Analysis of Clustering Algorithm for Lifetime Improvement in Wireless Sensor Networks

Pooja Mishra¹, Sanjiv Sharma²
¹M. Tech. (IT) Scholar, Department of CSE/IT, MITS Gwalior, India
²Assistant Professor, Department of CSE/IT, MITS Gwalior, India

Abstract — Due to limited available resource of sensor nodes, energy efficiency and prolonged network lifetime has become one of key design in wireless sensor networks (WSNs). Many algorithms have been proposed to address the aforementioned issues, among which, clustering is considered efficient technique to minimize the energy consumption. This paper proposed an clustering algorithm to provide minimum energy consumption and improved network lifetime in WSNs. The main objective of this algorithm is to reduce the transmission distance of sensor nodes in WSN by transferring the longer distance node from one cluster to another. The proposed approach is implemented in MATLAB, simulation result shows that it can prolong the network lifetime than existing localization algorithm and achieve the better performance of energy efficiency.

Keywords — Wireless sensor networks, Network lifetime, Energy efficiency, Clustering.

I. INTRODUCTION

Wireless Sensor Networks (WSNs) [1] is a densely deployed communication network, which consists of huge number of sensor nodes and monitor specific target and responsible for gathering information from their surroundings. All of this information is sent to the sink node or base station (BS) so that it can be accessed by the end user only. WSN has several applications such as military reconnaissance, industrial automation, security surveillance, disaster management, habitat monitoring, medical and health care monitoring, environmental/earth sensing [2],[3] etc.

A WSN node combines sensing, computation and communication into a single tiny device [15]. Prolonged network lifetime, load balancing, scalability and minimum energy consumption are important requirements for various WSN applications. Minimised energy consumption and prolonged network lifetime are two important objectives of WSNs. Therefore, the elegant approach is clustering in which network is divided into disjoint groups and each group is managed by a representative node known as cluster head (CH) and others are member nodes. In two levels hierarchical approach, only CH nodes communicate directly to the BS, so energy consumption is more than that of member nodes. Therefore, selection of CH plays an important role in all clustering algorithm for efficient performance in WSNs. Energy consumption of a sensor node is generally during the transmission and receiving packets [1]. In WSN, main power source of sensor node is battery. Therefore, its large number of sensor nodes replacement of batteries is quite impossible task. Therefore, efficient energy consumption becomes the major concern in WSNs. In order to increase the energy efficiency and network lifetime of WSN, energy efficient algorithm must be developed.

In the proposed algorithm, the selection of CHs is made by using combined weight function. This weight function includes following different parameters.

(1) Number of node’s neighbors
(2) Remaining energy
(3) Transmission power.

Clustering reduces network contention because every member node communicates their data over smaller distances to their respective CHs. Now, CHs perform aggregation and send this aggregated information to the BS [4] as shown in Fig.1.

The rest of the paper is formulated as follow: Section II describes the brief overview of existing weight based energy efficient clustering algorithm in WSNs. Section III presents the energy model for the calculation of the energy consumption in WSNs. Section IV describes the proposed methodology.
Section V presents the simulation result and analysis. Finally, section VI describes the conclusion.

II. REVIEW WORK

In the literature, huge number of cluster-based algorithms has been proposed in WSNs. Every algorithm has its own specific goal. This section reviews all the related energy efficient clustering algorithms in brief. These are as follows:

M. Chatterjee et al. 2000 [10],[11] proposed the first weight based clustering algorithm named as on-demand weighted clustering algorithm (WCA) for selecting CHs in mobile ad-hoc networks. Sensor networks generally have more constraints than traditional networks. Thus, WCA always is not so appropriate to apply directly in sensor networks.

Ding et al. 2005 [5] proposed an algorithm named as Distributed Energy-Efficient Hierarchical Clustering for WSNs (DWEHC). The main aim of this algorithm is minimum energy consumption and improved network lifetime. This algorithm utilizes two parameters these are: residual energy and distance with neighbors node in order to calculate the combined weight function.

Vieu et al. 2006 [12] proposed an algorithm named as weighted clustering algorithm using local cluster-heads election for QoS in MANETs (WCA-L). Its CH election process is similar to WCA algorithm. The main goal of WCA-L to is deform the isolated nodes into CHs and form their clusters efficiently.

H. Safa et al. 2008 [6] proposed an algorithm named as Dynamic Energy-efficient Clustering Algorithm (DEECA). It has two phases: cluster formation and network maintenance. The main aim is to achieve the load balancing to the CHs by defining the two energy thresholds within the network.

S. Zainalie et al. 2008 [4] proposed an algorithm named as Clustering Algorithm for Localization in Wireless Sensor Network (CFL). The main aim of CFL algorithm is achieving the optimal cluster size with minimum number of clusters in order to achieve improved network lifetime the performance of clustering algorithm and achieves good distribution of cluster heads.

