Chapter 4

Base Station Positioning Algorithm in a Wireless Sensor Network

4.1 Introduction:

WSN is a densely deployed collection of a large number of self-organising wireless sensor nodes. It has a limited energy resource with a base station to collect and process the data from sensor nodes. Base station location is an important factor in a WSN as it affects its lifetime. The objective is to minimize the overall energy consumption in a WSN. In WSN usually a proposed heuristic algorithm is being used to find the location of a base station. Considering that some of the nodes to be far enough to use a different path loss model for their signals to the base station, this proposed algorithm considers two categories of nodes and hence two different path loss models based on their distance from the base station. In this study investigation has been done to find out the appropriate location of the base station in a two-tiered WSN field. The objective is to minimise the overall energy consumption in a WSN. Base Station Positioning Routing Algorithm is proposed by Tripathy et al. [25]. The optimal location of a base station can be analysed with respect to minimum energy expenditure or maximum lifetime of a sensor network. Here this algorithm has been simulated using performance parameters like Energy Values, Latency Values, Packet Delivery Ratio and Residual Energy Values. The overall energy consumption is quite close to the optimal solution.

4.2 Problem Formulation:

The energy consumption in a network for one round is the sum of energy dissipated by all the clusters.

$$E_{Round} = \sum_{j=1}^{k} E_{Cluster}(j) \tag{4. 1}$$

Now using equation from energy consumption model,

$$E_{Round} = L.(2n-k).E_{elec} + n.L.E_{DA} + \sum_{i=1}^{k} E_{amp}\left(L, d_{bs}(i)\right) + \sum_{i=1}^{n} E_{amp}(L, d_{ch}(i)) \tag{4.2}$$

As signals from all the nodes are assumed to suffer free space loss in reaching to respective cluster head, and following [69],

$$\sum_{i=1}^{n} E_{amp}\left(L, d_{ch}(i)\right) = L.(n-k).\varepsilon_{fs}.\frac{M^2}{2\pi k} \tag{4.3}$$

Here, M is the length of the square field used for WSN deployment. There are three different cases depending on distance between cluster head node and the base station.

Case 1: When all the nodes in a sensor network are near to the base station, such that there is free space loss for the transmission from all nodes to base station. Then the E_{Round} is given by

$$E_{Round} = L\left[(2n-k).E_{elec} + n.E_{DA} + (n-k).\varepsilon_{fs}.\frac{M^2}{2\pi k} + \varepsilon_{fs}\sum_{j=1}^{k} d_j^2\right] \tag{4.4}$$

Here d_j is the distance between cluster head and the base station. After n/k rounds when every node has become cluster head once, then the total energy spent is given by

$$E_{total} = L.\frac{n}{k}\left[(2n-k).E_{elec} + n.E_{DA} + (n-k).\varepsilon_{fs}.\frac{M^2}{2\pi k}\right] + L.\varepsilon_{fs}\sum_{j=1}^{n} d_j^2 \tag{4.5}$$

Case 2: When base station is far away from all the nodes, that is multipath loss exists for transmission from nodes to base station. Then E_{total} spent in n/k rounds is given by

$$E_{total} = E_1 + L.\varepsilon_{mp}\sum_{j=1}^{n} d_j^4 \tag{4.6}$$

Where

$$E_1 = L.\frac{n}{k}\left[(2n-k).E_{elec} + n.E_{DA} + (n-k).\varepsilon_{fs}.\frac{M^2}{2\pi k}\right] \tag{4.7}$$

Case 3: When some nodes are near and some nodes are far away from the base station then E_{total} is given by

$$E_{total} = E_1 + L.\varepsilon_{fs}\sum_{i=1}^{p} (d_i^2) + L.\varepsilon_{mp}\sum_{j=1}^{q} d_j^4 \tag{4.8}$$

Here node i and node j are from different sets, and p number of nodes are nearer to base station and q number of nodes are farther from base station ($d_i < d_0$ => nearer nodes and $d_j \geq d_0$ => farther nodes). Though E_1 is same in all the three cases, the second and third term in equation (4.2.8) is used for further investigation.

