# CHAPTER 4. UNILATERAL METHOD – IMPROVED TRILATERATION

AdHoc Sensor Network is one of the promising technologies presently brief used for node localization. A lot of potential of this technique lies in post disaster management which is quiet promising. Focusing on post disaster condition, the chapter presents unilateral algorithm which has an advantage over trilateration algorithm to help in localization of trapped people. The unilateral technique uses the state of the art VPM (Vector Parameter based Mapping) protocol to track trapped people from communication deprived area. Several tests have been performed on a designed test bed to find the location of trapped node. The results obtained from network are very encouraging as the trapped nodes are completely discoverable using a hybrid model having RSSI (Remote Signal Strength Indicator) as a key component. It has already been discussed in chapter 2

The most widely proposed and simple method currently to locate the trapped person is trilateration algorithm[105] (refer Figure 4-1). In trilateration algorithm four different nodes are present, out of which three become fixed (anchor node) and one moving node is the trapped node. Trapped node to be placed in between the fixed nodes & using euclidian distance from the fixed nodes, trapped node can be located. Assuming that all nodes have omnidirectional antenna, each one of fixed node can calculate the distance in between and the location of the trapped node using equation:

$$P_r = P_T - 10 \times n \times log_{10}(f) - 10 \times n \times log_{10}(r) + 30 \times n - 32.44 \text{ (dBm)} \qquad 4.1$$

$P_T$ = Transmitted power in dBm

$P_r$ = RSSI value at fixed node

n = Path loss exponent (2.4) in our case [22] )

r= distance in meters

f= transmitted signal frequency in MHz

Also the individual distance of trapped node from fixed node say $r_1$, $r_2$ or $r_3$ can be found through Euclidean distance.

$$r_1 = (x_1 - x_4)^2 + (y_1 - y_4)^2 \quad 4.2$$

Here $r_1$ = Euclidean distance

$x_1, y_1$ = coordinates of node 1

$x_4, y_4$ = coordinates if node 4 (Trapped node)

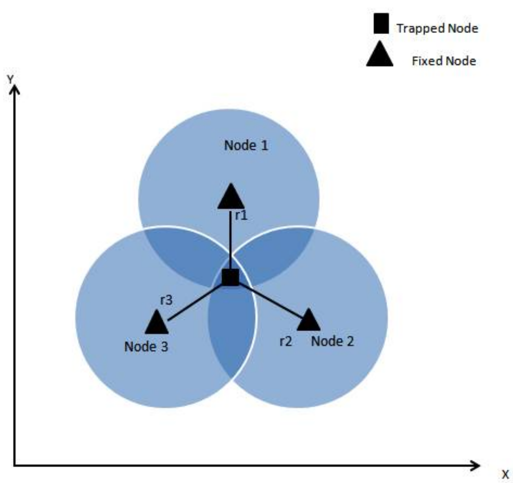


Figure 4-1 Trilateration Algorithm

Another method is based upon Location Fingerprinting [22, 87] as represented in Figure 4-2. In this method, all RSSI are stored in the form of array and the representation is in logarithmic scale denoted as ss. During offline training the receiver is placed at predefined location. So the array of RSSI for first location $L_1$ is represented as