Fayyaz et al., 2010 [14] proposed an algorithm known as maximal weight topology discovery in ad-hoc wireless sensor networks (Max Weight). The main aim of this algorithm is to minimize the number of CHs to get the optimal topology in the network.

T. Hong et al. 2011 [7] proposed an algorithm named as Improved Weighted Clustering Algorithm for Heterogeneous WSNs (IWCA). The main aim of IWCA is to increase the network lifetime and it includes network maintenance phase in addition to cluster formation phase. Network maintenance phase checks threshold for energy amount of nodes, which activates the recalculation of the clustering algorithm.

E. Alizadeh 2014 [8] proposed an clustering algorithm named as Life Time Sensitive Weighted Clustering on WSN (LTS-WCA). The main aim of LTS-WCA algorithm is to solve the problem involved in reviewed weighted clustering algorithm and increasing the network lifetime. It is a fully distributed algorithm and applicable for both homogeneous and heterogeneous network.

III. ENERGY CONSUMPTION MODEL

The energy and radio consumption model considered in this work is shown in Fig. 2. This model is used to evaluate the energy consumption and lifetime of WSNs. The accurate network lifetime and energy consumption of node can be predicted by accurate energy consumption model. Sensor node mostly consumes energy during transmission and receiving the packet. Therefore, the model proposed by Heinzelman et al. [9] considers energy consumption during microcontroller processing and radio transmission and receiving only.

The transmission of k bit message over a given distance d, an acceptable signal to noise ratio (SNR) can be achieved. The calculation of energy consumption during transmission, $E_{\text{Tx}}(k,d)$ is given by:

$$E_{\text{Tx}}(k,d) = E_{\text{elec, tx}}(k)+E_{\text{amp, tx}}(k,d) = \begin{cases} k E_{\text{elec}} + k E_{\text{fa}} d^2 & \text{if } d < d_0 \\ k E_{\text{elec}} + k E_{\text{fa}} d^4 & \text{if } d \geq d_0 \end{cases}$$

The energy consumption during receiving k bit message by the radio, $E_{\text{Rx}}(k)$ is given by:

$$E_{\text{Rx}}(k) = k E_{\text{elec}}$$

where $E_{\text{elec}}$ is the energy is dissipated per bit to run the transmitter or the receiver circuit, $E_{\text{fa}}$ and $E_{\text{mp}}$ energies used by the transmitter amplifier for short distances (free space model) and long distances (multi path model) respectively and $E_{\text{Rx}}$ is the energy of fusion per bit. Distance between the sender and the receiver is given by d and $d_0$ is the distance
threshold or crossover distance which is calculated by equating \( d = d_0 \), given by following formula:

\[
d_0 = \frac{\epsilon_{n0}}{\epsilon_{mp}}
\]

It is known that data transmission consumes more energy as compared to data processing [1]. Therefore, data aggregation/fusion should be performed. Data aggregation/fusion is referred to as reducing the gathered data packet into a single packet by spatial correlation. Generally, it is performed by cluster heads.

**IV. PROPOSED METHODOLOGY**

This section presents the proposed algorithm. It is a distributed clustering algorithm. Initially all the nodes are randomly distributed in network area. After execution of this algorithm each node will be placed either CLUSTERHEAD or CLUSTERMEMBER state. There are some basic steps for selecting the cluster head efficiently. These are as follows:

**Step 1** Initially, all the nodes broadcast the ‘Hello’ message to know about the neighbors, when node receive ‘Hello’ message, it makes the entry in neighbors table and calculate its own distance to sender using RSSI algorithm.

**Step 2** Every node calculates the value according to weight function (\( W_i \)), which includes three important parameters. These are: reminding energy (\( E_i \)), number of neighbors node (\( N_i \)) and transmission power (\( P_i \)). The formula to calculate the weight function [4] for every node \( i \) is given by:

\[
W_i = a N_i + b E_i + c \left( \frac{1}{P_i} \right)
\]

where \( a, b, c \) are non-negative constant such that \( a + b + c \leq 1 \). After the weight function calculation, each node broadcast its weight in the network.

**Step 3** Node with maximum weight function than its neighbors is selected as CH and changed their state to CLUSTERHEAD. Now, CH sends the cluster message to its neighbor and find out nodes which are within its specified range acts as CLUSTERMEMBER.

**Step 4** When new node selected as a CH (second cluster head onwards) then transfer the previous member nodes from one cluster to another based on minimum distance, as shown in Fig. 3.

**Step 5** Now, after completion of the first iteration, several other iterations are also followed by the same way until all clusters are formed.

The clustering process is made in such a way that all CHs are distributed all over the network. The number of neighbor nodes is high then there is more chance that node is selected as CH.

Therefore, the maximum weight will be considered as a CH. The flow chart of proposed algorithm is shown in Fig. 4.

