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IMPLEMENTATION OF IMPROVED NETWORK LIFETIME TECHNIQUE FOR WSN USING CLUSTER HEAD ROTATION AND SIMULTANEOUS RECEPTION

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Abstract

There are number of potential applications of Wireless Sensor Networks (WSNs) like wild habitat monitoring, forest fire detection, military surveillance etc. All these applications are constrained for power from a stand along battery power source. So it becomes of paramount importance to conserve the energy utilized from this power source. A lot of efforts have gone into this area recently and it remains as one of the hot research areas. In order to improve network lifetime and reduce average power consumption, this study proposes a novel cluster head selection algorithm. Clustering is the preferred architecture when the numbers of nodes are larger because it results in considerable power savings for large networks as compared to other ones like tree or star. Since majority of the applications generally involve more than 30 nodes, clustering has gained widespread importance and is most used network architecture. The optimum number of clusters is first selected based on the number of nodes in the network. When the network is in operation the cluster heads in a cluster are rotated periodically based on the proposed cluster head selection algorithm to increase the network lifetime. Throughout the network single-hop communication methodology is assumed. This work will serve as an encouragement for further advances in the low power techniques for implementing Wireless Sensor Networks (WSNs).

Keywords:
Cluster, HEED, SIC, Energy Evaluation Factor, Cluster Head

1. INTRODUCTION

Minimizing the power consumption of the network has become an important and hot research topic in Wireless Sensor Networks (WSNs) in recent years. Almost all applications of WSN are constrained for power from a standalone source of power. The network life is largely dependent on how the WSN efficiently utilizes this power source. Lot of efforts has been directed to improving network lifetime recently.

Generally some clustering algorithms such as [1] Low Energy Adaptive Clustering Hierarchy algorithm (LEACH) are used in large scale networks since clustering is an efficient architecture from energy point of view. The network is for majority of the times grouped into several nodes to form a cluster with one node among them as Cluster Head (CH). We also use this approach in our work. Also note that the Single-Hop method of is used for communication between nodes to CH and CH to sink. CH is responsible for collecting data from sensor nodes, doing required aggregation if necessary and transmitting the data back to the sink for the user. As is evident, there is a heavy burden on CH for power consumption. In the last few decades many efforts have been made to reduce this burden. Thus balancing the load of the network in regards to power consumption is a hot research area in WSN.

This paper is organized as follows: Section 2 deals with the previous works in relation to the power control methods. In this of particular interest is the Successive Interference Cancellation (SIC) algorithm for receiving multiple packets. Section 3 shows our algorithm for efficiently controlling the power consumption at CH side. Section 4 represents the experimentally verified results along with the graphs for various parameters of power control strategy. Section 5 concludes with a direction for future research in this area.

2. LITERATURE REVIEW

To better acknowledge the proposed work, previous research in SIC algorithm, clustering approaches and model for transmission power needs to be mentioned here. SIC algorithm is used for detecting multiple packets [2]. Typically we observe that in WSN, if there are multiple simultaneous transmissions, the receiver only considers the intended transmission from a single source and everything else as noise. Now if the signal strength of this signal is greater than a threshold, say β then the intended signal is received successfully. To put mathematically,

If $\dfrac{P_{ij}}{\sum_{k\in N}^{k\neq i} P_{kj}} \geq \beta$ then, the transmission from i to j meets success, where P_{ij} is received power, N is all transmitters that receiver j can be intercepted.

So it's not a perfect multi-user reception scheme. SIC comes to rescue here and has the ability to decode a number of concurrent signals rather than treating them as noise. Because of this ability SIC can improve the effective throughput of the network. Hence we use this algorithm at the sink.

This action of the SIC algorithm is explained in Fig.1. There are M transmitters with received signal $P_1 < P_2 < P_3 < \dots P_m$ in the ascending order. As per the algorithm, the strongest among these signals i.e. P_m is decoded first, considering all others as noise. This signal is then discarded (after decoding) and the next strongest signal is taken for decoding, considering others as noise. This iterative procedure is continued till the last signal is decoded and received successfully. It is assumed that the last signal received has signal strength greater than the threshold, β.

