Optimization of Base Station and Maximizing the Lifetime of Wireless Sensor Network

P.Parthiban[1], G.Sundararaj[2], K.A.Jagadheesh[3], P.Maniiarasan[4]
[SS1]Research Scholar, P.S.G College of Technology, Coimbatore, India
[2,3]Associate Professor, P.S.G College of Technology, Coimbatore, India
[4]Professor,Nehru Institute of Engineering and Technology, Coimbatore, India
[1]parthibanmephd@gmail.com, [2]gsraj_557@yahoo.com,[3] jagu_psgtech@yahoo.com,[4] maniiarasan@gmail.com

Abstract— **Maximizing the Wireless Sensor Networks (WSNs) lifetime is one of the most remarkable studies in the academic and the industrial research. In the existing Base station locations, the sensor network lifetime is short due to higher energy consumption. Higher energy consumption is due to the non-optimized location of base station. Non optimized location increases the distance between the sensor nodes to the base station, so it will not transfer the data directly to the base station. Each node transfer the data to the neighbor node and finally it reaches the base station. Due to transferring of the data to the neighbor node increases the data rate step by step and also the number of sensor nodes increases the optimal location of base station to become complex. So the main objective is to find optimal base station location to reduce energy consumption and to maximize the network's lifetime in wireless sensor networks and to find the optimal path for all sensor nodes to the base station to analyze its lifetime. In this paper, an algorithm based on Gravity Location Model and data routing based on particle swarm optimization (PSO) are thus proposed for efficient energy consumption and data routing.**

Keyword-Wireless sensor network, Base station, Gravity location, network lifetime, particle swarm Optimization.

I. INTRODUCTION

A wireless sensor network (WSN) consists of wireless sensors nodes that are distributed accordingly to their functionality, to monitor physical or environmental conditions, such as temperature, sound, pressure, etc. These sensors pass their data through the network to a data center via base stations consecutively. During the past decades, the development of wireless sensor networks were motivated by military applications but today such networks are used in many industrial and consumer applications which includes industrial process monitoring and control, machine health monitoring, and so forth. The WSN is made of nodes, from a few to several hundred, where each node is connected to one (or sometimes several) sensors. Each such sensor network node has typically several parts such as a radio transceiver, a microcontroller, an electronic circuit for interfacing with the sensors and an energy source, usually a battery enabled with a solar panel form of energy harvesting. A sensor node might vary in size, depending on the functions. The cost of sensor nodes is similarly variable, depending on the complexity of the individual sensor nodes.

An important performance metric for wireless sensor networks is the so-called network lifetime, which is highly dependent upon the physical topology of the network. This is because energy expenditure at a node to transmit data to another node not only depends on the data bit rate, but also on the physical distance between these two nodes. Consequently, it is important to understand the impact of location related issues on network lifetime performance and to optimize topology during network deployment stage. This article considers the important base station placement problem for a given sensor networks such that network lifetime can be maximized. The following problem has been specifically considered and analyzed. Given a sensor network with each node I producing sensing data at a rate of r, where should we place the base station in this sensor network such that all the data can be forwarded to the base station such that the network lifetime is maximized.

