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On the Impact of Reference Node Placement in Wireless Indoor Positioning Systems

Supattra Aomumpai and Chutima Prommak

Abstract**—**This paper presents a studyof the impact of reference node locations on the accuracy of the indoor positioning systems. In particular, we analyze the localization accuracy of the RSSI database mapping techniques, deploying on the IEEE 802.15.4 wireless networks. The results show that the locations of the reference nodes used in the positioning systems affect the signal propagation characteristics in the service area. Thisin turn affects the accuracy of the wireless indoor positioning system. We found that suitable location of reference nodes could reduce the positioning error upto 35 %.

Keywords**—**Indoor positioning systems, IEEE 802.15.4 wireless networks, Signal propagation characteristics

I. Introduction

Wireless sensor network technologies have developed continuously.The sensor technologieshave several advantages such as low cost, small size, and low power consumption with capabilities to measure and store data from practicalsitescorrectly. The sensors are designed toself-process and are capable to communicate by using wireless transceivers. The wireless sensor technology has been applied in many areas.One of the promising applicationsis to identify the location of objects within the building.

Localization accuracy is one of the most important performance indicators of the indoor positioning systems. Thus, in the designing of the systems the network designers should pay attention onthe efficiency of the system's location within the building. Due to the limitations of wireless sensor networks that are available, the sensor network nodes are typically resource constraintsfor instance the size of the processor, the number of the memory,and the power supply. The radius of the communication areawasalso limited. This is why it is important to consider the appropriate indoor positioning of the referencenodes in the service area.

Mostliteraturefocused on the study of techniques and systems to locate objects within the building using the IEEE 802.15.4 wireless networks.[1] studied the factors affecting the received signal strength (RSS)with Tmote Sky node for finding a wireless sensor network. [2] studied the relationship of the positioning systems in wireless sensor networks with comparison to the methods used to locate objects and how to measure RSS with how to convert from time to receive packets from reference nodes. Time of Arrival is used to calculate theCramér-Rao Bound. [3] studiedhow the systemto locate objects within the building, and estimate the distance by measuring the intensity signals strength. [4] presented the fingerprinting technique to create signal strength database and [5] developed a system where the standard hypothesis testing by measuring the RSS distribution of interest area in order to obtain the probability density function (probability density function: pdf) of the RSS in the position of the cluster-head.[6]presented some experimental results to explore different environment parameters of access point placement that impact localization error of WLAN indoor positioning system. And [7] proposed the algorithm requiring a strategic placement of nodes in each room by using new range-free solution based on simple RSSI measurements.

From the literature review, most of themwere interested in the impact of nodes placement and only studied the problem of designing networks that aim to increase the efficiency of the localization system but not consider the optimal reference nodes placement of wireless sensor network. Therefore, this paper presentsa novel approach which differs from the literature by analyzing the effect of reference nodes placement for the location accuracy inside buildings. The remainder of this paper is organized as followed. Section II presents the indoor positioning techniques. Section III presents the analysis of RSS distribution of the reference nodes in building. Section VI shows the measurement result and the analysis of the accuracy of the location of the references nodes in variousconfigurations.Finally, section V concludes the results and guidelines for research in the future.

II. Indoor Positioning Technique

Indoor Positioning techniques can be achieved in several ways.

The technique can be divided into two main categories, namely, the principles of the triangle (Trilateration) and matching the signal strength in the reference database (RSSI Database Mapping) [3,4].The trilateration techniques calculate the positions by using the intersection of the circle which is the location of the object.

There are several ways to find the radius of the circle, for example, [8] converted the signal strength at the receiving end from reference nodes,converted time to receive packets from

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reference node (Time of Arrival) [8] or converted the received signal from the node reference (Angle of Arrival).