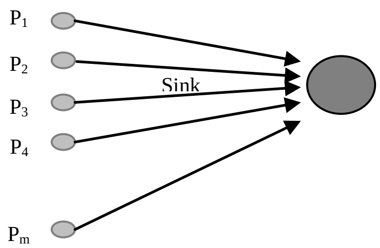

Fig.1. Successive Interference Cancellation

Formation of Clustering in WSNs is shown in Fig.2. LEACH is a typical algorithm for clustering WSN. It is an algorithm to select CH by energy threshold. It is the oldest routing algorithm for clustering and has influenced many other algorithms in clustering that came later. The CH selecting strategy has gained significance from then. In some algorithm CH selection is based on information exchange between nodes. Mamdani fuzzy logic algorithm can also be used for CH election. The Energy Efficient Hierarchical Clustering Algorithm (EEHCA) adopts a new scheme for cluster head election, which avoids frequent election scheme for cluster heads [3]. In Single-hop Energy Efficient Clustering Protocol (S-EECP) the CHs are elected by a weighted probability based on the ratio between residual energy of each node and average energy of the network [4].

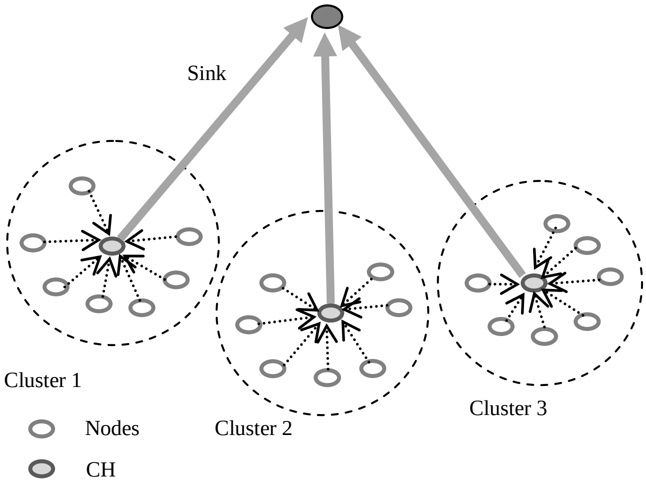

Fig.2. Clustering

Hybrid Energy Efficient Distribution Protocol (HEED) also has remarkable savings in energy because of the energy CH election process [5]. The proposed algorithm will be compared with this (HEED) algorithm to show its effectiveness in power management.

The management of power is based on the models of transmission power which include overall energy consumption, network connectivity and throughput. Proper management strategy of power can adjust transmission power to reduce energy consumption. The optimal transmission is determined according to Friis in free space propagation by the following equation:

$$P_r = \frac{P_t G_t G_r \lambda^2}{16\pi^2 d^2 L} \quad (1)$$

where, P_r is received power, P_t is transmitted power, G_t and G_r antenna gain for transmitter and receiver respectively, λ is wavelength, d is distance between transmitter and receiver and L is the loss factor ($L > 1$).

Sensor nodes use received signal intensity to judge if there is a data packet transmitting in channel. When received signal is higher than a particular threshold, it understands that there is a data packet transmission occurring in the channel. This minimum transmission power can be calculated from the following equation:

$$P_{min} = \frac{R_t L d^2 16\pi^2}{G_t G_r \lambda^2} \quad (2)$$

where, P_{min} and R_t are thresholds of received power and transmission power respectively.

Our power management strategy can accurately adjust CH's transmission power according to network conditions in real time.

3. PROPOSED POWER CONTROL METHODOLOGY

For networks of considerable size, clustering is an efficient form of organizing WSN in terms of power. So we deploy clustering architecture for our work. The proposed algorithm consists primarily of: Optimum clustering and Energy Evaluation Factor.