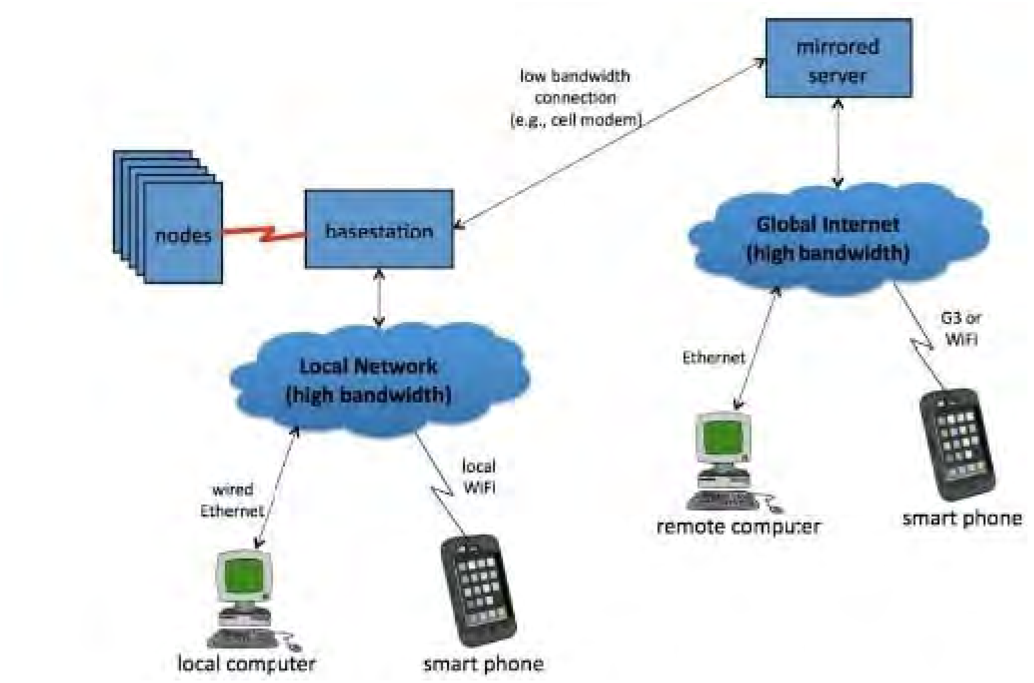

Fig 1. A Wireless Sensor Network

The Section II provides the related work. The Section III provides the existing system. Followed by the Gravity location model, it deals with the location of the optimum point using gravity location algorithm in the section IV. Section V provides the simulation of the algorithm and finding the new optimum location for the base station. The energy consumed for data transfer among the sensor nodes is also discussed in the previous section. The section VI deals with the Particle swarm optimization and the optimized data routing.

II. Related Work

The following are the relevant literature pertaining to the process placing base station in an optimized location. Yi Shi et al [20] this paper deals with the approximation algorithm that can guarantee optimal network lifetime performance for base station placement problem. Cerulli.R et al [3] author explained most power dissipation occurs during communication, thus routing protocols in wireless sensor networks (WSNs) mainly aim at power conservation. A routing protocol should be scalable, so that its effectiveness does not degrade as the network size increases. Konstantinos Kalpakis et al [7] discussed the maximum lifetime data gathering problem. Ming Yu et al [4-5] addressed how to dynamically organize these sensors into wireless communication network and effectively route the information among sensors to a remote collection station. Mohamed Younis [13] proposed Reliable Energy Aware Routing (REAR), which is a distributed, on-demand, reactive routing protocol that is intended to provide a reliable transmission environment for data packet delivery. An energy-aware QoS routing protocol for sensor networks which can also run efficiently with best-effort traffic [8]. The problem involving clustering of wireless sensor nodes and coverage area is given in [9-11]. The optimized routing techniques in the wireless sensor networks and the lifetime maximization are discussed in the literatures in [12-20].

III.Existing System

In the existing system the sensor nodes are spatially distributed and the base station locations were not optimized. Due to this the energy consumption was very high due to data transmission distance. This causes the degradation in the lifetime of the sensor nodes which in-turn causes the entire network to consume more energy. The following table indicates the sensor node location, data transmission rate and the total energy consumed by each sensor node in the existing system.

