Energy Efficient Sensor Positioning in Wireless Sensor Networks

N. Pushpalatha, C Sreekanth, Y Penchalaiah

ABSTRACT---Wireless sensor networks spread everywhere in our daily life from health care to environment monitoring. In these applications sensor positioning plays a crucial role. The existing sensor positioning techniques are resulted in increased cost, energy consumption, connectivity failure and less accuracy. In the present work, Range-free sensor positioning based on Bacterial Foraging Algorithm is applied to reduce energy consumption by sensor nodes in hexagonal geographical area. The results are compared with Artificial Bee Colony algorithm. The results show, the improvement in accuracy, shortest path computation, residual energy, and an energy efficient wireless sensor network and the proposed method is implemented using NS-2.

Index Terms - Sensor Positioning, RSPBFA, Shortest path, Residual Energy and Energy Consumption.

I. INTRODUCTION

Wireless Sensor Networks (WSNs) are networks of distributed autonomous nodes that can sense or monitor physical or environmental conditions cooperatively [1]. Due to its potential applications in many areas ranging from environmental observation, natural habitat monitoring, medical, industry and military applications, WSN has attracted a lot of research interests in recent years [2, 3]. The deployment of mobile sensor nodes in the Region Of Interest (ROI), where interesting events may happen and the corresponding event detection mechanism is one of the key issues in this area. Sensor must be deployed in a location that is contexually appropriate to sense useful data. Optimized way of placing sensors may result in maximum utilization of the available sensors [4]. In addition to the coverage problem of the randomly deployed sensor networks, energy consumption is another major concern for mobile wireless sensor networks. In most applications, the lifetime of wireless sensor nodes is critical to its effectiveness, especially for mobile sensor networks whose mobile nodes consume more energy than the other components and processing devices. Energy consumption is a primary constraint for wireless sensor network nodes as they are self-powered. The source of energy for sensor is battery, with or without rechargeable facility during its lifetime. All sensor node activities, such as, sensing, communicating, computing, and moving will consume energy. Thus, once the battery of a sensor runs out of power, then sensor node is not usable anymore. Therefore, this can degrade the quality of service of the entire sensor network.

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II. RELATED WORK

Wireless Sensor Networks (WSNs) find wide range applications such as healthcare monitoring, industry automation, food graining, fire dection in forests, and military applications etc [5]. In wireless sensor networks the major research is taking place in the areas related to sensor positioning, coverage, communication, etc [6]. Maximizing the total coverage area of the entire sensor network is one of the major objectives of Wireless Sensor Network [7]. The area coverage problem is closely related to the performance of Wireless systems in applications, such as, target detection and tracking, monitoring the battlefield, homeland security, personal protection, and animal habitat monitoring [8]. Therefore, position of the sensors plays the most critical role in network coverage [9]. In order to obtain a good coverage, sensors are deployed deterministically [8 &9]. However, there are certain conditions when sensors cannot be deployed deterministically, for example in applications involving areas of natural disasters or turbulent environments [15]. The effectiveness of Wireless sensor networks depends on the coverage provided by the sensor deployment scheme.

Glowworm Swarm Optimization (GSO) sensor deployment scheme is proposed by Wen-Hwa Liao et al. [10] based on, which enhances the coverage after initial random deployment of the sensors. In this scheme, the coverage area of the sensing field is maximized as the sensor nodes tend to move towards the region having lower sensor density. However, it considers only the distance between the sensor nodes. CelalOzturk et al [11] has used the Artificial Bee Colony (ABC) algorithm for the dynamic deployment of stationary and as well as mobile sensor networks, where a probabilistic detection model is considered to obtain more realistic results while computing the effective coverage area. This scheme maximizes the coverage rate of the network by estimating the coverage ratio. Though both the schemes provide accurate positioning, but do not satisfy the other parameters, such as residual energy (sensor life time) and energy consumption. Naveed Salman et al [12] proposed Received Signal Strength (RSS)-based localization technique and improved the performance w.r.to coverage area. Though RSS-based positioning techniques in [12 & 13] provide low complexity, but, they did not ensure energy and cost reduction. Specifically, the present work proposes novel sensor deployment techniques for Sensor Positioning and coverage

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area. In this work, a Range-Free Sensor Positioning technique based on number of Nodes, Range and Simulation time using Bacterial Foraging Algorithm (BFA) is proposed to reduce energy consumption and residual energy.