$ssL_1 = [ss_{L11}\ ss_{L12}\ s_{L13} \ldots\ldots ss_{L1i}]$

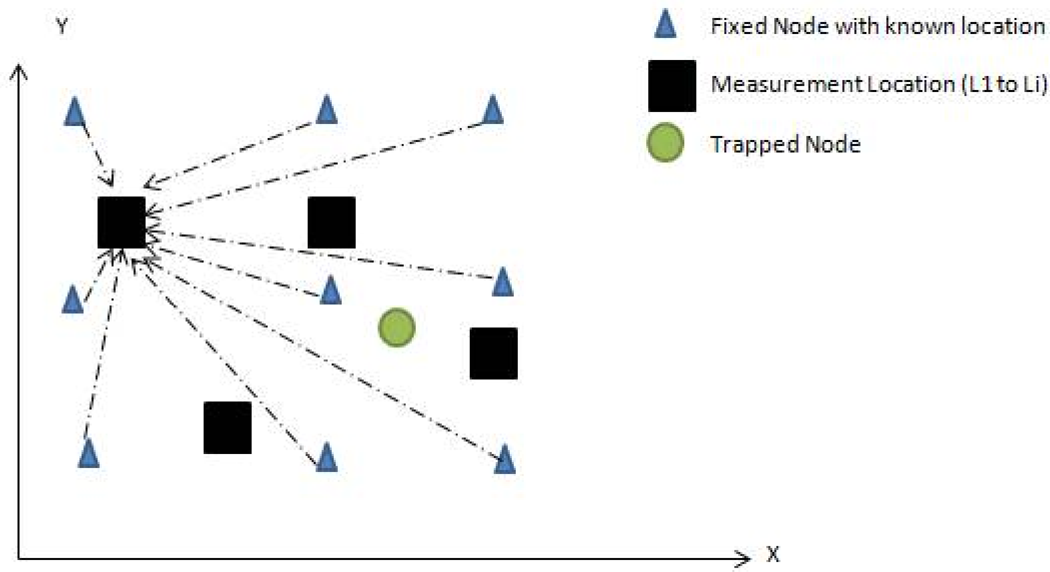


Figure 4-2 Location Fingerprinting Algorithm

It is shown in[87] that location fingerprinting is more efficient than ML (maximum likelihood) estimation method. Even in [89] the analysis have shown and reaches to the accuracy of 1.5m. The study utilizes Bayesian technique. In location fingerprinting, the fixed nodes (anchor nodes) are placed in predefined paths and movable node is allowed to move in that particular predefined path. When the movable node moves around the fixed node then the RF signatures is captured and stored in the anchor nodes. The smallest distance in between the nodes (anchor node) is known as Grid. During this offline training the RSSI values may vary for the same path taken repeatedly as sometimes the nodes are in LOS (Line of Sight) or sometimes out of LOS (Line of sight). The accuracy can further be increased by creating a database of different data sets.

This chapter focusses on the design of a hybrid algorithm for localization based on a combination of location fingerprint and unilateral algorithm which is a improved version of trilateration algorithm[32]. The hybrid algorithm is tested in experimental test bed. The algorithm developed is used to create a radio map with the use of fingerprinting algorithm and saving the last location of moving node (visitor node). The saved location is updated every time in the main central node away from the disaster prone area. This phase is pre disaster phase. Then in case if disaster takes place, the rescue team node will firstly focus on the nearest location found in radio map of trapped node. In post disaster phase, the rescue team node uses unilateral technique with VPM (Vector parameter based mapping) to search the trapped node.

The algorithm is tested and validated in the hardware designed and fabricated in University campus.

This database is also known as radio map. If all the information of RSSI is stored from location $L_1$ to $L_i$ then the array is known as *RF signature or fingerprint*.

## 4. 1 Description of Experimental Test Bed (Outdoor Location)

A dedicated hardware node has been designed in situ based on Xbee- Series2. The network for fingerprinting algorithm, trapped node and rescue team node consists of Xbee module based device. Figure 4-5 shows the designed hardware node. The Figure 1-2 shows the overview of anchor node installed in the field, where it is shown that the vehicle is carrying movable node and the two registration points is having updated information of vehicle node. The vehicle node will become the trapped node if disaster happens. The nodes deployed in the field are fixed nodes (anchor nodes), visitor node and Rescue operation node (RescOp node) are shown in Figure 4-3 & Figure 4-4.

Firstly a network has to be established in disaster prone area using some fixed nodes. These fixed nodes are intelligent to get the information of vehicles passing across it and making a radio map. As the vehicles are already registered at the registration point (refer Figure 1-2) far away from the disaster prone area, updated information regarding the estimated location of vehicles and also the no. of vehicles can be obtained at each and every point. The same information is routed through fixed nodes to registration points. So a radio map can be generated in registration point. In case disaster happens and fixed nodes get damaged, then also the updated estimated location is safe with registration points. The proposed system starts from the authentication point in disaster prone area i.e. Registration point 1 (Figure 1-2), where the vehicle entry gets registered and vehicle gets the wireless node.

