obstructions present in the building.



Free space path loss model

Environment	Path Loss Exponent, n
Free Space	2
Urban area cellular radio	2.7 to 3.5
Shadowed urban cellular radio	3 to 5
In building line-of sight	1.6 to 1.8
Obstructed in building	4 to 6
Obstructed in factories	2 to 3

Path loss exponent, n for different environments



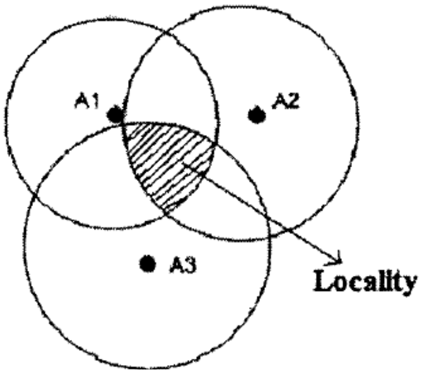
Best fit curve of the average curves of the attenuation loss factor at 2.4 GHz

Wall material	Thickness	First Wall	Second wall
Concrete	10 cm	16 dB	14 dB
Concrete	20 cm	29 dB	24 dB
Dry concrete		35 dB	29 dB
Porous concrete		34 dB	26 dB
Plywood	0.4 cm	0.9 dB	0.8 dB

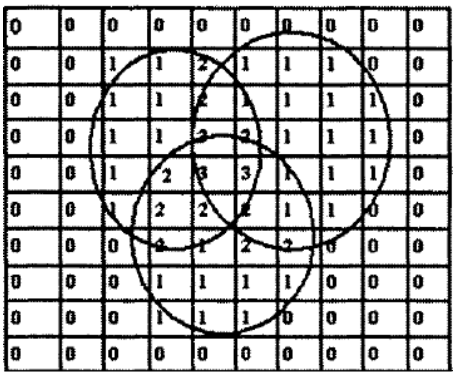
Penetration loss values for different material characteristics

IV. First level (Coarse level)

Coarse level applies range-free technique to estimate the Locality of user node. Range-free technique uses the overlapping coverage region of reference nodes to estimate the required area. The reference nodes having ID_s – ID_1 to ID_n are situated at positions (X_1 Y_1) to (X_n, Y_n) with transmission ranges R_1 to R_n respectively. These reference nodes broadcast messages periodically which contain their ID and location coordinates. User node listens for these broadcast messages for a period of time and lists the reference nodes which it is able to hear. User node can receive the broadcast messages of the reference node if and only if it is in the coverage region of the reference node, which is the circle drawn with the reference node location as the center and its transmission range as the radius. If user node is able to hear from more than one reference node, then the overlapping coverage region of all these reference nodes correspond to the Locality of user node. Here it has to be observed that the signal strength of the messages from the reference node is not being taken into consideration, so the accuracy of the returned Locality will not be affected by the attenuation error caused by the obstructions.



Intersection Approach


Cell Table

The whole operating environment is divided into cells, where each square represents one cell. Each cell is assigned an integer called cell rank which is set to zero initially for all the cells. This cell rank represents the number of reference nodes in its range. Each cell is checked for the validation of In-range property to decide if the cell is included in the transmission range of the reference node. If the cell satisfies this property, the rank of the cell is incremented by one otherwise the value remains unchanged. This process is repeated for all the reference nodes from which user node has received the broadcast messages.

The In-Range property checks whether the cell is in the coverage region of the corresponding reference node or not, which can be formulated as below:

$$P: (x_c - x_i)^2 + (y_c - y_i)^2 <= R_i^2$$

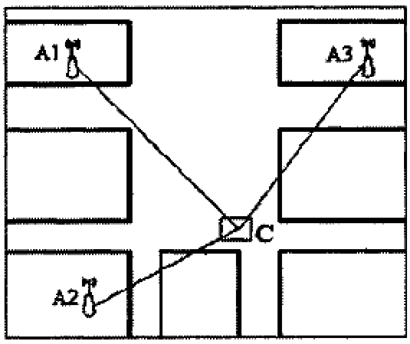
The pseudo code for Cell Ranking is as follows:
For each cell C of the building

For each reference node ID_j user node is hearing
If $((x_c - x_i)^2 + (y_c - y_i)^2 - R_i^2 \leq 0)$
Then increment cell rank by 1;

V. Second level (Fine level)

Fine level estimates the cell in which user node is residing from the set of cells obtained in coarse level. Most of the error in indoor environments is due to the attenuation caused by obstructions between the transmitter and the receiver. If the number of obstructions between the reference node and user node were known, then the distance to the reference node can be determined using the multi-wall propagation model equation by applying the correction. However, the actual number of obstructions between the reference node and user node depends on the exact location of user node then it is unknown. To circumvent this problem, for all the cells obtained in the coarse level, signal strength vector is estimated by finding the obstructions and using multi-wall propagation model equation, which is then compared with the received signal strength vector. The location of user node is defined as the center of the cell whose estimated signal strength vector best matches with the received signal strength vector.