By matching the intensity of the signal in order to locate the position of an object, the database is created.The intensity of the signal of the node reference in the area is called the finger printing.By installing four reference nodes (A, B, C, D) within the buildingas shown in Fig. 1,the positioning system determines the location of the object by matching the signal strengthreceived from the reference nodes with the signal strength in the fingerprinting database.Matching algorithm of the signal strength by the distance, namely,the Euclidian Distance [9] and Manhattan Distance [10] are used to achievethe signal strength matching.

The most common pattern classification technique is distance based technique such as the Euclidean distance between the sample of RSSI pattern and the location fingerprints. The location association with the fingerprint that has the smallest Euclidean distance (d_i) is return as the location i estimate of the location of the object:

$$d_i = \sqrt{\sum_{k=1}^{n} \left| x_k - y_k^i \right|^2} \qquad (1)$$

Where d_i denotesEuclidian distance, n denotesthe number of reference nodes, x_k denotesthe receiving signal strength from reference node k and y_k^i denotesthe receiving signal strength database from reference node k at location i

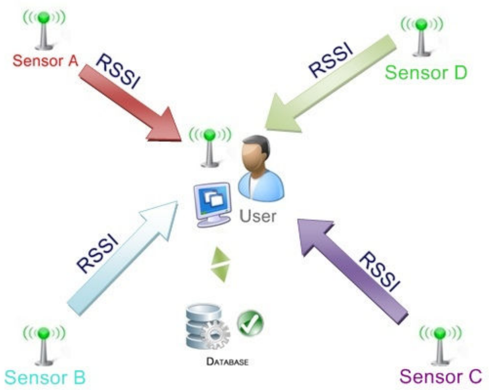


Fig. 1 The positioning system using 4 reference nodes

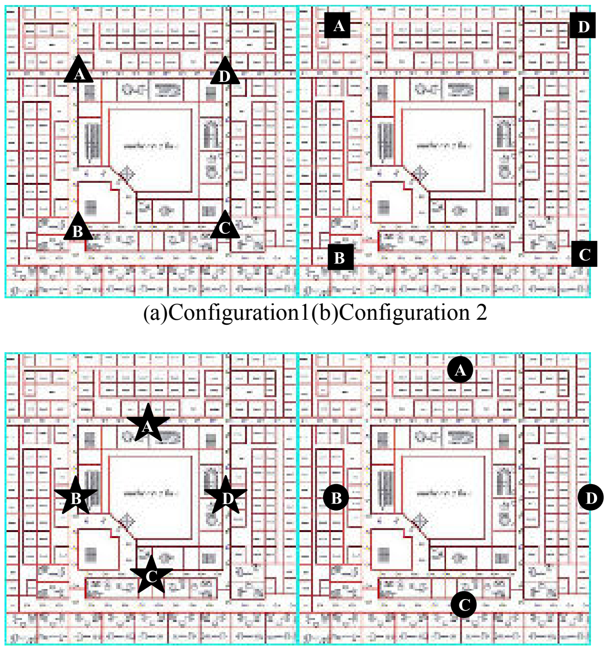
III. Experimental Setup

This paper aims to analyze the effect of positioning a reference node for the accuracy of the location in indoor positioning system of wireless sensor network. Euclidean distance is used for matching the RSSI in the reference database which was created to store the signal intensity at different positions (Finger printing). In this paper, the building with 70 mx80 mand 4 and 8 reference nodeswhich are A, B, C, D and A, B, C, D, E, F, G, H, andeightdifferentconfigurations, as shown in Fig. 2 and 3 are used.

We obtained the RSSI database (Finger printing) from the measurement within the area of the experimental setup. In the experiment, total of 152 pointsof signal test points with grid spacing of4 m, and the RSS values at various points with 10 times of measurement are applied, then the graphical results of the distribution of RSS from each reference nodes placement formsare shown in Fig. 4-11.

