CHAPTER 5. HYBRID TLBO (TEACHING LEARNING BASED OPTIMIZATION) - UNILATERAL TECHNIQUE

In this chapter two methods for node localization are discussed in detail. For node localization many methods and algorithms are available since the evolution of wireless sensor networks. Each method and algorithm is unique for the localization of node. The two methods chosen for the localization of sensor node in this research are LNSM (Log Normal Shadowing Method) and Hybrid TLBO (Teacher Learning Based Optimization Algorithm) - Unilateral Algorithm[32]. This hybrid algorithm is based on classical TLBO [106] (Teacher Learning Based Optimization) and modified trilateration algorithm. The first approach is LNSM [107] based which is classical approach for localization of nodes. In the localization process ZigBee protocol has been used. The ZigBee uses RSSI (Received Signal Strength Indicator) values in dBm for localization of nodes. LNSM approach has been studied in outdoor location using the self-designed nodes. The statistical analysis has been studied using RMSE (Root mean square error) using distance as a parameter and distance error is found to be 35 mtrs in outdoor locations. For the same outdoor location, statistical analysis is performed on the data and it has been found that the distance error calculation for outdoor location using Hybrid TLBO- unilateral algorithm is 0.7 mtrs. The RSSI values captured during the experiments are observed to be normally distributed and standard deviation is found to be 1.01 for these outdoor locations. All the statistics calculated for hybrid TLBO- unilateral algorithm makes the node completely discoverable.

In this chapter, RSSI values have been used for the localization process as discussed above. It has been observed during the experiments that the RSSI values are very fluctuating or sometimes faded too. To remove the problem of fluctuating RSSI values, it is very important to model the channel. The modelling of wireless channel is necessary so that the RSSI values obtained will be linear with respect to their respective distance values. RSSI values are highly affected by the real time environmental conditions. After channel modeling, experiments have been conducted in outdoor locations. The first experiment uses LNSM approach. The two nodes have been placed in outdoor location. One node is anchor (fixed) node and another one is pursuit node. Both the nodes have been equipped with Xbee transceiver module. Xbee module is equipped to give RSSI values. These RSSI values are stored in SD card module (in built feature of self-designed nodes). The anchor node is fixed in outdoor location and pursuit node is subjected to move around anchor node using modeled wireless channel. The probable distance has been estimated using LNSM by obtaining RSSI values. Using LNSM, distance can easily be calculated and localization of the nodes can be achieved. The second experiment hybrid TLBO- unilateral algorithm has been conducted for the localization of node. TLBO is teacher learner based algorithm that mainly focusses on the learning given by the teacher node to the learner node so that the best learner node will become the teacher node for other nodes. It will be explained further in detail in this chapter and the unilateral algorithm is the improved version of trilateration algorithm. So in both the experiments RSSI values have been obtained and through the RSSI values the pursuit node is subjected to discover the trapped node.

The structure of this chapter is as follows:

1. Modeling of the wireless channel to be done using LNSM
2. Study of TLBO – Teacher Learner Based Optimization algorithm
3. Design of Hybrid TLBO-unilateral algorithm

5. 1 Channel Model

The transmission of message signal via wireless channel is very noisy due to no. of environmental parameters. Therefore it is recommended to model the channel before the transmission of RSSI values. To model the wireless channel there are many propagation model like free space model, two ray model, LNSM (Log Normal Shadowing Model) etc. In this research LNSM has been used because of its universal acceptance. LNSM is widely used in wireless sensor networks. LNSM model has a feature to set the environmental parameter in real time. Hence for any geographical as well as environmental condition one can model the channel. LNSM technique is discussed in detail in next section.

LNSM (Log-Normal Shadowing Model)

The message signals to be transmitted through wireless channel are very much affected by effects such as reflections, diffractions and scattering. So the wireless channels are modelled by analytical or empirical methods. In analytical method the channel is modelled by taking measure data and in empirical method one has to deal with curve fitting. In the research carried out here, analytical method has been adopted for modelling of wireless channel. To model a wireless channel in this research, a node has been placed in outdoor environment and signal strength has been observed for 1 mtrs distance. For 1 mtrs of distance signal strength should be -40dBm in case of ZigBee[108]. This is the first step to model the channel in case of ZigBee.

