Node Position Estimation for Efficient Coverage Hole-Detection in Wireless Sensor Network

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Abstract. In recent times, Wireless Sensor Networks (WSNs) have active involvement in diverse applications such as: environment monitoring, security & surveillance, health care, precision agriculture, industrial applications and many more. Generally, sensor nodes are deployed randomly in such applications. Therefore, estimation of node location is a legitimate problem in WSNs, due to the fact that uncovered region can result in coverage-holes in the network. One state-of-art solution of this problem is Global Positioning System (GPS) but GPS based solution to localize a node might not be worthy due to the cost of extra hardware and power requirements. Therefore, a low cost solution to this problem might be Computational Geometry based approach to localize a node. In this paper, we first find out distance between Anchor Node (AN) and Unknown Node (UN) based on RSSI Profiling. Subsequently, the node location is estimated using Trilateration. Finally, a Delaunay Triangle is constructed on the basis of node location information. Then the property of empty circle is used to recognize whether coverage hole is present or not in the given ROI. Correctness of the algorithm is checked based on the simulations and theoretical proofs.

Keywords. Sensor node localization, GPS, RSSI profiling, coverage-hole, empty circle property, Delaunay triangulation.

1 Introduction

WSNs, well-known for their specialization on surveillance, are specifically used to monitor physical events like light, sound, temperature, pressure etc. with the help of small sensor nodes those have very less power requirements. A lot of applications like home automation, fire detection, air quality monitoring, habitat monitoring, endangered species recovery, battle field monitoring etc. depend on WSNs. In all such applications one needs to know the exact position of the sensor node and that is why localization is an important characteristic in research related to WSN. Although GPS can estimate the node location accurately, but it is not feasible due to the following drawbacks: GPS might exhibit errors while finding locations if satellite link is down; cost of GPS receiver might again increase the expenditure of the whole WSN; GPS is not energy efficient whereas, energy scarcity is very common problem faced in WSNs; sensor nodes are intentionally made very small in size but if accompanied with GPS receiver, due to increased size they might not be deployed very close to the event. So we have planned to identify the node location using GPS-free schemes.

With respect to the GPS-free schemes, the localization algorithms can be of different types, [9] like: centralized or distributed, range-based or range-free, indoor based or outdoor based, fine-grained or coarse-grained, static or dynamic etc. In case of centralized algorithm, a central processing unit collects some prerequisite information from all the nodes via their transceiver and then evaluates the node location based on the prerequisite information and sends back the results to each node. Centralized algorithms have a lot of communication overhead, propagation delays and they are not at all energy efficient. Furthermore, they are not appropriate for the ad-hoc character of WSNs and the whole localization approach may be unsuccessful if the central unit falls short.

On the other hand, unknown nodes determine their location based on local processing which

makes distributed localization approach free from all the above drawbacks. Again, range-based localization approach uses distance or angle information between different nodes to estimate node locations. Range-based algorithm is much accurate but has the drawback of extra hardware requirement and energy usage. In range-free approach, node location information is determined based on discovering the anchor node in the proximity. This approach is not as much of accurate as range-based approach but they don't need any extra hardware and are energy efficient. The localization approaches may be indoor-based or outdoor-based is reliant on the environment in which the nodes are deployed into. Another type of localization approach is coarse-grained where node location is roughly estimated which may be a symbolic location and not the accurate one. Alternatively, fine-grained approach needs the exact node location along with its coordinate values. Finally, static or dynamic localization algorithm depends on the nature of the node whether it is fixed or movable. If the nodes are moving throughout the ROI, then dynamic approach is suitable although in maximum applications nodes are considered to be fixed in some location. Therefore, in this work we are considering a range-based localization algorithm that is operating on several randomly distributed fixed nodes deployed in some indoor environment.

Also the quality of monitoring depends on the fact that whether every point in the ROI is covered by at least one sensor or not. Therefore, along with localization, coverage also plays an important role in the design of WSNs. While covering the ROI with sensors, we have to keep in mind that full coverage is actually not possible and a few sub-regions might not be wrapped up by any of the deployed nodes and are termed as coverage-holes. If coverage-holes are present in the network then definitely performance of the network is affected due to communication gap. The reasons behind creation of coverage-holes are: obstacle present in the ROI, node replacement due to design changes, random deployment of sensor nodes, unfavorable environmental condition, drainage of power etc. Therefore, we need to detect the coverage-holes so that we can recognize whether a node is active

or not and also we can define how many extra nodes are required to fill up the holes.

