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LIGHTNING SEARCH ALGORITHM FOR SOLVING COVERAGE PROBLEM IN WIRELESS SENSOR NETWORK

T. ASVANY[1], J. AMUDHAVEL[2] and P. SUJATHA[3]

[1,3]Department of Computer Science
Pondicherry University
Puducherry, India
E-mail: asvanytandabani@gmail.com
spothula@gmail.com

[2]Department of CSE
K.L. University
Andhra Pradesh, India
E-mail: info.amudhavel@gmail.com

Abstract

This paper describes Lightning search optimization algorithm for solving coverage problem in wireless sensor networks and it is closely related to quality of service. The coverage problem makes sure each and every node in the targeted field is within the transmission range which forms the network. The proposed methodology is measured using four performance metrics for solving coverage problem. The test bed is created for two grids of 50×50 meters and 100×100 meters. The performance of Lightning search algorithm in solving coverage problem was evaluated on larger set of generated problems. The experimental results showed that lightning search algorithm produced highly productive solutions for coverage problem in wireless sensor network.

1. Introduction

The most operating research areas in wireless ad-hoc communication are the WSN environment. It permits continuous and self-governing supply of data on a specific field. The network is highly reliable and its information gets updated at regular intervals with easy communication. It contains many

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critical issues which brings the field into limelight among researchers. The WSN consist of set of sensor nodes, used to collect large amount of data in dynamic changing environment. The size of the sensor nodes is small, low battery powered, minimum cost, and randomly node deployment. There are numerous of issues which can easily collapse the network, one of the main issues to be noted in the environment is Coverage. It is a key issue in WSN, mainly used for evaluating the Quality of Service (QoS) of a network. A wireless network doesn't have the ability to cover the dynamic environment. If network fails to have proper topology, it will produce poor quality of coverage. The migration of sensor nodes is the highest energy consumption task, where the rate of energy consumption is high.

In this work, the proposed algorithm helps to enhance the maximum coverage in WSN by deploying nodes in its optimal position. Here we use Lightning Search algorithm for handling node related issues. At the time of thunderstorm, separation of charges will occur in the cloud. This emits a positive and negative charge that creates a powerful electric field and lead to ionization process. It contains strong electric fields, with distribution of electron, and it creates required energy to ionize air. The electric field contains accelerated free electrons, which denotes the attachment probability is lesser than ionization probability this process is known as avalanche. This process sources a negative halo streamer. When the streamers are not strong enough to bombard, hence they get separated from their origin. If its probability of attachment is higher than its ionization probability is less than the attachment probability it is referred streamer-to-leader transition. This streamer to leader occurs; when the numbers of electron particles are higher and the channels are narrow in size. The flow of the step leader from cloud towards ground is in regular and discrete basis [7]. In order to enhance the leader for carrying their operation a selection of leader process is done and this is known as a space leader. The main theme of LSA is to know inspire the natural phenomenon of lightning in order to achieve a modelized optimization process.

2. Literature Study

Shareef, Hussain et al. [1] introduced an optimization method known as Lightning Search Algorithm (LSA). The maximum streams on solving optimization problems are mostly on constrained problems. It completely depends on lightning nature inspiration and its propagation process of step leader. This process is carried by the fast movement of particles known as projectiles; it is classified into three types to show the transition projectiles. The initial step leader generation is created by its space projectile which further turns as leader. The lead projectile denotes the projectile fired from best positioned step leader. The random behavior of the space is also one of the main features of the algorithm.

Abd Ali Jamal, et al. [3, 14] proposed the Lightning Search Algorithm (LSA) using quantum mechanics theories to form a quantum-inspired LSA. It improvises the finding of each step leader to attain the best position for a projectile. To calculate the accuracy and efficiency of the proposed algorithm, and eighteen benchmark functions with various characteristics. To enhance the design of the fuzzy logic controller (FLC) increasing the speed response controlling of the induction motor drive. It also used for avoiding exhaustive conventional trial-and-error procedure for obtaining membership functions (MFs).

