Energy Efficient Cluster Head Selection in Wireless Sensor Networks

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Abstract— Given the fact that LEACH (Low Energy Adaptive Clustering Hierarchy) protocol didn't take the residual energy of nodes when choosing the cluster heads. Cluster head selection based on threshold value, In this process, If low energy node is being selected as the cluster head, then low-energy node to be dead at an early stage, then the network fails soon. Here in this paper, we introduced an energy factor when choosing a cluster head, which can selects a node with high-energy to be a cluster head. Meanwhile, we conducted a simulation specific to LEACH protocol and this (Energy Efficient-LEACH) EE-LEACH in terms of network lifetime, and energy consumption. Simulation results show that EE-LEACH has better performance compared with LEACH protocol in these aspects.

Key words: LEACH Protocol, EE-LEACH, Residual Energy, Wireless Sensor Networks (WSN)

I. Introduction

Nowadays, wireless sensor networks (WSNs) [2] are playing an essential role in the effective operation of many applications such as smart transportation, health monitoring, battlefield surveillance, smart grids, weather forecasting, satellite communication, IOT etc. WSNs attractive features such as low cost, low power radios and sensing capability have increased its use in day to day life.WSN consists of a large collection of resource constrained(especially battery power) sensor nodes. These sensor nodes sense analog data (e.g. temperature humidity) from the environment and convert into digital form for processing. This processed data is aggregated and reported back to the sink or base station (BS).WSNs suffer from many issues such as coverage, security, energy-efficiency, localization, etc. Among these issues energy-efficiency is the critical issue, as sensor nodes are battery operated. Depending upon the application requirements, sometimes, WSN is deployed in the unattended region or harsh environment where human intervention is impossible. In such environments, efficient use of battery power plays a critical role in the effective operation of WSN as they are equipped with non-replaceable battery resource. A number of efforts have been made to make WSN energy efficient by saving energy from the physical level to routing level, by improving data acquisition strategies and by incorporating mobility into the nodes. However, it is established that most of the energy is consumed in data transmission and reception. Therefore, energy saving routing protocols are required.

II. Related work

LEACH [5] was introduced as a hierarchical clustering algorithm for WSNs, called Low-Energy Adaptive Clustering Hierarchy (LEACH). LEACH is a good approximation of a proactive network protocol, with some minor differences which includes a distributed cluster formation algorithm. LEACH randomly selects Sensor Nodes (SNs) as Cluster Heads (CHs) and rotates this role amongst the cluster members so as to evenly distribute the energy dissipation. In LEACH, the CH SNs compress data arriving from SNs that belong to the respective cluster, and send an aggregated packet to the BS in order to reduce the amount of information that must be transmitted. LEACH uses a TDMA and CDMA MAC to reduce intra-cluster and inter-cluster collisions, respectively however, data collection is centralized and is performed periodically, and therefore, this protocol is better appropriate when there is a need for constant monitoring by the WSN. On the other hand, a user may not need all the data immediately, making periodic data transmissions unnecessary. After a given interval of time, a randomized rotation of the role of the CH is conducted so that uniform energy dissipation in the WSN is obtained.

The operation of LEACH is classified into two phases, the setup phase and a longer steady state phase. In the setup phase, the clusters are organized and CHs are selected. In the Steady state phase, actual data transfer to the BS takes place. During the setup phase, a predetermined fraction of SNs, say p, elect themselves as CHs as follows. A SN chooses a random number, say r, between 0 and1. If this random number is less than a threshold value, say T(n), the SN becomes a CH for the current round. The threshold value, in turn, is calculated based on an equation that incorporates the desired percentage to become a CH, the current round, and the set of SNs that have not been selected as a CH in the last (1/p) rounds, denoted by G. As a result, T(n) is given by:

$$T(n) = \frac{p}{1-p\left(r \bmod \frac{1}{p}\right)} \quad \text{if } n \in G \qquad (1)$$

Where G is the set of SNs that are involved in the CH election. All the non-CH SNs, after receiving advertisement from newly elected CH. Decide on the cluster to which they want to attach to. In LEACH, this decision is based on the signal strength of the Advertisement. The non-CH SNs then inform the corresponding CH of their decision to be a member of its cluster. Based on the number of SNs in the cluster, the CH SN creates a TDMA schedule and assigns each SN a time slot. During the Steady state phase, SNs begin sensing and transmitting data to their respective CHs. Once the CH receives the data from all of its members, it aggregates before relaying data to the BS. After a period time. Which is determined a priori, the network goes back into setup phase and initiates another round of selecting new CHs.