In this paper firstly, we have estimated the node position based on Trilateration technique. For this, the distance between UN and AN is calculated using RSSI (Received Signal Strength Indicator). Secondly, we have constructed a Delaunay Triangle from the coordinate value of the nodes. Finally, on the basis of empty circle property we have checked whether any coverage-hole is present or not in the given ROI.

The rest of our paper is organized as follows: Section 2 describes Related Work followed by Section 3 describing Preliminaries. Section 4 and 5 describe Proposed System and Experiment & Result Analysis respectively. Finally, section 6 concludes the work with future scope.

2 Related Work

In this section, we have studied several recent literature on localization algorithms as well as on hole-detection. Localization algorithms follow three major steps: firstly, collection of data from unknown nodes; secondly, distance estimation between AN and UN and finally, determining the actual position of the UN. For collection of data from source node to destination node, several network protocols [19] have already been configured. In case of WSN, data is collected from some unknown node and in each round of the network protocol; data is transmitted to the base station through node's transceiver. Based on network structure, [15] the various data gathering protocols available are: Flat network routing protocol (e.g. Direct Diffusion, Flooding, Gossiping, Rumor Routing etc.), Hierarchical network routing protocol (e.g. TEEN, APTEEN, LEACH, SOP, PEGASIS etc.), and Location based routing protocol (e.g. SPAN, SPEED, MECN, SMECN etc). The review on data gathering protocol is beyond the scope of this paper.

In the next step, the distance between AN and UN is estimated based on either range-based or range-free algorithms. Basically, this section reviews the range-based distance estimation techniques as they are much accurate as compared to range-free approaches. The main

range-based approaches are: Time of Arrival (ToA) [10], Time Difference of Arrival (TDoA) [3], Angle of Arrival (AoA) [16] etc. The authors in [1] suggested that Received Signal Strength Indicator (RSSI) is less expensive and high energy efficient. Also RSSI is equipped with very small hardware and better accuracy rate as compared with some other range-based distance estimation techniques. Hence, in this paper the distance between AN and UN is calculated using RSSI Profiling. In this method, the absolute distance between two sensor nodes is calculated with the help of the received signal strength by another sensor node. As the distance between the nodes increases, the signal strength gradually attenuates. Although, RSSI depends on antenna types, noise, obstacles etc., still it is the simplest and low-priced distance estimation technique between nodes. The last step of localization is to estimate the node position. Once the distance between AN and UN is calculated, this phase estimates the location of node by using Triangulation, Trilateration or Multi-lateration [14]. In triangulation method, node location is estimated based on AoA information via three anchor nodes using computational geometry. In tri-lateration or multi-lateration process, again computational geometry is used along with distance measurement by three or more anchor nodes.

The authors in [8], introduced RSSI based distance estimation technique for 802.15.4 network, based on CC2420 radio core. In this method the standard deviation (SD) of the RSSI value and the packet loss information were optimized along with the curve parameters to minimize the distance error. The authors of [4] suggested two RSSI based models for distance estimation between two wireless nodes. In the first method, based on static calibration of log-normal shadowing radio propagation model (LNSM) parameters, distance estimation was done and in the second method authors have used dynamic calibration in LNSM parameters which implies that environment can change its properties. In this approach, the best parameters were chosen after measuring the whole interval of distances. In [6], the authors made a comparison between the indoor and outdoor environment node positioning scheme

using one of the three chosen ISM bands. Here they have calculated distance using RSSI and again estimated node position using Trilateration.

In [17] authors proposed a hybrid approach of localization that is extended over two consecutive phases called: Multi-dimensional Scaling (MDS) and refined Trilateration. In this approach, MDS algorithm estimated the location in the first step and then Trilateration refined the estimated locations and acted as a post optimizer which improves the accuracy of the estimated positions of sensor nodes. The authors in [21] proposed a Trilateration based on Point in Triangle testing Localization (TPITL) algorithm to enhance the localization accuracy. Authors claimed a novel approach called point in triangle testing (PIT) that was introduced in TPITL algorithm to select the anchor nodes. The selected anchor nodes formed the smallest triangle based on Trilateration which enclosed the unknown node. In [18] authors estimated node location based on Trilateration and Iterative Multi-lateration separately. For distance estimation authors used RSSI profiling and by experiment they have shown that Trilateration outperforms Iterative Multi-lateration.