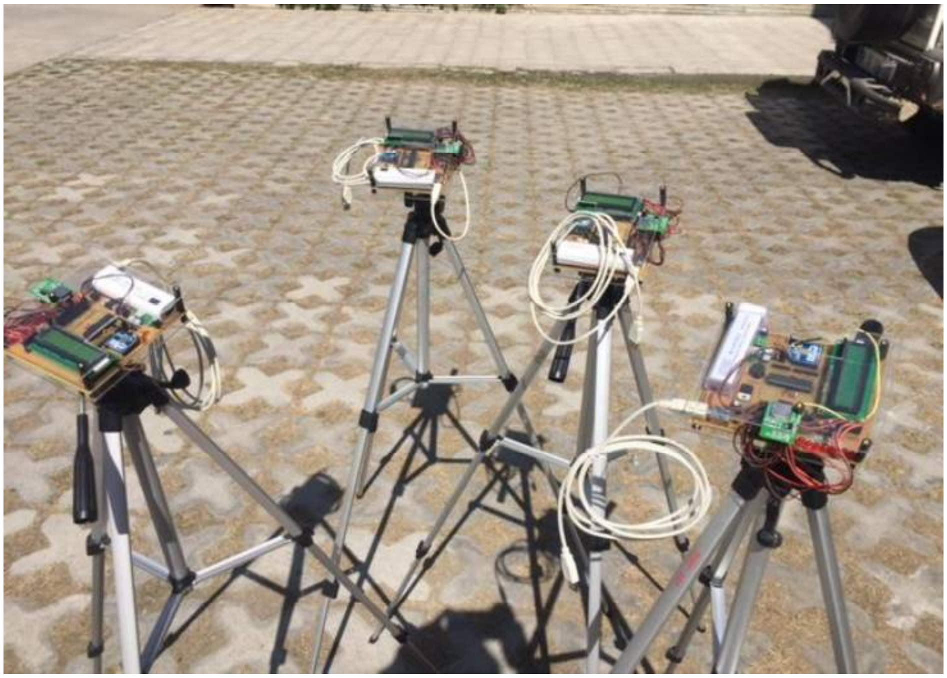

Figure 4-3Anchor Node (AN1)

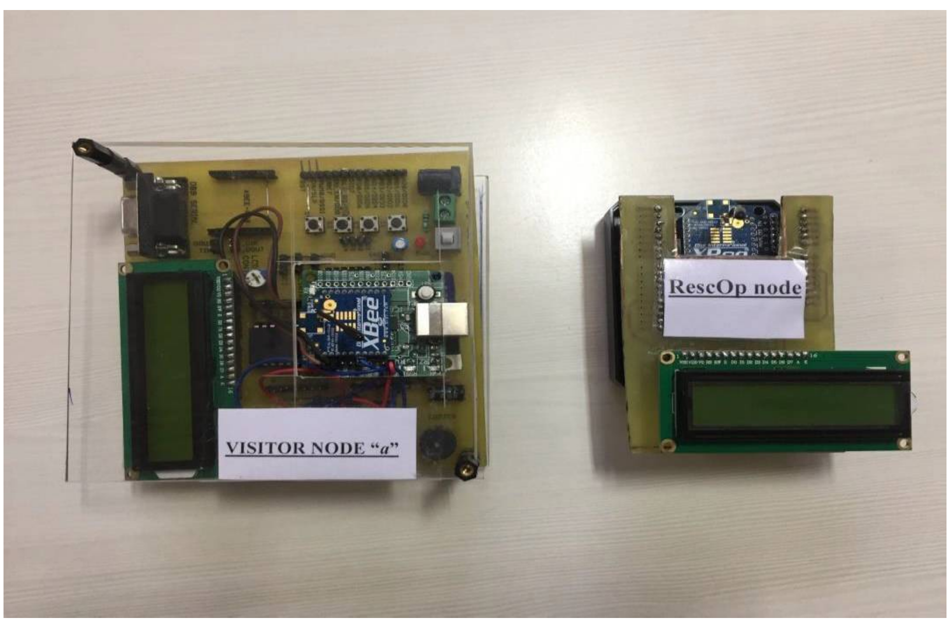

Figure 4-4Visitor Node (MN1) & Pursuit Node (RS1)