VANET network used various performance based surveys some article are Saravanan et al.[17], Jaiganesh et al. [18], and some authors discussed in web services like Amudhavel et al. [20], Thenmozhi et al. [19], Rajeswari et al. [21], hybrid cloud environment proposed by Raju et al. [16].

Sevgi, Cüneyt, and Altan Koçyiğit [4] discuss a novel framework for solving optimal deployment problems for randomly deployed and clustered WSNs. The theme of the work is to study the partial connected coverage. The cluster size formulations were introduced in this paper which describes design of the network. The evaluation of the partial coverage is carried easily. The degree of connectivity is used for analyzing the targeted degree of partial-coverage. To scheduling problem the authors used bio-inspired algorithm [22].

Mostafaei, Habib, et al. [5] focuses on the problem of partial coverage; it looks for continuous monitoring of a limited portion of the environment. On node deployment, the approaches are OTLBO [11], relay bound and energy efficient routing [13] and the application includes fire hazard detection [12]. In this work, they proposed PCLA, algorithm which completely based upon Learning Automata. The implementation of the algorithm is generated to implement sleep scheduling approaches. The goal of the paper is to minimize the count of sensors to cover a desired portion of the environment protecting the connectivity among sensors. Some of the other research articles on WSN coverage are [7-10].

Ab Aziz, Nor Azlina [6] discuss an algorithm to enhance its coverage by migrating the sensor nodes, to achieve the task a better deployment is needed. However the movement of sensors consumes more amount of energy. In this paper three algorithms are shown to have an optimize coverage of WSN. The proposed algorithms are based on particle swarm optimization (PSO) which has the ability to give better performance record.

3. Problem Framework

In wireless sensor networks (WSN) the effectiveness is important to sensor coverage while evaluating the effect of network. A life time of network, the WSN performance parameters can be described between time intervals. The time interval can decide the functioning of networks when they starts and when network dies. Fewer cases only WSN dies, because of connectivity problem or coverage and sufficient battery power.

Let us assume sensor nodes n are $\{S_1, S_2, \ldots, S_n\}$ randomly arranging nodes to cover the area A with m targets $\{T_1, T_2, \ldots, T_m\}$. The initial energy e_0 an each sensor node, a s_r represents sensing radius and c_r represents communication radius. A S_i sensor node, $1 \le i \le n$, is aforementioned to cover a target T_j, $1 \le j \le m$, the distance $d(S_i, T_j)$ between S_i and T_j is less than sensing radius S_r. Usually in this problem two nodes (sensor nodes) are connected in the network, within the communication range one sensor node lies to other nodes. The coverage matrix is described as

$$mat_{ij} = \begin{cases} 1 & if\ S_i monitors\ T_j, \\ 0 & otherwise, \end{cases}$$

where the matrix $i = 1, 2, \ldots, n$ and $j = 1, 2, \ldots, m$.

The Figure 1 shows there are three sensor nodes $\{S_1, S_2, S_3\}$ where a deployment of two targets $\{T_1, T_2\}$ to monitor. In this network, every node has a communication range c_r and a sensing range S_r. For simple nonconnected coverage to be satisfied, it is adequate S_1 and S_3 nodes are activated suddenly. For connected simple coverage, in adding up S_1 and S_3, S_2 also activated since S_2 connects S_3 and S_1.

4. Lightning Search Algorithm

The natural phenomenon lightning is an impressive and interesting one. The proposed lighting search algorithm is generalized at the proposed mechanism of step leader propagation. In the proposed system they consider fast particle involvement as projectiles in the structure formation is binary tree of the step leader and also consider the concurrent formulation of leader tips at fork points.