For Case 1, Energy for transmitting data to base station E_{bs} in each n/k rounds is

$$E_{bs} = L.\varepsilon_{fs}\sum_{j=1}^{n} d_j^2 \tag{4.9}$$

For Case 2,

$$E_{bs} = L.\varepsilon_{mp}\sum_{j=1}^{n} d_j^4 \tag{4.10}$$

For Case 3,

$$E_{bs} = L.\varepsilon_{fs}\sum_{i=1}^{p} d_i^2 + L.\varepsilon_{mp}\sum_{j=1}^{q} d_j^4 \quad (4.11)$$

To find optimal location for the base station, which minimizes E_{bs}.

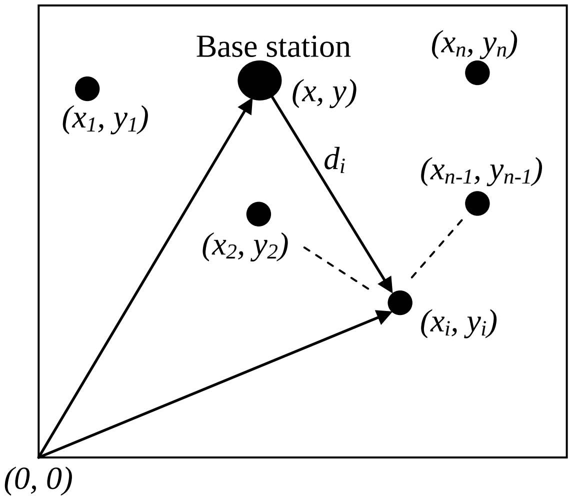

Figure 4.1: A Wireless Sensor Network topology

Let n sensor nodes be uniformly distributed in a rectangular field at $(x_1; y_1)$; $(x_2; y_2)$; ….,$(x_n; y_n)$ respectively, and base station be deployed at $(x; y)$ can be seen in Figure 4.1. The Euclidean distance between the base station and the nodes are $d_1; d_2; d_3...,d_n$ respectively. Here d_i is

$$d_i = \sqrt{(x - x_i)^2 + (y - y_i)^2} \quad (4.12)$$

Case 1: $(d_i < d_0; \forall_i)$: Let d_2 be the sum of squares of all the Euclidean distances. As all the nodes will have only free space loss, energy consumption in amplification, E_d^2 in the sensor network will be sum of amplifier energy consumption of the all the nodes.

$$E_{d^2} = L.\varepsilon_{fs}.\left(d_1^2 + d_2^2 + d_3^2 + ... + d_n^2\right) \quad (4.13)$$

Sum of square of all the Euclidean distances, d_2 will be minimum at the centroid of nodes. Thus amplification energy consumption E_d^2 will also be minimum if base station is placed at the centroid.

Case 2 ($d_i \geq d_0;\ \forall_i$): When all the nodes are far away from the base station and will have only multi-path loss. Then it is required to minimize

$$E_{d^4} = L.\varepsilon_{mp}.\left(d_1^4 + d_2^4 + d_3^4 + ... + d_n^4\right) \tag{4.14}$$

for optimal base station location. E_d^4 will be minimum at a point, say F; the point F can be determined only by heuristic search methods. This point F converge to the centroid of nodes when all the nodes are placed symmetrically.

Case 3 (Some nodes with $d_i < d_0$ and remaining nodes with $d_i \geq d_0$): When few node are near and other remaining nodes are far away from the base station then it is required to minimize the following equation.

$$E_{d^{2,4}} = L.\varepsilon_{fs}.\left(d_1^2 + ... + d_p^2\right) + L.\varepsilon_{mp}.\left(d_1^4 + ... + d_p^4\right) \tag{4.15}$$

where $p + q = n$ and $p, q \geq 1$.

Now minimizing $E_{d^{2,4}}$ will depend on which type of nodes (nearby nodes or farther nodes) are dominating in energy expenditure. If nearby nodes are dominating i.e. p >> q, then centroid of p nodes will be the optimal position. If $q \geq p$, then farther nodes will decide the optimal location for the base station and then centroid of q nodes (if q nodes are symmetrically placed) will be the optimal position. When both type of nodes are equally dominating, the optimal location of the base station can be found by the proposed algorithm.

4.3 Algorithm for Base Station Location:

Problem: To find the location of base station where $E_{d^{2,4}}$ is minimized.

