A LOCAL TOPOLOGY RECONFIGURATION MECHANISM TO IMPROVE THE ENERGY EFFICIENCY IN WIRELESS SENSOR NETWORK

1P.K.POONGUZHALI 2V.S.JAYANTHI

1Assistant Professor, Department of Electronics and Communication Engineering, Hindusthan College of Engineering and Technology, Coimbatore-641032, India
2Professor, Department of Electronics and Communication Engineering, Hindusthan College of Engineering and Technology, Coimbatore-641032, India
E-mail: 1pkp18671santhosh@gmail.com, 2jayanthivs@gmail.com

ABSTRACT

A wireless sensor network (WSN) is a self organizing wireless network system consists of number of energy limited sensor nodes. Since sensor nodes are battery powered devices, they have limited processing and transmission power and with limited communication ability. In order to transmit sensing data to receiver effectively, it is necessary to design an energy efficient routing protocol for WSNs. The nodes with greater signal strength will have more communication link and result in faster energy consumption as a whole network cannot always work under the same topology structure. A topology reconnecting mechanism of the cluster head rotation algorithm is needed. This paper presents an Enhanced Forward Aware Factor -Energy Balanced Routing Method (EFAF-EBRM) based on the selection of appropriate cluster head to improve the energy efficiency. In this technique the sensor node may prefer to select cluster head that makes the total energy consumption least. This proposed cluster formation strategy decreases the communication overhead and increases the packet delivery ratio. More over this technique over come the problem in the existing routing method FAF-EBRM when local topology reconfiguration is needed. In this method an optimal solution for cluster head selection is proposed. The sensor nodes in the proposed algorithm pick out their appropriate cluster heads rather than the nearest for the sake of energy efficiency. The newly proposed cluster formation strategy reduces the delay even for the long distance link. Simulations results also prove that the proposed cluster formation strategy is better performance compared with FAF-EBRM and LEACH in terms of Energy balanced factor, Network lifetime, communication overhead and delay.

Keywords: Forward Aware Factor (FAF), Cluster Formation, Communication Over Head, Wireless Sensor Networks (WSNs).

1. INTRODUCTION

A Wireless Sensor Networks (WSNs) consists of tiny sensing device that are physically small, communicate wireless among each other. Due to the limitation of their physical size, the sensors tend to have short storage space, energy supply and communication bandwidth so limited that every possible means of reducing the usage of these resources is aggressively sought. The use of the WSN potential will provide efficient and cost-effective solutions for several problems[1][2]. Hot spots in a WSNs emerge as locations under high traffic load. Nodes in such areas quickly drain energy resources, leading to disconnection in network services. Cluster based routing algorithms in WSNs have recently gained increased interest, and energy efficiency is of particular interest.

However it is necessary to implement mechanisms or procedures to deal with the sensor constraints. The hierarchal organization of the sensors, grouping them and assigning those specific tasks to the group before transferring the information to higher levels, is one of the mechanism proposed to deal with the sensors limitations and is commonly referred to as clustering. The creation of clusters in a WSN field is generally done by taking into account the proximity between the sensors, measured through the radio frequency signal they emit. Each cluster has a cluster head CH which is the node that directly communicate with the sink (base station) BS for the user data collection. By assuming the roles within a cluster hierarchy, the nodes in a WSN can control the activities they perform and therefore reduce their energy consumption. However the election of when to act...
as a simple data provider (saving energy) and when to act as gateway (cluster head) between the nodes and then base station is difficult problem[1][4]. To make this decision it is necessary to take into account several aspects including power level signal, transmission schedules, nodes localization and networking function. Clustering helps in solving some of the sensors constraint by reducing the cost (energy consumption) of transmitting data to base station. Clustering technique reduces the power consumption in the devices facilitating the gathering of sensed data, and maximizing the routing process execution and allowing scalability.