Considering the pattern of four reference nodes placementas shown infig.2,the location of reference nodes inconfiguration 1gives the distribution of RSS (fig. 4) in the range of -30 dBm to -100 dBmwhich rather proper than any other configuration. The distribution of RSS of each reference nodes is symmetric.Similarly in fig. 5, the distribution of the RSS of the node in configuration 2 ranges from -50 dBm to -100 dBm. It can be seen that the RSS values of each reference nodes yields different characteristics. Configuration3 (fig. 6) shows the distribution of RSS in the range -30 dBm to -100 dBm. It can be seen that the RSS measurement from four reference nodes gives the maximum at about -80 dBm, and fig. 7 shows the distribution of RSS of the node in configuration 4that distribution of RSS is in the range of-60 dBm to -100 dBm. It can be seen that value of RSS measurement from each reference nodes is less than other configurations.

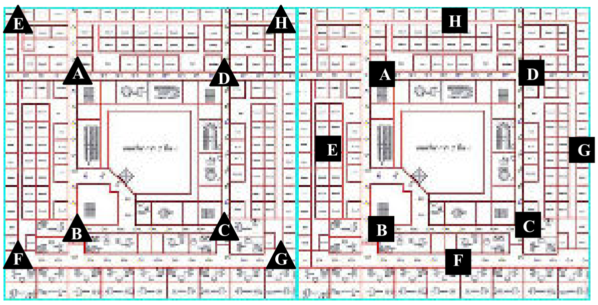
Considering the 8-reference nodes from the fig. 3, it's can be seen that the location of reference nodes in configuration 5 gives the distribution of RSS (fig. 8) in the range of -30 dBm to -110 dBm whose RSS is stronger than that of the other formats (configuration 6, 7, 8),shown in fig. 9, 10, 11. Moreover, the RSS distribution of each reference node in configuration 5 issymmetric.



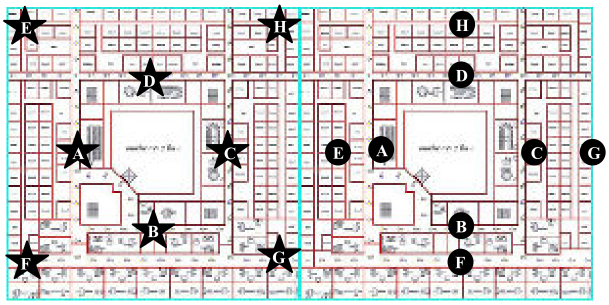
(a)Configuration1(b)Configuration 2

(c)Configuration3 (d)Configuration4

Fig. 2 Locations offour reference nodes



(a) Configuration5(b) Configuration6



(c) Configuration7 (d) Configuration8

Fig. 3 Locations ofeight reference nodes

IV. Experimental Results and Analysis

In our experiments, wemeasured the RSS values for each configuration of reference nodes as discussed in Section III. The average values of RSSI are recorded in the finger-printing database. This database is used to determine the location of the object by matchingthe RSS that the object receives from the reference nodeswith the RSS value in the database and computing the Euclidean distance. In the experiments,the accuracy of the locationswasanalyzed and compared among different configurations of the reference nodes placement. We conducted the test to determine ten locations of objects as shown in fig. 12.

Table I shows the error from the location determination. When using fourreference nodes, we can see that the configuration 1yields the highest accuracy. The margin of minimum error is 0 m., average error is 3.75 m., maximum error is 9 m. and the standard deviation is about 2.46 m.In case of using eight reference nodes, the configuration 5 yields the highest accuracy; the average errors is 3.47 m., the maximum error is 7.5 m., and the standard deviation is about 2.33 m.We can see that as the number of reference nodes increases the location accuracy improves.The results show that the suitable location of reference nodes could reduce the positioning error up to 35 %.