TABLE I
Location Of The Sensor, Data Transmission Rate And The Energy Consumed

S.NO	LOCATION X	Y	DATA RATE(Kbps)	ENERGY(J)
1	8.5	1.3	1	1600
2	3.1	0.6	9	4300
3	6.5	5.6	3	3100
4	6.3	7.4	9	4700
5	9.1	4.8	1	1900
6	2.6	3.5	8	1500
7	4.2	7.3	3	1000
8	9.3	1.5	7	1500
9	6.3	9.6	6	1100
10	0.3	2.7	1	3500
11	6.7	4.0	6	2300
12	2.1	1.6	7	4300
13	8.6	9.6	1	900
14	5.6	0.9	9	2700
15	8.8	5.1	3	1100
16	8.0	9.2	8	1700
17	8.7	3.8	1	1500
18	7.1	1.2	8	5000
19	3.8	9.0	2	1800
20	4.4	3.4	9	2000
21	4.4	4.8	1	4500
22	9.1	0.4	7	2200
23	6.1	7.7	4	1600
24	3.9	4.1	8	1900
25	2.5	0.7	3	3100
26	4.3	4.4	5	2900
27	2.7	7.1	1	1900
28	7.7	7.7	2	3200
29	3.5	8.3	5	1900
30	0.8	2.7	8	2100
31	2	7.4	10	4700
32	6.6	1.2	10	1900
33	6.1	0.5	7	2100
34	5.2	8.5	1	4400
35	4.9	1.6	8	3800
36	2.7	5.0	4	1400
37	7.7	4.6	6	3700
38	9.5	9.5	3	800
39	9.1	8.6	7	2800
40	3.8	3.3	1	4900
41	0.7	1.9	3	2300
42	9.5	7.2	8	3700
43	5.1	9.4	2	1700
44	2.6	4.8	2	700
45	8.0	4.7	6	4400
46	1.3	6.8	8	2100
47	8.9	0.1	7	4300
48	0.9	0.9	3	2600
49	0.1	7.2	1	1700
50	0.3	6.9	5	1900
51	7.4	9.9	5	2500
52	9.3	6.7	7	2400
53	7.5	1.2	4	900
54	8.8	1.7	9	4400
55	9.4	0.2	9	2200
56	7.7	3.5	5	1600
57	6.5	5.8	5	3200
58	3.2	0.4	2	2300
59	5.1	7.5	5	3600

60	6.4	4.3	1	3600
61	8.4	3.8	1	2100
62	3.7	9.3	9	4600
63	7.7	4.8	6	2700
64	7.2	2.6	10	2600
65	6.6	4.9	1	900
66	4.8	7.8	1	700
67	9.2	6.8	1	600
68	6.9	7.9	1	2000
69	7.7	10	2	1200
70	5.4	2.1	10	3400
71	5.4	0.5	6	1300
72	5.7	2.1	2	2200
73	7.5	5.5	2	1700
74	2.6	3.2	8	2300
75	3.5	9.4	3	2900
76	9.8	1.6	8	1600
77	6.8	0.9	2	1300
78	4.9	4.4	4	4000
79	8.8	1.2	4	4600
80	7.7	7.2	1	3800
81	2.0	5.6	7	3200
82	4.4	0.6	5	4500
83	1.0	2.6	7	4800
84	0.6	6.5	4	3200
85	7.9	1.5	4	4800
86	2.2	8.1	6	2900
87	0.6	0.4	8	2300
88	1.0	4.2	4	2500
89	3.3	5.5	7	4900
90	0.1	8.8	9	4200
91	1.2	3.1	9	4700
92	8.5	6.5	10	2100
93	2.4	7.8	6	2500
94	8.7	7.4	4	1500
95	7.1	0.6	8	3800
96	6.0	9.8	2	4600
97	9.5	3.3	2	4300
98	3.3	8.6	5	4900
99	1.5	4.2	1	1600
100	0.1	2.7	6	1200

IV. Gravity Location Algorithm

Gravity location model is one of the supply chain management techniques using for locating the ware house optimally. The same technique is used for locating the base station optimally. Data rate and energy is the main factor influencing the location the base station. The main problem is 100 sensor nodes are placed randomly in the sensible area 100m x 100m according to their functionality, all nodes having the different load and different energy level. So this work locates the base station optimally to all nodes. The gravity location model is very useful method to find out the optimal location. In supply chain, cost and load (how much quantity is transferred) are considered, to locate the ware house. Here the energy and data rate is considered to locate the base station optimally. Gravity models are used to find locations that minimize the energy of transmitting sensed data from sensor node to the base station. All distances are calculated as the geometric distance between two points on a plane. Gravity location model is used to find the optimal location of base station and the total energy spent for transmitting data to base station. Location, data rate (load) and energy is the input data for the gravity location model. The obtained data are plotted and the location of the sensor nodes is shown in the figure 2.