3.1 OPTIMUM CLUSTERING

Generally clustering is used when the number of nodes is higher. When we group nodes into clusters we need to find an optimum number of clusters for the network. The sensor nodes are evenly distributed into K-clusters. The optimum number of clusters R_{opt} [1] can be calculated according to the following formula:

$$K_{opt} = \sqrt{\frac{N}{2\pi}} \sqrt{\frac{\xi_{fs}}{\xi_{mp}}} \frac{M}{d^{\alpha}}$$

$$R_{opt} = \sqrt{\frac{N}{2\pi}} \sqrt{\frac{\xi_{fs}}{\xi_{mp}}} \frac{W}{r^{\alpha}} \quad (3)$$

where, $\xi_{fs} = 10$, $\xi_{mp} = 0.0013$, $\alpha = 2$, W is the field area and r is the distance between CHs and sensor nodes. So the sink will receive R-packets simultaneously from R-cluster heads.

3.2 ENERGY EVALUATION FACTOR (EEF)

In the monitoring area there are N sensor nodes divided into R clusters. So each cluster will have N/R nodes. To reduce the load on CH, they are elected considering current energy of the nodes.

We define a probability factor Energy Evaluation Factor (EEF) to denote the ratio of one node's energy to nodes' average energy in a cluster. If a node 'i' is in a cluster 'j' then EEF for the node 'i' in the r^{th} round is calculated as:

$$F_{i,r} = \frac{\text{Energy\_Current}_{i,r}}{\text{Energy}_{Avg}} (r = 1) \quad (4)$$

$$F_{i,r} = \frac{\text{Energy\_Current}_{i,r}}{\text{Energy\_Avg\_Cluster}_{j,r-1}} (r > 1) \quad (5)$$

where, $F_{i,r}$ is the EEF of node 'i' in the r^{th} round, $\text{Energy\_Current}_{i,r}$ is current energy of node 'i' in the r^{th} round, $\text{Energy\_Avg\_Cluster}_{j,r-1}$ is the average energy in the j^{th} cluster in $(r - 1)^{th}$ round and Energy_Avg is the average energy of the network.

Thus from the previous round information, probability of each node becoming a CH based on the EEF factor is obtained, so as to have balanced energy consumption. If a node has higher EEF it has greater current energy. At the same time EEF also considers average energy in the cluster.

For the first round ($r = 1$): At the beginning all the nodes have same energy. So the EEF factor for the first round comes out to be:

$$F_{i,r} = 1$$

From the second round onwards ($r > 1$): C_j is the number of nodes in a cluster. The initial energy of a node 'i' in a cluster C_j is Energy_Current$_{i,r-1}$ in round ($r - 1$). So the total initial energy of 'j' clusters is:

$$\text{Energy\_total\_begining}_{i,r-1} = \sum_{i=1}^{c_j} \text{Energy\_Current}_{i,r-1} \quad (6)$$

In ($r - 1$) round, energy consumption of node 'i' in j^{th} cluster is:

$$\begin{aligned}\text{Energy\_Consumed\_node}_{i,j,r-1} &= l.\text{Energy}_{Election} C_j \\ &+ l.\text{Energy}_{DA}.C_j \\ &+ l.\xi_{mp} d^4 \ldots (\text{'}i\text{' is a } CH)\end{aligned}$$

$$\begin{aligned}&\text{Energy\_Consumed\_node}_{i,j,r-1} \\ &= l.\text{Energy}_{Election} + l.\xi_{fs} \frac{W^4}{R^2} \frac{1}{2\pi} \ldots (\text{'}i\text{' is not } CH)\end{aligned} \quad (7)$$

where, Energy_Consumed_node$_{i,j,r-1}$ is energy consumed by node 'i' of cluster 'j' in the $(r - 1)^{th}$ round, $Energy_{Election}$ is the energy spent in the election process, M is the field area, R is the number of clusters