III. PROPOSED METHOD

A Wireless Sensor Network is deployed in a Region of Interest to monitor certain environmental conditions or changes in a given application. The efficiency of a WSN depends on coverage area. The Bacterial Foraging Algorithm is applied to many engineering problems to solve optimization issues. In this paper a Range-Free Sensor Positioning technique is proposed and it has two parts as follows:

- Bacterial Forarging Optimization (BFO) algorithm is used to calculate coverage ratio, and to maximize residual energy and minimize energy consumption.
- Shortest Path calculation between sensor nodes.

The Principle of Bacterial Foraging Algorithm (BFA) is based on the following steps:

(i) Chemotaxis- represents the motion pattern generated by the bacteria in presence of chemical attractants and repellents.

(ii) Swarming-A group of E.coli cells arrange themselves in a traveling ring by moving up the nutrient gradient when placed amidst a semisolid matrix with a single nutrient chemo-effecter. The cells when stimulated by a high level of succinate, release an attractant aspertate, which helps them to aggregate into groups and thus move as concentric patterns of swarms with high bacterial density [14 & 16].

(iii) Reproduction –Reproduction step takes place after all chemotatic steps. To keep a constant production size, the bacteria with least health will die and the healthier bacteria will split into two and replaces it.

(iv) Eliminational-Dispersal- Events can occur such that all the bacteria in a region are killed or a group is dispersed into a new part of the environment. Elimination and dispersal events have the effect of possibly destroying chemotactic progress, but they also have the effect of assisting in chemotaxis, since dispersal may place the bacteria near good food sources.[14 & 16]

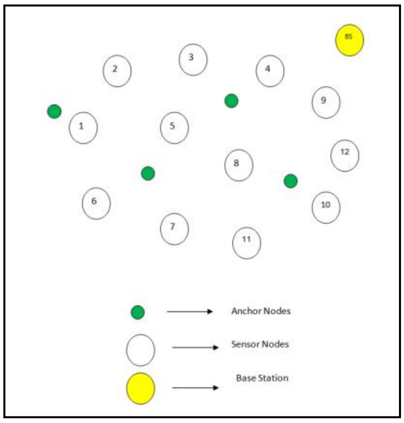

Fig 1. Anchor Node Deployment [15]

Applying Range-Free Sensor Positioning technique through Bacterial Foraging Algorithm (RFPBFA) for Wireless sensor networks is as follows:

In RSPBFA method, initially all anchor nodes are placed using the coverage ratio. The coverage ratio depends on the network size in given WSN and the anchor nodes use the BFO algorithm to estimate the distance between the unknown sensor nodes using neighbor density. Each sensor is aware of its own position and it communicates with other sensor nodes and the mobile nodes will change their positions by using the other nodes information received by them.

The coverage ratio (R) of a given sensor network is estimated using the Eqn. (1)

$$R=\frac{CAS_i}{T};\ i \in N \qquad (1)$$

Where CAS_i= coverage area of a sensor ‘ i’

N = set of nodes

T= total size (It is based on the network space considered)

The Anchor Node deployment in WSN is application dependent and it affects the performance of the routing protocol of the network. The deployment can be either deterministic or randomized. In deterministic deployment, the sensors are manually placed and data is routed through fixed paths; but in random node deployment, the sensor nodes are scattered randomly creating an infrastructure in an ad hoc manner. Hence, random deployment raises several issues as coverage, optimal clustering etc. which need to be addressed [15].

Let us assume that ‘ A_n ‘ be the number of anchor nodes

‘S’ be the number of steps

‘C_c’ and ‘P_c’ be the number of chemotactic steps and its probability respectively,

‘R_r’ and ‘P_r’ be the reproduction steps and its probability respectively

‘E_e’ and ‘P_e’ be the number of elimination disperses steps and its probability respectively.

‘S (i)’ be the step size, where i = 1, 2, … ,A_n

‘β^i ’ be the position of the anchors, i = 1, 2, ……, A_n

‘Kβ ’ is the combined factor of attractants and repellants of the nodes from the

network, where K represents the gradient.

i.e. If Kβ <0 ;then the anchor nodes are in active environment.

Kβ =0 ; then the anchor nodes are in neutral environment.

Kβ >0 ; then the anchor nodes are in harmful environment.

$$\text{Let } M(c,r,e) = \beta^i(c,r,e);\ i = 1, 2, \ldots A_n \qquad (2)$$

The above Eqn(2) reveals the position of each member in ‘A_n’.