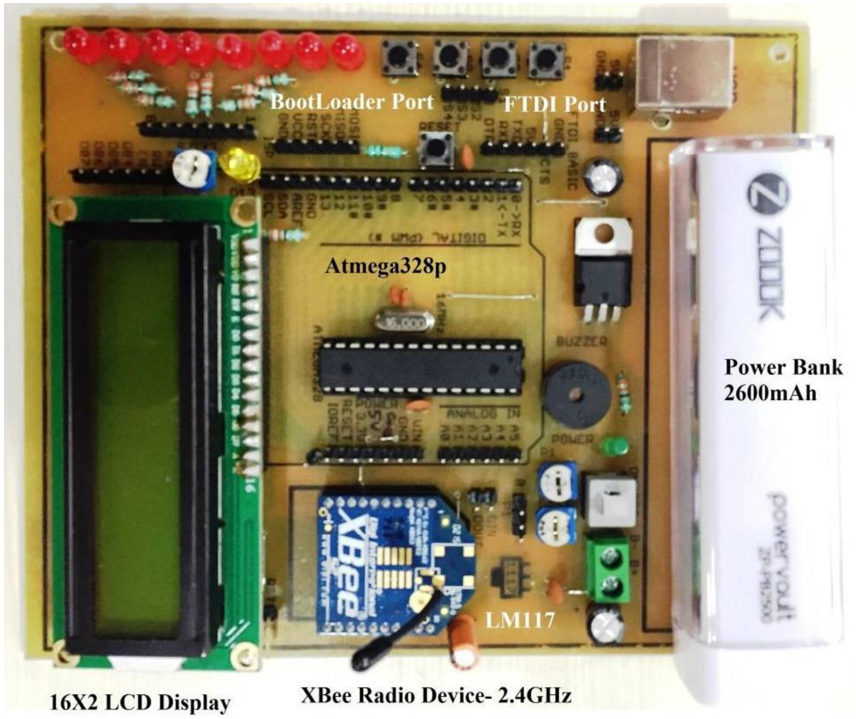


Figure 4-5 Hardware Node

During registration process, the info pertaining to no. of persons and vehicle no. that are going to travel through that disaster prone area is noted. After the handover of wireless node, vehicle enters the disaster prone area and the wireless network is initialized. There are anchor nodes already present and which are communicating with the node present in vehicle as soon as they are in communication range. Estimated location of the vehicle is updated all the time and data is logged wirelessly to the Registration Point. As soon as vehicle crosses the disaster prone area end point, the smart device is handed over to the Registration point 2. This technique is capable of making a radio map of the vehicle node. All the vehicle nodes get different node Id. Node Id is installed using X-CTU firmware. If disaster happens then the vehicle node will become the trapped node. By this time, the trapped node gets localized with rescue team node. The last estimated location can be tracked by radio map and after getting the

estimated location further localization will be done using unilateral technique using VPM. It is explained further in this chapter.
The proposed architecture is designed keeping in mind its role in post disaster. This primarily includes identification of fixed node placement in the predefined path. The nodes are placed at such a position so as to optimally cover in between registration point 1 and registration point 2. Survey pertaining to this also includes the study of geographical region so that important aspects will be covered like battery life time of nodes, durability of nodes in specific geographical region etc. After survey, the nodes are placed in a pre-defined path.

The experiments have been conducted in both outdoor as well as indoor location for location fingerprinting and unilateral algorithm. The experiments have been conducted keeping in view the performance of the network. The placements of nodes have been discussed with respect to the coverage.

## 4. 2 Outdoor Location:

The two OSA (outdoor seismic area) locations have been chosen for experiments. The first OSA location is between the dense infrastructural buildings (refer Figure 4-7) and the other OSA location is the dense forest (refer Figure 4-8). The network consist of 150 × 100 square mtrs with four fixed nodes and one visitor node subjected to move around the fixed nodes in the predefined path. The node position placement is shown in Figure 4-6. The node positioning is done keeping in view of proper handshaking of visitor node while moving from one fixed node to another fixed node.


Figure 4-6Node placement in OSA location

Figure 4-7 First OSA location

Figure 4-8Second OSA location

## 4. 3 Indoor Location

The validation of the system is checked for indoor location too. The first CIB (complex indoor building) location is covering 90×90 square meters (refer Figure 4-9) and second indoor location is 60×80 square meters refer Figure 4-10). The fixed nodes in first Indoor location is placed in between the pathways of one building to another and in second indoor location it is placed in close room consist of 20 chambers with no LOS in between the nodes.

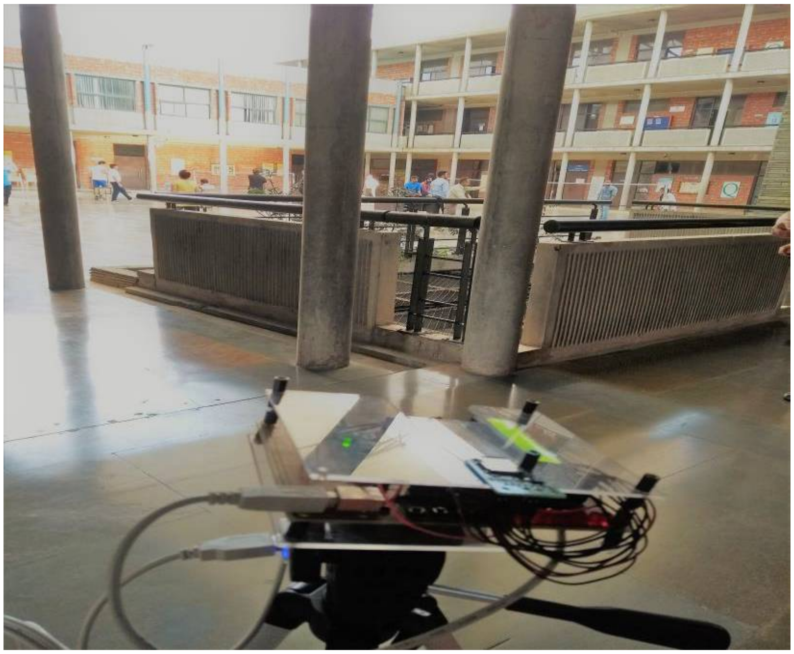

Figure 4-9CIB location 1

Figure 4-10CIB location 2

## 4. 4 Experimental setup with RescOp (indoor & outdoor locations)

In order to test the network in replica post disaster scenario, experiment is conducted for both indoor and outdoor locations. For this purpose, visitor node is assumed to be trapped (immobile) at some random location in the network. Then, the task of localizing this trapped visitor node is initiated with the help of RescOp node (Rescue Operation). The results are discussed in further chapters