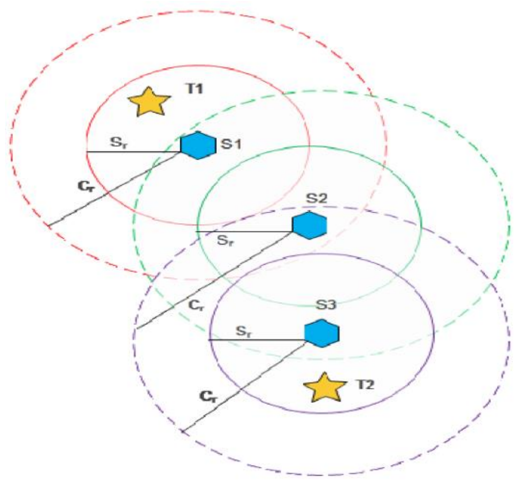

Figure 1. An example of connected coverage network.

- Projectile and step leader propagation
- Properties of the projective

$$V_p = \left[1 - \left(\frac{1}{\sqrt{1 - \left(\frac{V_0}{c}\right)^2}} - \frac{l\alpha_i}{mc^2}\right)^{-2}\right]^{-1/2}, \quad (1)$$

where V_p and V_0 are the current and initial velocity of the projectile, c is the speed of the light, α_i is the ionization rate, m and l are the mass of the projectile and length of the path travelled.

The nuclei collision of the projectile can be realized using opposite number as represented in

$$\hat{p}_i = lb + ub - pi \tag{2}$$

Where p_i and $\hat{p}_i$ are the original and opposite projectiles, lb and ub are the boundary limits.

- Projectile modelling and step leader movement
- Transition projectile

$$f(Z^T) = \begin{cases} 1/ub - lb & \text{for } lb \leq Z^T \leq ub \\ 0 & \text{for } X \langle ubor Z^T \rangle lb \end{cases}, \tag{3}$$

where Z^T is the random number which provide a solution,

- Space projectile

The probability density function of exponential distribution is represented as

$$f(Z^S) = \begin{cases} 1/\mu e^{-Z^S/\mu} & \text{for } Z^S \geq 0 \\ 0 & \text{for } Z^S \leq 0 \end{cases}, \tag{4}$$

where μ is the shaping parameter.

$$p_{new\_i}^S = p_i^S \pm \exp r \text{ and } (\mu_i) \tag{5}$$

- Lead Projectile

The probability density function is represented as

$$f(Z^L) = \frac{1}{\sigma\sqrt{2\pi}} e^{-(Z^L - \mu)^2/2\sigma^2}, \tag{6}$$

where σ is the scale parameter.