Total energy consumption of the j^{th} cluster in ($r - 1$) round is:

$$\begin{aligned}\text{Energy\_Consumed\_total} &= l.\text{Energy}_{Election}.C_j \\ &+ l.\text{Energy}_{DA}.C_j \\ &+ \left(C_{j-1} \left(l.\xi_{fs} \frac{W^4}{R^2} \frac{1}{2\pi} \right) \right)\end{aligned} \quad (8)$$

At the end of ($r - 1$) round, the total energy is given by:

$$\begin{aligned}&\text{Energy\_Consumed\_total}_{j,r-1} \\ &= \text{Energy\_total\_beginning}_{j,r-1} \\ &- \text{Energy\_consumed\_total}_{j,r-1}\end{aligned} \quad (9)$$

At the end of ($r - 1$) round, the average energy of 'j' clusters is given by:

$$\text{Energy\_Avg\_Cluster}_{j,r-1} = \frac{\text{Energy\_Total}_j}{C_j} \quad (10)$$

The current energy of node 'i' is given by:

$$\begin{aligned}\text{Energy\_Current}_{i,r} &= \text{Energy\_Current}_{i,r-1} \\ &- \text{Energy\_Consumed\_node}_{i,j,r-1}\end{aligned} \quad (11)$$

From Eq.(11) it can be shown that,

$$\text{Energy\_total}_{j,r-1} = \sum_{i-1}^{C_j} \text{Energy\_Current}_{i,r} \quad (12)$$

From the above equations the EEF of node 'i' in the r^{th} round is given by:

$$F_{i,r} = \frac{\text{Energy\_Current}_{i,r}}{\text{Energy\_Avg\_Cluster}_{j,r-1}} \quad (13)$$

From Eq.(13) it is proved that if a node has higher EEF it has greater current energy.

$$\sum_{i=1}^{C_j} F_{i,r} = \frac{\sum_{i=1}^{C_j} \text{Energy\_Current}_{i,r}}{\text{Energy\_Avg\_Cluster}_{j,r-1}} = C_j \quad (14)$$

The total EEF is given by:

$$\begin{aligned}\sum_{i-1}^{N} F_{i,r} &= \sum_{j=1}^{M} \sum_{i=1}^{C_j} \frac{\text{Energy\_Current}_{i,r}}{\text{Energy\_Avg\_Cluster}_{j,r-1}} \\ &= \sum_{j=1}^{M} C_j = N\end{aligned} \quad (15)$$

If a node has greater energy, it has more probabilities of becoming CH and also it has shorter CH rotation.

4. IMPLEMENTATION RESULTS

The proposed work is analyzed from the perspectives of network lifetime, throughput and packet delivery ratio. All these aspects are compared with an earlier algorithm for power control known as Hybrid Energy Efficient Distribution (HEED) algorithm and the differences are brought out.

4.1 NETWORK LIFETIME

Sensor nodes are randomly distributed in a clustered network as shown in Fig.2. There are 50 nodes with 4 clusters and CHs in our implementation. The comparison for proposed scheme and HEED with regards to network lifetime is as shown in Fig.3. As can be seen the proposed algorithm for cluster head selection has more number of nodes alive than HEED. Thus the proposed work has greater network lifetime. This is because there is proper load balancing at the cluster head level which causes the network lifetime to be more for the proposed algorithm.