Many energy efficient routing algorithms and protocols have been proposed to prolong network life time for WSNs in recent years [19]. In most of the routing scenarios, the sink node is usually assumed to be fixed either inside or outside the WSNs. This will inevitably cause the hot spot phenomenon, primarily then sensors close to sink nodes will have more traffic load to transmit than nodes further away from the sink nodes under multi hop transmission. Traditionally, there are two approaches to accomplish the data collection task: Direct communication, and Multi-hop forwarding. In one hop wireless communication, the sensor nodes upload data directly to the sink, which may result in long communication distances and degrade the energy efficiency of sensor nodes. On the other hand, in multi-hop forwarding, data are transferred from the nodes to the sink through multiple relays, and thus communication distance is reduced [11]. However, since nodes closer to the sink have a much heavier forwarding load, their energy may be depleted rapidly, which degrades the network performance.

In EFAF-EBRM, a spontaneous reconstruction mechanism for local topology is designed based on maximizing the co-alive life span and minimizing the total energy consumption, in this routing method protocol the nodes pick out their appropriate cluster heads rather than the nearest for the sake of energy efficiency. This paper aims to balance the energy consumption based on the requirement of the network. First case the total energy expenditure of a packet from the departure node to the destination base station is reuced when the sensor node tends to select a cluster head which minimizes the total energy consumption of a single packet deliverying and in the second case the node prefers to choose a cluster head that maximizes the life time of both, even if more energy is consumed.

The rest of paper is organized as follows: Section 2 presents the related work. Section 3 describes the problem statement. Section 4 presents the proposed method performance analysis. Section 5 gives the simulation results. Section 6 represents a summary of conclusion.

2. RELATED WORK

2.1 Low energy adaptive clustering hierarchy (LEACH) protocol

LEACH protocol is one of the most famous hierarchical routing protocols for wireless sensor networks to increase the life time of network. LEACH, is the probabilistic –based cluster head selection [5]. All the nodes in a network organize themselves into local clusters. The protocol is divided into a setup phase each node chooses a random number between 0 and 1 , if this number is less than certain threshold T(n) the node will broadcast itself as cluster head. The non cluster head node chooses the cluster head with greater signal strength and joins the cluster and then the cluster head node receives data from all of the cluster members and transmits the data to the remote sink. The threshold T(n) is given by

$$T(n) = \begin{cases} p/(1 - p \times \text{mod}(\frac{1}{p})), & \text{if } r = \text{true} \\ 0, & \text{else} \end{cases}$$ (1)

Where p is the desired percentage of cluster heads, r is the current round and G is the set of nodes that have not served as cluster heads in the last rounds.

LEACH allows randomized rotation of the high-energy cluster-head position such that it rotates among the sensors. In this way, the energy load associated with being a CH is evenly distributed among the sensing nodes. The CH node will know all the sensor node in the cluster. Therefore it can create a TDMA schedule that informs each node exactly when to transmit its collected data.

2.2 Forward Aware Factor –Energy Balanced Routing Method.

In FAF-EBRM a new energy-balance routing protocol that computes forward transmission area (FTA) based on position of sink and cluster node for final data flow direction. In other words, FTA[3] define forward energy density which constitutes forward-aware factor with link weight, and proposed a communication protocol based on forward-aware factor, thus balancing the energy consumption and prolonging the network function.
lifetime. FAF-EBRM network model is shown in the figure 1.

1) All sensor nodes are isomorphic and they have limited energy and communication ability. Here, identifier for a node is represented as ‘i’.

2) CH is more energy intensive than a sensor nodes. Thus, when a CH in a cluster dies, all the sensor nodes inside that cluster lose communication ability. However, addition of energy of sink node is possible. But, it is not possible to change the location of nodes and sink after being fixed [3].

3) According to distance to receiver, nodes can vary its transmission power. The sink node can broadcast advertisement message to all nodes in the sensing field. The distance between source and receiver can be determined by received signal strength. When the data transmission distance is more than certain threshold $d_{th}$, the energy consumption would rise sharply. The threshold value is given by,

$$d_{th} = \sqrt{\frac{E^{2}_{F2}}{E_{max}}}$$

where $E_{F2}$ and $E_{max}$ are the energy coefficients.