Let NT_B be the network lifetime of the anchor nodes and is estimated during each chemotactic step.

Let ‘Cω> 0’ represents the basic chemotactic step size; which is used to define the length of steps during chemotactic process.

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Let ‘ωβ ’ be the unit length random direction representing tumble.

The steps involved in RSPBFA algorithm are as follows:

Step 1: Compute ‘β’ which is the control and is randomly distributed across the nodes.

Step 2: Elimination – Dispersal Loop: e = e +1

Step 3: Reproduction loop : r = r+1

Step 4: Chemotaxis loop: c = c+1

[a]. Chemotaxis simulates the movement of anchor nodes which is estimated as follows:

For i = 1, 2,…A_n

[b]. Estimate the objective function C (i, c, r, e)

Let C (i, c, r, e) = C (i, c, r, e) + Css (β^i(c, r, e), P(c, r, e))

Where Css (β^i (c, r, e)) = objective function value represented as attractant and repellent to be added to the actual objective function

Let C_{last} = C (i, c, r, e) to save this value as the better solution need to be found through execution

[c]. Tumble: Generate a random vector, Rp, with each element v , p = 1, 2 ….n

[d]. Move: βi (c+1, r, e) + βi (c,r,e) + S(i) $\frac{\Delta(i)}{\sqrt{\Delta^t(i) i \Delta(i)}}$

This reveals the step size S (i) in the direction of tumble for anchor nodes, i.

• Estimate next objective function C(i, c + 1, r, e) as given below:

C(i, c+1, r, e) = C (i, c, r, e) + Css (β^i (c+1, r, e), P(c+1, r, e))

• Estimate the neighbor nodes density. If the density is minimum, then

Go to next step else

Go to reproduction step

• Swim

Let v = 0 (counter for swim length)

While (v< S)

v = v+1

If [C (i, c + 1, r, e) =$C_{last}$and (c+1, r, e) = (c, r, e) + S (i)] use (c+1, r, e) to estimate C (i, c + 1, r, e)

Else

v =S

end of While

Go to next anchor node, i+1 if i ≠ S

• If c < C_c, go to reproduction stage. Otherwise continue chemotaxis as the node is still active.

Step 5: Reproduction

For a given r and e, and for each i = 1, 2,… A_n

Let $C_{Active}^i = \sum_{c=1}^{c+1} C(\omega, c, r, e)$ be the strength of the node i.

• Sort the X anchor nodes and chemotactic parameter S (i) in the order of ascending value of C_{Active}^i

• The nodes with high C_{Active}^i value dies and other nodes with best values split into two. (In this reproduction process, the node population is sorted in such a way that the least active node will die and the most active node will split into two and placed in the same location.)

• If r <R_r, go to elimination step. In this case, we have not reached the number of specified reproduction steps

6. Elimination Dispersal

For i = 1, 2,…, X with probability P_e, eliminate and disperse each anchor nodes, eliminate node and disperse one to a random location on the optimization domain.

• If e <P_e, then go to step 1. Otherwise terminate the event.

Thus, based on the neighbor node density, the anchor nodes estimate the distance between the unknown sensor nodes.

IV. SIMULATION RESULTS

The present work is implemented on IEEE 802.11 wireless sensor networks in MAC layer protocol. The NS-2 network simulator is used to implement Bacterial Foraging Algorithm (BFOA) with varying number of nodes 50, 100, 150 and 200 nodes and the coverage area of 500mts X 500mts. Energy consumption is measured at the radio layer during the simulation based on the specification of IEEE 802.11- WLAN. The energy consumption varies from 0.12 Watt to 0.31 Watt, transmitting and receiving states, respectively.

Table 1: Simulation parameters of RSPBFA

No. of Nodes	50,100,150 and 200
Area	500 X 500 m^2
MAC	802.11
Traffic Source	Constant Bit Rate
Rate	50Kbs
Antenna	Omni Antenna
Propagation	Two Ray Ground
Simulation Time	25,50,75 and 100 sec
Range	250,300,350 and 400m/s
Initial Energy	10.3 J
Transmission Power	0.660W
Receiving Power	0.395W

The simulation results of RSPBFA are comapred with ABC algorithm and comparison results are as follows:

Fig 2.shows that with the increased number of sensor nodes the energy consumption of RSPBFA is reduced by 37% compared to ABC technique. Fig. 3 represents 49% reduction of Energy Consumption w.r.to range, Fig. 4 shows that 42% reduction of Energy Consumption w.r.to simulation time. Fig. 5 represents 31% of improvement in Residual energy in RSPBFA over ABC technique, even with increased number of nodes. Fig. 6 shows 25% of improvement in life time of the proposed technique over ABC with increased range. Fig.7 indicates 16% of improvement in Residual energy w.r.to simulation time.