Step 1: Find centroid (C_x; C_y) of the nodes distributed in the field. This is the point, where E_{d^2} is minimized, and is given by

$$C_x = \frac{\sum_{i=1}^{n} x_i}{n} \tag{4.16}$$

and

$$C_y = \frac{\sum_{i=1}^{n} y_i}{n} \tag{4.17}$$

Step 2: Find the nodes which are at less than d_0 distance from the centroid.

Step 3: Weights are calculated using centroid for all the nodes as

$$w_i = \begin{cases} 1 & if\ d_{iC} < d_0 \\ \frac{d_{iC}^2}{d_0^2} & if\ d_{iC} \geq d_0 \end{cases} \tag{4.18}$$

Here d_{iC} is the distance between i^{th} node and the Centroid.

Calculation of weights for proposed algorithm: In this algorithm the weight *w* is assigned to *1* for the nodes which are at less than d_0 distance from the centroid, and something else for other nodes which are at equal or higher distance than d_0 from the centroid. As the proposed point will be weighted average of all points, the weights *w* for all the node will be *1*, when all the nodes are closer than d_0 from centroid. Thus proposed point *P* is same as centroid. The proposed point will be different only when some nodes are farther than d_0 distance from centroid.

For a square field with length of side `*M*'. It is assumed that $M = d_0/sqrt\ 2$. In this case wherever the base station will be placed, only free space loss will be suffered by transmission from all the nodes inside the field

Three nodes have been taken at ($x_1; y_1$); ($x_2; y_2$) and ($x_3; y_3$) in the field, then the base station location P ($P_x; P_y$) is given by proposed point will be P ($P_x; P_y$) as all the nodes can suffer only free space loss

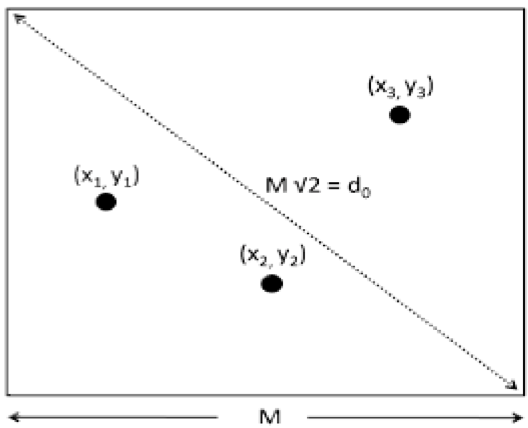

Figure 4.2: Weights calculation for Algorithm

$$P_x = \frac{x_1 + x_2 + x_3}{3} \qquad (4.19)$$

and

$$P_y = \frac{y_1 + y_2 + y_3}{3} \qquad (4.20)$$

But when side $M > d_0/sqrt\ 2$ and let the base station is at centroid of nodes. Then two nodes will suffer free space loss and third node will suffer multipath loss. If weight to (x_3; y_3) is w and for other nodes it is 1, then proposed point P ($P_x; P_y$) is given by

$$P_x = \frac{x_1 + x_2 + w.x_3}{2 + w} \qquad (4.21)$$

and

$$P_y = \frac{y_1 + y_2 + w.y_3}{2 + w} \qquad (4.22)$$

From the above equations, assume w is very large say 1, then P_x will become x_3 and P_y will be y_3. If w is very small say 0, then P_x will become $x_1+x_2/2$ and P_y will be $y_1+y_2/2$.

Thus, it is required to make these weights more than *1* so that proposed point shifts towards nodes, which are having multipath loss.

Weights must increase with distance from the centroid for shifting proposed point towards nodes which are having multipath loss. Using w as $\frac{d_{iC}^2}{d_0^2}$ provide good results as w is always greater than *1* and proportional to the distance and thus with amplifier energy also.

$$w = \frac{\varepsilon_{mp}.d_{iC}^4}{\varepsilon_{fs}.d_{iC}^2} = \frac{\varepsilon_{mp}.d_{iC}^2}{\varepsilon_{fs}} = \frac{\left(d_{iC}\right)^2}{\left(d_0\right)^2} \tag{4.23}$$

Step 4: Determine the weighted average of nodes' positions as proposed optimal position ($x_p; y_p$) for the base station

$$x_p = \frac{\sum_{i=1}^{n} w_i.x_i}{\sum_{i=1}^{n} w_i} \tag{4.24}$$

and

$$y_p = \frac{\sum_{i=1}^{n} w_i.y_i}{\sum_{i=1}^{n} w_i} \tag{4.25}$$

This is a heuristic algorithm which provides an approximate solution. For more accurate solution (theoretical optimal point), the base station can be placed in such a way that the distance from all the nodes which are at less than d_0 from the centroid, may increase up to the maximum of d_0 while reducing the distance from the remaining nodes which are at greater than d_0 distance from centroid.