Now while discussing about the hole-detection, the most recent literature suggests the following: The authors in [12] proposed a graph based coverage hole description algorithm. Based on empty circle property, coverage-hole was detected and then a graphic hole-description method was introduced to show the vulnerable parts in the holes. In addition, a redeployment algorithm was proposed to heal the coverage holes. Authors of [14] proposed empty circle property based algorithm to detect coverage-holes by forming Delaunay triangulation of the network. Additionally, the holes were classified by connecting the centre of empty circles of each Delaunay triangle with its neighbor by a line segment. In [7], authors proposed Voronoi diagram based coverage-hole detection algorithm (VCHDA) that was able to identify the coverage-holes and could label the border nodes of the coverage-hole area. To construct the Voronoi diagram prior node location information was required.

Authors in [11] suggested a distributed coverage-hole detection (DCHD) algorithm

to detect the bounded or non-bounded coverage-holes in a WSN. This method calculated the critical intersection point (CIP) set and then verifies if any point belongs to a covered points (CP) set or not. Finally, every sensor in the clock-wise direction joins with its one-hop neighbors and connects to its CIP to detect the occurrence of a coverage-hole. Authors of [13] suggested a tree based algorithm for coverage hole-detection and healing. Here, based on tree concept location, size and shape of the detected coverage-hole could be estimated. in addition this algorithm provided a solution to heal the coverage holes based on optimal patch position determination.

In [2], authors suggested an algorithm having two phases namely: coverage hole-detection (CHD) and coverage restoration (CR). In CHD, each sensor node was able to detect coverage-hole based on updating definite information with its neighbor nodes. And in CR, a sensor node with relatively high residual energy was given precedence to cover up the hole closer to it by increasing its sensing range up to a maximum limit.

From the above discussions, it is very much clear that graph-based computational geometry approaches are very promising for coverage hole-detection. Also, distributed algorithms for coverage hole-detection is much fruitful. Further, we had the observation that node location information is the most important prerequisites for coverage hole-detection algorithm. And for this, RSSI based distance estimation and Trilateration based position estimation is very efficient.

3 Preliminaries

In this section, we have discussed about few assumptions and terminologies required clarifying our proposed system. The first phase of the proposed method is to determine the node location information prior to detection of coverage-hole. At the very beginning, we assumed that all the required nodes are static in nature with same initial energy and the links between the nodes are symmetric in nature. Let us consider a WSN having n number of sensor nodes deployed randomly over a 2D rectangular monitoring area. Due to this random deployment, somewhere nodes may be densely arranged with overlapping sensing range and somewhere sparsely arranged with uncovered regions called holes. Now let us consider the sensor network as a 2D graph $G(V, E)$ where V is the set of all sensor nodes and E is the set of all edges existing between node v_m and v_n (say) provided distance $(v_m, v_n) \leq max - distance(v_m, v_n)$.

Therefore, concerning the anchor node A with known location (x_a, y_a) we have to find out all unknown node set say, $U = u_1, u_2, \ldots u_n$ with the location as: $u_i = (x_i, y_i)$. For the second phase of hole-detection, additionally we assume that the relation between sensing and communication radius is $R_C = 2R_S$. However, sensing efficiency may not be the same in all routes around a sensor node. This asymmetrical sensing ability [5] of nodes has a lower bound in which R_S is set for convenience. Since R_S is assumed to be larger than actual value in the sensing model, thus practical errors caused due to position or angle estimation can be ignored. Therefore, considering R_S very small, all the transmissions inside R_S are assumed to be detected with a probability of 1 for large scale WSNs.