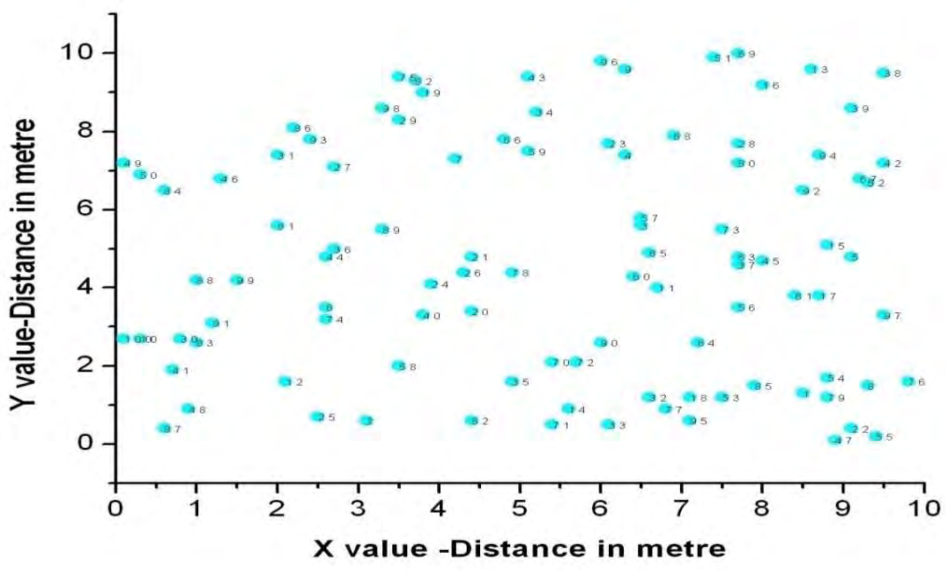

Fig 2. Location of the sensor nodes

The location that minimizes the total energy E_j is obtained by iterating through the following three steps where (x,y)is the location of the base station to begin each iteration.

1. station n, evaluate using the formula dn
2. Obtain a new location (x', y') for the base station.

$$X' = \frac{\sum_{n=1}^{k} \frac{Dn\,Fn\,Xn}{dn}}{\sum_{n=1}^{k} \frac{Dn\,Fn}{dn}} \qquad 4.1$$

$$Y' = \frac{\sum_{n=1}^{k} \frac{Dn\,Fn\,Xn}{dn}}{\sum_{n=1}^{k} \frac{Dn\,Fn}{dn}} \qquad 4.2$$

3. If the new location (x', y') is almost the same as (x, y), stop.
4. Otherwise, set (x, y) = (x', y')and go to 1

The placement of the base station should be optimized among the dispersed location of the wireless sensor nodes. The optimum location can be obtained by using the gravity location model. Using the gravity location model, the base station location can be identified and also the total energy also can be obtained.

A. The Total Energy Calculation

Total energy spends for transmitting data from sensor node to base station.

$$E_j = \sum_{n=1}^{k} d_n D_n F_n \qquad 4.3$$

$F_{n\text{ - Energy}}$ of transmitting one bit for one meter between the sensor nodes to base station n

D_n - Load (data) to be transmitted between sensor nodes to base station

x_n, y_n - Coordinate location of either a sensor node or base station

d_n – Euclidean Distance

If (x, y) is the location selected for the sensor node, the distance d_n facility at location (x, y)

$$d_n = \sqrt{(x - x_n)2 + (y - y_n)2} \qquad 4.4$$

In this method, the optimal location of base station is obtained by evaluating the above formulae and the collected data.