$$p_{new}^L = p^L + normr \text{ and } (\mu_L, \sigma_L) \tag{7}$$

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Algorithm : Lightning Search Algorithm
1. Initialize the population
2. Generate the population randomly
3. Initialize the direction for each dimension
in Eachpopulation
3. while(Termination condition satisfies) do
4.      Calculate the Fitness for each solution
5.      Sort the population
6.      Define the best and worst population
7.      Update the energy using Eq. (1)
8.      Update the direction for each dimension
UsingEq. (3)
/* Update the position of each population as
follows */
9.      for each I =1:N where N ∈ Pop
10.         if(pop(i)==Leader solution)then
11.             Update the position of pop using
Eq. (7)
12.         else if(pop(i)==Space solution)then
13.             Update the position of pop using
Eq. (5)
14.         end if
15.         if(Pop (i) is not improvised)then
16.                 Initialize new pop using Eq. (2)
17.         end if
18.     end for
19.end while
OUTPUT: Best Step Leader
```

Figure 2. Pseudo code for Lightning Search Algorithm.

5. Experimental Results and Discussions

The experimental evaluation of the proposed Lightning search algorithm for solving m-connected k-coverage optimization problem in Wireless Sensor Networks are done in the system with the configuration of Intel Core i7 Processor, 3.2GHz speed and 6GB RAM. The proposed methodology is implemented in MATLAB version 8.3. The proposed methodology performance is measured using four three performance metrics namely F-value, computational time of algorithm for solving the problem stated, and total number of sensors deployed at the end of algorithm simulation. For testing the performance of proposed algorithm, two different test bed designs are prepared. One set of simulations are done with a grid of 50×50 meters which consists of 50 targets and 40 sensors positions. One more simulation region of 100×100 grid square meter which consists of 100 targets and 80 available sensor positions. The performance metrics are computational time, F value and total number of sensors deployed for efficient coverage of targets.

The Parameter settings for environment configuration are shown in Table 1 as follows:

Table 1. Parameter Settings.

Population size	100
Maximum iterations	500
R	3
C	10
Threshold Value (∂)	0.5

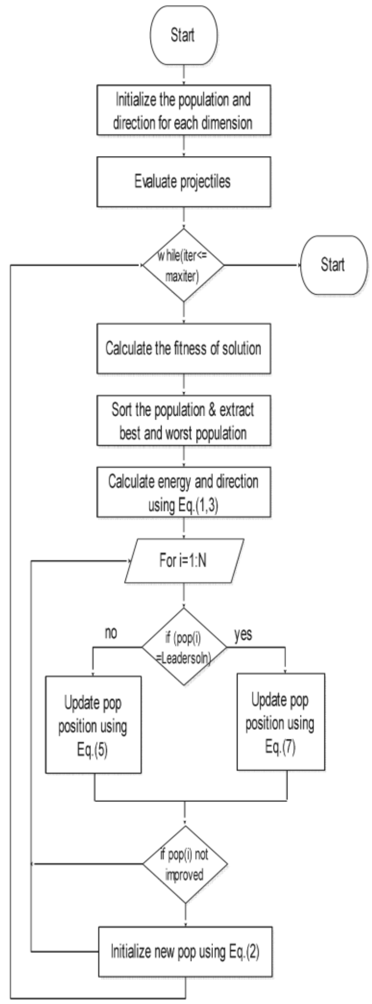


Figure 3. Flowchart of Lightning Search Algorithm.

5.1. Performance Metrics

5.1.1. Computational Time

Computational time is defined as the total time taken to complete the runtime of proposed algorithm. Best solution is not set as an epoch value for termination of algorithm since this evaluation is purely based on random location.

$$\text{Computational Time} = \text{Runtime of proposed algorithm}$$

5.1.2. No. of sensor nodes deployed

Number of nodes that are placed in the grid to cover all the targets located in the simulated area.

5.1.3. *F* Value

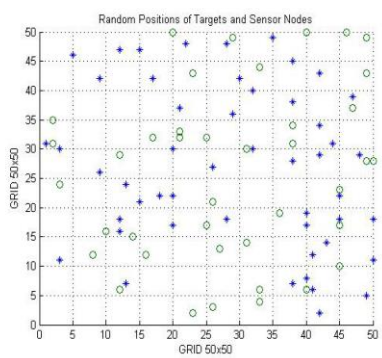
The ratio between the number of available positions to plot the sensor nodes and the total number of sensor node deployed at the end of the cycle.

$$F = \frac{\# TP}{\# AP},$$