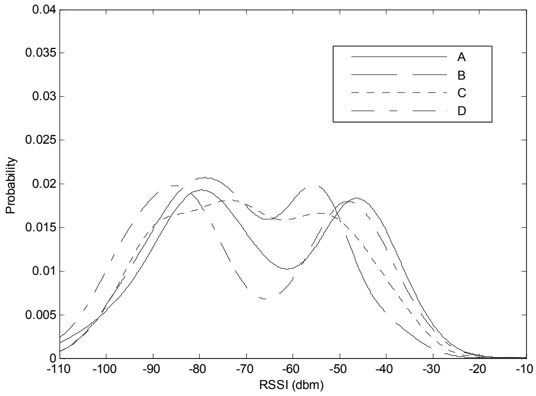


Fig. 4 Distributions of RSSI in configuration 1

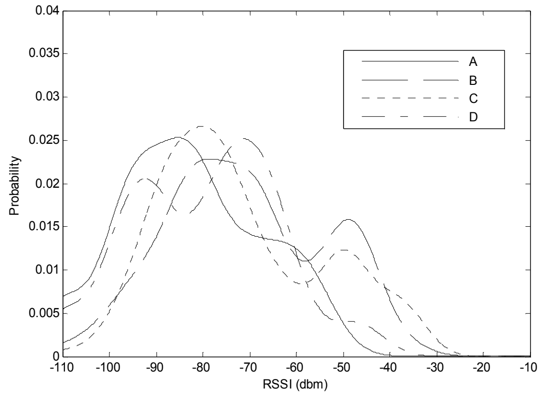


Fig. 5 Distributions of RSSI in configuration 2

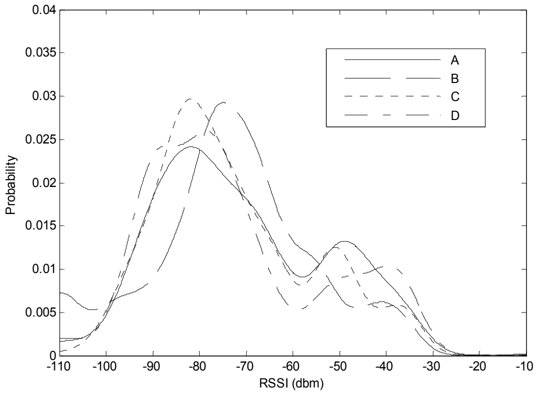


Fig. 6 Distributions of RSSI in configuration 3

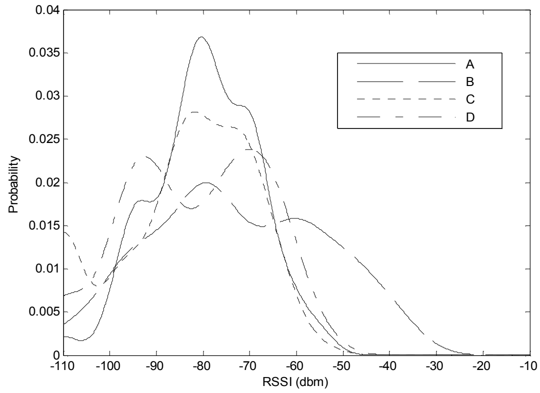


Fig. 7 Distributions of RSSI in configuration 4

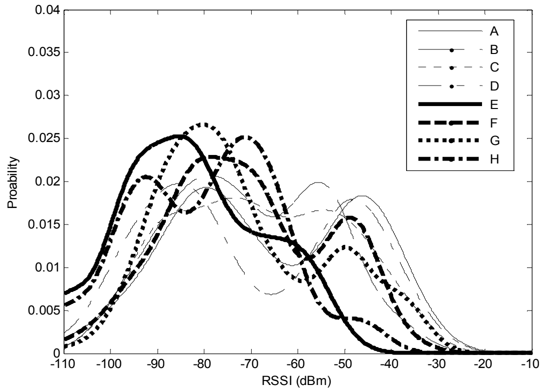


Fig. 8 Distributions of RSSI in configuration 5

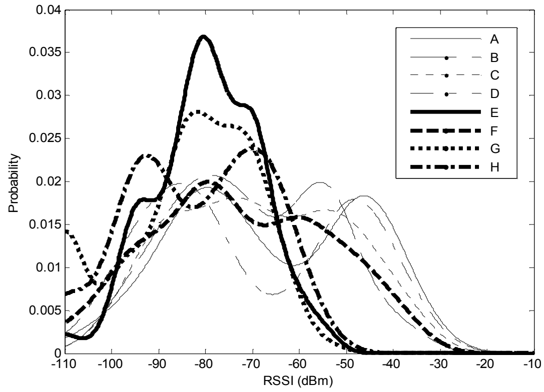


Fig. 9 Distributions of RSSI in configuration 6

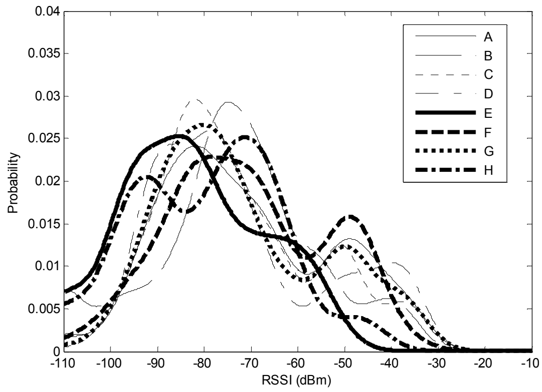


Fig. 10 Distributions of RSSI in configuration 7

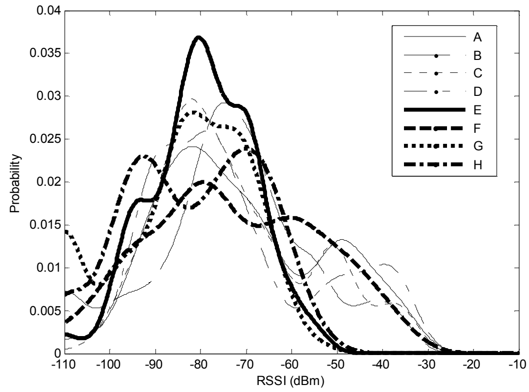


Fig. 11 Distributions of RSSI in configuration 8

In fig. 12, the actual locations of the objects and the estimated locations are compared. It is the results from using the reference node placement in configuration 5 (fig.3 a)

In order to evaluate the RSSI distribution proposed in Section 3, The reference nodes placement on the configuration 5 (Fig. 3 (a)) that is the distribution of RSS from the each reference nodes (A, B, C, D, E, F, G, H) gives a symmetry which is similar to the distribution of RSS in Fig. 8 while comparing to distribution of RSS from using four and eight reference nodes(fig. 4-7 and fig. 9-11). The node placement referring to the symmetry of RSS distribution as shown in configuration 5 increases the accuracy and reduces location errors of the objects which optimize by the technique of matching the RSSI.

TABLE I
COMPARE THE ACCURACY OF LOCATION

Reference node placement	Error (meter)			
	Min	Mean	Max	SD
Configuration1	0	3.75	9	2.460
Configuration 2	1	9.80	27	8.506
Configuration 3	2	5.80	16	4.570
Configuration 4	0	6.10	18	5.310
Configuration 5	0	3.47	7.5	2.333
Configuration 6	0	5.20	18	4.969
Configuration 7	2	4.15	11.5	3.090
Configuration 8	0	5.00	10	3.612