Table 2

Calculated Data With Euclidean Distance

S.No	**Energy Spent (fn) j**	**Data rate (dn) kbps**	**Coordinates**		**Equlidian distance (dn) m**
			X	**Y**	
1	1600	1	8.5	1.3	4.75
2	4300	9	3.1	0.6	3.90
3	3100	3	6.5	5.6	2.30
4	4700	9	6.3	7.4	3.61
5	1900	1	9.1	4.8	4.44
6	1500	8	2.6	3.5	2.21
7	1000	3	4.2	7.3	8.42
8	1500	7	9.3	1.5	5.30
9	1100	6	6.3	9.6	5.67
10	3500	1	0.3	2.7	4.64
11	2300	6	6.7	4	2.00
12	4300	7	2.1	1.6	3.65
13	900	1	8.6	9.6	6.69
14	2700	9	5.6	0.9	3.37
15	1100	3	8.8	5.1	4.20
16	1700	8	8	9.2	6.02
17	1500	1	8.7	3.8	4.01
18	5000	8	7.1	1.2	3.80
19	1800	2	3.8	9	4.93
20	2000	9	4.4	3.4	0.81
21	4500	1	4.4	4.8	0.72
22	2200	7	9.1	0.4	5.78
23	1600	4	6.1	7.7	3.81
24	1900	8	3.9	4.1	0.81
25	3100	3	2.5	0.7	4.10
26	2900	5	4.3	4.4	0.48
27	1900	1	2.7	7.1	3.56
28	3200	2	7.7	7.7	4.64
29	1900	5	3.5	8.3	4.32
30	2100	8	0.8	2.7	4.17
31	4700	1	2	7.4	4.23
32	1900	9	6.6	1.2	3.51
33	2100	6	6.1	0.5	3.91
34	4400	10	5.2	8.5	4.37
35	3800	1	4.9	1.6	2.56
36	1400	1	2.7	5	2.18
37	3700	1	7.7	4.6	3.02
38	800	1	9.5	9.5	7.18
39	2800	2	9.1	8.6	6.25
40	4900	10	3.8	3.3	1.25
41	2300	6	0.7	1.9	4.60
42	3700	2	9.5	7.2	5.68
43	1700	2	5.1	9.4	5.26
44	700	8	2.6	4.8	2.20
45	4400	3	8	4.7	3.34
46	2100	8	1.3	6.8	4.31
47	4300	2	8.9	0.1	5.83
48	2600	4	0.9	0.9	5.01
49	1700	4	0.1	7.2	5.52
50	1900	1	0.3	6.9	5.19
51	2500	7	7.4	9.9	6.34
52	2400	5	9.3	6.7	5.25
53	900	7	7.5	1.2	4.06
54	4400	4	8.8	1.7	4.77
55	2200	4	9.4	0.2	6.14