For getting the condition of channel in outdoor location experiment have been conducted. Several trails have been made in between the pursuit node (rescue operation team node) and anchor node (Fixed Node). The anchor node has fixed location and pursuit node is subjected to move towards the anchor node from different angle and directions. Sometimes the pursuit node and anchor node has non line of sight. The maximum distance is kept 100 mtrs. This distance can be increased. The outdoor location is almost flat where the anchor node has been placed. As already discussed the nodes have been equipped with Xbee and SD card module. So, when the pursuit node is moving towards the anchor node the RSSI value are captured and stored in SD card module. For several trials, RSSI values have been captured and a data set has been designed from where the estimated distance can be calculated[20]. It has been observed that

$P_{L(d)}$ in dBm = $P_{L(d0)} + 10n \log10 (d/d_0) + X\sigma$ 5.1

Where $P_{L(d)}$ dBm= Path loss in mtrs at distance d,

$P_{L(d0)}$ is path loss in mtrs at distance d_0

d_0 is a reference distance taken as 1 mtrs with -40dBm RSSI values.

n is path loss exponent. Path loss exponent is obtained from the analytical method.

X_σ is known as zero mean Gaussian random variable (dB) with standard deviation σ.

The RSSI values can be calculated as

RSSI = P_t(dBm) -$P_{L(d)}$dBm. 5.2

Where P_t(dBm) is the transmitted power of anchor node.

So the RSSI at the pursuit node will be

RSSI = P_t(dBm) - $P_{L(do)} + 10\ n\ log_{10}\left(\frac{d}{do}\right) + X_\sigma$ 5.3

The value of "n" (path loss exponent) can be calculated as shown in Table 5-1Path Loss exponent for different environments. The value of n will change for different geographical and environmental conditions

Table 5-1 Path Loss exponent for different environments

S.No	Path Loss Exponent (n)	Environment
1	2.0	Free Space
2	1.6-1.8	Inside Building (Line of Sight)
3	1.8	Super Market Store
4	2.09	Conference Room with table & Chairs
5	2.2	Factory
6	2-3	Inside Factory (no line of sight)
7	2.8	Indoor residential area
8	2.4	Outdoor environment (in our paper)

5. 2 System Architecture

The backbone of the proposed system is wireless Ad-Hoc Network. The network consists of anchor (fixed nodes) and pursuit node (movable node). From the Figure **5-1** System Architecture it is shown that anchor node and pursuit node is having Xbee –S2 module which is based on ZigBee protocol. The detail architecture of all the hardware nodes is discussed in next chapter (Analysis of hardware node). After the modeling of wireless channel, an equivalent firmware is designed and uploaded in hardware nodes so as to localize the anchor node. The nodes start sharing their local as well as remote RSSI values whenever they will come in contact with each other. All the information shared in between the anchor and pursuit node is shared with the data center at the same time.

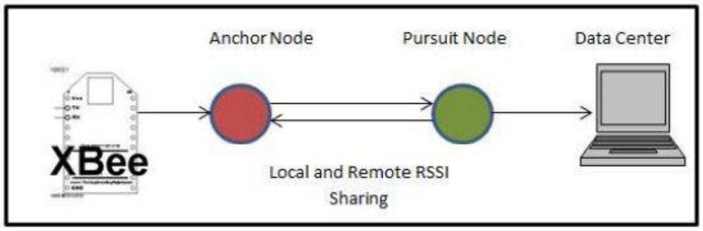

Figure 5-1 System Architecture

5. 3 Methodology

In order to pursue the trapped node which is considered as anchor (fixed node) node, two experiments are performed. The node can be located either using LNSM technique or Hybrid TLBO- unilateral technique. The two experiments were conducted in outdoor location as shown in Figure 5-2. The whole experiment is based on finding the RSSI values of nodes and based on these RSSI values localization process is executed.

Figure 5-2 Outdoor location

The outdoor location as discussed earlier an area of 200 × 100 square meters under seismic zone. Several trials have been attempted in this outdoor location to search the trapped node. The placement of the trapped node is random in this outdoor location which is unknown to the pursuit node. Pursuit node is subjected to move around the outdoor location in search for trapped node. The further sections in this chapter show the study of LNSM, TLBO, unilateral technique and hybrid TLBO- unilateral technique in outdoor location.

5. 4 LNSM Technique

The first experiment is based on LNSM technique, which is already discussed earlier. For hardware nodes an equivalent embedded C based firmware has been designed.