3.1 RSSI Profiling

For distance estimation between the ANs and UNs, we have used the RSSI Profiling technique. According to [20], RSSI value in free-space is inversely proportional to the squared distance between the transmitter and the receiver. Also, the radio signals deteriorate with the increasing distance, hence the signal propagation may be influenced by reflection, diffraction or scattering. When base node receives the signal sent from anchor node, RSSI value can be calculated as:

$$RSSI = -[10\eta log(d) + A], \tag{1}$$

where d is the distance between sender and receiver, A is the absolute value of RSSI for a standard distance of 1 meter and η is the environmental path loss coefficient that can vary from 1.6 to 6. Now, η can be computed as:

$$\eta = \frac{RSSI + A}{-10log(d)}, \tag{2}$$

and the distance d can be calculated as:

$$d = 10^{\frac{RSSI+A}{-10\eta}}.$$ (3)

This calculated d is used to estimate the node position of the UN in the next phase.

3.2 Triletaration

With the help of computed distance between AN and UN,Trilateration is further used to determine the absolute location of the unknown node. In figure 1, an illustration of the Trilateration algorithm is shown.
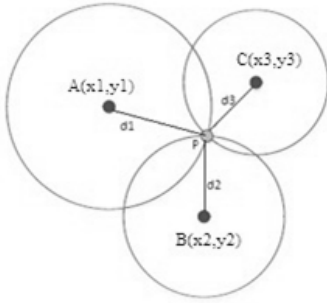

Fig. 1. Illustration of the Trilateration algorithm

Here $P(x,y)$ is the unknown node whose coordinates are required to be computed via Trilateration. Let $A(x_1,y_1), B(x_2,y_2)$ and $C(x_3,y_3)$ are the 3 anchor nodes whose coordinates are already known. Using the general formula of a circle we have:

$$PA = d_1 = \sqrt{(x-x_1)^2 + (y-y_1)^2},$$ (4)

$$PB = d_2 = \sqrt{(x-x_2)^2 + (y-y_2)^2},$$ (5)

$$PC = d_3 = \sqrt{(x-x_3)^2 + (y-y_3)^2}.$$ (6)

Using (4) and (5) we have:
$$(PA)^2 - (PB)^2 = (d_1)^2 - (d_2)^2$$
$$= (x-x_1)^2 + (y-y_1)^2 - (x-x_2)^2 - (y-y_2)^2.$$

Therefore,

$$2x(x_1-x_2)+2y(y_1-y_2) = (x_1^2-x_2^2)+(y_1^2-y_2^2)-(d_1^2-d_2^2).$$ (7)

Again, using (4) and (6) we have:
$$(PA)^2 - (PC)^2 = (d_1)^2 - (d_3)^2$$
$$= (x-x_1)^2 + (y-y_1)^2 - (x-x_3)^2 - (y-y_3)^2.$$
Therefore,

$$2x(x_1-x_3)+2y(y_1-y_3) = (x_1^2-x_3^2)+(y_1^2-y_3^2)-(d_1^2-d_3^2).$$ (8)

From (7) and (8) we have the following matrix:

$$2\begin{bmatrix} (x_1-x_2) & (y_1-y_2) \\ (x_1-x_3) & (y_1-y_3) \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} =$$

$$\begin{bmatrix} (x_1^2-x_2^2) + (y_1^2-y_2^2) - (d_1^2-d_2^2) \\ (x_1^2-x_3^2) + (y_1^2-y_3^2) - (d_1^2-d_3^2). \end{bmatrix}$$

By solving the above matrix, center of empty circle $P(x,y)$ is calculated as shown in Table 1.

3.3 Delaunay Triangulation

It is a technique from computational geometry that can be very much useful in sensor network construction for a given set of sensor nodes. A triangulation of a finite point set S is called a Delaunay triangulation, if the circumcircle of every triangle is empty, i.e., there is no point from S in its interior. Figure 2 shows [1] such a Delaunay Triangulation. Let us assume a connected WSN where no four sensors are co-circular. Based on the node positioning we have to create the Delaunay triangulation.

3.4 Empty Circle Property

This property is used to define the Delaunay Triangulation. The circumcircle of a triangle is the unique circle that passes through the three vertices of the triangle, as shown in figure 3. Here $P(a,b)$ is the centre of the circumcircle whose coordinates are required to be calculated based on the position of the sensor nodes X, Y and Z. If $X(a_1,b_1), Y(a_2,b_2)$ and $Z(a_3,b_3)$ are the 3 points (sensors) in the triangle whose coordinates are known, then using computational geometry, $P(a,b)$ can be easily computed.