![Figure 1: Forward Transmission Area of node i](image)

Let FTA (i) be the forward transmission area of node i, N(i) be the set of nodes that have communication link with node i, N’(i) be the set of nodes of N(i) that have edge with node i, $d_{ij}$ be the distance between node i and node j. Consider a circle $\mathcal{C}_1$ with sink as the centre and another circle $\mathcal{C}_2$ with node i as the centre and $d_{ip}$ as the radius as shown in figure 1:

$$FTA(i) = \bigcup_{j \in N(i)} \mathcal{C}_j$$

$$d_{ip} = \max\{d_{ij} \mid j \in N'(i)\}$$

In FAF-EBRM every time node i finishes transmission check the point strength of the next-hop node, if it it less than the average value of all of the sensor’s strength in FTA, the local topology reconfiguration mechanisms should be launched in node i’s FTA. Before the topology reconfiguration mechanism is launched the existing link must be removed and new set of FTA(i) should be computed. The node removed may be the possible next hop node when the next transmission is finished. The nodes real-time strength is needed to calculate the sum of strength.

Due to the spontaneous topology reconstruction mechanism 1) communication radius should be computed to find the distance whenever the topology construction changes and as a result communication overhead results 2) The frequent changes adversely affect the performance of the network because the routing method spend more time selecting CH rather than relying on packets. 3) Cluster formation consumes certain amount of energy. Periodic advertisements are needed to form hierarchy this results communication over head in the routing path. 4) Change in network traffic will affect the cluster head and sensor node energy level results in re-clustering which is not acceptable as some of the parameters in computing the total energy consumption changes which in turn will affect the throughput and delay.

3. PROBLEM STATEMENT

All existing clustering algorithms including the mentioned above FAF-EBRM have concentrated on the data transmission distance and when the distance larger than the threshold $d_{th}$ the energy consumption would rise sharply, therefore the communication radius is set to $d_{th}$. In the traditional hierarchical cluster based routing protocol LEACH, the primary aim is to balance energy utilization in wireless sensor network. In addition probabilistic-based cluster head selection method is used, each ordinary node chooses its closest cluster head with the largest received signal strength and each member node selects its cluster head with single hop to reduce the communication distance, in other point of view the cluster head to based station distance is not considered in the popular routing algorithm. In FAF-EBRM based on uneven clustering the routing algorithm is computed based
on the forward transmission area FTA and the communication link is determined. The forward energy density FED is calculated to find out the next hop node the whole network cannot always work under the same topology structure. As a result the node which is closer to the sink will result in faster energy consumption. This problem exists in many WSN routing protocols such as ECLP and T-MAC.

In FAF-EBRM, every time the node after finishes the transmission check the status of the link weight, it is less than the average value of all the sensors strength in FTA the local topology reconfiguration mechanism should be launched. Due to the spontaneous topology reconstruction mechanism communication radius should be computed to find the distance whenever the topology construction changes and as a result communication overhead results. More over in existing protocol FAF-EBRM if the base station is among the forward transmit nodes the cluster member node will transmit the data directly to base station to overcome the backward transmission which result in waste of energy[7] but the node close to sink will exhaust all the energy due to over load in the traffic and biconnectivity results.

4. PROPOSED MEHOD

4.1 Protocol Description for Analysis-EFAF-EBRM

To improve the energy efficiency in wireless communication. Since wireless communication always consumes higher percentage of energy than wired communication when the data's are transmitted to the destination end, to improve the energy efficiency in wireless communication this paper suggests a new cluster formation technique. Few modification is done in the existing clustering technique.

As shown in the figure 2 suppose the N sensor nodes are randomly distributed in rectangular field of M x M(m²). Data are sent to the regional central node (cluster head), then transferred to the sink node (sink). Each head has communication radius $R_c$ to send advertisement. Suppose traditional cluster head selection algorithm has been operated many nodes can receive the messages from more than one cluster head as follows.

$$N_c = \left( \pi \sum_{i=1}^{k} R_i^2 - M^2 \right) \rho$$  \hspace{1cm} (5)

Where $N_c$ represents the number of nodes receiving more than one advertisement, $\rho$ denotes node density and $\epsilon$ indicates the overlapping ratio between the covering area of a cluster heads and deployment regions of all node. Two cases are considered to minimize the energy consumption. First case all the cluster heads are in square $M^2$. Second case all heads are at boundaries of the square then $\epsilon=0.5$ therefore the overlapping ratio $\epsilon$ is between 0.5 and 1.