5. 5 TLBO (Teacher learner based optimization)

There is a need for optimization of RSSI values so as to localize the trapped node with less distance error. TLBO is teacher learner based optimization algorithm. It is best suited in this research because it does not require algorithm specific parameters like GA (Genetic Algorithm) which is most depended upon some algorithm specific parameters like mutation probability or cross-over probability[106, 109], ABC (Artificial Bee colonial) algorithm requires number of bees and limits[110], PSO requires its own parameters like inertial weights, social & cognitive parameters[111]. There are some others algorithm also like ES (Evolution Strategy), DE (Differential Evolution), BBO (Biogeography-Based Optimizer), AIA (Attack Intention Analysis) etc. that also requires some algorithm specific parameters only. The tuning of these parameters should be fine otherwise the convergence result will not be accurate and unnecessarily it will increase the computational efforts also. TLBO algorithm is one optimization technique in which one has not to optimize such critical parameters. It does not require any algorithm specific parameters. TLBO consist of teacher and learner phase. The equations 5.4, 5.5, 5.6, 5.7, 5.8, 5.9, 5.10 explained the TLBO in detail [106]. During Teachers phase, for iteration i, there are m number of design variables and n numbers of learners of population size, k= 1, 2,.....n. and $M_{j,i}$ is the mean result of learners in a subject j= 1,2,......,m. The best result overall is X_{total}-$k_{best,\ i}$ is considered as a best learner kbest. Then the best learner in the algorithm is treated a teacher. So the final result is expressed as

Difference Mean j, k, i = ri (Xj, $k_{best,i} - TF_{Mj,i}$) 5.4

Here Xj, kbest,i is the result of the best learner in j subject. r_i is the random number. TF is the teaching factor and can be decided by equation (5.5)

TF = round [1+ rand (0, 1) [109]] 5.5

Based on the solution of Difference of Mean j, k, i the teacher phase update the existing solution with equation (5.6)

$X'_{j,\,k,\,i} = X_{j,\,k,\,i}$ + Difference of Mean j, k, i 5.6

Here X'j, k, i is the update value.

During learner phase, learners interact with each other to gather more knowledge.

Here $X'_{total\ -\ first\ value,\ i} \neq X'_{total\ -\ Second\ value,\ i}$ where $X'_{total\ -\ first\ value,\ i}$ and $X'_{total\ -\ Second\ value,\ i}$ are the updated values of $X_{total\ -\ first\ value,\ i}$ and $X_{total\ -\ Second\ value,\ i}$ in the teacher phase. Equations 5.7 and 5.8 are for minimization while equations 5.9 & 5.10 are for maximization

$X''_{j,\ first\ value,\ i} = X'_{j,\ first\ value\ ,i} + r_i\,(X'_{j,\ first\ value\ ,i} - X'_{j,\ Second\ value\ ,i})$ 5.7

If $X'_{total\ -\ first\ value,\ i} < X'_{total\ -\ Second\ value,\ i}$

$X''_{j,\ first\ value\ ,i} = X'_{j,\ first\ value\ ,i} + r_i\,(X'_{j,\ Second\ value\ ,i} - X'_{j,\ first\ value\ ,i})$ 5.8

If $X'_{total\ -\ Second\ value\ ,i} < X'_{total\ -\ first\ value\ ,i}$

$$X''_{j,\ \text{first value},i} = X'_{j,\ \text{first value},i} + r_i\,(X'_{j,\ \text{first value},i} - X'_{j,\ \text{second value},i}) \qquad 5.9$$

If $X'_{\text{total - Second value},i} < X'_{\text{total - first value},i}$

$$X''_{j,\ \text{first value},i} = X'_{j,\ \text{first value},i} + r_i\,(X'_{j,\ \text{Second value},i} - X'_{j,\ \text{first value},i}) \qquad 5.10$$

If $X'_{\text{total - first value},i} < X'_{\text{total - Second value},i}$

5. 6 Hybrid TLBO- Unilateral Algorithm

As discussed in previous chapter that the most classical approach to locate the trapped node is trilateration and a state of the art unilateral technique has also been discussed to locate the trapped node. Particularly for this research, unilateral algorithm is proposed which reduces the number of nodes in the network. Trilateration algorithm used three nodes in a fixed location and one node placed exactly in the middle of these fixed nodes as shown in Figure 4-1. And by calculating the euclidian distance in between the fixed node and trapped node one can locate the target. To overcome the network size, power issues and dependency on the fixed node of the wireless network unilateral algorithm- state of the art localization algorithm has been discussed in previous chapter. Unilateral algorithm is dependent upon VPM (Vector Parameter based Mapping) protocol. The unilateral algorithm is the improved trilateration algorithm in terms of number of nodes required for searching the trapped node. The pursuit node searches the RSSI values of the trapped node and once it will get the RSSI value of the trapped node, the pursuit node keep on moving towards the stronger RSSI value and reach the target when it will get the - 40dBm value recommended as the strongest value in 1 mtrs[108] (refer Figure 4-16). Now to optimize the localization process in terms of distance error hybrid TLBO- unilateral algorithm has been proposed. In the proposed algorithm the pursuit node will search for the

RSSI values and once it will get the RSSI values of the trapped node, it teaches the pursuit nodes to get the strongest RSSI value at that very first step. After the first step the learner pursuit node will become the teacher pursuit node and starts the steps of following the maximum value of RSSI till it will get -40dBm value. The offline training is also done in SCILAB virtual environment. The error estimation is based on RMSE (Root mean Square error). As discussed earlier, the outdoor location used for the experiments, the nodes have omnidirectional RF coverage. So the probability based localization can be introduced.