Table 2 .The energy consumption in RSPBFA vs ABC methods w. r.t number of Nodes.

Nodes	Energy Consumption(Watts)		Reducing Energy Consumption Percentage (%)
	Proposed RSPBFA	Existing ABC	
50	0.12	0.19	36.84211

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100	0.15	0.22	31.81818
150	0.21	0.32	34.375
200	0.19	0.35	45.71429

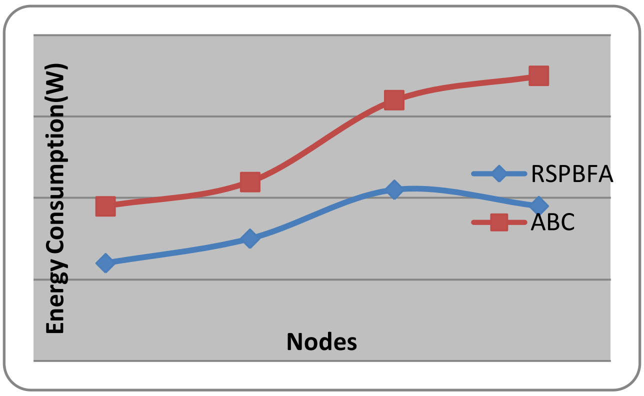

Fig 2. Nodes vs. Energy Consumption

Table 3. The energy consumption in RSPBFA vs ABC methods w. r.t Range.

Range(m)	Energy Consumption(Watts)		Reduction in Energy Consumption Percentage (%)
	Proposed RSPBFA	Existing ABC	
250	0.23	0.42	45.2381
300	0.24	0.53	54.71698
350	0.31	0.56	44.64286
400	0.25	0.55	54.54545

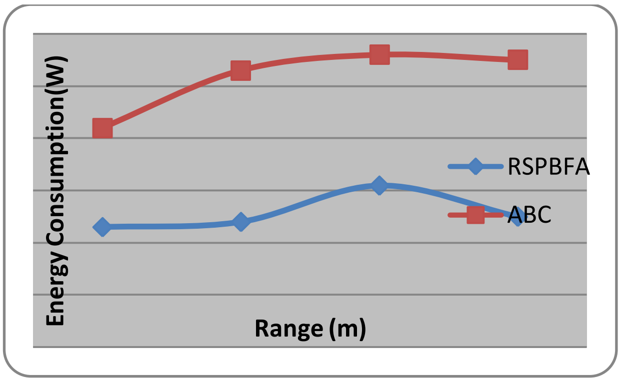

Fig 3. Range vs. Energy Consumption

Table 4. The energy consumption in RSPBFA vs ABC methods w. r.t Simulation Time.

Simulation Tme (Sec)	Energy Consumption(Watts)		Reduction in Energy Consumption Percentage (%)
	Proposed RSPBFA	Existing ABC	
25	0.19	0.34	44.11765
50	0.21	0.36	41.66667
75	0.24	0.42	42.85714
100	0.26	0.44	40.90909

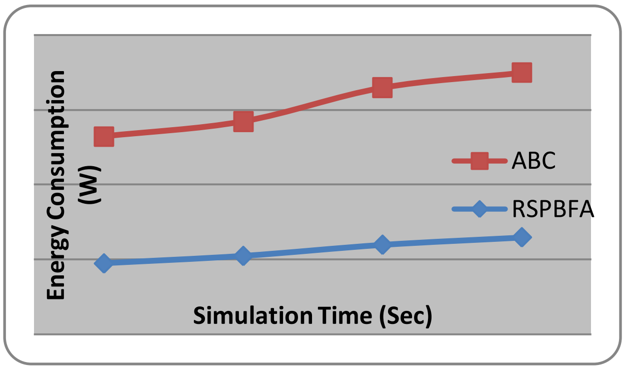

Fig 4. Simulation Time vs. Energy Consumption

Table 5. The Residual energy in RSPBFA vs ABC methods w. r.to Number of Nodes.