where AP is the allocated positions with sensor nodes and TP total number of available positions. The required number of targets and sensor nodes that are randomly generated in 50×50 grids in MATLAB 8.3 is as follows. In 50×50 grids, the targets and sensor nodes are generated as 50 and 40 respectively. For fair comparison, similar set of nodes are generated with same dimensions of grid. The results for 50×50 grids are tabulated in Table 2 and Figure 4 shows the results.

Table 2. Experimental result for 50×50.

	Comp. Time (*s*)	**# Nodes Deployed**	***F*-Value**
GA	6.17	34	1.17
PSO	5.54	27	1.48
Lightning	5.72	23	1.73



o-Sensor Nodes ∗-Targets

Figure 4. Simulation region for 50×50 grids.

From Table 2, the results of GA [2], PSO [15] and the Lightning search algorithm are tabulated for the given performance metrics. On comparing the results in terms of computational time, PSOconverges in short period of time than other algorithms. In other two performance metrics *F*-value and #nodes deployed out proposed algorithm performs better than other given algorithms.

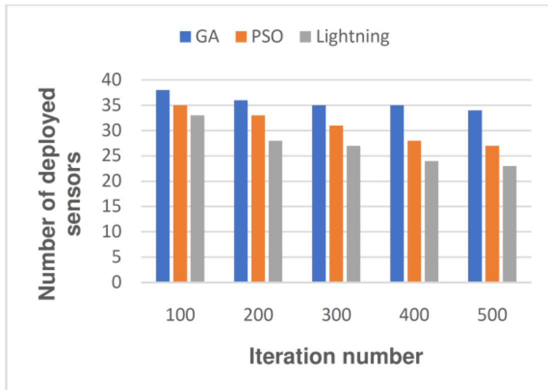
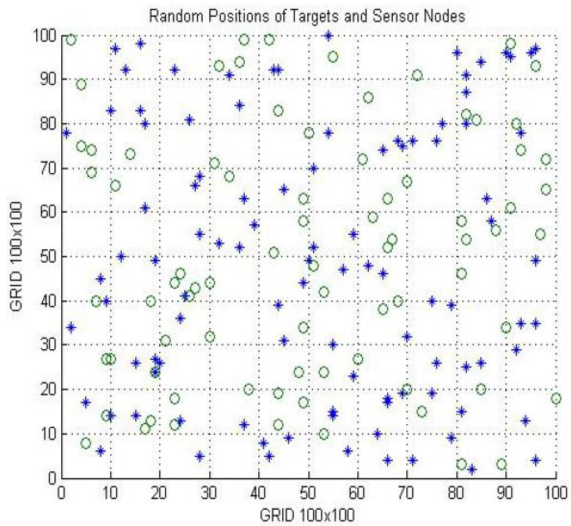


Figure 5. Comparison of convergence for 50×50.

The convergence of total number of nodes deployed in the given grid 50×50 on every 100 iterations are given in Figure 5.

The Lighting search algorithm results for 50x50 grids are tabulated in Table 2. The performance results of LSA on coverage problem, other two existing approaches namely *GA* and PSO are tabulated for comparing the efficiency of proposed algorithm. The lighting search algorithm MATLAB simulation region for grid 100×100 is given in Figure 6.

In 50×50 grids, the targets and sensor nodes are generated as 100 and 80 respectively. For fair comparison, similar set of nodes are generated with same dimensions of grid. The result for 100×100 grids is tabulated in Table 3.



o-Sensor Nodes ∗-Targets

Figure 6. Simulation region for 100×100.

Table 3. Experimental result for 100×100.

	Comp. Time (s)	**# Nodes Deployed**	***F*-Value**
GA	10.56	61	1.31
PSO	8.45	56	1.42
Lightning	8.64	49	1.63

From Table 3, the results of GA, PSO and the Lighting Search Algorithm are tabulated for the given performance metrics. The simulation results are given and show the efficiency of proposed algorithms in terms of *F*-value and # nodes deployed to cover the targets in simulated region. The comparison results a detailed representation on performance of proposed algorithm is given in Figure 7.

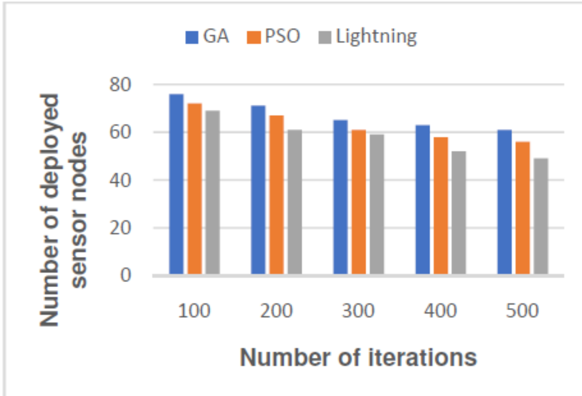


Figure 7. Comparison of convergence for 100×100.

6. Conclusion

In this paper, the author have presented Lightning search algorithm for finding minimum number of selected potential for sensor nodes by fulfilling coverage problem. The coverage problem is modelled as decision problem to determine location of the target and sensing the coverage area. The effectiveness of lightning search algorithm on solving coverage problem is measured using performance metrics. The experiments showed interesting performance with respect to F-value, computational time and node deployment. From the empirical results, lightning search algorithm is capable in covering sensing targets for medium sized as well as large sized environment.

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