Assuming the estimated distance is $d_{E,}$ with probability function is P_{DEi} for all i^{th} nodes and actual distance is d_A, with probability function of P_{DAi}. Probability theory states that

$$P_{Ti}(D_{Ai}) = \mathrm{P}(D_{Ei} \mid D_{Ai}) \qquad 5.11$$

P_{Ti} is the deployment probability field functions for anchor node (to be pursued).

Considering RSSI value, the probable estimated distance

$$P_{Ti}(D_{Ai}) = \frac{1}{\sqrt{2\pi}\sigma D_E} \exp\left[-\left(\frac{1}{2}\right)\left[\frac{(D_{Ai} - D_{Ei})^2}{\sigma^2 D_E}\right]\right. \qquad 5.12$$

$$\sigma_{D_E} = \mathrm{RSSI} \times \mathrm{P} \text{ is a standard deviation} \qquad 5.13$$

P is the error factor of the device (generally considered as 0.1). If the anchor node (i^{th} node) receives the packet from pursuit node (j^{th} node) the probability function will be defined as

$$\mathrm{P}_{(i\ ,\ j)}(\mathrm{P}_{DEi}) = \mathrm{P}(\mathrm{d}_{noise(ij)} \mid \mathrm{P}_{DEi}, \widehat{P_{DEJ}}) \qquad 5.14$$

$d_{noise\ (ij)}$ is measurement of distance using noisy RSSI value. The RSSI values are Gaussian distributed so the probability function becomes

$$\mathrm{P}(d_{(noise(ij)} \mid D_{Ai},\ D_{Ej}) = \mathrm{P}(\mathrm{d}_{noise(ij)} \mid \delta\ (\mathrm{P}_{dEi}, \widehat{P_{dEJ}}) \qquad 5.15$$

$$P(d_{(noise(ij)} \mid D_{Ai}, D_{Ej}) = \frac{1}{\sqrt{2\pi}\, r.\, d_{noise(ij)}} \exp\left[- \frac{((DAi, \;\; DEj\;\;) - d_{(noise(ij)})^{2}}{2(r.d_{(noise(ij)})^{2}}\right] \qquad 5.16$$

Here r = range error factor taken as 0.1

Combining equation 5.14 and 5.16

$$F = \frac{(D_{Ai} - D_{Ei})^{2}}{\sigma^{2} D_{E}} + \sum_{j \in ji} \frac{((DAi, \;\; DEj\;\;) - d_{(noise(ij)})^{2}}{2(r.d_{(noise(ij)})^{2}} \qquad 5.17$$

The equation 5.17 is used in Hybrid TLBO-Unilateral technique to obtain the distance error.

Table 5-2Algorithm Hybrid tlbo- unilateral technique

Step 1- Connection established- RSSI values received

Step2- *n* particles starts searching RSSI value, Run TLBO

Step3- *if RSSI value received is > the previous value*

particle update the position (Run Unilateral Technique)

Step4- *if RSSI value received is < the previous value* particle requests the other particles for their RSSI value

Step5- The position of i^{th} *particle* with *highest value RSSI* is K_{Best} and other particle converges to the i^{th} particle

Step6- The i^{th} particle becomes the teacher in learner phase

Step7- goto Step2 to find the highest RSSI value

Step8- Node searching stops

5. 7 Conclusion

In this chapter two approaches of localization have been discussed. The first approach is classical LNSM technique and second is hybrid TLBO- unilateral technique. In LNSM technique the modelling of wireless channel has been studied. In the second approach Hybrid TLBO- unilateral technique the pursuit node is trained as teacher and then it trains the best learner to follow the path of strongest RSSI value than the previous RSSI value received from the trapped node. The Hybrid TLBO- unilateral is a flexible and easy to use algorithm which can be applied to any mobile node or fixed node. The localization problem in WSN can be deal with hybrid TLBO- unilateral Algorithm. The algorithm has been designed keeping strictly in mind the reliability of narrow band communication. This is to ensure that the network is always available thereby providing the sole purpose of localization, and hence helping in tracing trapped people. It is to be noted that high bandwidth signals such as video transmission etc. are not the objective of such study.