LIFETIME MAXIMIZATION OF WIRELESS SENSOR NETWORKS USING ODTS ALGORITHM

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Abstract—In WSN communication lifetime is very important issue. It can be achieved by less energy consumption and good energy balancing for sensor nodes. Many researchers are working on network lifetime maximization and have developed effective transmission strategies. Ant Colony Optimization (ACO) is one of the intelligence methods and has gained popularity now days. Here, in this paper, WSN network lifetime maximization achieved in terms of ACO algorithm. The next neighbor node of the routing is getting selected by the distance to sink, residual energy of the next node and average energy of the path. And WSN lifetime maximization is achieved by Most Energy Efficient Distance (MEED) and Most Energy Balanced Distance (MEBD).

Keywords—Ant Colony Optimization; Most Energy Efficient Distance and Most Energy Balanced Distance

1. INTRODUCTION

Wireless Sensor Network (WSN) has the sensors that distributed in the space for tracking physical and environmental conditions [1]. WSN built nodes and the nodes connected to one or more sensors. Energy efficiency and maximization of the network lifetime are the most difficult job for the researchers and users. There are some hop techniques like Single Hop (SH), Multi Hop and Hybrid etc. Sometimes, there is only one or single node between the source station and destination, both the source station and destination are connected the sensor node via router [2]. If source station and destination are connected via number of intermediate nodes to communicate with each other, then it is called as multi hop (MH) network. And the combination of the SH and MH is known as Hybrid network. Ant Colony Optimization (ACO) is one of the swarm intelligence methods. The ACO algorithm is the technique by which the computational problem is getting sold and reduces by searching good path [3].

In a typical ACO system, some artificial ants are placed on the nodes in network in accordance with uniform randomization rule. Each ant will build a tour by applying the state transition rule. During this process and modifies pheromone amount on the edges and travelled from starting nodes to the destination. The amount of pheromone getting modified again as all the ants is written to the starting nodes. The heuristic information and pheromone information are used together in state transition rule. This rule is getting applied during tour building process to select the next edge to travel from its current node. This process repeats till the algorithm finds the optimal path. By using optimal path the energy balancing and network lifetime maximization can be achieved [4].

There are many protocols using ACO methods. For example an energy efficient ant based routing algorithm (EEABR), a dynamic and reliable routing protocol (DRRP) and energy aware ant colony algorithm (EAACA). In EEABR, the forward ants and backward ants are taken into consideration. Actual energy level of the nodes and distance travelled by forward ant is used to choose a path by the ant. DRRP makes ants to choose path by node’s energy level and total numbers of nodes visited by the ant. With the purpose of extension of network lifetime, the EAACA was introduced. The algorithm chooses the next neighbor node of the routing according to node’s distance to the sink, its residual energy and average energy of the path. But the above transmission methods have some drawbacks:

- SH technique consumes high energy due to long transmission distance, result seen low energy efficiency.
- MH technique failed due to heavy traffic load around the sink because of fix transmission distance. And gives bad energy balancing.
- Hybrid transmission includes SH and MH, so gives poor results.
- Some energy balancing approaches which consider residual energy of node are passive techniques and cannot give network lifetime maximization

To overcome all above drawbacks Optimal Distance based Transmission Strategy (ODTS) to extend lifetime. In ODTS, to most important terms are there,

- Most Energy Efficient Distance (MEED)
- Most Energy Balanced Distance (MEBD)

Also a network lifetime maximization approach is designed in this paper by a global optimal transmission distance acquirement technique for energy efficiency and energy balancing in wireless sensor networks. This MEED and MEBD are the mechanism helps to maximize the network lifetime [5].