Node s	Residual Energy (Joules)		Immprovemen t in Residual Energy Percentage (%)
	Proposed RSPBFA	Existing ABC	
50	6.954583	4.83269	30.51072
100	7.937369	5.202018	34.46168
150	8.615694	5.423543	37.05042
200	8.248378	6.54246	20.68186

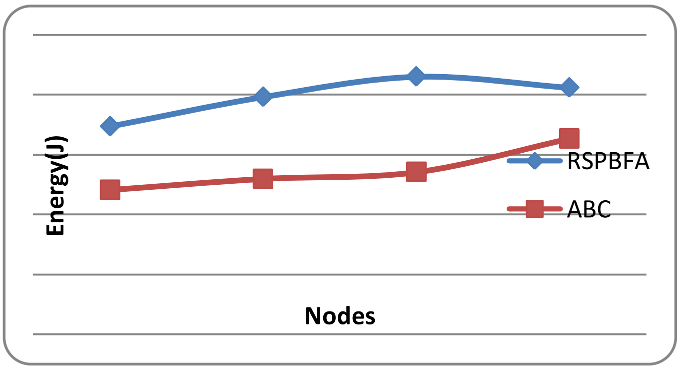

Fig 5. Nodes vs. Residual Energy

Table 6.The Residual energy in RSPBFA vs. ABC methods w. r.to Range.

Range(m)	Residual Energy(Joules)		Improvement in Residual Energy Percentage (%)
	Proposed RSPBFA	Existing ABC	
250	8.248378	6.54246	20.68186
300	8.504021	6.646211	21.84625
350	8.313915	5.943902	28.50658
400	8.938961	6.408332	28.3101

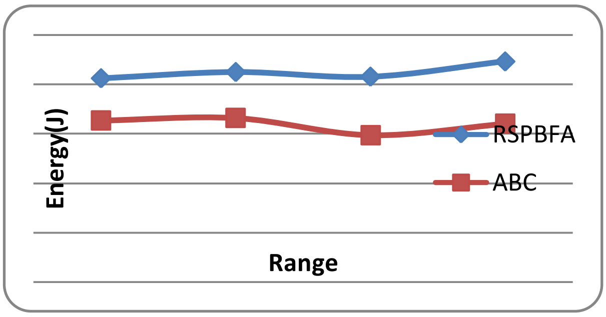

Fig 6. Range vs. Residual Energy

Table 7.The Residual energy in RSPBFA vs ABC methods w. r.to Simulation Time.

Simulation Tme (Sec)	Residual Energy(Joules)		Improvement in Residual Energy Percentage (%)
	Proposed RSPBFA	Existing ABC	
25	7.93737	5.202018	34.46168
50	5.16525	4.756864	7.906377
75	5.16525	4.756864	7.906377
100	5.16525	4.756864	7.906377

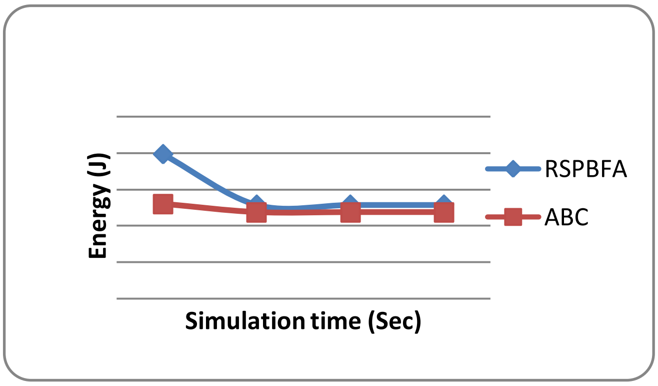

Fig 7. Simulation time vs. Residual Energy

V. CONCLUSION AND FUTURE WORK

A new Range free sensor positioning (RSPBFA) algorithm is proposed to enhance the accuracy and reduces the energy consumption. In this method the simulation results are presented based on Nodes, radio range and simulation time. The performance metrics like residual energy, and energy consumption are calculated for the RSPBFA algorithm and obtained results prove that RSPBFA is efficient compared to ABC (Artificial Bee Colony) algorithm in enhancing the lifetime of the nodes and reducing the energy consumption in a WSN. Further, the performance of RSPBFA technique on network throughput has to study as future work.

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