![Figure 2: Distribution Map of Sink Node and Sensor Node.](image)

Through LEACH Protocol the Optimal cluster head number is given [5]

$$R_{opt} = \sqrt{\frac{2\pi}{\epsilon \ln(1+\epsilon)}}$$  \hspace{1cm} (6)

The average node density is $\rho = \frac{N_c}{M^2}$. Consider all the cluster heads have the same communication radius $R$ then

$$N_c = \frac{\epsilon \left( \pi R^2 - M^2 \right) N}{M^2}$$  \hspace{1cm} (7)

Suppose for $R=0.3M$ and $\epsilon=0.5$ then

$$N_c = (0.1771 \sqrt{N} - 1)N$$  \hspace{1cm} (8)

For largely densely deployed network there always exist a considerable number of nodes to have more than one cluster head.
4.2 Performance Analysis using Radio Model

For the sake of energy efficiency it is necessary to select the proper cluster head rather than the nearest cluster head. Consider the figure 3. The member node has to connect to CH2 rather CH1 for the data transmission because the energy consumption would rise sharply if the transmission distance is larger. However, the sensor node saves energy in this case but CH2 probably waste energy on transmitting packets to the sink node. Therefore the total energy consumed for transmitting the data to the base station from the sensor node to the base station is taken into account.

4.2.1 Establishment of the model

Assume the energy models described in LEACH. The energy to transmit, receive and aggregate a 1-bit message is

\[ E_{Tx}(d, l) = \begin{cases} l(E_r + e_r d^2) & \text{if } d < \theta \\ l(E_r + e_r d^2) & \text{if } d \geq \theta \end{cases} \]  

(9)

\[ E_{Rx}(d) = lE_r \]  

(10)

\[ E_{agg} = lE_r \]  

(11)

Where \( d \) is the distance between two nodes and \( E_r \) is the energy dissipated on prebit. \( e_T \) and \( e_r \) are the factors of free space model and multipath model and \( \theta \) is a threshold to decide which transmission model is used and \( \theta = \frac{C_T}{C_r} \)

Energy dissipated on per bit.

Energy consumption mainly consists of four parts: 1) Transmitter energy from node to cluster head 2) Receiving energy dissipated by a cluster head 3) Aggregation energy spend by a cluster head 4) Transmitting energy from a cluster head to the base station. Thus the total energy dissipation of a \( l \) bits packet from sensor node SN to cluster head CH and arrives to base station is expressed as

\[ E_{T} = E_{Tx}(d, l) + E_{Rx}(l) + E_{agg}(l) + E_{Tr}(d, CH) \]  

(12)

The aggregation ability of a cluster head is defined as ratio \( \mu \) therefore the cluster head can aggregate a \( l \) bits length packet to be \( \mu l \) bits.

The two factors that have influenced on the energy consumption can be analyzed on the two cases.

Case 1: Minimizing the total energy consumption.

If the network is able to detect some events as long as there are a few alive nodes, then the sensor node selects the cluster head CH from available CH’s can be formulated as:

\[ CH = \arg \min_{i} E_{t} \]

\[ \begin{align*}
    & E_{t} = E_{Tx}(d, l) + E_{Rx}(l) + E_{agg}(l) + E_{Tr}(d, CH) \\
    & \text{if } d_{s, CH} < \theta, \quad e_{s, CH} = e_{T} \\
    & \text{else}, \quad e_{s, CH} = e_{r}
\end{align*} \]

Case 2: Maximizing the co-alive lifespan

If the network requires nodes alive as much as possible to collaborate with each other then the network life span is divided into many rounds. Node S will choose a CH that makes \( E_{t} \) but this cannot equalize the energy consumption between S and CH this imbalance will greatly degrade the network life time, in order to overcome this problem node S select a CH that maximize the co-alive life span, to select a CH in inorder to make co-alive life span to be maximum can be formulated:

\[ CH = \arg \max_{i} R_{co} \]

\[ R_{co} = \min \left\{ R_{s, CH}, R_{C, CH} \right\} \]

\[ = \min \left\{ \frac{E_{s, CH}(l)}{E_{r}(l)}, \frac{E_{Rx}(l, CH)}{E_{r}(l)} \right\} \]
Stage 1: A new round begins and a cluster head selection algorithm runs. The elected cluster head broadcasts their advertisement with information about the position to the base station, their aggregation ability and residual energy.