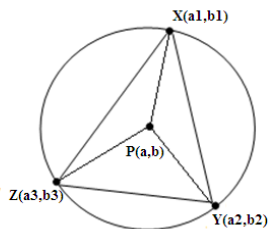[1] https://support.esri.com/en/other-resources/gis-dictionary/term/2bdd9813-7ae2-4213-832a-cd025f655aa6

Table 1. Formula for center of empty circle $P(x, y)$

$$X = \frac{(y_1-y_3)(x_1^2-x_2^2+y_1^2-y_2^2-d_1^2+d_2^2)-(y_1-y_2)(x_1^2-x_3^2+y_1^2-y_3^2-d_1^2+d_3^2)}{2(x_1-x_2)(y_1-y_3)-2(x_1-x_3)(y_1-y_2)},$$

$$Y = \frac{(x_1-x_3)(x_1^2-x_2^2+y_1^2-y_2^2-d_1^2+d_2^2)-(x_1-x_2)(x_1^2-x_3^2+y_1^2-y_3^2-d_1^2+d_3^2)}{2(x_1-x_3)(y_1-y_2)-2(x_1-x_2)(y_1-y_3)}.$$
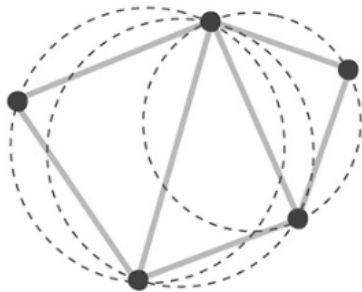
Fig. 2. Delaunay Triangulation

Fig. 3. Representation of Empty Circle

4 Proposed Method

Here we have discussed about the required Experimental Setup and the steps required to execute the proposed system.

4.1 Experimental Setup

At the outset, all the static nodes are assumed to be with same initial energy and the links between the nodes are symmetric in nature. Also it is assumed that n number of sensor nodes are deployed randomly over a 2D rectangular indoor monitoring area. For the ROI of the indoor environment, Network & Data Communication

Fig. 4. Sample Node Placement in indoor location

Lab of CSE Department is chosen which is a rectangular room having dimensions 15 m X 9 m with concrete ceiling and four half-brick & half-window walls.

All the three ANs are placed in three predefined locations as: $A(3, 8)$, $B(12, 5)$ and $C(7, 2)$. The unknown node $P(x, y)$ is experimentally placed in 10 random locations in the ROI ranging from minimum 1 meter to maximum 10 meter distance from A, B or C. Figure 1 shows one such random instance carried out in the lab.

For the experiment, IRIS (Manufacturer: Crossbow Technology, Inc.) sensor nodes are used and Moteview 2.1 GUI (Memsic) provides the interfacing with the HP Laptop. Among the sensors, one XM2110 radio board is used as the base station and is attached upon one MIB520 Gateway to interface with the PC.Three more radio boards along with MDA100CB data acquisition board have been placed at three predefined locations mentioned earlier as ANs. The orientation of the antenna in all nodes is kept vertically upwards.

The ANs send the health packets which contain the node id, board id, battery, quality-tx, quality-rx, path cost, parent RSSI and time. The received radio signal by the motes can be measured in

terms of RSSI and then be calibrated to map into distance.

4.2 Node Position Estimation

In IRIS mote, measured RSSI is displayed as signed 2's complement in Moteview GUI. To convert the raw count of RSSI to dBm, the following formula is used:

$$RSSI = Base\_RSSI\_Value + 3 \times (RSSI\_measured\_in\_Sensor - 1). \tag{9}$$

In IRIS mote with Atmel ATmega1281, RSSI base value is its receive sensitivity which is typically given as: -101 dBm. With the help of this experimental setup, average parent RSSI value is measured and then converted to RSSI (dBm). Table 2 shows the average measured RSSI value from the experiment setup.