III. Proposed method

LEACH protocol did not consider the residual energy of nodes when selecting cluster heads, which may lead to the nodes with very low energy to be cluster heads and premature death of clusters, affecting the lifetime of the whole network.

A. Energy Consumption Model of Sensor Nodes

In the EE-LEACH, we use the same radio communication energy consumption model as used in LEACH protocol. This model consists of two parts: transmitting energy consumption module and receiving energy consumption module. When sending data, nodes need to consume some energy, and its amplifier will consume some energy too; and when receiving data, nodes will consume energy too. Hence, total energy consumed is as the following formula:

$$E_{total}=E_{send}+E_{receive}$$

According to the radio communication energy consumption model, we know that when sending l bit data, sensor nodes will consume the below energy:

$$E_{Tx}(l,d)=E_{Txelec}(l)+E_{Txamp}(l,d)= \begin{cases} l*E_{elec}+l*\epsilon_{efs}*d2, & d<d0 \\ l*E_{elec}+l*\epsilon_{amp}*d4, & d>=d0 \end{cases} \quad (2)$$

The meaning of each symbol in the formula is as follows: Energy consumed when sending l bit data by sensor nodes from d distance; E_{TX}: Transmit energy for l bit d distance; $E_{Tx-elec}(l)$: Transmit electronic energy consumption; $E_{Tx-amp}(l,d)$: Transmit amplifier energy consumption; The length of data package sent; d: Data transmission distance; E_{elec}: Energy consumed by radiating circuit when processing 1 bit data; ϵ_{efs}: Energy consumed by transmit power amplifier when sending 1 bit data to unit area in free space channel model; ϵ_{amp}: Energy consumed by transmit power amplifier when sending 1 bit data to unit area in multipath fading channel model;

$$E_{Rx}(l)=E_{Rx-elec}(l)=l*E_{elec} \quad (3)$$

The meaning of each symbol in the formula is as follows: $E_{Rx-elec}(l)$: Energy consumed by the interface circuit E_{elec}: Energy consumed by the interface circuit when processing 1 bit data; Put d_0 into the formula (2), we can obtain its critical value:

$$d_0=\sqrt{(\epsilon_{fs}/\epsilon_{amp})} \quad (4)$$

B. EE-Leach

When selecting cluster heads, LEACH protocol selects cluster heads according to the random number the node generates and the threshold, while the threshold did not considering remaining energy, which may result in the node with low energy to be a cluster head, thus bringing premature death to clusters and affecting the lifetime of network. We introduce the remaining energy factor based on LEACH protocol, that is:

$$T(i) = \frac{p_i}{1-p_i\left(r \bmod \frac{1}{p_i}\right)} \quad \text{if } N \in G \quad (5)$$

There into, $P_i=(E_i-E_r)^2/E_R$ (6)

E_i: Residual energy of each node in I round; E_r: average energy of rest nodes in the I round; E_R: total residual energy of rest nodes in the I round; Calculating formula of average energy of rest nodes E_r:

$$E_r= E_R*(1-(r_i-r_{max}))/N \quad (7)$$

r_i: The current round r_{max}: Maximum rounds of network simulation;

In the formula (5) and (6), if there is much residual energy of the node, then the value of P_i will increase, which demonstrates that this node has a high proportion of energy in the rest energy. With the increase of P_i, T(i) will increase too, thus the probability of this node being a cluster head is enlarged too. Therefore, considering the residual energy of nodes enable the nodes with higher remaining energy to be cluster heads, which can form an optimized cluster heads, avoiding premature death of the network lifetime and prolonging the network lifetime.

Parameters	Values
Coordinates of x-axis and y-axis	100,100
Sink node location	50,50
Total number of nodes	100
Initial energy	0.5 j
Tx and Rx energy for each node	$5.0X10^{-9}$
Data aggregation energy	$5.0X10^{-9}$
Total number of rounds	4000
No. of packets	4000

Table 1: Simulation Parameters

C. Flow Diagram

Initialize the parameters, in the first round the cluster head selection is based on the threshold value. Which node satisfies the threshold condition that node selected as cluster head otherwise that node as normal node. Where as in the second round cluster head selection is based on the residual energy. After completion of first round which node has highest energy that node selected as cluster head otherwise that node act as normal node. The cluster head sends an advertisement to all nodes which are presented in the network, some of the nodes sends request messages to cluster head then the cluster head accept their requests and join in the cluster. Then the normal nodes send the packets/data to cluster head, and then the cluster head aggregates the all messages in to a single message then send it to the Base Station (BS).