- analytic model
- Network Model
A WSN is taken into consideration in which nodes are evenly distributed on disk. This disk is divided into \( M \) disjoint concentric coronas and has width, \( \omega = R/M \). Where, \( R \) is the disk radius and \( M \) is the number of concentric coronas. Also consider an arbitrary wedge with angle \( \Theta \) and the wedge also subdivided into \( M \) sectors. These sectors are denoted by \( \Omega_1, \Omega_2, \ldots, \Omega_M \). Initial energy of each node is uniform and denoted by \( \epsilon_0 \) and \( \varphi \) bits per second data is generated. So, for any sector \( \Omega_i \), self-generated data volume per second is calculated as,

\[
\xi_i = \varphi \cdot \sigma \cdot \frac{\theta}{2\pi} \left\{ \pi \left( i \omega \right)^2 - \pi \left( (i-1) \omega \right)^2 \right\} \tag{1}
\]

The self-generated data volume is same for all nodes which are presented in the same sector. Sector division gives more scalability and robustness. And this is an impact full method to achieve load balancing.

### A. Node Aspects

In this network model, one stationary sink is there. This stationary sink has power supply with require amount of power and has topology knowledge of the whole network. Various stationary ordinary nodes are available in network and that are battery powered with restricted energy. All these nodes have equal initial energy and maximum transmission range. This maximum transmission range subdivided into \( K \) levels with the corona thickness \( \omega \). Transmission distance of the nodes is varying with the coronas.

### 2. PROPOSED MODEL

#### A. Transmission strategy of ant

An ant is present on every sector. Every ant moves from one sector to another as per probability towards the sink. Sequence is in order of the largest to the smallest number of the sector. Every ant moves after the ant of adjacent outer sector and finishes the trip.

Suppose an ant moves from one sector \( \Omega_i \) to another sector \( \Omega_j \) to reach the sink. Then a path is created whose transmission distance is \( d_{ij} \). It’s given by,

\[
d_{ij} = \left( i - j \right) \omega \tag{2}
\]

Once all ants have finished their tasks, that time \( d_{ij} \) of nodes for all sectors have been achieved. Then the best solution is updated after several iterations.

If the ant situated in sector \( \Omega_i \), wants to choose any candidate sector \( \Omega_q \), then it is necessary that it must have visited to as direct source sector (DSS) of sector \( \Omega_i \). Also it must be informed of \( \Phi_i \), i.e. total volume of it received data. Thus, according to formula (2) and (3) the per nodeaverage energy consumption (PNAEC) of sector \( \Omega_i \) can be given,

\[
E_i = \frac{E_{Ei} \left( \Phi_i \right) + E_{Oi} \left( \Gamma_i, d_{ij} \right)}{Q_i} \tag{3}
\]

Here, \( Q_i \) is the node number of this sector.

The conventional ACO algorithms deals with multiple hops for each ant, but the ACO algorithm used here can also deal with the single hop too. This moving mechanism of ACO makes this algorithm different and algorithm complexity get reduced. The ants present in outer sectors finishes their trips one by one. These ants are aware of the total amount of data required for the shifting by the corresponding sector.

#### B. Important Terms

- **The Most Energy-Efficient Distance (MEED)**
  
  The aim of minimizing energy usage can be obtained by choosing good transmission path or distance at hops. So, the optimal distance at each hop must be final out. Suppose the data transmitter and the data receivers are placed at distance \( D \) from each other. Then the \( D \) is divided into \( x \) hops by (\( x-1 \)) intervening relay nodes. Purpose of division is that, it can be shown that when each hop has the same transmission distance \( d \) for given distance \( D \) and \( x \) number of hops, then overall energy usage in that path get reduced. Then,

\[
d = \frac{D}{x} \tag{4}
\]

It can be written as,

\[
x = \frac{D}{d} \tag{5}
\]

Consider that data delivered to the sink is 1 bit, then total energy can be calculate as,

\[
E_{\text{Total}} = (x-1)E_T(1) + x \times E_T(1) \tag{6}
\]

Calculating further finally, we get,

\[
E_{\text{Total}} = e_{\text{amp}} D d^{\gamma-1} + 2 e_{\text{elec}} D - e_{\text{elec}} \tag{7}
\]

By taking first derivation of above formula equal to zero, the equation (7) will be,

\[
\left( \gamma - 1 \right) e_{\text{amp}} D d^{\gamma-2} - 2 e_{\text{elec}} D d^{\gamma-2} = 0 \tag{8}
\]

Then simplifying,

\[
d = \sqrt[\gamma-1]{\frac{2e_{\text{elec}}}{e_{\text{amp}}}} \tag{9}
\]

Here, \( d \) is the most energy-efficient distance (MEED) and denoted by \( d_{\text{MEED}} \).