56	1600	6	7.7	3.5	3.06
57	3200	8	6.5	5.8	2.43
58	2300	4	3.5	1.9	2.56
59	3600	7	5.1	7.5	3.37
60	3600	9	6.4	4.3	1.70
61	2100	1	8.4	3.8	3.71
62	4600	9	3.7	9.3	5.24
63	2700	6	7.7	4.8	3.06
64	2600	10	7.2	2.6	2.94
65	900	1	6.6	4.9	2.03
66	700	1	4.8	7.8	3.65
67	600	1	9.2	6.8	5.21
68	2000	1	6.9	7.9	4.34
69	1200	2	7.7	10	6.57
70	3400	10	5.4	2.1	2.17
71	1300	6	5.4	0.5	3.72
72	2200	2	5.7	2.1	2.28
73	1700	2	7.5	5.5	3.10
74	2300	8	2.6	3.2	2.31
75	2900	3	3.5	9.4	5.38
76	1600	8	9.8	1.6	5.70
77	1300	2	6.8	0.9	3.87
78	4000	4	4.9	4.4	0.31
79	4600	4	8.8	1.2	5.05
80	3800	1	7.7	7.2	4.27
81	3200	7	2	5.6	3.07
82	4500	5	4.4	0.6	3.57
83	4800	7	1	2.6	4.02
84	3200	4	0.6	6.5	4.73
85	4800	4	7.9	1.5	4.15
86	2900	6	2.2	8.1	4.68
87	2300	8	0.6	0.4	5.57
88	2500	4	1	4.2	3.71
89	4900	7	3.3	5.5	1.95
90	4200	9	6.1	2.3	2.32
91	4700	9	1.2	3.1	3.66
92	2100	10	8.5	6.5	4.46
93	2500	6	2.4	7.8	4.31
94	1500	4	8.7	7.4	5.14
95	3800	8	7.1	0.6	4.28
96	4600	2	6	9.8	5.79
97	4300	2	9.5	3.3	4.87
98	4900	5	3.3	8.6	4.66
99	1600	1	1.5	4.2	3.21
100	1200	6	0.1	2.7	4.83
X AXIS VALUE FOR BASESTATION LOCATION X = 4.71 Y AXIS VALUE FOR BASESTATION LOCATION Y = 4.15 TOTAL ENERGY CONSUMPTION=5267020.011J					

B. The Optimal Base Station Location

There are 100 nodes placed in 100m x100m, each node is placed according to its x, y co ordinates value. Optimal base station is placed between the 100 nodes. It is denoted 101_{th} node shown in fig 3 (4.71, 4.15) represents the optimal location of base station. Newly located base station is the optimum location from each node.