### 4. 5 Study of RSSI versus Distance- Outdoor Location

The unilateral algorithm to be designed is based on RSSI values obtained from Xbee, hence it is important to study the behavior of RSSI in outdoor environment. This section examines the omnidirectional nature of Xbee antenna. To study the nature of RSSI in outdoor location specifically in disaster prone area, it is important to draw the RSSI versus distance map. The unilateral technique with VPM is dependent upon the nature of RSSI versus distance map. The unilateral method can be implemented in real time after designing RSSI map of Xbee node in seismic zone or disaster prone area. Real time RSSI values have been collected in the seismic area using designed wireless nodes. Values have been gathered in the seismic area in eight direction putting anchor node in middle of the field named ‘O’ refer Figure 4-11. Refer Figure 4-12 for real time experimental test field (outdoor location). The test bench is 80×50 mtrs field in seismic zone of Uttarakhand, India. The design is shown in. Figure 4-11. Receiver is moved around in all the directions. Firstly the receiver is subjected to move to $T_1$ direction with angle$\frac{\pi}{2}$. RSSI drop per meter has been observed and calculated as -1.3777 dBm/m. Same receiver is subjected to move to $OT_2$, $OT_3$, $OT_4$, $OT_5$, $OT_6$, $OT_7$, $OT_8$ direction and RSSI Drop/m has been calculated as -1.14, -1.533, -0.88, -1.02, -1.1, -1.16, -1.06 dBm/m respectively refer Table 4-1. The calculated value observed shows the omnidirectional behavior of Xbee in disaster prone area. The same has been plotted refer Table 4-1.