BSP assumes that the sensor nodes always have data to send, thus it is not suitable for event driven applications, such as the tracking of enemy activities, fault detection and diagnosis in machinery.

4.4 Simulation and Results:

The aim of this simulation is to evaluate the characteristics of cluster based routing scheme for sensor network. Base Station Positioning Routing Algorithm based on the performance matrices like Energy Values, Latency Values, Packet Delivery Ratio and Residual Energy Values. This simulation of Clustering is done in NS2. The Number of nodes considered here is 40.

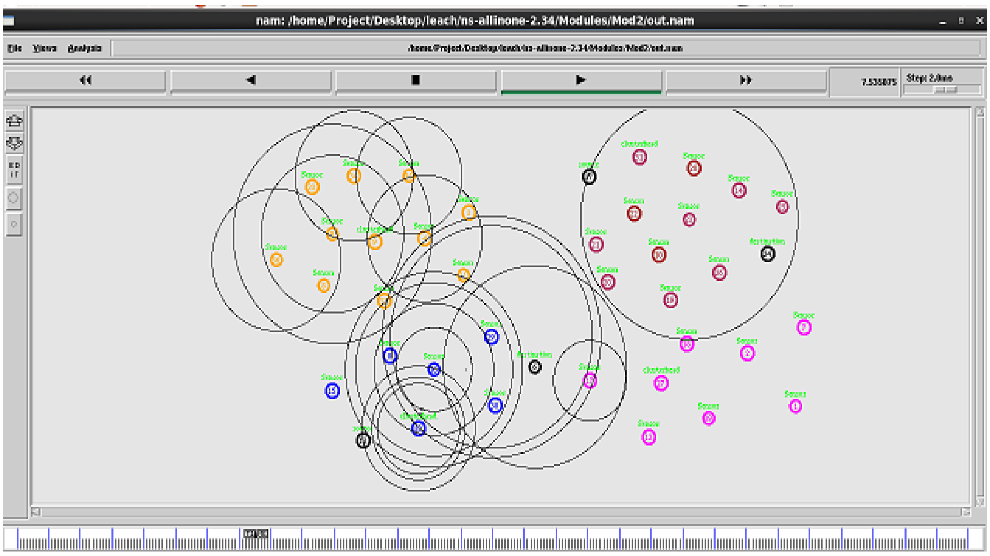

Figure 4.3: Layout of BSP Simulation

Simulation Parameters:

```
#====================================
#      Simulation parameters setup
#====================================
set NS /home/Project/Desktop/leach/ns-allinone-2.34/ns-2.34/
set val(chan)   Channel/WirelessChannel    ;# channel type
set val(prop)   Propagation/TwoRayGround   ;# radio-propagation model
set val(netif)  Phy/WirelessPhy            ;# network interface type
set val(mac)    Mac/802_11                 ;# MAC type
set val(ifq)    Queue/DropTail/PriQueue    ;# interface queue type
set val(ll)     LL                         ;# link layer type
set val(ant)    Antenna/OmniAntenna        ;# antenna model
set val(ifqlen) 50                         ;# max packet in ifq
set val(nn)     40                         ;# number of mobile nodes
set val(rp)     BSP                        ;# routing protocol
set val(x)      1407                       ;# X dimension of topography
set val(y)      732                        ;# Y dimension of topography
set val(stop)   30.0                       ;# time of simulation end
set val(em)     EnergyModel                ;# energy model
set val(Energy) 1000                       ;#Joules
set speed       0.5                        ;#
set packet_size 590                        ;#
set interval .05                         ;#
source $NS.ns1
#====================================
```

Table 4.1: Simulation Results BSP

Time(Sec)	Energy Values	Latency Values	PDR Values	Residual Energy Values
10.000	33.184	37.215	0.9889	38966.8
15.000	49.585	36.4202	0.9919	38950.7
20.000	65.996	35.9687	0.9961	38934.5
25.000	83.403	35.7532	0.9969	38917.3
30.000	98.808	35.5849	0.9974	38901.2