**V. SIMULATION RESULTS**

In the simulation, it is assumed that all the sensor nodes are deployed randomly in the network. The simulation has been performed on a network of 100 nodes and a fixed BS deployed at center of the network. This paper uses several different parameters to examine and compare the performance.
of the proposed algorithm. These are, number of alive nodes, number of dead nodes, time required for the failure of first node (stability period) and number of CHs etc. The main aim of proposed algorithm is to attain fine distribution of CHs, minimum energy consumption and increased network lifetime. All parameter values used in energy model (for both simulation and the analysis) are listed in Table 1.

The performance comparison in terms of energy efficiency and network lifetime of proposed algorithm and CFL algorithm [4] is shown in Fig. 5.

Similarly, comparison of dead nodes at each stage shown in fig. 6. By the time, this can also be analysed that the time required for failure of first node (stability period) is also high for proposed algorithm. The comparison of stability period for different transmission range is shown in Table II.

<table>
<thead>
<tr>
<th>Parameters Name</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transmitter Electronics (E_{Tx-elec})</td>
<td>50 nj/bit</td>
</tr>
<tr>
<td>Receiver Electronics (E_{Rx-elec}) (E_{Tx-elec} = E_{Rx-elec} = E_{elec})</td>
<td>50 nj/bit</td>
</tr>
<tr>
<td>Amplifier energy for free space loss ($E_{fs}$)</td>
<td>10 pj/bit/m$^2$</td>
</tr>
<tr>
<td>Amplifier energy for multipath loss ($E_{mp}$)</td>
<td>0.0013 pj/bit/m$^4$</td>
</tr>
<tr>
<td>Sensing area</td>
<td>1000 x1000m$^2$</td>
</tr>
<tr>
<td>Number of sensor nodes</td>
<td>20-100</td>
</tr>
<tr>
<td>Initial energy of nodes</td>
<td>1J</td>
</tr>
<tr>
<td>Data packet size</td>
<td>500</td>
</tr>
<tr>
<td>Position of base station</td>
<td>500 x500m$^2$</td>
</tr>
<tr>
<td>Transmission range</td>
<td>10-120m</td>
</tr>
<tr>
<td>a, b, c</td>
<td>0.6, 0.3, 0.1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Algorithm</th>
<th>Stability period</th>
</tr>
</thead>
<tbody>
<tr>
<td>CFL</td>
<td>Tx-Range=60m</td>
</tr>
<tr>
<td></td>
<td>63</td>
</tr>
<tr>
<td>Proposed algorithm</td>
<td>Tx-Range=120m</td>
</tr>
<tr>
<td></td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>55</td>
</tr>
</tbody>
</table>

Fig. 6 Comparing CFL, proposed algorithm in terms of dead nodes and Number of round.

Fig. 7 presents comparative result considering two parameters, namely the number of clusters and number of nodes.

<table>
<thead>
<tr>
<th>Algorithm</th>
<th>No. of nodes vs No. of clusters</th>
</tr>
</thead>
<tbody>
<tr>
<td>CFL</td>
<td>No. of nodes</td>
</tr>
<tr>
<td></td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>80</td>
</tr>
<tr>
<td></td>
<td>60</td>
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<tr>
<td></td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>20</td>
</tr>
<tr>
<td>Proposed algorithm</td>
<td>No. of clusters</td>
</tr>
<tr>
<td></td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>10</td>
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<tr>
<td></td>
<td>15</td>
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<tr>
<td></td>
<td>20</td>
</tr>
</tbody>
</table>

Fig. 7 Comparison of CFL, proposed algorithm for number of cluster and number of nodes.
This clearly shows that as compared to CFL algorithm, proposed algorithm is better in terms of number of cluster present in the network.

![No. of nodes vs No of cluster heads](image)

**Fig. 8** Comparison of CFL, proposed algorithm for number of CHs and number of nodes.

Fig. 8 presents comparative result considering two parameters, namely the number of CHs and number of nodes. This shows that as compared to CFL algorithm, proposed algorithm is better in terms of number of CHs present in the network.

![No. of cluster heads vs Transmission Range](image)

**Fig. 9** Comparison of CFL, proposed algorithm for no. of CHs and Tx-range.

As we can see in Fig. 9 as increases the distance the number of clusters formed is decreasing.

**VI. CONCLUSION**

This paper analyzed that huge number of weight based clustering algorithm has been proposed for different types of network, namely ad-hoc network and WSNs. The main motivations concentrating mostly on the energy efficiency and network lifetime, this is most emphasized area of present study. There are several parameters such as number of neighbors, remaining battery power and distances with neighbors, which play important roles in the process of selecting CHs and these parameters should be thoroughly worked out and developed further. In the present paper, cluster formation process is proposed as an enhancement and prolonged network lifetime is achieved. Proposed algorithm increases network life time by decreasing the number of clusters within the network environment. Decreasing the number of clusters leads to less usage of transmission power and finally keeping the nodes alive for much longer within the network environment.

**REFERENCES**