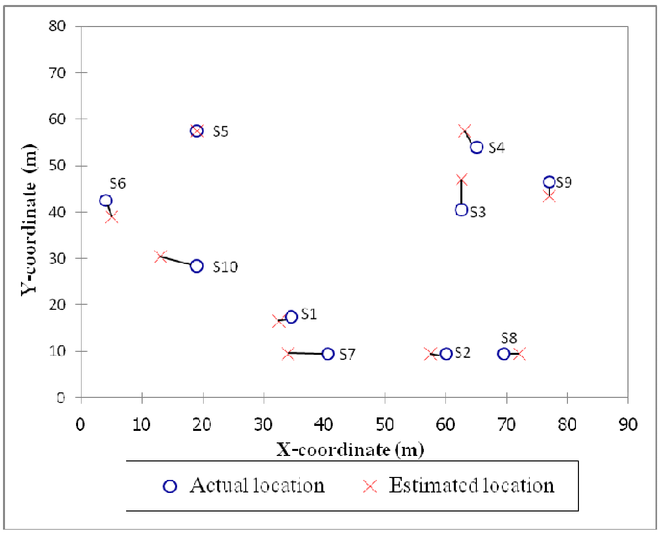


Fig. 12 Position estimation error

V. CONCLUSION

In this paper, we analyzed the effect of the placement of a reference node on the accuracy of the indoor positioning systems using the IEEE 802.15.4 wireless sensor networks. The Euclidean distance technique was used in matching the RSSI with the database that is created to store the signal strength at different positions (fingerprinting). The results showed that the location and the number of reference nodes affect the localization accuracy. We also found that placing the reference nodes at the intersection of corridors within the building could reduce the positioning error up to 35 % compared with others locations of reference nodes. Our ongoing work investigates the optimal placement of reference nodes for the wireless indoor positioning systems.

REFERENCES

[1] T.Stoyanova, F.Kerasiotis, A.Prayati and G. Papadopoulos, “Evaluation of Impact Factors on RSS Accuracy for Localization and Tracking Applications in Sensor Networks,” *Telecommunication System,* July 2009, pp. 235–248.

[2] N. Patwari, A.O. Hero, M. Perkins,N. S. Correal and R. J. O’Dea, “Relative Location Estimation in Wireless Sensor Networks,” *IEEE Transactions on Signal Processing,* vol. 51, August 2003, pp. 2137-2148.

[3] M. Sugano, T. Kawazoe, Y. Ohta and M. Murata, “Indoor Localization System Using RSSI Measurement of Wireless Sensor Network Based on ZigBee Standard,”*International Conference on Wireless Network and Emerging Technologies,* July 2006, pp. 1-6.

[4] Q. Yao, F. Wang, Fellow, H. Gao, K. Wang andH.Zhao,“Location Estimation in ZigBee Network Based on Fingerprinting,” *IEEE International Conference on Vehicular Electronics and Safety,* December 2007.

[5] Paschalidis, I. Ch. and D. Guo, “Robust and Distributed Stochastic Localization in Sensor Networks: Theory and Experimental Results,” *ACM Transactions on Sensor Networks,* vol. 5, No. 4, November 2009, pp. 1-22.

[6] O.Baala, Y. Zheng and A.Caminada, “The Impact of AP Placement in WLAN-Based Indoor Positioning System,”*International Conference on Networks,* 2009, pp. 12-17.

[7] Olga E. Segou, Stelios A. Mitilineos, Stelios C.A. Thomopoulos, “DALE: A Range-Free, Adaptive Indoor Localization Method Enhanced by Limited Fingerprinting”, *International Conference on Indoor Positioning and Indoor Navigation,*September 2010.

[8] M. Baunach, R. Kolla and C. Muhlberger, “Beyond Theory: Development of a Real World Localization Application as Low Power WSN,” *IEEE Conference on Local Computer Networks,*October 2007, pp. 872-897.

[9] U. Grossmann, M. Schauch and S. Hakobyan, “RSSI Based WLAN Indoor Positioning with Personal Digital Assistants,”*IEEE Workshop on Intelligent Data Acquisition and Advanced Computing Systems: Technology and Applications,* September 2007, pp.653-656.

[10] W.Y. Chiu and B.S. Chen, “Mobile positioning problem in Manhattan-like Urban Areas: Uniqueness of Solution, Optimal Deployment of BSs, and Fuzzy Implementation,” *IEEE Transactions on Signal Processing,* vol. 57, December 2009, pp. 4918 - 4929.

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