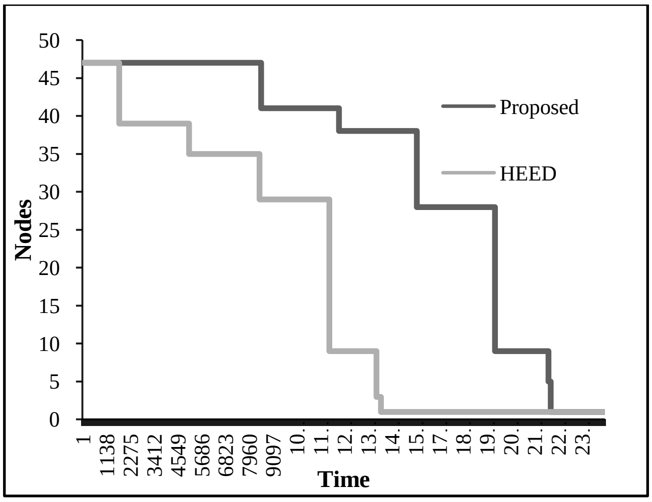

Fig.3. Nodes Alive

4.2 THROUGHPUT

The proposed algorithm employs SIC at the sink. Hence the packets lost are greatly minimized. To give an analysis of throughput of proposed algorithm, it is compared with throughput of HEED using NS2 simulator. The output of simulation is as shown in Fig.4. The proposed algorithm has better throughput than HEED because of the use of simultaneous reception and the proposed cluster head selection algorithm.

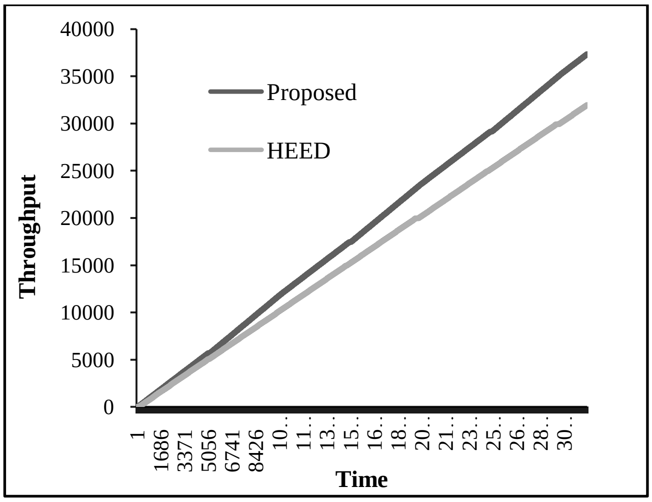

Fig.4. Throughput

4.3 PACKET DELIVERY RATIO

Packet Delivery Ratio (PDR) is the measure of effective successful transmission of the WSN. It is defined as the ratio of the total packets received to the total packets sent. An NS2 simulation output graph in Fig.5 shows the PDR of the proposed scheme as compared with HEED. As is evident from Fig.5, the proposed algorithm has better PDR than HEED. This is because the packets lost would be very less due to simultaneous reception and the proposed CH selection algorithm.

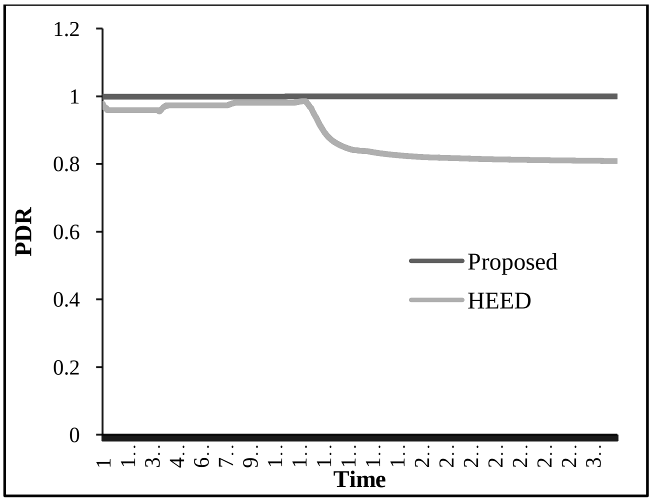

Fig.5. Packet Delivery Ratio

5. CONCLUSION AND FUTURE SCOPE

With the aid of rotating CHs based on the current energy balanced load in the clustered WSN is achieved, which increases the network lifetime. The optimum number of cluster is calculated depending on the number of nodes. Then the EEF for each node was determined and CHs periodically rotated to achieve power savings via load balancing the network. Also increased throughput is obtained due to the use of simultaneous reception technique at sink. Thus the proposed work provides a way of optimizing the WSN for power. This work can be further extended to include data aggregation techniques along with cluster head rotation to further reduce power consumption of nodes and improve network lifetime.

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