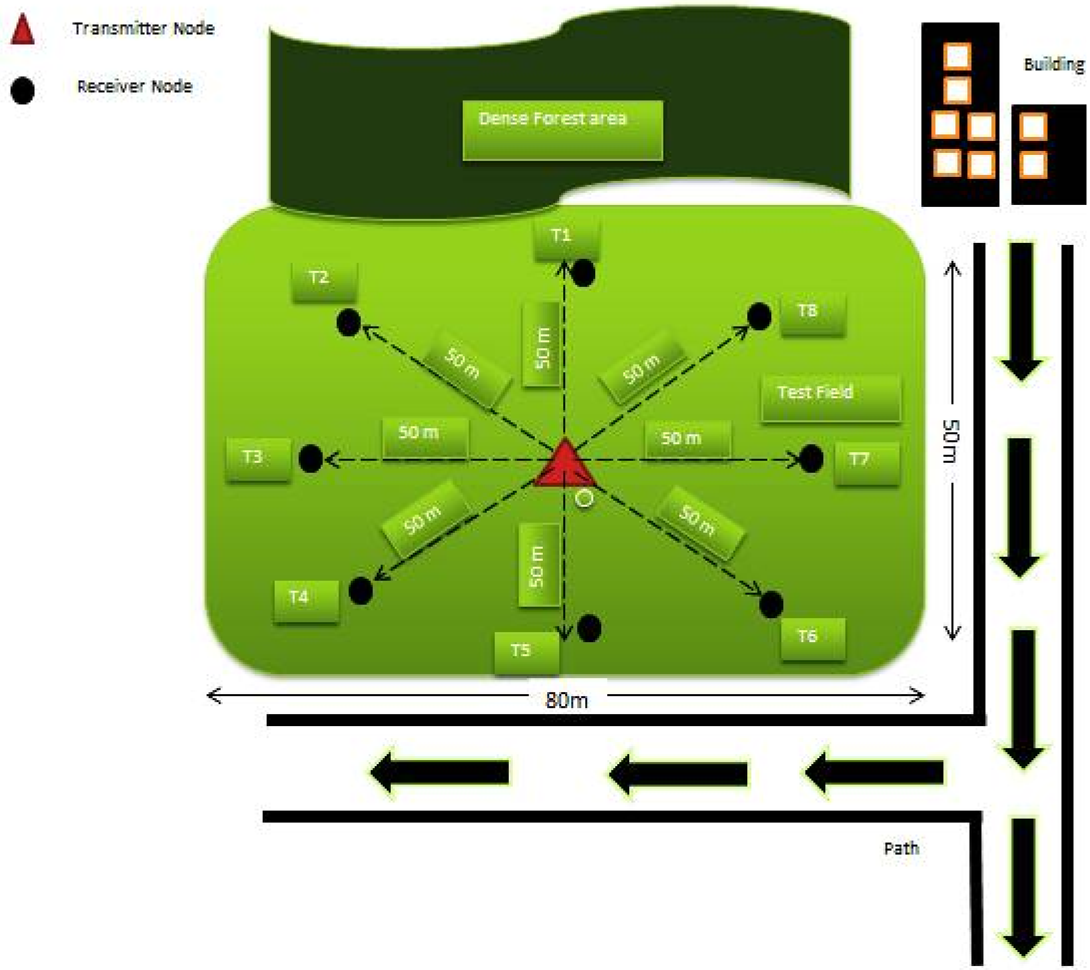


Figure 4-11 Experimental test bench with deployed WSN for outdoor location


Figure 4-12 Real Experimental test bench with deployed WSN for outdoor location

Table 4-1 Measured Parameters of RSSI drop/m for outdoor location

| **Direction** | **Distance from center O (in mtrs)** | **Angle** | **Signal Strength dBm** | | **RSSI Drop/m** | **Total Distance Covered (in mtrs)** |
|---|---|---|---|---|---|---|
| | | | **Start** | **Stop** | | |
| $OT_1$ | 45 | $\frac{\pi}{2}$ | -28 | -90 | -1.3777dBm/m | 36 |
| $OT_2$ | 50 | $\frac{3\pi}{2}$ | -35 | -90 | -1.14 dBm/m | 44 |
| $OT_3$ | 30 | $\pi$ | -35 | -80 | -1.533 dBm/m | 33 |
| $OT_4$ | 50 | 0 | -38 | -78 | -0.88 dBm/m | 57 |
| $OT_5$ | 50 | $\frac{5\pi}{4}$ | -38 | -87 | -1.02 dBm/m | 49 |

| | | | | | | |
|---|---|---|---|---|---|---|
| $OT_6$ | 50 | $\frac{7\pi}{4}$ | -25 | -88 | -1.1 dBm/m | 45 |
| $OT_7$ | 50 | $\frac{3\pi}{4}$ | -25 | -85 | -1.16 dBm/m | 43 |
| $OT_8$ | 50 | $\frac{\pi}{4}$ | -28 | -85 | -1.06 dBm/m | 47 |

Polynomial Quintic Regression using the field data gives the mathematical relationship (refer equation 3.3) between distance vs RSSI drop for $6^{th}$ order polynomial equation.

$$Y = -3.6 \times 10^{-3} x^6 + 9.888 \times 10^{-2} x^5 - 1.0715 x^4 + 5.7359 x^3 - 15.686x^2 + 20.343 x - 10.79 \quad \text{(equation 4.3)}$$

where,

Y = Distance in meters

x= RSSI in dBm

This gives us the approximate distance from the node in communication based on the RSSI of the signal obtained. Figure 4-11 shows -50dBm points from a fixed point in all directions. It is clear from the Figure 4-13 that a polynomial fit for the curvature will give good results considering the current application in disaster prone area.

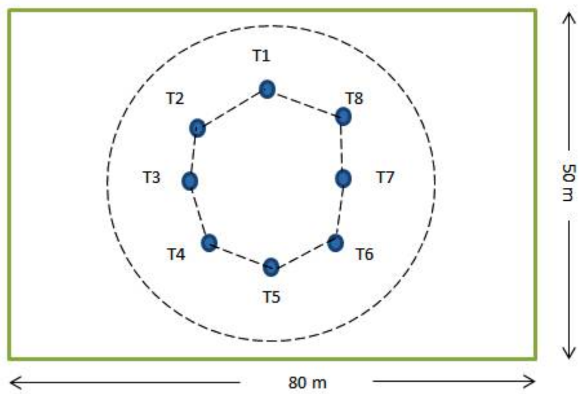


Figure 4-13 Real plot of Omnidirectional behavior in specific Outdoor location

## 4. 6 Algorithm for Unilateral Method – VPM protocol Based

The aim of the algorithm is to reach the anchor (target) node by VPM (Vector Parameter based mapping). In the first step, the node will search for the local as well as remote RSSI and thereby calculating the estimated distance. The RSSI results are stored in the local memory of rescue team node. The node will calculate the least remote RSSI value and inform to move to the new location as illustrated in Figure 4-14. The rescue team node continues the steps till it reaches the target node. The algorithm is independent of the other anchor nodes unlike in the trilateration algorithm.

### 4. 6. 1 VPM (Vector Parameter based Mapping) Protocol

VPM protocol is state of the art design based on unilateral technique. The blue dot is the trapped node and red dot is the node with rescue or searching team (refer Figure 4-15). The disaster prone area, where the node is trapped is divided into the vectors. Let's assume that the current position of searching node is in position (x, y). Now the best possible move of node is 90° in direction towards (x', y') or (x'', y'').