Table 2. Measured RSSI from the experimental setup

SI No.	Actual Distance (m)	Measured RSSI (dBm)
1	1	-54
2	2	-59
3	3	-63
4	4	-66
5	5	-72
6	6	-76
7	7	-78
8	8	-76
9	9	-79
10	10	-83

It has been observed that the RSSI value varies due to shadowing, fading or multipath effect. Also in indoor environment signal strength becomes weak due to reflection in wall, ceiling or windows. In fact, a very small change in the position of the node can result a significant difference in RSSI value. Thus, RSSI value is measured in several iterations for each position to collect the average value. The plot in figure 5 shows the relationship between Measured RSSI vs Actual Distance.

The distance estimation error is calculated as: $E = D_E - D_A$ where D_E is the estimated distance and D_A is the actual distance. Now the UN
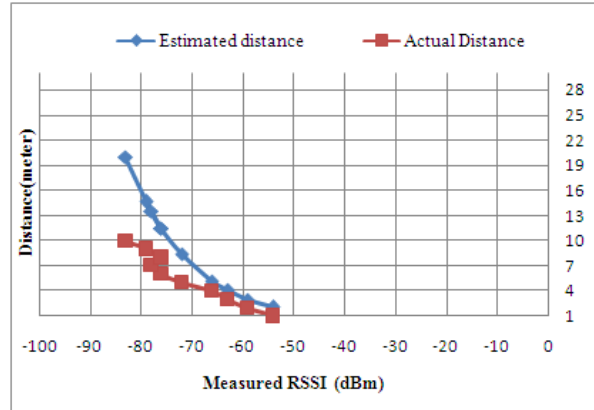
Fig. 5. Plot for measured RSSI vs actual & estimated distance

location $P(x, y)$ can be accurately calculated when the sum of square error is going to be minimal, i.e.,

$$\sum_{i=1}^{N} E_i^2 = minimum.$$

From the data in Table 2, the estimated distance is calculated based on equation 3 and is compared with the actual distance. With these experimental data, the mean estimated distance is found to be 9.399m with a standard deviation of 5.837m. The simulator provided an average distance estimation error of 1.528m in the mentioned indoor environment. To reduce this distance estimation error, the calibration equation between computed signal strength vs estimated distance is found as:

$$Y = -35.9X - 45. \tag{10}$$

Here, Y is the computed RSSI in dBm and X is the $log_{10}(D)$ where D is the estimated distance and is given as:

$$D = 10^{(Y+45)/-35.9}. \tag{11}$$

From equation (9) and (10) the environmental path loss exponent, $\eta = 3.59$ is found for the mentioned indoor environment. Also the new mean estimated distance is now found to be 5.678m with a standard deviation of 3.428m.

The plot in figure 6 shows the relationship between the calculated RSSI vs estimated log distance. The average distance estimation error
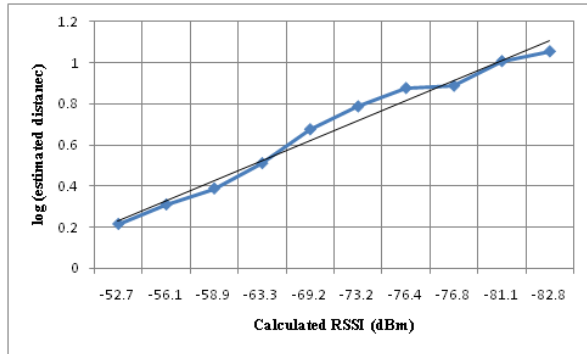
Fig. 6. Plot for calculated RSSI vs $log_{10}(D)$

is now reduced to 0.217m. After the distance estimation, based on section 3.2, Trilateration is used to locate the node position.

4.3 Coverage Hole-Detection

This phase needs the Construction of Delaunay Triangle prior to Coverage Hole-detection. For constructing the DT, node location information is essential. For this, RSSI based distance estimation and Trilateration technique has been employed to estimate the node position. Now when node location information of all sensors is collected with this process, the circum-center and circum-radius of the empty circle can be formulated and the DT can be constructed.
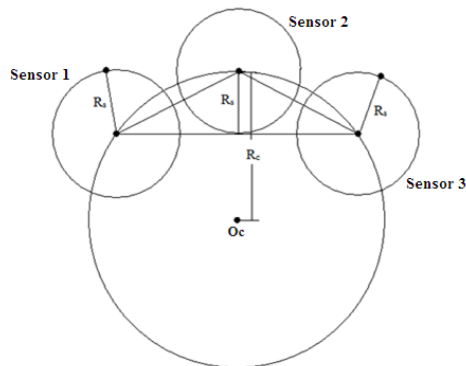
Fig. 7. Uncovered region denoting coverage-hole inside empty circle

Fig. 8. Algorithm for Node position estimation & Coverage hole-detection

For coverage hole-detection we have to assume R_S and R_C as the sensing range of sensor node and radius of the 'empty circle' respectively. Then there must be some uncovered region, i.e. coverage-hole in the empty circle for the relation $R_C > R_S$.