Stage 2: Each non-cluster head node collects all received advertisements and calculates the total energy dissipation $E_t$ according to the equation (12).

Stage 3: Cluster head that makes $E_t$ least and the sensor node belongs to the cluster as long as there are a few alive nodes to improve the energy efficiency.

5. SIMULATION RESULTS

As shown in Table 1 there are 100 sensor nodes deployed in a (200,200) m² with the initial energy 0.5 joules. The maximum transmission radius is assumed to be 30 meters R. Simulation were carried out in NS2. In this simulation the objectives of clustering algorithm under test are 1) cluster formation 2) selecting cluster head 3) comparison of various parameters such as energy-balanced factor (EBF), number of last-surviving nodes (NLN) and packets reception ratio (PRR) with existing algorithm LEACH and FAF-EBRM is implemented.

![Fig 4: Cluster Head Selections](image)

![Fig 5: Cluster Formations](image)

### Table 1: Node specification parameters

<table>
<thead>
<tr>
<th>Simulation tool NS2</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Network coverage</td>
<td>(200,200)m²</td>
</tr>
<tr>
<td>Number of nodes</td>
<td>100</td>
</tr>
<tr>
<td>Initial energy</td>
<td>0.5J</td>
</tr>
<tr>
<td>R</td>
<td>30m</td>
</tr>
</tbody>
</table>

5.1 EFAF-EBRM Performance Analysis

Figure 4 and figure 5 illustrates the cluster head selection and the cluster formation strategy, a node tends to select cluster head which minimizes the total energy consumption of as single packet delivering.
time scale. Figs. 6–8 show that the EBF, NLN, and PRR of three protocols in 200 rounds experiments. In Fig. 6, the EBF of FAF-EBRM increase slightly at first and keep a stable situation, then increase a little time, and return to 0 as the energy of the whole network is using up. In Fig. 7, the first death of FAF-EBRM node turns up until Round 200, and the procedure of the nodes’ death is fast and late. In Fig. 8, the PRR of FAF-EBRM keeps 100% ratio for 200 rounds, and the decline stage accounting for small portion.

The three parameters of EFAF-EBRM is same as that of FAF-EBRM but the proposed new cluster formation technique out performs LEACH. In addition to these parameters, proposed methods have other advantages. The additional advantages of EFAF-EBRM over existing methods 1) Decreases communication overhead 2) Increased throughput and packet delivery ratio.

Communication overhead means the ratio of routing packet to the received packet.

**Figure 6: Comparison of Energy Balanced Factor (EBF)**

**Figure 7: Comparison of Number of Last-surviving Nodes (NLN)**

**Figure 8: Comparison of Packet Reception Ratio (PRR) in %**

**Figure 9: Communication overhead versus time of EFAF-EBRM**

Packet Delivery Ratio (PDR) means the ratio of the received packet to the Generated packet.

**Figure 10: Packet Delivery Ratio versus Time of EFAF-EBRM**

Delay means the difference between packet received time and packet transmitted time.

**Figure 11: Delay versus Time of EFAF-EBRM**
From the figure 9-11 the simulation results show the communication overhead and packet delivery ratio gradually decreases as the time increases. The proposed cluster formation strategy EFAF-EBRM has a higher performance than LEACH and FAF-EBRM, which balances the energy consumption, prolongs the function lifetime, and guarantees high QoS (such as Energy-Balanced, prolonged network life, Packets Reception Radio) of WSNs.

6. CONCLUSION

This paper proposed an enhanced energy balanced routing method based new clustering formation from the point of cluster members. In this technique the sensor node may prefer to select cluster head that makes the total energy consumption least. This technique is implemented to overcome the problem in FAF-EBRM when local topology reconfiguration is needed and to decrease the communication overhead. In the experiments, EFAF-EBRM is compared with traditional LEACH algorithm and experimental results show that EFAF-EBRM outperforms LEACH, which balances the energy consumption, prolongs the network function lifetime. The performance of the proposed algorithm also increases the throughput by reducing the communication overhead and delay.

REFERENCES:


