Available online at www.sciencedirect.com

ScienceDirect

Procedia Computer Science 98 (2016) 16 – 23

Procedia Computer Science

The 7th International Conference on Emerging Ubiquitous Systems and Pervasive Networks (EUSPN 2016)

Comparative Study of Fingerprint and Centroid Localization Protocol Using COOJA

Essa Q. Shahra*, Tarek R. Sheltami, Elhadi M. Shakshuki

{g201302670,tarek}@kfupm.edu.sa, King Fahd University of Petroleum and Minerals, Dhaharan, Saudi Arabia
elhadi.shakshuki@acadiau.ca, Aacadia University, Nova Scotia, Canada

Abstract

Sensor networks are in a numerous number of applications. However, implementing wireless sensor networks present new challenges compared with theoretical networks. Cooja is the Contiki network simulator. It allows large and small networks of Contiki motes to be simulated; moreover, motes can be emulated at the hardware level. In this paper, we evaluate the accuracy performance of two very well-known localization protocols, namely: fingerprint and centroid protocols using Tmote sky in Cooja. It is worth mentioning that this the first time this study is conducted in Cooja. The results conform to the theory that fingerprint protocol has a better performance than centroid in terms of accuracy when accuracy is quantified.

Peer-review under responsibility of the Program Chairs

Keywords: COOJA; Fingerprint; Centroid; Wireless sensor network; Localization

* Corresponding author. Tel.: +966-13-860-4678; fax:+966-13-860-3059
E-mail address: g201302670@kfupm.edu.sa

Peer-review under responsibility of the Program Chairs
doi:10.1016/j.procs.2016.09.006

1. Introduction

Wireless Sensor Network (WSN) has turned into an essential research need, because of their extensive applications including civil, manufacturing, farming, and military [1]. A sensor network comprises of sensor devices, which are small in size, inexpensive, and short transmission range. Generally, a sensor device includes four fundamental parts (processing, sensing, transmission, and power) [2,3].

Researchers have concentrated on various parts of WSN that includes equipment outline, routing, protection, and localization [4]. One of the basic viewpoints, which should be taken into account is localizing mobile node through deploying sensor networks. Node localization is the issue of finding the physical position of a mobile node (the node with obscure position); depends on other reference nodes (nodes with predefine locations) [5,6].

Numerous localization methods have been recommended to provide location data of nodes. The localization protocols are classified based on different aspects to estimation location, range-free and range-based, centralized and decentralized (distributed) [7]. In range-based approach, nodes decide their position taking into account angle or distance calculation to some anchor nodes with well-known positions. These estimations may be obtained using different methodologies such as Receive Signal Strength Indicator (RSSI) [8], Time of Arrival (TOA) [9], Time Difference of Arrival (TDOA) [10], and the Angle of Arrival (AOA) [11]. There are two fundamental types of range-free localization protocols that are recommended for sensor networks: (1) local strategies that depend on a high thickness of points of interest so that each sensor node can hear a few historic points, this represents by centroid algorithm and (2) hop based strategies that depend on flooding the connectivity information in the network such as hop count and the rang-free algorithms include Centroid and DV-hop [12].

One of the well-understood localization methodologies is the Receive Signal Strength (RSS). RSS-based localization systems are one of the most well-known and cheap methods and are progressively acknowledged as a localizing solution for positioning mobile nodes in both indoor and outdoor environments. RSS-based localization frameworks operate by transforming the Signal Strength (SS) to a transmitter-beneficiary utilizing separate distance estimations. In any case, walls and obstacles that may reflect and spread the signal can influence RSS value. Therefore, this manner offers a non-straight change between the RSS values and the distance. Because of the previously stated impediments, conveying RSS-based localization technique in indoor situations turns into a convoluted task, which is hard to designer who utilizing established numerical models. The RSS data can be utilized to assess the distance between the transmitter and the recipient using two methods. In the first method, the signal proliferation model transforms SS to distance estimation, utilizing past information about the reference point nodes' location, and sends a geometry strategy to process the location of mobile nodes. This is called a triangulation localization strategy [13].

The second approach depends on the conduct of signal engendering and data about the geometry of the working to convert RSS values into distance values. This approach is known as a fingerprinting localization strategy. Fingerprinting frameworks require just the accumulation of RSS qualities at a few locations to construct a database of location fingerprints.

The fingerprinting-based localization framework is usually divided into two principle stages: 1) Offline stage: this stage incorporates measuring the area of a portable focus in a few arranges and putting away the gathered RSS values at every point with the compared area in a database document; and 2) Online stage: the versatile target gathers a few RSS values from various guide nodes in its reach and sends the information to a server which applies a situating calculation to evaluate the versatile target's area [14].

The focus of this paper is to study two different protocols of indoor localization algorithms, namely: Fingerprint and Centroid protocols for both range-free and range-based localization protocols to compare the accuracy of each. The rest of the paper is organized as follows: section 2 explores the fingerprint localization approach. Section 3 discusses the centroid localization approach. Section 4 discusses the simulation results by COOJA simulator. Finally, section 5 provides the conclusion.

2. Fingerprint Localization Approach

A fingerprinting based localization approach is introduced in this section keeping in mind the end goal is to reduce the localization error accomplished in the trilateration based methodologies. Location fingerprinting strategies are the most encouraging arrangement because of their minimal effort and high exactness regarding localization [15]. Nevertheless, fingerprinting strategies require the accumulation of a substantial number of reference points in the tracking range to accomplish sensible localization precision. There are two fundamental difficulties to build up a fingerprinting framework. Firstly, there is an issue of gathering the RSS values and putting away them in the Data Base (DB), as this procedure requires a drawn out stretch of time when the localization study area is large. Furthermore, seeking strategy through the values stored in DB to figure the location is troublesome. In this section, a fingerprinting based localization methodology is proposed. This method diminishes the aggregate number of reference nodes, which needs to gather the offline stage while accomplishing low localization error of somewhere between 1 and 3.5 m.

The indoor fingerprinting can be incorporated into three principle stages: the creation of the fingerprint database, the feature identification stage, and the estimation stage. The initial two stages are executed in offline phase while the third one is performed in online phase.

2.1 Fingerprint DB Creation Stage

This phase starts by dividing the study area into grid points, and each grid point has its own coordinate P= (X, Y). This phase involves two steps:

- For each grid collected point, the RSS values from the three beacons $\{b_1 , b_2 , b_3 \}$ in its transmission range and store them in DB.
- Determine the number off grid points for each sub-area and the range of each sub-area based on RSS values.

In the first step, manually, the mobile target goes through the grid points one by one and collects the RSS values from the beacons. A vector of RSS can be created at each grid point as: (rss_{b1}), (rss_{b2}), (rss_{b3}). All of these vectors are collected to build the DB. The second step aims to determine the number of grid points for each subarea. The reasons of knowing the range of each sub-area can be described in the following three reasons. Firstly, any changes in the network topology can be recovered by the RSS for the same grid points in the same sub-area. Secondly, by knowing the number of grids points in each sub-area the search space is reduced and enhanced. The RSS values are stored in DB as shown in Table 1.

Table 1. Fingerprint DB

GridNo.	Coordinates		RSS From	RSS From	RSS From	Sub-area Identifier
	X	Y	B_i	B_j	B_k	
1	x_1	y_1	rss_{i1}	rss_{j1}	rss_{k1}	A1
. . .	. . .	. . .	. . .	. . .	. . .	. . .
N	x_n	y_n	rss_{in}	rss_{jn}	rss_{kn}	An

2.2 Dividing Stage

In this stage, a group of beacon ID address is used as an identifier for each sub-area. Three beacons IDs can determine each sub-area. Assume that the first sub-area is represented by Ac, and its identifier beacons are (B_1,B_2,B_3), so all RSS values that are received from these three beacons belong to sub-area A_c and each sub-area has its own range of RSS, for example sub-area A_c has the range from 1 to 30. This range is used by mobile node in the estimation phase to get the nearest three grid points for each mobile from fingerprint DB.

2.3 Estimation Stage

In this stage, the location of a mobile node is calculated. This stage contains involves the following two steps:

- Determine the sub-area A_c where the mobile target is in; rely on the sub-area identifier used in previous stage.
- Find the nearest three grid-points to the target point depend on the RSS values readings from the beacons in the same sub-area.

In the first step, to compute the location of a mobile node, a mobile start measures the RSS values to all the beacons (B_i, B_j, B_k) in its transmission range. The ID address of the received beacons is used as an identifier to determine in which sub-area the mobile target is founded. In the second step, to be more exact to locate the mobile node in sub-area, it necessary to find the nearest three points to mobile by comparing the mobile RSS values with RSS values stored in DB for the same sub-area. This can be achieved by isolating the RSS values of each beacon in the same sub-area to two vectors V_{max} and V_{min}. The first vector includes all RSS values greater than the RSS value of mobile, and second vector includes all RSS values that are less than mobile RSS value. Select the small RSS value from V_{max} and the largest RSS value from V_{min} . Then, calculate the difference between these two values and mobile value to get the nearest one. This process is repeated for all three beacons in the sub-area. The three nearest points to mobile target is centroid to get the position of the mobile node.

3. Centroid Localization Approach

Centroid localization depends on a great thickness of references so that each mobile node can get notification from a few beacons. Depending on the round radio propagation presumption, every mobile node computes its location by determining the center of the position of all anchor nodes it hears. The primary point of interest of the centroid localization methodology is no requirement for any coordination between references nodes. This methodology offers reasonable localization precision. The algorithm implementation includes two stages. In the first stage, all anchors send their position B_j(x, y) (j = 1,…, n) to all mobile sensor nodes inside of their transmission area. In the second stage, all mobile sensor nodes compute their own location M (x, y) by getting the average for the coordinates of all *n* locations of the anchors in range, using Equation 1.

$$M(X, Y) = \frac{1}{n}\sum_{j=1}^{n} B_j(X, Y) \qquad (1)$$

Where, M (X ,Y): is the coordination of the Mobile target, *n* is the total number of beacons in the transmission area of mobile, and B (X, Y) is the coordination of the beacon nodes.

4. Simulation Results

4.1. The Simulation Platform

COOJA is a new sensor network simulator for the Contiki OS. The Contiki OS is a portable OS design for restricted resource devices, for example, sensor node. It is constructed around even driven kernel; however, it supporting multi-threading. Likewise, it supports full TCP/IP stack by means of uIP and programming protothreads. The principle outlined objective of COOJA is extendibility for which interface and plug-ins are utilized. Where interface represents the devices or mote, while the plug-in is used to interact with the simulator such as to control the speed of simulation or watch network traffic between nodes.

The sensor devices are utilized, as a part of our work is the Tmote sky. Tmote Sky is wire sensor module that has numerous capabilities to offer like high information rate sensor system applications requiring ultra-low power. Some different components to pay special mind are high unwavering quality and simplicity of advancement. It is generally demonstrated stage for remote sensor frameworks organizations.

Fig.1. TmoteSky

4.2. Fingerprint Simulation Results

The network deployment area is 40 × 20 meters and the number of nodes is 15. There are 5 anchor devices and 10 unknown devices and the unknown devices can be tested in many points inside the study area. The percentage of the beacon is 33%, and the wireless communication range is 30 meters. The study area is divided into three sub-areas; each has its own identifier and numbers of grid points. The total number of grid points is 30 and it covers the total study area. We start by collecting the RSS values of grid points and store them in DB during offline stage. To analyze the processes of localization in Fingerprint system, the COOJA simulator interface is shown in Figure 2.

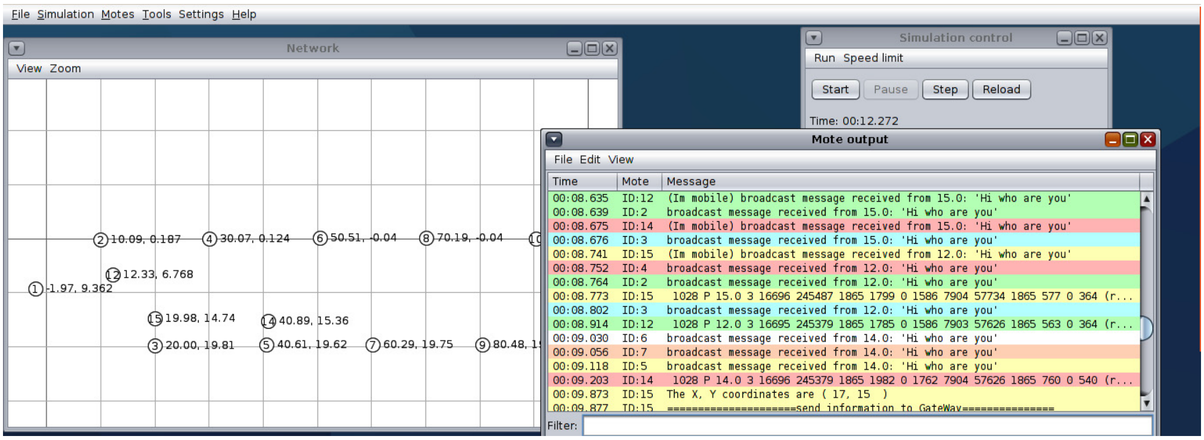

Fig.2. Fingerprint localization system

During our experiments, the processing steps started by sending a broadcast HELLO message from mobile to all anchor nodes in its transmission range, then the mobile node receives the responses from the anchors and measure the RSS values for all beacons. After that, the identifier of the sub-area in which the mobile is found is determined. Then, all RSS values of grid points in that sub-area are compared with RSS values measured between the mobile node and the beacons to select the nearest three grid point to mobile node. Finally, the location of the mobile target is computed depending on the locations of the selected three grids points and sends it to the Gateway.

The above localization system is evaluated by analyzing the error of the calculated location. To grasp the accuracy of this system, we computed the location error between the exact coordination of mobile node and the estimated location using Equation 2:

$$\boldsymbol{Error} = \sqrt{(\boldsymbol{X_{exact}} - \boldsymbol{X_{estimated}})^2 + (\boldsymbol{Y_{exact}} - \boldsymbol{Y_{estimated}})^2} \qquad (2)$$

Table 2 provides the results of the fingerprint localization system. It contains the node ID, exact coordination of all unknown nodes and the estimated coordination of unknown nodes computed by fingerprint localization system. The table shows that fingerprint localization gets the accuracy ranging from 2 meters for the best case and 3.162 meters for the worst case. The average error is 2.422 meters. This means that the accuracy is excellent and accepted by applications that need a high accuracy.

Table 2. Fingerprint Localization Accuracy

	Exact Coordination		Estimated Coordination		Error (m)
Node ID	X	Y	X	Y	
1	19	14	17	15	2.236
2	12	6	15	5	3.162
3	40	15	42	13	2.828
4	27	10	27	8	2
5	39	3	39	2	2
6	43	10	41	10	2
7	31	10	29	9	2.236
8	23	7	20	8	3.162
9	15	16	17	15	2.236
10	44	3	45	5	2.236
AVG					2.422

4.3. Centroid Simulation Results

The network deployment area is 90 × 17 meters and the number of nodes is 20. There are 8 anchor devices and 12 unknown devices. The percentage of the beacon is 40%, and the wireless communication range is 28 meters. We are able to perform and test our experiments in many different locations for unknown nodes in this area. The deployment of nodes for the localization systems is shown in Figure 3

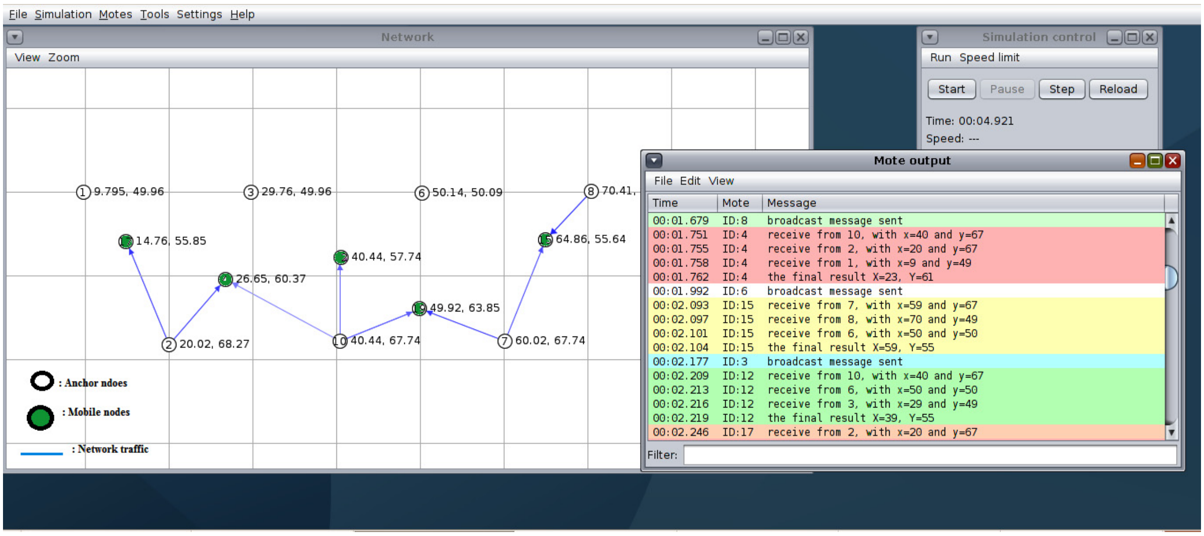

Fig. 3. Centroid localization system

By running COOJA simulator, the steps of this system are demonstrated. First, the beacons send their location information in their transmission area. Second, the unknown mobile receives the beacons' information of the first three beacons and then calculates its position, as shown in the Figure 3. Nodes with IDs 4, 15 and 12 have the coordination of (33, 52), (58, 55) and (39, 55) respectively.

To evaluate this localization system, the location error between the exact locations and estimated locations are computed by centroid localization, using Equation 2.

Table 3. Centroid Localization Accuracy

	Exact Coordination		Estimated Coordination		
Node ID	X	Y	X	Y	Error (m)
1	14.76	55	19	55	4.24
2	26.65	60.37	23	61	3.7039708
3	40.44	57.74	39	55	3.0953514
4	49.92	63.83	49	61	2.9757856
5	64.81	55.64	59	55	5.8451433
6	21.18	59.85	19	55	5.3174148
7	25.49	65.64	29	61	5.8180495
8	38.65	60.37	39	55	5.3813939
9	51.18	58.48	49	61	3.3320864
10	60.65	60.22	59	55	5.4745685
AVG					4.518

Table 3 shows the results and a summary of location errors for the Centroid localization system. Table 3 contains the node ID, exact coordination of all unknown nodes and the estimated coordination of unknown nodes that are computed by centroid localization system. Base on the achieved results, the centroid localization accuracy ranging from 2.975785 meters in the best case to 5.8180495 meters in the worst case. Other values are in the range of 3 to 5 meters. The average error is 4.518 meters. The accuracy should be accepted by less number of applications than that of fingerprint localization system method. Also, the results showed that all unknown nodes located in the same block that are covered by the same three anchors get the same location. This is because the average value of the three anchors has the same value.

5. Conclusion

A performance evaluation in terms of accuracy between fingerprint and centroid localization protocols has been conducted. Cooja simulator is used. The anchor nodes were arranged in triangle topology and every moving target was in the range of at least three anchors. The results showed that the fingerprint localization gets the accuracy ranging between 2 and 3.162 meters and the average error is 2.422 meters. On the other hand, centroid localization gets the accuracy ranging between 2.976 to 5.818 meters and the average error is 4.518 meters. The study is conducted using TmoteSky; however, other motes such as Zolertia and MICAz could also be used. In our future work, we intend to measure the power performance with different types of motes. We also plan to use and test different localization protocols.

Acknowledgements

The authors would also like to thank King Fahd University of Petroleum & Minerals and Acadia University for their support.

References

1. Son, Byungrak, Yong-sork Her, and Jung-Gyu Kim. "A design and implementation of forest-fires surveillance system based on wireless sensor networks for South Korea mountains." International Journal of Computer Science and Network Security (IJCSNS) 6, no. 9 (2006): 124-130.2.
2. Hamdi, Mohamed, Noureddine Boudriga, and Mohammad S. Obaidat. "WHOMoVeS: An optimized broadband sensor network for military vehicle tracking." International Journal of Communication Systems 21, no. 3 (2008): 277-300.
3. Antoine-Santoni, Thierry, Jean-François Santucci, Emmanuelle De Gentili, Xavier Silvani, and Frederic Morandini. "Performance of a protected wireless sensor network in a fire. Analysis of fire spread and data transmission." Sensors 9, no. 8 (2009): 5878-5893.
4. Taleb, Anas Abu, Dhiraj K. Pradhan, and Taskin Kocak. "A technique to identify and substitute faulty nodes in wireless sensor networks." In Sensor Technologies and Applications, 2009. SENSORCOMM'09. Third International Conference on, pp. 346-351. IEEE, 2009.
5. Alhmiedat, Tareq Ali, and Shuang-Hua Yang. "Tracking multiple mobile targets based on the ZigBee standard." (2009).
6. Abusaimeh, Hesham, and Shuang-Hua Yang. "Reducing the transmission and reception powers in the AODV." In Networking, Sensing and Control, 2009. ICNSC'09. International Conference on, pp. 60-65. IEEE, 2009.
7. Shen, Xingfa, Zhi Wang, Peng Jiang, Ruizhong Lin, and Youxian Sun. "Connectivity and RSSI based localization scheme for wireless sensor networks." In International Conference on Intelligent Computing, pp. 578-587. Springer Berlin Heidelberg, 2005.
8. Honma, Naoki, Kazuki Ishii, Yoshitaka Tsunekawa, Hiroto Minamizawa, and Atsushi Miura. "DOD-based localization technique using RSSI of indoor beacons." In 2015 International Symposium on Antennas and Propagation (ISAP), pp. 1-2. IEEE, 2015.
9. Zhang, Heng, Chee Kiat Seow, and Soon Yim Tan. "Virtual reference device-based narrowband TOA localization using LOS and NLOS path." In 2016 IEEE/ION Position, Location and Navigation Symposium (PLANS), pp. 225-231. IEEE, 2016.
10. Schmitz, Johannes, Manuel Hernández, and Rudolf Mathar. "Real-time indoor localization with TDOA and distributed software defined radio: demonstration abstract." In Proceedings of the 15th International Conference on Information Processing in Sensor Networks, pp. 1-2. IEEE Press, 2016.
11. Kułakowski, Paweł, Javier Vales-Alonso, Esteban Egea-López, Wiesław Ludwin, and Joan García-Haro. "Angle-of-arrival localization based on antenna arrays for wireless sensor networks." Computers & Electrical Engineering 36, no. 6 (2010): 1181-1186.
12. Feng, Wen-Jiang, Xiao-Wei Bi, and Rong Jiang. "A novel adaptive cooperative location algorithm for wireless sensor networks." International journal of Automation and computing 9, no. 5 (2012): 539-544.
13. Smailagic, Asim, Jason Small, and Daniel P. Siewiorek. "Determining user location for context aware computing through the use of a wireless LAN infrastructure." Institute for Complex Engineered Systems Carnegie Mellon University, Pittsburgh, PA 15213 (2000).
14. Cheng, Bing Hwa, Ralph E. Hudson, Flavio Lorenzelli, Lieven Vandenberghe, and Kung Yao. "Distributed gauss-newton method for node loclaization in wireless sensor networks." In IEEE 6th Workshop on Signal Processing Advances in Wireless Communications, 2005, pp. 915-919. IEEE, 2005.
15. Gogolak, Laslo, Silvester Pletl, and Dragan Kukolj. "Indoor fingerprint localization in WSN environment based on neural network." IEEE 9th International Symposium on Intelligent Systems and Informatics, pp. 293-296, 2011.