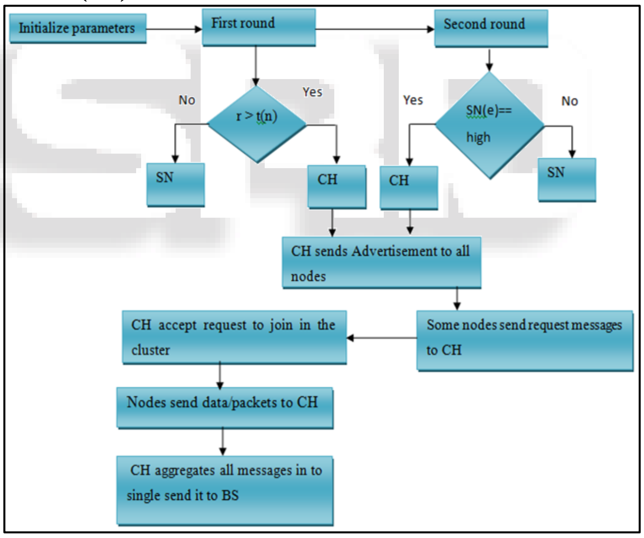

Fig. 1: Flow diagram of Proposed System

SN: Sensor node
CH: Cluster head
t(n): threshold value
r: random variable (0 > r > 1)

D. Algorithm

1) 1st round

– SN===> r
– If r > T(n) then, CH = SN else, goto step1
– CH ===> G : id(CH) , join adv
– A(i) ----> CH(j) : id(A(i)) , id(CH(j)) , join req
– CH(j) ----> A(i) : id(CH(j)), < t(i), id(A(i)) >

2) Steady phase

– A(i) ----> CH(j): id(A(i)), id(CH(j)), info
– CH ----> BS : id(CH) , id(BS) , aggr info

3) From 2nd round to last round

1) If SN(e) ---->high
2) Then , CH = SN else, goto step1

– CH ===> G : id(CH) , join adv
– A(i) ----> CH(j) : id(A(i)) , id(CH(j)) , join req
– CH(j)----> A(i) : id(CH(j)) , < t(i) , id(A(i)) >

4) Steady phase

– A(i) ----> CH(j) : id(A(i)) , id(CH(j)), info
– CH ----> BS: id(CH) , id(BS) , aggr info

The various symbols used here are:

– SN: Sensor node.
– SN(e): energy of Sensor node
– r: random variable(0 > r > 1)
– t(n) : threshold value
– CH: cluster head
– G: all nodes in the network
– id: identification number
– Join adv : advertisement to join the cluster
– A: normal node
– Join adv: request to join the cluster
– t: time-slot to send the sensed data
– ===>: broadcast
– ---->: unicast

IV. RESULTS AND DISCUSSIONS

The Simulation is executed using MATLAB. The various network parameters and their values are defined in the algorithm. Fig 2 relates the number of alive nodes to the number of rounds, showing that the number of alive nodes greater for EE-LEACH than for LEACH. In the LEACH the dead nodes started at round 996 but where as in the EE-LEACH there are no dead nodes up to 2200 rounds.

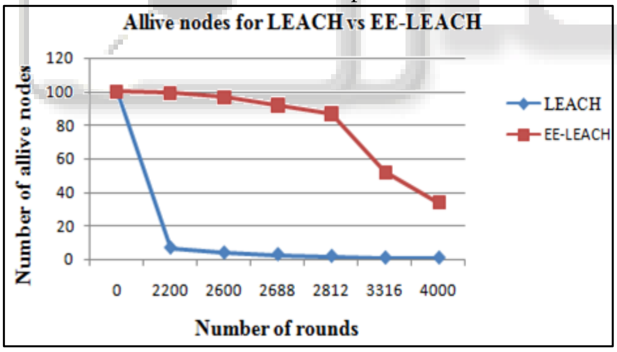

Fig. 2: Alive nodes for LEACH vs EE-LEACH

Figure 3 shows the election of cluster heads in leach and EE-LEACH also. But the proposed system elects more cluster heads when compared to existing system.