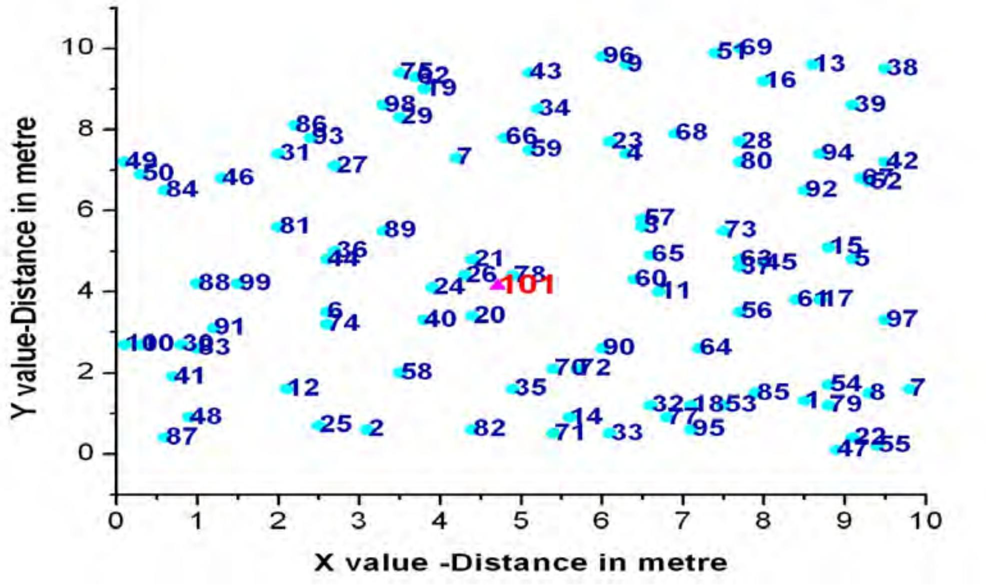

Fig 3. The Optimized Base Station Location

V. Particle Swarm Optimization

The Particle swarm optimization is a computational method that optimizes a problem by iteratively trying to improve the solution. PSO optimizes a problem by having a population of solutions, the particles are moved around in the search space with simple mathematical formulae over the particle's position and velocity. Each particle's movement is influenced by its local best known position. It is also guided toward the best known positions in the search-space, which are updated as better positions are found by other particles. This is expected to move the swarm toward the best solutions. The PSO algorithm works by having a population, termed as a swarm of particles. The movements of the particles are guided by their own best known position in the search-space as well as the entire swarm's best known position. When improved positions are being discovered these will then come to guide the movements of the swarm. The process is repeated and by doing so it is hoped to result in a best solution. Each particle keeps track of its coordinates in the solution space which are associated with the best solution (fitness) that has achieved so far by that particle. This value is called personal best, pbest. Another best value that is tracked by the PSO is the best value obtained so far by any particle in the neighborhood of that particle. This value is called gbest. The basic concept of PSO lies in accelerating each particle toward its pbest and the gbest locations, with a random weighted acceleration at each time step. In this work the weighted acceleration represents the data rate.

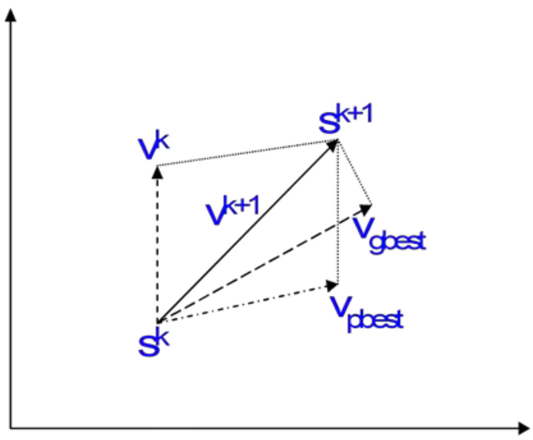

Fig 4. Particle swarm optimization velocity updating

sk : current searching point.

sk+1 : modified searching point.

Vk : current velocity.

Vk+1 : modified velocity.

Vpbest : velocity based on pbest.

Vgbest : velocity based on gbest

Figure 4 represents how the velocity is modified from current search space to new search space. pbest and gbest also indicated for new position.

A.FORMULA FOR CALCULATING THE ENERGY

$E_{ij} = (e_t \times r \times d_n) + (e_r \times r)$ 5.1

E_{ij} - total energy taken for transmitting data from i^{th} node to j^{th} node

e_t - Energy taken for transmitting the data from i^{th} node to j^{th} node in nj/bit

e_r - Energy taken for receiving the data from i^{th} node to j^{th} node in nj/bit

r - Data rate in Kbps.

d_n - Euclidian distance in m

$$d_n = \sqrt{(x - x_n)2 + (y - y_n)2} \quad 5.2$$

-

Xn,Yn- Coordinate location of either i_{th} sensor node

X, Y - Coordinate location of either jth sensor node

B. FORMULA FOR FITNESS CALCULATION

$$\text{Fitness} = \sum_{j=1}^{n} E_{ij} \quad 5.3$$

E_{ij} - total energy taken for transmitting data from i^{th} node to j^{th} node

C.MODEL CALCULATION

Energy calculation for 87_{th} node

$E_{ij} = (e_t \times r \times d) + (e_r \times r)$

Possible neighbor nodes are 48, 41, and 25

Each node taking for transmitting one bit to one meter is 0.1 nj/bit/m

Each node taking for receiving one bit is 5 nj/bit/m

E_1

$E_{87\text{-}48}$ = (0.1 x 8 x o.583) + (0 x5)

= 466 nj/bit/m

E_2

$E_{87\text{-}41}$= (0.1 x 8 x.50)

= 1200 nj/bit/m

E_3

$E_{87\text{-}25}$ = (0.1 x 8 x 1.923)

= 1538 nj/bit/m

D. FITNESS CALCULATION

$$Fitness = \min \sum_{j=1}^{n} E_{ij} \quad 5.4$$

Fitness = min∑ (E_1 , E_2 ,E_3)

= min (466, 1200, 1538)

Fitness = 466 nj/bit/m

Node E_{48} is selected for next iteration

Further search is continued until the data reach the optimal base station. Same steps are repeated for all nodes, finally will get the shortest path from each node to base station.

E. OPTIMAL ROUTING USING PARTICLE SWARM OPTIMIZATION

The data routing is a important parameter in maximizing the life time of the wireless sensor network. Here the Particle swarm optimization algorithm is employed to optimize the data routing from each sensor node to the base station, so that each node sends the data to base station through the minimum distance. These optimized data routes provide the efficient consumption of energy. The data routes are shown in the Table 3. It represents the distance travelled in each optimal route from the source to destination and the total data that are transferred in each route, amount of energy spend for transmitting data from the source node to the base station.

TABLE 3
Optimal Route for the data transmission

S.No	Routing	Total data (kbps)	Distance travelled (m)	Energy Spent(nj/bit)
1	2-25-12-74-40-20-101	24	4.50	10800
2	5-15-45-37-11-60-78-101	27	4.72	12744
3	30-83-91-74-40-20-101	42	3.36	14112
4	31-27-89-21-101	19	4.48	8512
5	33-14-35-20-101	33	4.287	14147.1
6	38-39-94-92-73-65-60-78-101	32	8.09	25888
7	39-94-92-73-65-60-78-101	29	7.31	21199
8	41-83-91-74-40-20-101	37	4.49	16613
9	42-67-92-73-65-60-78-101	27	5.78	15606
10	44-36-89-22-101	11	3.36	3696
11	45-37-11-60-78-101	23	3.72	8556
12	46-81-36-26-101	24	4.48	10752
13	47-22-79-1-85-53-18-32-90-101	42	7.08	29736
14	48-12-74-40-20-101	28	5.49	15372
15	49-50-84-81-36-26	26	5.60	14560
16	52-67-92-73-65-60-78-101	28	5.84	16352
17	53-18-32-90-101	31	3.42	10602
18	55-22-79-1-85-64-90-101	33	7.53	24849
19	58-40-20-101	12	4.37	5244
20	61-56-11-60-78-101	17	4.10	6970
21	62-19-29-7-21-101	20	5.09	10180
22	63-37-11-60-78-101	23	3.63	8349
23	68-4-57-3-65-60-78-101	28	8.11	22708
24	69-51-9-43-34-66-7-21-101	24	11.34	27216
25	70-20-101	19	2.47	4693
26	71-35-58-40-20-101	23	7.65	17595
27	72-101	2	3.78	756
28	75-82-19-29-7-21-101	19	4.21	7999
29	76-8-54-1-85-53-18-77-32-72-90-101	48	8.20	39408
30	79-8-1-85-64-90-101	28	5.64	15792
31	86-93-27-89-21-101	21	6.64	13944
32	87-12-74-40-20-101	33	8.09	26697
33	99-6-74-40-20-101	31	7.33	22723
34	95-77-32-90-101	29	5.02	14558
35	96-43-34-66-7-21-101	37	8.43	31191
36	97-17-61-45-37-11-60-78-101	27	4.62	12474
37	98-29-7-21-101	14	2.47	3458
38	100-10-30-83-91-74-101	40	9.06	36240

VI. Conclusion

A wireless sensor network has been considered and the gravity location optimization and particle swarm optimization are employed to minimize the Energy consumption in this paper. The proposed approach can search for nearly optimal Base Station Locations and the optimized routing of data in the wireless sensor networks, where each sensor nodes may own different data transmission rates, initial energies and parameter values. Experiments and simulations have also been made to show the performance of the proposed approach and the effects of the parameters on the results. This helps in analyzing the proximity of the sensors which minimizes the energy spend on the sensor node to transmit the data. As a result of the simulations, it can be concluded that the proposed Gravity location algorithm and the PSO algorithm converges very fast and also to reduce the data traffic among the nodes with the help of optimal routing, when compared to the exhaustive search. This work can be extended to optimize wireless sensor network with multiple base stations.

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