Consider the layout plan shown in the Figure below, where reference nodes are shown as A1, A2 and A3 and square C represents one of the cells obtained from the coarse level. The obstructions between cell C and each of the reference nodes can be determined as the positions of cell, reference nodes and layout plan is known. Taking this information into consideration signal strength vector is estimated using Multi-wall propagation equation.



Building Layout

This signal strength vector is estimated for each cell obtained from the coarse level. It is of the form $S_I= (S_{I1},S_{I2},S_{I3},.. ..,S_{IK})$, for all I=1 to N, where N is number of cells obtained in coarse level and k is the number of reference nodes covering the obtained cells and S_{IJ} denotes the signal strength at cell i from the J^{th} reference node.

The received signal strength vector is represented as $R= (r_1, r_2, r_3,....,r_k)$. The Euclidean distance given in the following equation is calculated between the received signal strength vector and the estimated signal strength vector for all the cells.

$$D(S_i, R) = \sqrt{\sum_{j=1}^{k}(S_{ij} - r_j)^2}$$

The *Cell Numbe*r with minimum Euclidean distance is found as shown in the following equation, whose center is taken as the location of user node.

$$\text{Cell Number} = \min [D (S_I, R)]$$

VI. The Experiment

A series of experiments were done under controlled conditions to evaluate the performance of this work. All the experiments are conducted in two-dimensions by keeping all the reference nodes and user node at the same height.

The considered infrastructure contains four reference nodes and one user node. The reference nodes were static.

Xirrus Wi-Fi Inspector software package was installed in user node to capture the signal strength of the messages sent by the reference nodes, or you can install any another Wi-Fi inspector softwar. The building was divided into cells of size 0.9 x 0.9 m. User moved along various cells and measured both the actual position and signal strength readings from the reference nodes. The location of user node was estimated with these signal strength vectors using the proposed two-level approach. The location estimation error was calculated as the distance between the actual location and estimated location. Let (x, y) represent the actual location and (x_{est}, y_{est}) represent the estimated location. The error is given by:

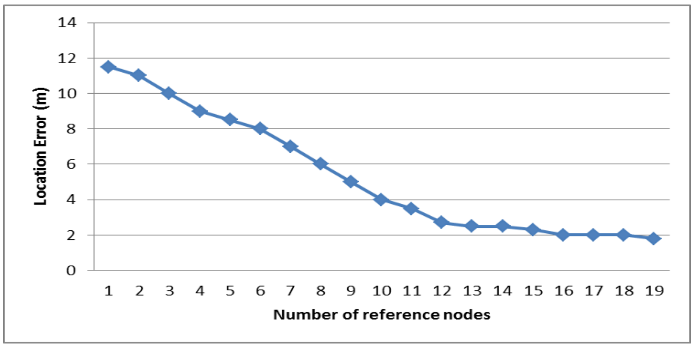
$$Error = \sqrt{(x_{est} - x)^2 + (y_{est} - y)^2}$$

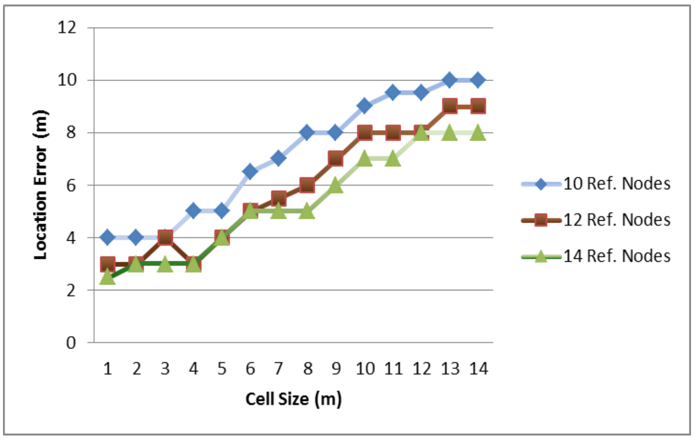
VII. Simulation Results

Simulation was done to see the effect of number of reference nodes and size of cell on location accuracy. Size of the building was taken as 60x30 m2 and parameter values of the multi-wall propagation model used are given in Table below. A random noise with δ2 =4 dB was added to the model and positions of the reference nodes and user nodes were selected inside the building.