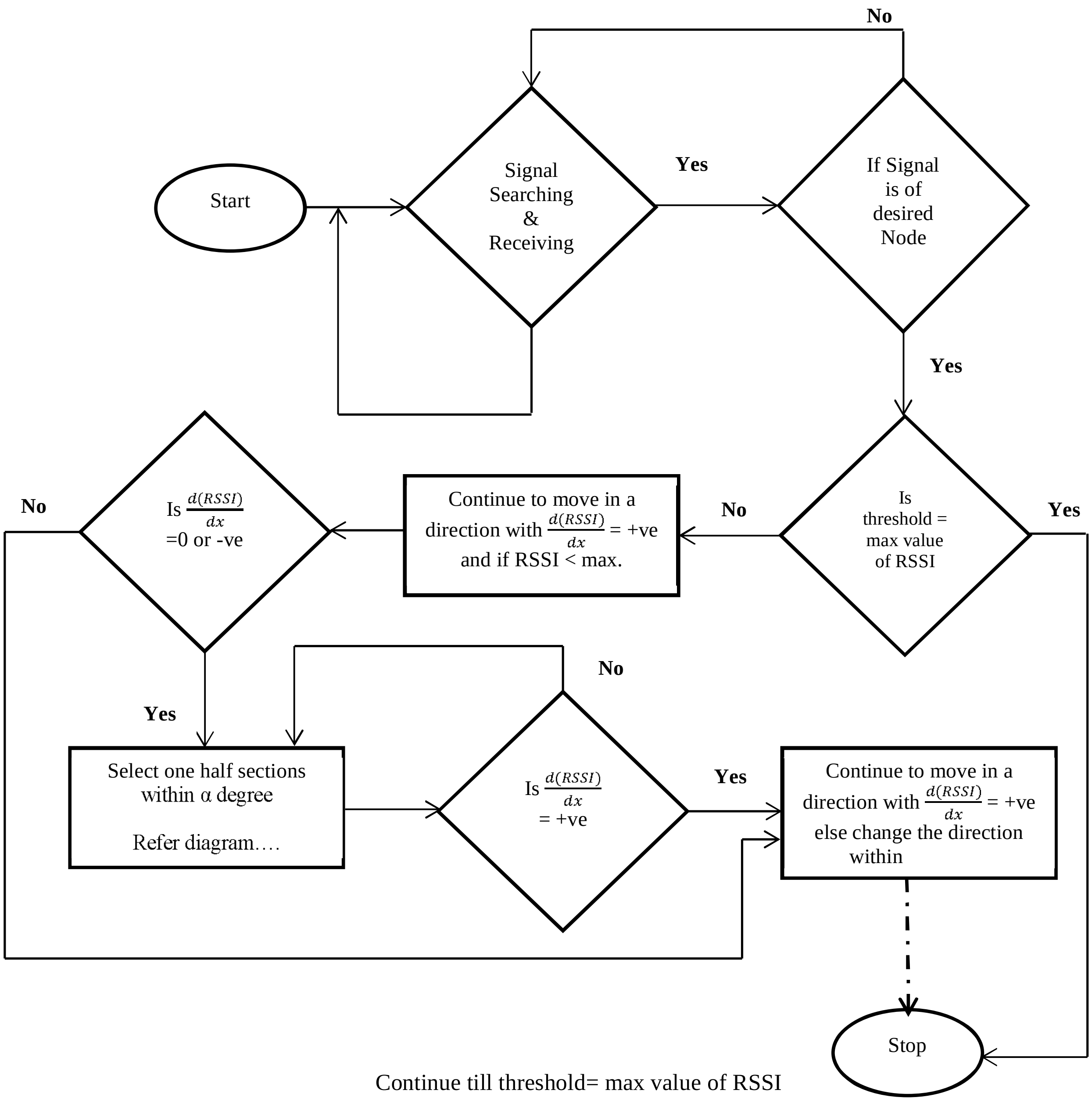


Figure 4-14 Flowchart for Unilateral Algorithm

There is no way situation to move to angle more than 90° because it leads to increase of RSSI value. So the minimal angle of movement will be 90°. If the searching node move towards (x', y') or (x'', y'') to distance x or move towards (x''', y''') to distance y then it will get same RSSI value due to omnidirectional behavior of Xbee antenna. Important point to note is the distance y < x, so the node gets more strong RSSI signal in (x''', y''') as compare to the points (x', y') or (x'', y''). So the best possible move of searching node is towards (x''', y''') i.e. to the angle of 45°. Practically it will be always α° <90°. So the new coordinates of searching node will be (x''', y'''). Again the searching node map the area through vectorization and move accordingly towards the trapped node by α° angle which is always less than (<) 90°.