Let us first presume that, $R_C > R_S$ as per figure 7, then the sensing range of any sensor node is smaller than the radius of empty circle. Hence, there must be some region in the empty circle which is uncovered and thus proves the existence of a coverage-hole.

Conversely, if we assume that there is some uncovered region in the empty circle then the center of the empty circle may be out of coverage of sensing range of any sensor node. It again implies that radius of empty circle must be larger than the sensing range of sensor node.

The pseudo code for node position estimation & hole-detection algorithm is given in figure 8.

5 Experiment and Result Analysis

In this section, some simulations are shown to check the correctness of hole-detection algorithm. At first the nodes are detected using RSSI and Trilateration. After that the node positions are used to construct the DTs. In the simulation we have first detected the DTs and then based on empty circle property hole-detection is done.
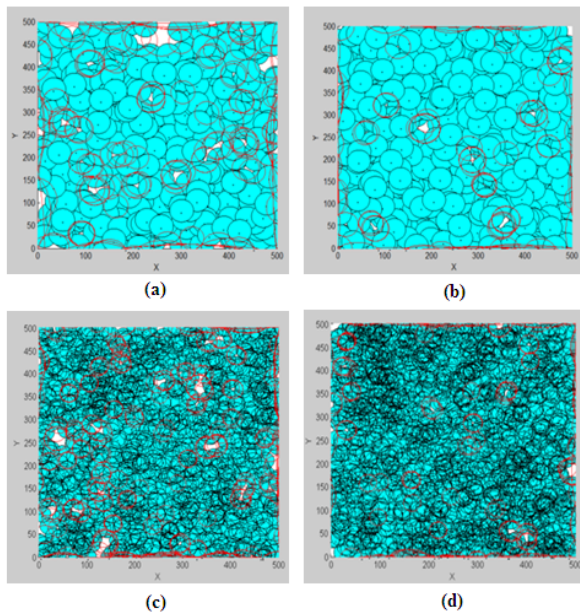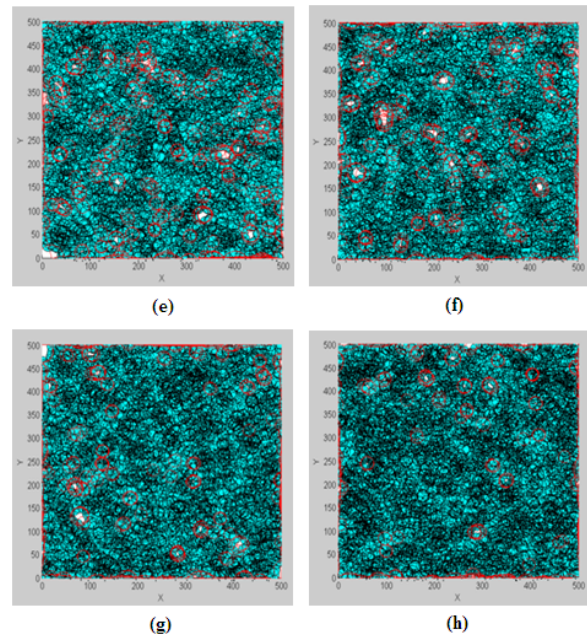

Fig. 9. Detection of Coverage-Hole with R_S= 45m (a) 400 nodes (b) 500 nodes and R_S= 35m (c) 1200 nodes (d) 1400 nodes

Figure 9 shows the detection of coverage-hole when $R_S = 0.45$ for 400 and 500 number of nodes. Again sensing range is minimized and number of nodes are increased, i.e. $R_S = 0.35$ and number of nodes are 1200 and 1400.