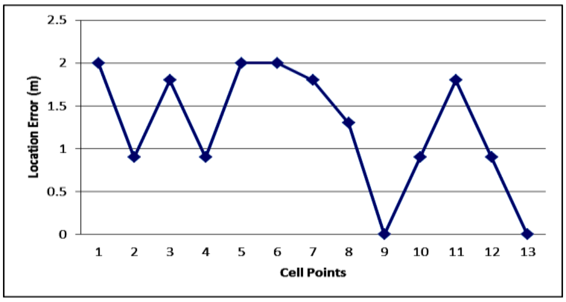
d_0	1 meter
$P_t - P_L(d_0)$	-38 dBm
µ	2.5
R	30 meter

Table: Parameter values for propagation model





The graph in Figure below shows the location error for various points. The x-axis shows various points in the building and the y-axis shows error in meters. It can be observed from this Figure that the error of the proposed technique is less than 2 meter for all the cells.



VIII. Conclusions

In this work we have proposed a technique which works in two levels using both range-free and range-based techniques in a sequence. This work uses the range-free technique to find the Locality of user node and then use multi-wall propagation model inside this Locality to find out the exact position. This work provides improved accuracy because we are using multi-wall propagation model which corrects the attenuation caused by obstructions in the building. We have shown through experiments that the error obtained is less than two meters, which is appreciable, as the exact location is estimated from the Locality identified by the coarse-level part of the This work as opposed to considering the whole operating environment.

References

[1] Nissanka B. Priyantha, Anit Chakraborty and Hari Balakrishnan, The Cricket Location-Support system, Proc. 6th ACM MOBICOM, August 2000.

[2] R. Want, A. Hopper, V. Falcao, and J. Gibbons, The active badge location system, ACM Transactions on Information Systems, vol. 10, pp. 91-102, Jan. 1992.

[3] D. Niculescu and B. Nath, Ad hoc positioning system (APS) using AoA, In Proceedings of IEEE INFOCOM 2003, pp 1734-1743, April 2003.

[4] P. Bahl and V. N. Padmanabhan, RADAR: An in-building RF-based user location and tracking system, In proceedings of the IEEE INFOCOM, pp 775-784, March 2000.

[5] Loukas Lazos and Radha Poovendran, SeRLoc: Robust Localization for Wireless Sensor Networks, ACM Transactions on Sensor Networks, Vol. 1, pp 73-100, August 2005.

[6] D. Niculescu and Badrinath, DV Based Positioning in Ad Hoc Networks, In Journal of Telecommunication Systems, 2003.

[7] T. S. Rappport, Wireless Communications - Principles and Practice, IEEE Press 1996.

[8] Tian He, Chengdu Huang, Brian M. Blum, John A. Stankovic and Tarek Abdelzaher, Range-Free Localization Schemes for Large Scale Sensor Networks, In Proceedings of MobiCom '03, September 2003.

[9] P. Enge and P. Misra, Special Issue on GPS: The Global Positioning Systems, Proceedings of the IEEE, January 1999.

[10] Najar M., Vidal J., Kalman Tracking for Mobile Location in NLOS Situations, 14th IEEE Proceedings on Personal, Indoor and Mobile Radio Communication, Volume 3, pp. 2203-2207, September 2003.

[11] Niculescu D., Positioning in Ad Hoc Sensor Networks, Communication Magazine, IEEE, Volume 43, Issue 3, pp. 116-122, March 2005.

[12] Patwari N., Location Estimation in Sensor Networks, Electrical Engineering PhD thesis, The Univerisity of Michigan, USA, 2005.

[13] H. Laitinen et al, “Experimental Evaluation of Location Methods Based on Signal-Strength Measurements,” IEEE Trans. on Vehicular Technology, vol.56, no.1, pp.287-296, Jan.2007.

[14] G. Zanca, F. Zorzi, A. Zanella, and M. Zorzi, “Experimental comparison of RSSI-based localization algorithms for indoor wireless sensor networks,” in Proc. ACM REALWSN, pp. 1-5, Apr. 2008.