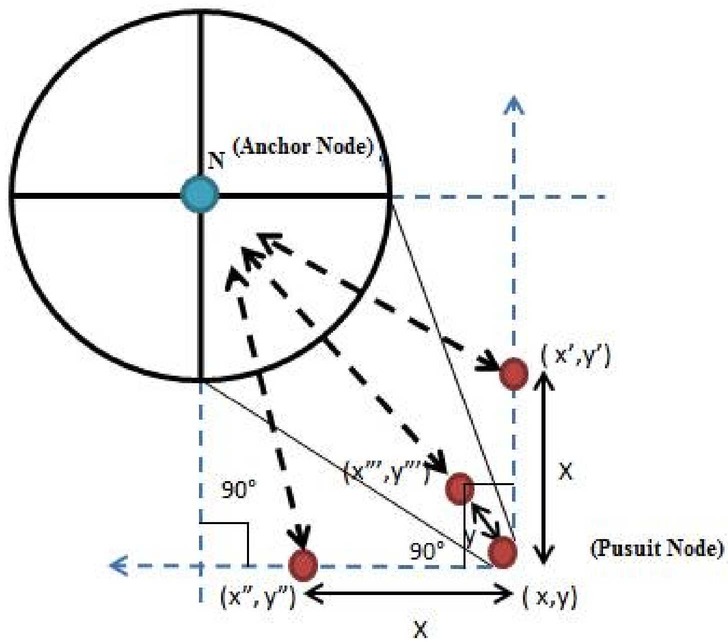


Figure 4-15 Approach towards Anchor Node- VPM Protocol based

The rescue team node (pursuit node) always do the search training in +x, -x, +y and –y directions. And move accordingly towards the anchor (target) node (refer Figure 4-16). The search training is explain in algorithm (refer Figure 4-14).

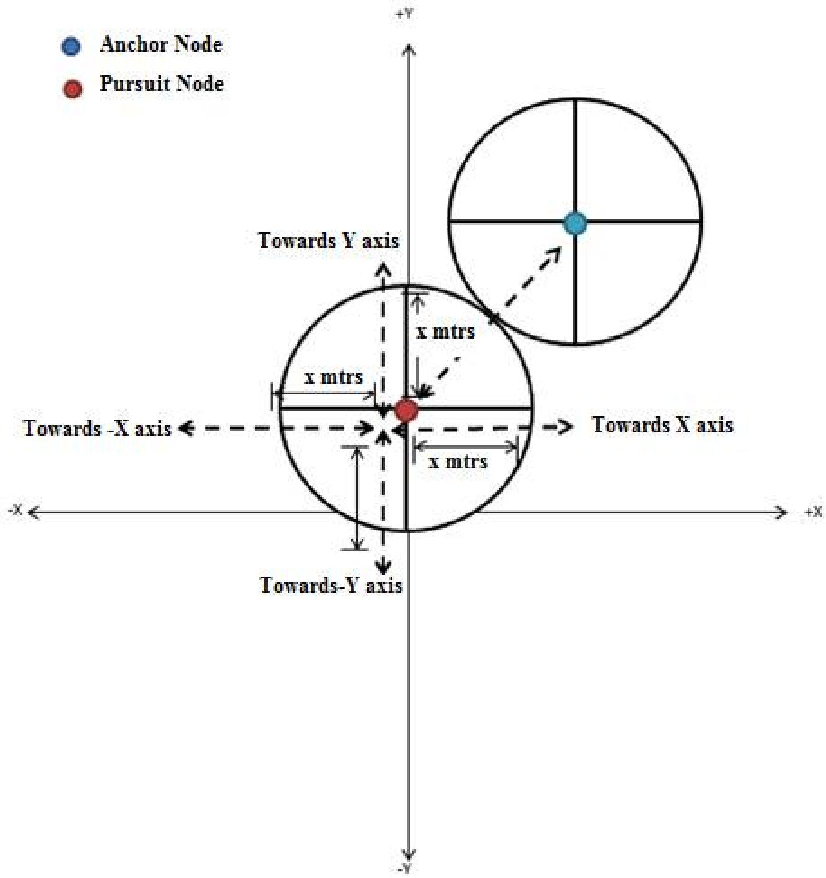


Figure 4-16 Training pattern in -X, X, -Y, Y direction using VPM Protocol

## 4. 7 Conclusion

In this chapter, a novel approach for localization of nodes in disaster area test field has been explained and then the experiments on test field are shown. The modules have been tested for omnidirectional radiation pattren and then using these modules a state of the art unilateral technique has been introduced over trilateration algorithm. Following the selection of sensor module, a new approach to localize has been introduced which uses RSSI as a tool. The algorithm designed is tested and the trapped node is completely discoverable.