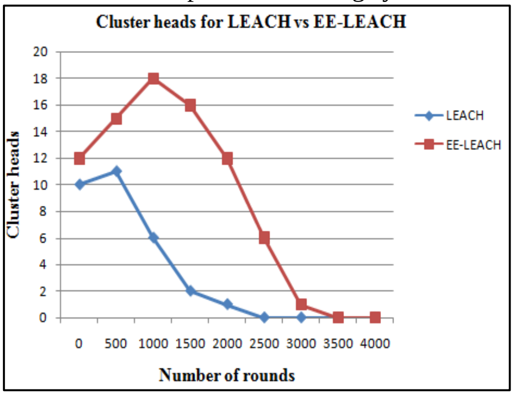

Fig. 3: Cluster heads for LEACH vs EE-LEACH

Fig 4 relates the number of dead nodes to the number of rounds, showing that the number of dead nodes is smaller for EE-LEACH than for LEACH. At round 4000 all LEACH nodes are dead, but some of the nodes remain alive at round 4000 in EE-LEACH. The lifetime of the network is increased in EE-LEACH. As shown in fig 2 because the lifetime of network is increased by the presence of the remaining live nodes, CH selection is also executed until round 4000 in EE-LEACH, as is clearly plotted in Fig 4 Fig. 5 demonstrates that the proposed protocol delivers a greater number of packets to CH compared to LEACH

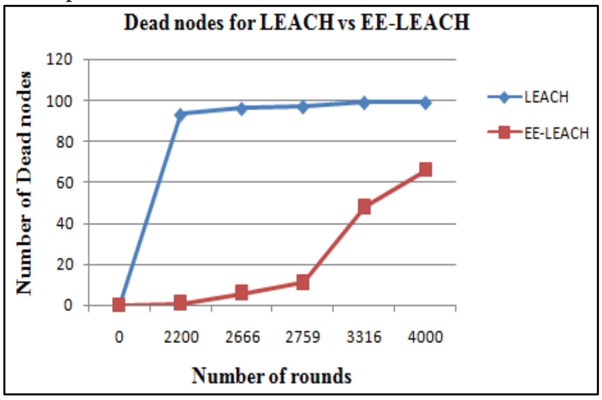

Fig. 4: Dead nodes for LEACH vs EE-LEACH

Figure 5 relates to energy consumption in existing system cluster heads selected based on threshold value so the low energy node selected as cluster head then it will die soon. in the proposed system the cluster heads selected based on residual energy thats why nodes working long time in the network. So in the proposed system the nodes have more energy when compared to existing system.

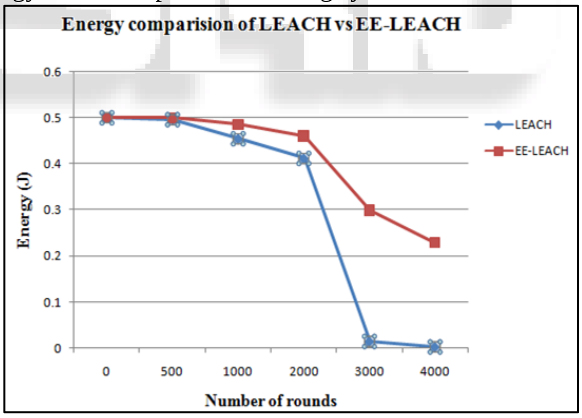

Fig. 5: Energy comparision of LEACH vs EE-LEACH

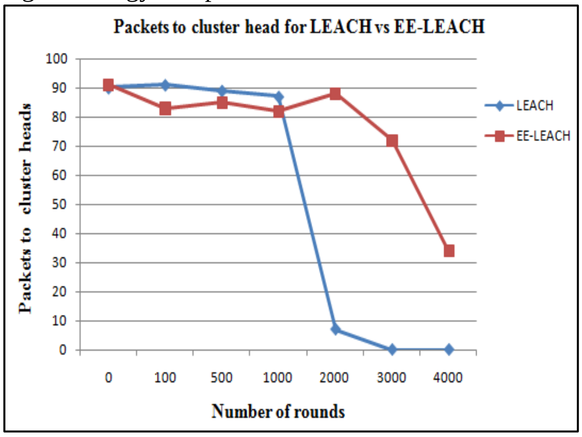

Fig. 6: Packets to CH for LEACH vs EE-LEACH

Fig 6 demonstrates that the proposed protocol delivers a greater number of packets to BS compared to LEACH. Because In the existing system network lifetime decreased at 2500 round so packets transformation stopped. Where as in the proposed protocol packets transformed up to 4000 round.

V. CONCLUSION

LEACH protocol is a typical routing algorithm in cluster based routing protocol with many advantages. However, this protocol did not consider residual energy of nodes when choose cluster heads which effects the network lifetime. We introduced energy factor. When selecting cluster heads, we consider the rest energy of nodes, thus avoiding nodes with low energy to be cluster heads. Simulation results show that the EE-LEACH is superior to LEACH protocol in terms of network lifetime, and energy utilization. By using the EE-LEACH 40% of energy is saved when compared to LEACH. Of course, there are any short comings in the algorithm, and then those are deserved in further research.

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