Similarly, Figure 10 shows the detection of coverage-hole when $R_S = 0.25$ for 2200 and 2300 number of nodes. Again sensing range is minimized and number of nodes are increased, i.e. $R_S = 0.20$ and number of nodes are 2800 and 3000.

While detecting coverage-hole, we have found the run-time of hole-detection, number of DT and Number of coverage-holes from the number of


Fig. 10. Detection of Coverage-Hole with R_S= 25m (e) 2200 nodes (f) 2300 nodes and R_S= 20m (g) 2800 nodes (h) 3000 nodes

nodes, size of ROI and dimension of sensing radius.

While the number of sensor nodes are varying from 400 to 3000, sensing radius also varies between 20m to 45m. In figure 11 we can find the number of coverage-holes identified with sensing range of 0.45 and 0.25 along with different number of sensor nodes. It is very clear that the number of coverage-holes decreases with the increasing number of sensor nodes.

Figure 12 shows the number of DTs created while detecting holes with sensing range of 0.45 and 0.25 with different number of sensor nodes. From the above mentioned graph it is found that number of DT rapidly increases with the increasing number of nodes and decreasing sensing range.

Figure 13 depicts the required run time for varying sensing range of 0.45 and 0.25 along with different number of sensor nodes. Here the sensing range is decreased with the increasing number of sensor nodes and run time will increase drastically with increasing number of nodes and decreasing sensing range. When number of nodes
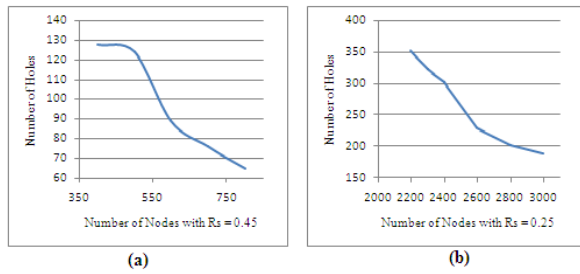
Fig. 11. Number of coverage-holes with varying sensor nodes and sensing range
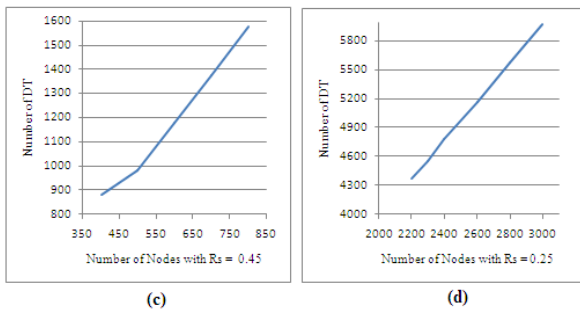
Fig. 12. Number of DTs with varying sensor nodes and sensing range
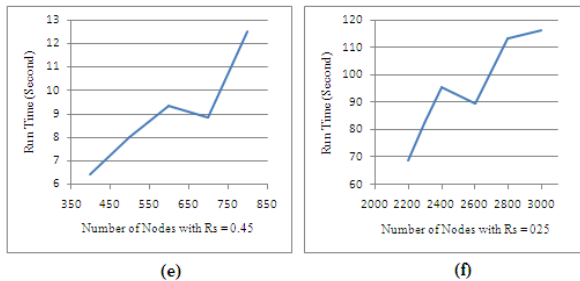
Fig. 13. Required run-time for coverage-hole detection with varying sensor nodes and sensing range

are higher, number of DT and run-time gets higher but number of holes gets lower because increasing number of nodes fill up the ROI.

6 Conclusion

As nodes are deployed randomly in the ROI, hence chances of occurrences of coverage-hole is very common in WSNs. That is why, our main goal in this paper is to check whether any coverage-hole is present or not in the given ROI. For this purpose, first an experiment setup is prepared to estimate the distance between nodes based on RSSI profiling. Then using the distance information, actual node position is estimated with the help of Trilateration technique. Now Delaunay Triangle is constructed on the basis of estimated node location. Finally, using the empty circle property it is checked whether coverage-hole is present or not in the given ROI. The relation between number of nodes, number of DTs and run-time is checked on the basis of number of nodes in the ROI and sensing range of a sensor node with the help of simulator.

Our future scope of work may be to determine the actual number of coverage-holes by merging those empty circles falling in the boundary of the same coverage holes.

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