International Journal of Advanced Engineering Research and Science (IJAERS)
ISSN: 2349-6495(P) | 2456-1908(O)
Vol-8, Issue-2; Feb, 2021
Journal Home Page Available: https://ijaers.com/
Journal DOI: 10.22161/ijaers
Article DOI: https://dx.doi.org/10.22161/ijaers.82.6

Improvement of LEACH based on K-means and Bat Algorithm

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Received: 07 Nov 2020;
Received in revised form:
11 Jan 2021;
Accepted: 03 Feb 2021;
Available online: 11 Feb 2021

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Keywords— ***Low-energy adaptive clustering hierarchy protocol, Bat algorithm, Energy efficiency.***

Abstract— *A low-energy adaptive clustering hierarchy (LEACH) routing protocol has been proposed specifically for wireless sensor networks (WSNs). However, in LEACH protocol the criteria for clustering and selecting cluster heads (CHs) nodes were not mentioned. In this paper, we propose to improve the LEACH protocol by combining the use of K-means algorithm for clustering and bat algorithm (BA) to select nodes as CHs. The proposed routing algorithm, called BA-LEACH, is superior to other algorithms, namely PSO-LEACH, which using particle swarm optimization (PSO) to improve LEACH. Simulation analysis shows that the BA-LEACH can obviously reduce network energy consumption and optimize the lifetime of WSNs.*

I. INTRODUCTION

The WSNs consist of sensor nodes (SNs) with limited energy, SNs collect environmental parameters and transmits information to the base station (BS). In WSNs, routing protocols aim to optimize the energy use of SNs. Several routing protocols were proposed of which LEACH was the first and most commonly used hierarchical routing protocol (Singh et al., 2017). In the LEACH protocol, SNs are clustered, each cluster randomly selects one SN as CH, and the clusters perform the function of collecting and transmitting data to the BS via CH. By the way, LEACH can extend the life of the network, reducing the energy consumption of each node. However, the LEACH protocol does not consider the current node energy and random selection of CHs can easily lead to uneven energy consumption between network nodes, shortening the network life. Recent LEACH improvement clustering routing protocols for WSNs will be proposed based on CH selection and cluster formation methods., many of which reduce energy consumption in the LEACH protocol; others consider the energy consumption balance (Cui et al., 2019; Singh et al., 2017). Most of the recent improvements are based on CHs selection using nature-inspired algorithms. Typical of which are improving LEACH using PSO (PSO-LEACH) (Edla et al., 2019; Nigam & Dabas, 2018).

The bat algorithm (BA) is a new stochastic optimization technique based on bat behavior. This algorithm has been successfully used to solve various kinds of engineering problems (X. Yang, 2014; X. S. Yang, 2010). BA better than PSO optimization in terms of speed of convergence, robustness, and accuracy (X. S. Yang, 2010).

In this paper, the BA-LEACH routing algorithm based on BA and K-means algorithm is proposed. The rest of this paper is organized as follows: In Section 2, we review the background of the LEACH convention and BA. Section 3 uses BA for CH selection optimization. Section 4, we verify the proposed improvements through simulation experiments by comparing with LEACH and PSO-LEACH, and at the end of the paper, the conclusions are presented.

II. RELATED WORK

2.1 Low-energy adaptive clustering hierarchy

LEACH protocol was the first hierarchical wireless sensor routing protocol, which was proposed by Wendi B. Heinzelman in 2002 (Heinzelman et al., 2002). Fig.1 shows the architecture of LEACH

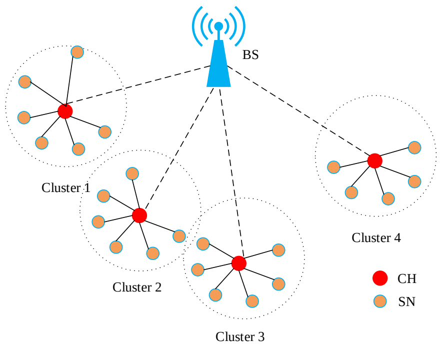

Fig.1: Architecture of LEACH

LEACH operation is divided into several rounds, each consisting of two phases: set-up phase, CHs selection processed and steady-state phase, the CH for each cluster receives and aggregates the data from cluster members and then transmits the aggregated data to the BS. CH selection is performed at the beginning of each round. Each sensor node decides independently of other senor nodes whether it will claim to be a CH or not, by generating a random number between 0 and 1 comparing with a threshold $T(n)$. The node is elected as a CH at current round if the number generated is less than a certain threshold $T(n)$. The threshold value is computed using (1)

$$T(n)=\begin{cases}\dfrac{P}{1-P\left(r \bmod \left(\dfrac{1}{P}\right)\right)} & , n\in G \\ 0 & , n\notin G\end{cases} \quad (1)$$

where n is the number of nodes, P is the denoted percentage of the node to be selected as CHs, r is the round for which cluster the head is selected, and G is the set of nodes that have not been accepted as CHs in the last $1/P$ rounds. After choosing the CH node, the entire network is informed by broadcast.