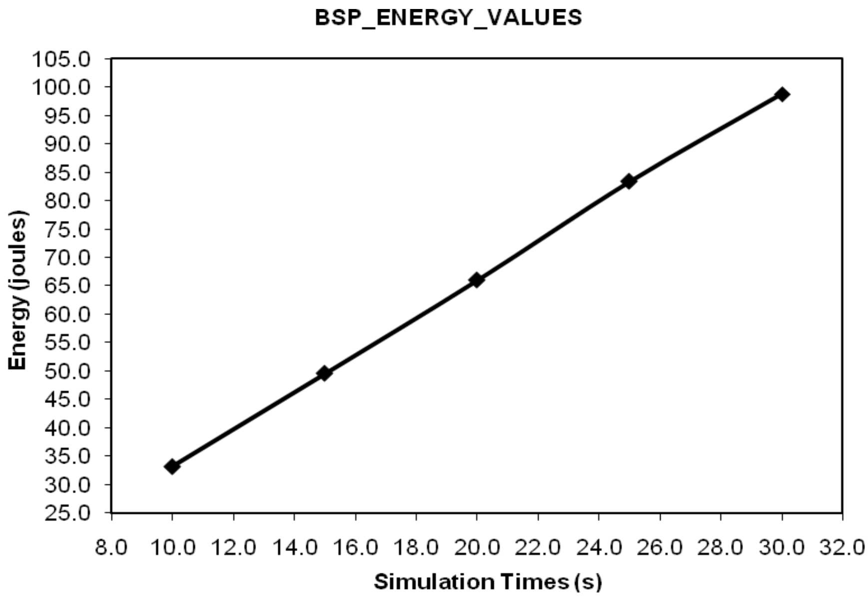

Figure 4.4: Simulation Time Vs Energy Values

The Energy Consumption Value at 10 sec Simulation Time is observed to be 33.184 for Energy-Balanced Routing Algorithm, at 15 sec, 20 sec, 25 sec, 30 sec are 49.585, 65.996, 83.403, 98.808 respectively. So it is clearly shown in Figure 4.4 that the variation of Energy Values with simulation time is increasing.

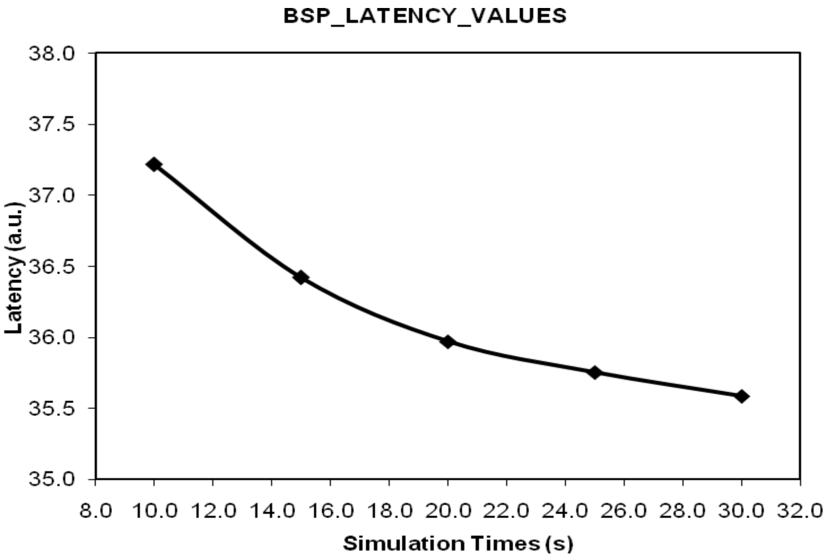

Figure 4.5: Simulation Time Vs Latency Values

Form the Figure 4.5 it is shown that the Latency Value at 10 sec Simulation Time is 37215. Then at 15 sec, 20 sec, 25 sec and 30 sec are observed to be 36.4202, 35.9687, 35.7532, and 35.5849 respectively. So from the above results we can say that the variation of Latency Values with Simulation Time is increasing.