- **The Most Energy-Balanced Distance (MEBD)**

  If same amount of energy consumed by a node in each sector, the same amount of energy \( \Theta \) is written as,

\[
\Theta = \Phi_i \left( \epsilon_{\text{elec}} + \left( \Phi_i + \xi_i \right) \epsilon_{\text{elec}} + \left( \Phi_i + \xi_i \right) e_{\text{amp}} d_{ij}^{\gamma} \right) \tag{10}
\]

and from equation (10), we get,

\[
d = \sqrt[\gamma-1]{\frac{Q_i \left[ -2 \left( \Phi_i + \xi_i \right) e_{\text{elec}} \right]}{\left( \Phi_i + \xi_i \right) e_{\text{amp}}}} \tag{11}
\]

Here, \( d_{ij} \) is the most energy-balanced distance (MEBD) and denoted as \( d_{\text{MEBD}} \).

While transmission from nodes situated in the sector to the sink, nodes in outermost sector \( Q_l \) consumes energy for data transmission without data reception. Thus, a node in outermost sector \( Q_l \) transfer data at different levels \( k \). \( k \) can be \( 1,2,3,4,\ldots,\ldots.K \). For difference levels of \( K \) the per node...
average energy consumption (PNAEC) in each sector is calculated as,

\[ \bar{E}_M = \frac{E_M(l_M, d_M)}{Q_M} \]  

(12)

Here, \(k\) varies 1, 2, 3, 4, ..., \(K\) and \(d_M = k\alpha_0\).

C. High energy efficiency and good energy balancing for Local Optimal Transmission Distance achievement technique

In this heuristic algorithm, the former is represented by the heuristic information and then it is described with the use of pheromone intensity. Heuristic factor is a value of any path. It is given by,

\[ \eta_i(t) = \left[ \frac{1}{(d_{ij} - d_{MEED}) + \lambda_1} \right]^{\gamma_1} \]  

(13)

\[ \eta_j(t) = \left[ \frac{1}{(d_{ij} - d_{MEED})^\gamma + \lambda_2} \right]^{\gamma_2} \]  

(14)

Where, \(d_{ij}\) is distance between sector \(\Omega_i\) and \(\Omega_j\), \(d_{MEED}\) and \(d_{MEED}\) are the parameters to determine importance level of high energy efficiency and good energy balancing. \(\lambda_1\) and \(\lambda_2\) are constants and are greater than zero to avoid denominator to be zero.

Then the transmission probability of the and from sector \(\Omega_i\) to sector \(\Omega_j\) is given by,

\[ p(t) = \frac{[\tau_i(t)]^\alpha[\eta_i(t)]^\beta}{\sum_{\alpha, \beta}[\tau_i(t)]^\alpha[\eta_i(t)]^\beta} \]  

(15)

Where, \(\tau_{ij}(t)\) is pheromone intensity \(\alpha\) and \(\beta\) are constants.

D. Network Lifetime Equation based global optimal transmission distance achievement technique

Optimal distance based transmission strategy decided the lifespan by the sector which has maximal PNAEC.

\[ f(t) = \frac{E_0}{\max \{E_i(t), i = 1, 2, ..., M\}} \]  

(16)

Where, \(E_0\) is constant and \(s\) initial energy of each node, \(E_i(t)\) is PNAEC of sector \(\Omega_i\) for the \(t^{th}\) iteration. This process repeats until maximum iteration is reached, at every iteration computed the transmission probability, updates the received data volume, pheromone intensity for every path and finally evaluates the solution and gives the network lifetime extension.

E. High energy efficiency and good energy balancing for Local Optimal Transmission Distance achievement technique

The Algorithm given below (Fig.1) is the ODTS Algorithm using ACO. The algorithm is described in form of flowchart so that the steps and operation of the algorithm can be understood. It starts and initializing all the parameters. Then computing the essential terms. The do while and do for loops are used here. After computing and finding the solution, the best solution is getting selected. The best solution also updated. And then the ant returns to the best solution. The ODTS algorithm thus processing and finding the distance and the path such a way that less energy efficiency and the good balancing of the energy can be obtained. This is helping to improve the life of WSN.

Fig.1 Flowchart for ODTS algorithm
3. PERFORMANCE ANALYSIS

Let us, set the system parameters for the computational results. The values are set as, $\omega = 5m$, $\sigma = 5/m^2$, $\epsilon_0 = 10J/\rho = 400$bits, $\theta = \pi/6$, $\lambda_1 = \lambda_2 = 5$, $\mu = 10^{-4}$, $\rho = 0.05$, $\psi_1 = 2$, $\psi_2 = 3$, $\delta = 3$, $\alpha = 3$, $\beta = 2$.

During packet collisions energy gets washed. So, it is not considered.

A. Influence of the maximal transmission level

The fig.2 shows the maximal transmission level on network lifetime of ODTS. Here we took network radius $R$ is equal to 100m, 150m and 200m. The maximal transmission levels are denoted by $K$. Figure indicates that as the transmission level increases, the network lifetime is rising in early stage. But the network lifetime stops climbing at $K = 8$ for $R=100m$, $K = 9$ for $R=150m$ and $K = 10$ for $R=200m$.

This happened due to requirement of high energy efficiency; this has restricted using too long transmission distance. Thus, it can be said that for variation in radius from $R=100m$ to $R=200m$, the maximal transmission distance varies from $K=8$ and $K=10$.

B. Energy usage comparison

Maximal Transmission Level $K$ ission schemes

The fig.3 and fig.4 are showing usage vs. distance to the sink performance. Overall five systems are compared in the graph, namely, single hop (SH), Multi hop (MH), Hybrid, Energy Aware Ant Colony Algorithm (EAACA) and Optimal Distance Transmission Strategy.

In SH, the energy usage is increasing rapidly as the distance of node from the sink gets increased. Hybrid transmission technique shows high energy consumption like in SH which is increasing with the increase in distance. As seen in the beginning of the paper, Energy efficiency is not possible in SH.

Most Energy Efficient Distance (MEED) and Most Energy Balanced Distance (MEBD) are used in ODTS. MEED gives high energy efficiency and MEBD gives good energy balancing. Heuristic value of ACO algorithm has important factor that is distance. It selects good distance for transmission that the energy consumption should be less and the energy balancing through the network can be obtained.

So, from the graphs, it can be seen that ODTS consumes less energy than other transmission strategies used for date transmission.

C. Network lifetime comparison for different network radii

For longer network range traffic load is very heavy. But as the network radius increases, the network lifetime decreases. Figure indicates SH, MH, Hybrid, EAACA and ODTS network lifetime for different radius. Single hop transmission technique achieving very low network lifetime for different network radius than other transmission strategies. All different transmission strategies get reduced with network radius. As the distance from the sink increases, the node consumes more energy to transfer the data. Thus, the fig.5 shows that for all the given methods network lifetime decreases with increased network radius. SH gives lowest performance but in ODTS technique comparatively longer lifetime is achieved. It is nearly five times more than SH.

This is because of mainly two mechanisms. One is the local optimal transmission distance acquisition mechanism and the global optimal transmission distance acquisition mechanism where transmission range is near $d_{MEED}$ and $d_{MEBD}$ to get high energy efficiency as well as energy balancing and the network lifetime is determined by the nodes with maximum energy consumption respectively.
In case of the global optimal transmission distance acquirement mechanism, the pheromone updating rule is defined by the maximal PNAEC of different sectors. In this way, path having low value of mechanism PNAEC is chosen to maximize the network lifetime [6].

4. CONCLUSION

Thus, Network lifetime can be raised by ODTS and ACO algorithm. The optimal distance based strategy implemented for high energy efficiency, good energy balancing. Also this strategy used to obtain minimum energy utilization of nodes with maximal energy consumption entire the network. In ODTS, the algorithm optimal distance based transmission strategy was proposed on the basis of ACO methods. So, the lifetime maximization of the wireless sensor. Network can be take placed by ODTS is greater than other strategies like SH, MH, Hybrid, and EAAAC. This lifetime longevity is obtaining by ACO algorithm. Ants on the node find the good transmission path and use less energy.

REFERENCES