2.2 Bat Algorithm

Bat algorithm proposed by Xin-She Yang in 2010, which utilizes the behavior of nature bats [5]. This algorithm shows its superior capabilities when applied to the problem of global optimization. The BA is summarized as follows:

In BA, the position and velocity of the $t-th$ bat at the iteration $(t+1)$ are given by (2):

$$\begin{aligned} f_i &= f_{\min}+(f_{\max}-f_{\min})\beta, \\ v_i^{t+1} &= v_i^t+(X_i^t-X_{best})f_i, \\ X_i^{t+1} &= X_i^t+v_i^{t+1} \end{aligned} \quad (2)$$

where β is a uniformly distributed random vector in the range $[0,1]$; X_{best} is the best solution after the $t-th$ iteration. To avoid falling into local optimization, a new solution for each bat is created around the most optimal solution chosen by (3)

$$X_{new}=X_{best}+\varepsilon A^t \quad (3)$$

In which $\varepsilon\in[0,1]$ and A^t is the average loudness value of all bats at $t-th$ iteration. During the optimal search process, the loudness and the emitted pulse rate are updated according to equations (4)

$$\begin{aligned} A_i^{t+1} &= \alpha A_i^t, \\ r_i^{t+1} &= r_i^0\left[1-\exp(-\kappa t)\right] \end{aligned} \quad (4)$$

where $0<\alpha<1$ and $0<\kappa<1$ are constants.

III. IMPROVED LEACH APPROACH

3.1 Fitness function

In WSNs using the LEACH protocol, energy consumed when transferring from $i-th$ sensor node (SN_i) to CH node is determined by (2) (Heinzelman et al., 2002)

$$E_{SN_i-CH}(k)=\begin{cases} k\left(E_{Tx}+\varepsilon_{mp}d^4_{(SN_i,CH)}\right) & \\ \quad if \quad d_{(SN_i,CH)}>d_0 \\ k\left(E_{Tx}+\varepsilon_{fs}d^2_{(SN_i,CH)}\right) & \\ \quad if \quad d_{(SN_i,CH)}\le d_0 \end{cases} \quad (5)$$

where E_{Tx} is transmitter energy per node, k is number of bit per data packet, θ_{mp} is amplification energy when distance from a sensor node to CH is greater than threshold d_0, θ_{fs} is amplification energy when distance from a SN to CH is less than threshold d_0

$$d_0=\sqrt{\frac{\theta_{fs}}{\theta_{mp}}} \quad (6)$$

$d_{(SN_i,CH)}$ is distance from $i-th$ SN to CH.

The energy consumed when transmitting the signal from $j-th$ cluster head (CH_j) to BS station is calculated by (4)

$$E_{CH_j-BS}(k)=\begin{cases} k(E_{Tx}+E_{DA}+\theta_{mp}d^4_{(CH_j,BS)}) \\ \quad if\ d_{(CH_j,BS)}>d_0 \\ k(E_{Tx}+E_{DA}+\theta_{fs}d^2_{(CH_j,BS)}) \\ \quad if\ d_{(CH_j,BS)}\le d_0 \end{cases} \quad (7)$$

where E_{DA} is data aggregation energy, $d_{(CH_j,BS)}$ is distance from $j-th$ CH to BS.

Our aim is to select the central node so that the total energy consumed during transmission and receiving data in the cluster is minimal. Furthermore, the energy transmitting and receiving data between sensor nodes were highly dependent on the distance between them. Therefore, we proposed the fitness function for selecting CH node as follows:

$$Fitness=\psi\left(E_{CH_j-BS}(k)+\sum_{i=1}^{M}E_{SN_i-CH}(k)\right) + (1-\psi)\left(d_{(CH_j,BS)}+\sum_{i=1}^{M}d_{(CH_j,SN_i)}\right) \quad (8)$$

In (5), $\psi\in(0,1)$ is the weight, set at 0.9 in this experiment based on study (Miao et al., 2016), M is the number of nodes in $j-th$ cluster.

3.2. Improved LEACH based on K-means and Bat algorithm

The BA is applied to determine SN as CH so that energy consumption and the total distance is minimum. In this algorithm, each bat has a position $X(x_d, y_d)$ with a velocity of movement is v_i. The position of each bat is evaluated by the fitness function, and the best position is the one that best matches the requirements of the problem. In the problem of finding the CH node in a cluster of sensor nodes, each network node in a cluster is considered as a bat with hypothetical coordinates in two-dimensional space with corresponding travel velocity v_i. The K-means algorithm is used for clustering, which aims to partition N sensor nodes into K clusters in which each SN belongs to the cluster with the nearest mean (cluster centers or cluster centroid). Combining K- means and BA algorithm to improve LEACH, called BA-LEACH. The pseudo-code of BA-LEACH is described as (2).