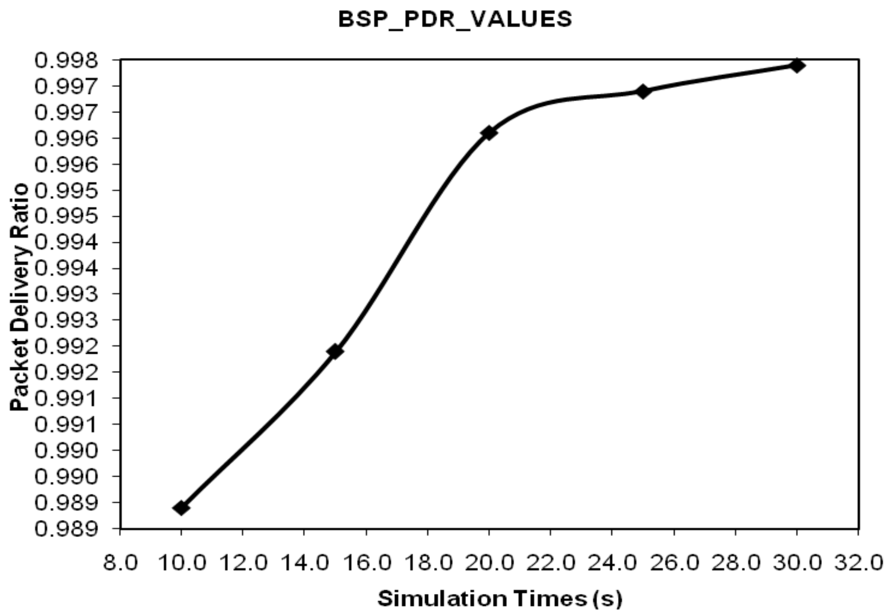

Figure 4.6: Simulation Time Vs PDR Values

Figure 4.6 shows the variation of Packet Delivery Ratio (PDR) values with simulation time from 10 sec to 30 sec at an interval of 5 sec. The PDR values are observed to be 0.9889, 0.9919, 0.9961, 0.9969 and 0.9974 respectively.

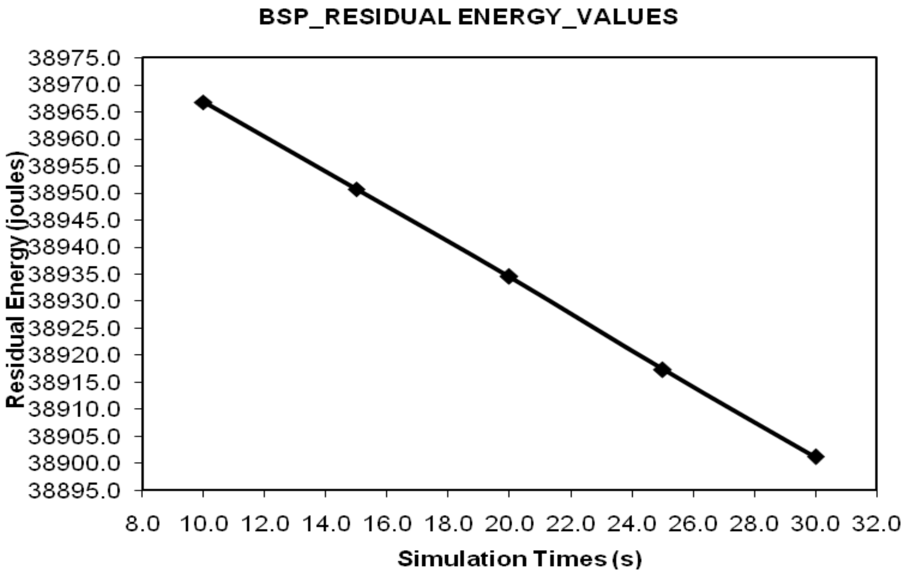

Figure 4.7: Simulation Time Vs Residual Energy Values

The Residual Energy Values at 10 sec Simulation Time is observed to be 38966.8 for Cluster Based Base Station Positioning Algorithm, at 15 sec, 20 sec, 25 sec, 30 sec are 38950.7, 38934.5, 38917.3, 38901.2 respectively as shown in Figure 4.7.

4.5 Conclusion:

The present simulation represents the variation of different performance parameters for the Cluster Based Base Station Positioning Algorithm. These graphs show the Energy values, Latency values, Packet Delivery Ratio and Residual Energy Values using this algorithm. These results can be used for the deployment of a base station in two-tiered WSNs.