IV. SIMULATION RESULTS

```
Input: Positions, Energy of SNs, position of BS …
Output: CHs position, state of each SN, Energy consumption in each SN.
Set parameters: N (number of SN) f_min, r_i, A_i, Max_round (loop number)
While not all node dies
      Compute the number of cluster by (1)
      Clustering nodes according to K-means algorithm
      While (i< Max_round)
       Compute the Fitness(X_i), of each particle using equation (8) find the best position and set it to X_best .
       If rand > r_i
        Update the temp position for the corresponding bat use (3)
       Else
       Update the temp position for the corresponding bat use (2)
        Calculate Fitness(X_i)
        If Fitness(X_i) < Fitness(X_best), then update X_best = X_i .
         i = i+1
         Increase r_i and reduce A_i use (4)
        SN with the X_best position is selected as CH
end.
```

Fig.2: Pseudo-code of BA-LEACH

This section describes the various parameters in scenario simulation and the results of the proposed protocol. A 500 x 500-dimension field is taken for conducting the experiment. All sensor nodes are uniformly

Table 1: The parameters of BA-LEACH

Parameter	Value
Network field	500mx500m
Number of SN	100
Initial energy of Nodes E_0	0.5J
E_{Tx}	50 nJ/ bit
E_{Rx}	50 nJ/ bit
E_{DA}	5 nJ/ bit/
Message Size	4000 bits
θ_{mp}	0.00013pJ/bit
θ_{fs}	10pJ/bit
Maximum No. of Iteration	3000
ψ	0.9
P	0.1

dispersed in the above-mentioned sensor field and it is supposed that the BS is located in the corner of the sensor field. The parameter settings of simulation as described in Table 1.

Fig.3 shows the comparison of live nodes in each round for LEACH, PSO-LEACH, and BA-LEACH algorithms, and Fig.4 shows the average of energy in each

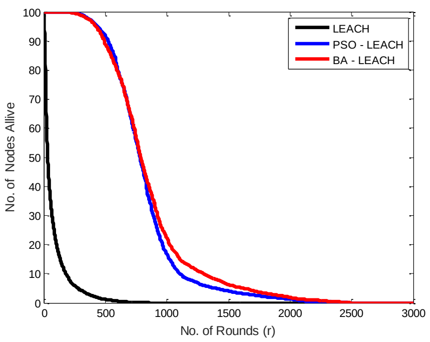

Fig.3: The number of live nodes

round of LEACH, PSO-LEACH with BA-LEACH protocol. In this, the number of live nodes and average energy corresponding rose considerably in BAT-LEACH and PSO-LEACH protocol when compared with LEACH protocol. Furthermore, the number of live nodes in BA-LEACH was higher than that of PSO-LEACH.

Fig.5 shows the time fist node, middle node, and all node dead in LEACH, PSO-LEACH, BA-LEACH protocol. It is clear that in LEACH all node dies after 631

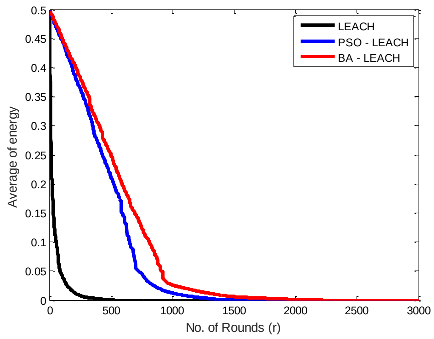

Fig.4 The average residual energy

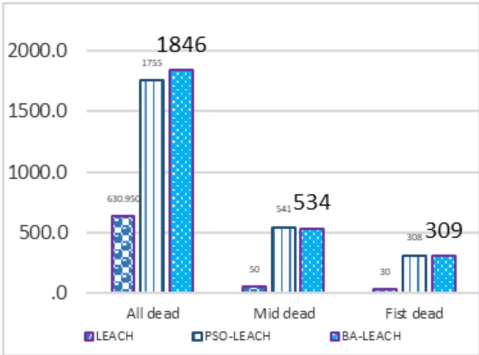

Fig.5 Compare the time when the fist, middle and all nodes dead

rounds, in PSO-LEACH all node dies after 1755 rounds, and that number in BA-LEACH is 1846 rounds. The time life of WSNs using the PSO algorithm increased 64% and using the BA algorithm increased 65.8% compared to LEACH.

The proposed protocol is implemented in MATLAB 2018b environment using window 10 based Lenovo Idea pad laptop with 2.0 GHz, Intel Core i3 processor and 6 GB RAM. Result simulation in Monte Carlo 300 times, the average time using in PSO-LEACH was 0.1269s and 0.0393s in BA-LEACH. So that, our suggestions improved LEACH protocol 65.8% in time life and reduced computation time compared to the PSO-LEACH algorithm 30,9%.

V. CONCLUSIONS

In this paper, an energy-efficient routing algorithm for WSNs has been proposed which considers selective clustering of CH nodes. By using the K-means algorithm for clustering, using BA to select SN as CH node leads to reduced average WSNs energy consumption, WSNs life is extended compared to LEACH, PSO-LEACH.

ACKNOWLEDGEMENT

This work was supported by the Hanoi University of Industry (HaUI) [grant number 27-2020-RD/HĐ-ĐHCN].

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